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ASME Code Safety Valve Rules— A Review and Discussion

Safety valve rules, i.e., rules for overpressure protection by the use of various pressure-relieving devices, vary somewhat among the five book sections of the ASME Boiler & Pressure Vessel Code which require such protection. This paper reviews those rules by discussing the following topics: Pressure relief device terminology and function. The problem of overpressure protection. Code rules for overpressure protection: rules for determining required relieving capacity; for allowable overpressure; for set pressure and set pressure tolerance; for blowdown. The various pressure relief devices permitted by the Code. Design of pressure relief valves. How relieving capacities are established and certified. The qualification of pressure relief device manufacturers. Installation guidelines. Concluding remarks.

1 Introduction

The ASME Boiler & Pressure Vessel Code (the Code) was developed between 1911 and 1914 as a set of safety rules to address the serious problem of boiler explosions in the United States, which at that time were almost a daily occurrence. Average steam pressures in boilers in those days had reached about 300 psi, and the explosions took a heavy toll of lives and property. The principal design basis for boilers and pressure vessels is the safe containment of design pressure. Protection against overpressure was therefore a very important aspect of pressure vessel design. Accordingly, that first edition of what is now Power Boilers, Section I of the Code, included rules for the overpressure protection of boilers, based on the best industry practice at the time. The principles of today's Code rules for overpressure protection are little changed from those of the first code.

That first ASME Code of 1914 has now grown into eleven so-called "book sections," covering a wide variety of subjects. Five of these book sections deal specifically with the design of pressure vessels and include requirements for overpressure protection. These five book sections are: Power Boilers (Section I), Nuclear Power Plant Components (Section III), Heating Boilers (Section IV), Pressure Vessels (Section VIII), and Fiberglass Reinforced Vessels (Section X). Rules for overpressure protection vary with the type of vessel to be protected. The various pressure relief devices used for overpressure protection may be categorized as "pressure relief valves" (commonly called "safety valves," and "nonreclosing devices," such as rupture disks.

The function of a pressure relief device is to open at a specified pressure and pass a sufficient amount of fluid to prevent pressure in the vessel or system being protected from exceeding an **allowable overpressure** above the design pres-

sure. In some book sections, the design pressure is referred to as the **Maximum Allowable Working Pressure (MAWP)**. Each book section provides rules for determining the required relieving capacity of pressure relief devices, for establishing allowable overpressure, for determining the maximum set pressure of the pressure relief devices, and for ensuring that pressure relief devices will function as required should an overpressure condition occur. Although fundamentally similar, the rules vary somewhat in detail and complexity, reflecting the nature of the application, and somewhat different design philosophies of the committees governing the various book sections. It happens that the Code offers only limited explanation of its rules on overpressure protection, and aside from certain functional requirements, very few rules to guide the designers of pressure relieving devices. The objective of this paper is to summarize the rules and to provide some explanation and discussion of them, and how they are applied.

ASME has a policy that rules on a given subject that appear in more than one book section should be similar and consistent, insofar as possible. However, due to the diversity of application, there is some variation among the pressure relief device rules which have evolved in five book sections of the Code. A governing subcommittee of the Boiler and Pressure Vessel Committee has the fundamental responsibility for writing, revising, adding to, and interpreting the rules of each book section of the Code. Assisting the book section subcommittees with technical advice are so-called "service committees," such as the Subcommittee on Design (SC-D) and the Subcommittee on Safety Valve Requirements (SC-SVR). The purviews of the book and of the service committees overlap somewhat, and the demarcation of their respective responsibilities is sometimes unclear. Traditionally, with regard to pressure relief devices, matters of application and installation, such as which devices are permitted, and where, fall within the domain of the book section committees. Technical matters dealing with design, testing, and capacity certification are covered by the SC-SVR. When inquiries dealing

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with these devices are received by ASME, they are sent to the concerned book section committees. Only if those committees think it necessary or advisable is the inquiry forwarded to SC-SVR for a recommended reply or rule change; and even in such cases, the book section committee is free to accept, modify, or reject that recommendation. Thus, despite ASME policy on consistency of rules, the independence of all the committees involved has resulted in some slight gradual divergence among the book sections with respect to their rules for overpressure protection.

To provide overpressure protection, the designer must first determine potential sources of overpressure, calculate the rate at which fluid must be removed under emergency conditions to maintain pressure within maximum allowable limits, and select appropriate relieving devices to provide this required capacity. The Code provides a variety of rules for the design, manufacture, capacity certification, selection, and application of pressure relief devices used to protect a broad variety of fired and unfired vessels. Early applications of the Code dealt with steam boilers, where the source of pressure is the application of heat to water in an enclosed vessel, producing steam. If the quantity of steam allowed to leave the vessel is less than that being generated, the pressure in the vessel rises. The same principle applies to other fluids heated in closed vessels. Providing sufficient overpressure protection is not always straightforward, however, and the Code rules differ depending on the type of vessel to be protected, as described in Section 2.

2 Overpressure Protection

2.1 Relieving Capacity Required. The first task in selecting appropriate pressure relief devices for a vessel or system is to determine the required relieving capacity (the rate at which fluid must be removed from the system during an emergency condition to maintain a safe level of pressure). This requires that all sources of fluid flow or energy into the system be considered and evaluated. Sources of energy might be heat, fire, chemical reaction, or mechanical work. Sources of fluid flow could include compressors, pumps, pressure-reducing valves stuck in the open position, malfunctioning control valves, inadvertent opening or closure of a valve connected to the vessel, failure of an internal tube in a heat exchanger, or some combination of these events. Each possible source of excess energy or fluid flow into the system must be taken into account to determine the worst case overpressure condition. The required relieving capacity is determined from this worst case; this determination can often require careful engineering study. The various book sections of the Code in some cases provide directly applicable rules, and in other cases only limited guidance for determining the worst-case overpressure condition. The following is a brief summary of those rules.

2.2 Summary of Rules for Determining Required Relieving Capacity, by Book Section

Section I, Power Boilers, still uses the rule from the first ASME Code in 1914 which, in brief, requires safety valve capacity sufficient to relieve all the steam a drum-type boiler can generate without allowing the pressure to rise more than 6 percent above the highest pressure at which any valve is set, and in no case more than 6 percent above the MAWP. This rule is now supplemented by others, for certain types of boilers and for various other components covered by Section I. For example, the required relieving capacity in lb/h for an isolable economizer (one with valves on either side, which could be inadvertently left closed) is equal to the maximum heat absorbed in Btu/h divided by 1000 (paragraph PG-67). This rule was based on the assumption that it takes 1000 Btu to boil a pound of water; a fair assumption at low pressures,

somewhat unconservative at higher pressures. For high-temperature water boilers, this rule is reversed: the designer is told to provide relieving capacity equal to the boiler output in Btu/h divided by 1000.

Until 1994, when its rules were revised, Section I had provided a table (Table PG-70) for certain types of boilers, stipulating the Minimum Safety Valve Relieving Capacity Required per Square Foot of Heating Surface, with the admonition that this was only a minimum, and that more might be required. This minimum capacity varied with boiler type, firing method, fuel, and type of heating surface. The table was originally intended as a guide for inspectors, who could then verify the boiler manufacturer's choice of safety valve capacity. In recent years, the capacities listed in Table PG-70 were found to be inappropriate for certain types of boilers, e.g., fluidized bed boilers, and stoker fired boilers firing refuse. To correct this problem, and also to eliminate some confusion between the maximum designed steaming capacity mentioned in PG-67 and the minimum required safety valve relieving capacity specified in PG-70, these two paragraphs were revised in the '93 Addenda to Section I. The new wording clearly placed on the boiler manufacturer the full responsibility for determining the maximum designed steaming capacity of the boiler, and for providing at least that much safety valve relieving capacity. At the same time a new rule was added, requiring the boiler manufacturer to stamp the maximum designed steaming capacity on the boiler nameplate. With these changes, the old Table PG-70 was no longer needed. However, to keep it available to inspectors accustomed to using it, it was moved to a nonmandatory appendix, Appendix A-44, where it is now called Table A-44.

The term "all the steam the boiler can generate" has traditionally been interpreted to mean the Maximum Continuous Rating (MCR) of the boiler at specified design conditions. Section I assigns the responsibility for the determination of this steaming rate to the boiler manufacturer, who calculates it based on experience, taking into account the various boiler systems: pumps, fans, and fuel. It is necessary in all such systems to provide some design margin to assure achieving design steam-generating capacity (MCR) and to permit the overfiring necessary when increasing load. Consequently, if all systems were pushed to their limits, it is possible to exceed the nominal design steam-generating capacity. However, the customary practice is to use the nominal capacity at MCR as the minimum safety valve relieving capacity required. This can be justified by the safety margins implicit in the certified capacities, in the design of the pressure parts, and in the overpressure limits of Section I, which are typically lower than those of Section VIII.

In 1965, Section I incorporated design rules for a then new type of boiler called a "forced-flow steam generator with no fixed steam and waterline, equipped with automatic controls and protective interlocks responsive to steam pressure." Such boilers have no steam drums; the fluid passes through the boiler only once, entering as water and leaving as steam. Unlike drum-type boilers, which are designed for a single design pressure and which achieve their pressure by firing, forced-flow steam generators with no fixed steam and waterline achieve their pressure from the boiler feed pump. These boilers are designed for different pressure levels along the path of water-steam flow, with a significant difference in pressure between the economizer inlet and superheater outlet, for example, 4350 psi versus 3740 psi (30 mPa versus 25.8 mPa).

Recognizing the special nature of these boilers, Section I provided alternative rules for their overpressure protection, in PG-67.4, which are quite different from the usual Section I rules. For drum-type boilers, Section I permits credit for use of spring-loaded safety valves only. However, for these once-through boilers, Section I permits a combination of safety

valves and power-actuated pressure relieving valves, the latter to provide a minimum of 10 percent, but to be credited with no more than 30 percent, of the required relieving capacity. In another departure from usual practice, any or all of the spring-loaded safety valves may be set up to 17 percent above the MAWP at the superheater outlet (the component with the lowest MAWP). Further, the power-actuated relieving valves must receive a signal to open when the MAWP at the superheater outlet is exceeded. When all pressure relief valves are in operation, the pressure is permitted to rise to a maximum of 20 percent above the master stamping pressure, the design pressure at the superheater outlet. When still further special conditions are met, Section I permits certain forced flow steam generators to be furnished with as few as two spring-loaded safety valves whose total relieving capacity is not less than 10 percent of the maximum design steaming capacity. These special conditions include the use of automatic controls and direct acting trip mechanisms for the fuel and feedwater supplies, actuated by the lifting of the valve stem of at least two spring-loaded safety valves. Further, the fuel and feedwater control circuitry must be fail-safe. These rules contrast with current practice in Germany and some other European countries, where overpressure protection for once-through units can now be provided by a power-actuated turbine bypass system alone, without spring-loaded pressure relief valves.

Section III, Nuclear Power Plant Components, is of relatively recent origin (1963) compared to the other sections of the Code. The governing committee (SC-III) has developed a well-organized, comprehensive set of rules for overpressure protection of nuclear power plant components, which reflect the unique service involved and leave virtually nothing to chance. These rules require the preparation of an Overpressure Protection Report, which includes an analysis of all conditions which could cause overpressure, and an analysis of pressure transient conditions. The required relieving capacity for the pressure-relieving devices is determined from this report. The report must also cover the selection of the pressure relief devices, and an analysis of their redundancy and independence, to ensure that overpressure protection is maintained in case of the failure of any element in the system, or loss of external power. This report must be certified by one or more Registered Professional Engineers qualified in accordance with ASME N626.3 [1].

Section IV, Heating Boilers, covers three types of relatively

low pressure equipment: steam heating boilers, hot water heating or supply boilers, and potable water heaters. The pressure-relieving capacity, in pounds of steam per hour, for both steam and water boilers may be determined in one of two ways: the maximum Btu output at the boiler nozzle divided by 1000 (again, the rule of thumb that 1000 Btu will boil a pound of water), or by use of a table of minimum steam-relieving capacity per hour per square foot of heating surface, similar to the method formerly used in Section I. The relieving capacity of safety relief valves on potable water heaters is specified in Btu/h, and in general must equal the maximum input to the heater. Paragraph HG-402.7(a) advises that the relieving capacity in terms of Btu/h may be determined by multiplying the capacity in pounds of steam per hour by 1000.

Of all the book sections, *Section VIII, Pressure Vessels*, covers the largest variety of vessels. These vessels are also potentially subject to overpressure conditions from many possible sources. When designers of Section I and Section IV equipment determine required relieving capacity, they often start with guidelines from the Code and knowledge of a boiler's maximum steam-generating capacity or heat input; by contrast, Section VIII designers are simply charged by UG-125 with preventing the pressure from rising more than a certain amount above the MAWP of the vessel, with few additional guidelines. Accordingly, the designer must often use the engineering principles outlined in Section 2.1 and have a thorough knowledge of the system being protected to determine the appropriate relieving capacity. Section VIII comprises 2 volumes, Divisions 1 and 2. Division 2 has alternative rules for the construction of pressure vessels, based on the design-by-analysis methods of Section III. However, the overpressure protection requirements of both divisions are virtually identical.

Section X, Fiberglass Reinforced Plastic Vessels, adopts the same basic overpressure rules as Section VIII, but is somewhat more restrictive as to the types of nonreclosing pressure relief devices permitted (see Table 1). As with Section VIII, the task of determining required relieving capacity is left to the designer.

2.3 Allowable Overpressure. Most pressure-relief devices, particularly pressure-relief valves, require a further increase in pressure above set pressure to reach a full open condition. Vessels with multiple valves may require an even

Table 1 Pressure relief devices allowed by the ASME Code

Pressure Relief Devices Allowed by the ASME Code	BOOK SECTION							
	I	III				IV	VIII	X
		NB	NC	ND	NE			
Direct Spring Loaded Pressure Relief Valve	•	•	•	•	•	•	•	•
Pilot Operated Pressure Relief Valve		•	•	•	•		•	•
Power Actuated Pressure Relief Valve	•	•	•	•	•			
Pressure Relief Valve with Auxiliary Actuating Device		•	•	•	•			
Rupture Disc Device	*	•	•	•			•	•
Breaking Pin Device with Pressure Relief Valve							•	
Spring Loaded Non-Reclosing Pressure Relief Device							•	
Vacuum Relief Valve			•	•	•			
Buckling Pin Device							+	

* In combination with pressure relief valve on organic fluid vaporizer only
+ Code Case 2901

greater increase over MAWP for all the relieving valves to open fully because some are allowed to be set above MAWP. Accordingly, each book section provides its own rules as to how much the pressure is allowed to increase above MAWP or design pressure during an overpressure event.

Section I provides for overpressure within very narrow limits. With some exceptions (see Section 2.2), pressure may not rise more than 6 percent above the highest pressure at which any valve is set, and in no case more than 6 percent above the MAWP.

Section III limits overpressure to 10 percent or 3 psi (20.7 kPa), whichever is greater, above the design pressure of any component within the pressure retaining boundary of the protected system.

Section IV overpressure limits vary somewhat depending on the type of equipment and its design pressure. For steam boilers, the design pressure is a minimum of 30 psi (207 kPa), but the operating limit set by Section IV is 15 psi (103 kPa); so the safety valves must be set at 15 psi, with an overpressure of 5 psi (34.5 kPa) allowed. For hot water boilers with only a single pressure relief valve, an overpressure 10 percent above MAWP is allowed. Where multiple valves are provided, the allowable overpressure is 10 percent above the set pressure of the highest set valve.

Section VIII limits on overpressure depend on the type of installation. In general, Section VIII mandates that pressure not be allowed to rise more than 10 percent or 3 psi (20.7 kPa), whichever is greater, above MAWP. When multiple

devices are used, or additional devices are provided to protect against exposure to fire, overpressures of 16 or 21 percent, respectively, are allowed. For valves which protect liquefied compressed gas storage vessels against exposure to fire, 20 percent overpressure is allowed.

Section X has the same overpressure requirements as Section VIII except that special rules for protection of liquefied compressed gas storage vessels exposed to fire are not considered.

2.4 Set Pressure of Pressure Relief Devices. Once the required relieving capacity and allowable overpressure have been established, the next step is to determine the set pressure of the pressure relief devices. The general rule for setting pressure relief devices is that at least one device must be set to open at or below maximum allowable working pressure (the design pressure) of the system or vessel being protected. On many small boilers or pressure vessels, only one relief device is required, and this device is typically set at MAWP. When more than one device is used, the allowable increase in set pressure over MAWP varies considerably throughout the Code (in general, from 3 to 10 percent above MAWP), depending on the application and the circumstances, as shown in Table 2.

Section I requires that at least one pressure relief valve be set at or below MAWP. Additional valves may be set up to 3 percent above MAWP. In no case, however, may the com-

Table 2(a) Section I requirements

PRESSURE RELIEF DEVICE OPERATING REQUIREMENTS				
APPLICATION	ALLOWABLE VESSEL OVERPRESSURE (ABOVE MAWP OR VESSEL DESIGN PRESSURE)	SPECIFIED PRESSURE SETTINGS	SET PRESSURE TOLERANCE WITH RESPECT TO SET PRESSURE	REQUIRED BLOWDOWN
SECTION I Boilers	6% (PG-67.2)*	One valve \leq MAWP Others up to 3% above MAWP (PG-67.3)	± 2 psi up to and including 70 psi ± 3 % for pressures above 70 psi up to and including 300 psi ± 10 psi for pressures above 300 psi up to and including 1000 psi ± 1 % for pressures above 1000 psi (PG-72.2)	Minimum: 2% of set pressure or 2 psi whichever is greater Maximum: 4% of set pressure or 4 psi whichever is greater, with some exceptions (see PG-72)
Forced Flow Steam Generators	20% (PG-67.4.2)	May be set above MAWP; Valves must meet overpressure requirements (PG-67.4.2)	Same as above (PG-72.2)	Maximum: 10% of set pressure (PG-72)

* Note: References in parentheses are to Code paragraphs.

1 psi = 6.89 kPa

Table 2(b) Section III requirements

PRESSURE RELIEF DEVICE OPERATING REQUIREMENTS				
APPLICATION	ALLOWABLE VESSEL OVERPRESSURE (ABOVE MAWP OR VESSEL DESIGN PRESSURE)	SPECIFIED PRESSURE SETTINGS	SET PRESSURE TOLERANCE WITH RESPECT TO SET PRESSURE	REQUIRED BLOWDOWN
SECTION III NB NC ND NE	10% above the design pressure of any component within the pressure retaining boundary of the protected system (NB-7311b) (NC-7311b) (ND-7311b) Overpressure may not exceed the service or test limits specified in the Design Specification (NE-7110a)	One valve \leq design pressure Additional valves higher provided limits on overpressure are maintained (NB-7410) (NC-7410) (ND-7410) Valves must be set to operate within overpressure limits (NE-7410)	Safety Valves ± 2 psi for pressures up to and including 70 psi ± 3 % for pressures above 70 psi up to and including 300 psi ± 10 psi for pressures above 300 psi up to and including 1000 psi ± 1 % for pressures above 1000 psi (NB-7512.2) (ND-7512.2) (NC-7512.2) Safety Relief and Relief Valves ± 2 % for pressures up to and including 70 psi (NB-7513.1a) (ND-7513.1a) (NC-7513.1a) (NE-7512.1a) ± 3 % for pressures over 70 psi (NB-7513.1a) (ND-7513.1a) (NC-7513.1a) (NE-7513.1a)	Safety Valves 95% of set pressure (maximum), or as specified in design specification (NB-7512.3) As specified in design specification (NC-7512.3) (ND-7512.3) (NE-7512.2) Safety Relief and Relief Valves As specified in design specification (NB-7513.2) (NC-7513.2) (ND-7513.2) (NE-7512.2)

(Continued)

1 psi = 6.89 kPa

Table 2(b) (Continued)

PRESSURE RELIEF DEVICE OPERATING REQUIREMENTS				
APPLICATION	ALLOWABLE VESSEL OVERPRESSURE (ABOVE MAWP OR VESSEL DESIGN PRESSURE)	SPECIFIED PRESSURE SETTINGS	SET PRESSURE TOLERANCE WITH RESPECT TO SET PRESSURE	REQUIRED BLOWDOWN
SECTION III (Continued)				
NB			<u>Pilot Operated Pressure Relief Valve</u> Same as safety valve above (NB-7525 b)	<u>Pilot Operated Pressure Relief Valve</u> Same as safety valve (NB-7524) (NC-7525 2) (ND-7524 2)
NC			Same as safety relief valve above (NC-7523 3) (ND-7523 3)	
ND			<u>Power Operated</u> ± 1% of set pressure (NB-7532 b 1) (NC-7533 b 1)	<u>Power Operated</u> Same as safety valve (NB-7532 b 2) (NC-7533 b 2) (ND-7533 b 2)
NE			Same as safety valve above (ND-7533 b 1)	
			<u>Rupture Disc</u> ± 2% of burst pressure for pressures up to 40 psi (NB-7611) (NC-7612) (ND-7612)	
			± 5% of burst pressure for pressures above 40 psi (NC-7612) (ND-7612)	

1 psi = 6.89 kPa

Table 2(c) Section IV requirements

PRESSURE RELIEF DEVICE OPERATING REQUIREMENTS				
APPLICATION	ALLOWABLE VESSEL OVERPRESSURE (ABOVE MAWP OR VESSEL DESIGN PRESSURE)	SPECIFIED PRESSURE SETTINGS	SET PRESSURE TOLERANCE WITH RESPECT TO SET PRESSURE	REQUIRED BLOWDOWN
SECTION IV				
Steam Boiler	5 psi (HG-400.1e)	≤15 psi (HG-401.1a)	±2 psi (HG-401.1k)	2 - 4 psi (HG-401.1e)
Hot Water Boiler	10% for a single valve 10% above highest set valve for multiple valves	One valve at or below MAWP Additional valves up to 6 psi above MAWP for pressures to and including 60 psi and up to 5% for pressures exceeding 60 psi (HG-400.2a)	±3 psi up to and including 60 psi ±5% for pressures above 60 psi (HG-401.1k)	None specified

1 psi = 6.89 kPa

Table 2(d) Section VIII requirements

PRESSURE RELIEF DEVICE OPERATING REQUIREMENTS				
APPLICATION	ALLOWABLE VESSEL OVERPRESSURE (ABOVE MAWP OR VESSEL DESIGN PRESSURE)	SPECIFIED PRESSURE SETTINGS	SET PRESSURE TOLERANCE WITH RESPECT TO SET PRESSURE	REQUIRED BLOWDOWN
SECTION VIII Div. 1 & 2				
All vessels unless an exception specified	10% or 3 psi - whichever is greater (UG-125c) (AR-150a)	≤ MAWP of vessel (UG-134a) (AR-141)	± 2 psi up to and including 70 psi	None specified
Exceptions: When multiple devices are used	16% or 4 psi - whichever is greater (UG-125 c1) (AR-150b)	One valve ≤ MAWP, additional valves up to 105% of MAWP (UG-134a) (AR-142a)	± 3% over 70 psi (UG-134 d1) (AR-120d)	
Supplemental device to protect against hazard due to fire	21% (UG-125 c2) (AR-150c)	Up to 110% MAWP (UG-134b) (AR-142b)		
Device to protect liquified compressed gas storage vessel in fire (Div. 1 only)	20% (UG-125c3a)	≤ MAWP (UG-125c3b)	- 0% + 10% (UG-134 d2)	
Bursting disc	Same as above	Stamped burst pressure to meet requirements noted above (UG-134 - Note 56) (AR-140 - Note 15)	± 2 psi up to and including 40 psi ± 5% of stamped burst pressure at specified coincident disk temperature (UG-127a1a) (AR-131.1)	Note: Pressure relief valves for compressible fluids having an adjustable blowdown construction must be adjusted prior to initial capacity certification testing so that blowdown does not exceed 5% of set pressure or 3 psi, whichever is greater (UG-131 c3a) (AR-512)

1 psi = 6.89 kPa

plete range of settings of all the saturated steam safety valves on a drum-type boiler exceed 10 percent of the highest pressure to which any such valve is set. These rules apply primarily to safety valves on the drum. Section I does not advise a specific setting for safety valves on superheaters. Industry practice is to set these valves sufficiently below

MAWP that they will lift before the valves on the drum, thus helping to maintain a cooling flow of steam through the superheater.

Section III requires at least one pressure relief device to be set at or below design pressure. Additional devices may be set at slightly higher (but unspecified) pressures, so long as

Table 2(e) Section X requirements

PRESSURE RELIEF DEVICE OPERATING REQUIREMENTS				
APPLICATION	ALLOWABLE VESSEL OVERPRESSURE (ABOVE MAWP OR VESSEL DESIGN PRESSURE)	SPECIFIED PRESSURE SETTINGS	SET PRESSURE TOLERANCE WITH RESPECT TO SET PRESSURE	REQUIRED BLOWDOWN
SECTION X				
All vessels unless exception specified	10% or 3 psi - whichever is greater (RR-130a)	≤ Design pressure (RR-120)	Ref. Section VIII (RR-111)	None specified
Exceptions	16% or 4 psi - whichever is greater (RR-130b)	One valve ≤ design pressure, Others up to 105% of design pressure		
When multiple devices are used				
Additional hazard due to fire	121% (RR-130c)			

1 psi = 6.89 kPa

the maximum overpressure does not exceed 10 percent of design pressure when all devices are discharging.

Section IV steam boilers have an operating limit of 15 psi (103 kPa), so the safety valves must be set at 15 psi. Hot water heating boilers and hot water supply boilers are designed for pressures between 30 and 160 psi (207 and 1103 kPa) and/or temperatures not exceeding 250°F (121°C). (Above these limits the boiler would, by definition, be a power boiler falling within the scope of Section I.) The safety relief valves used on hot water heating boilers must be set at or below the MAWP, but typically these boilers are supplied with valves set at 30 psi (207 kPa), unless higher pressure is needed, as might be the case for tall apartment buildings.

Potable water heaters are designed for pressures up to 160 psi (1103 kPa), with a minimum of 100 psi (689 kPa), and for temperatures not exceeding 210°F (99°C). Although Section IV calls for each such heater to have at least one safety relief valve or pressure-temperature relief valve, they are routinely furnished with the latter type, which is activated either by pressure or temperature. The purpose of the 210°F (99°C) limit is to prevent any water discharged from relief valves from flashing to steam. The pressure setting of a single relief valve, or the low set valve when multiple valves are used, must be less than or equal to the MAWP of the heater, but is further limited to the lowest pressure for which any other component of the hot water system is designed.

With the exception of steam boilers, additional relief valves used on Section IV equipment may be set at pressures higher than MAWP (see Table 2).

Sections VIII and X require one valve to be set at or below MAWP. If additional valves are utilized, they may be set up to 5 percent above MAWP. Section VIII further allows a supplemental valve added to a vessel to protect against hazard due to fire to be set up to 10 percent above MAWP.

2.5 Set Pressure Tolerance. Each book section provides set pressure tolerances for a variety of applications. These are summarized in Table 2.

2.6 Blowdown. A pressure relief valve will generally not reseal until the inlet pressure is reduced below set pressure. The difference between actual opening pressure and reseating pressure is called blowdown. For Section I, blowdown is generally specified as the greater of 2 percent of set pressure or 2 psi (13.8 kPa), minimum, to 4 percent of set pressure or 4 psi (27.6 kPa), maximum. Code Case 2071 permits a 6 percent blowdown for safety valves whose set pressure does not exceed 250 psi. Section III allows 5 percent blowdown for safety valves, unless a different value is allowed by the design specification. For other types of valves, blowdown is specified in the design specification. Section IV specifies 2–4 psi (13.8–27.6 kPa) blowdown for steam boilers, but is silent on other types of equipment. Sections VIII and X have no

specified blowdown requirements. Section VIII does, however, require that pressure relief valves for compressible fluids having an adjustable blowdown construction be adjusted prior to initial certification testing, so that blowdown does not exceed 5 percent of set pressure or 3 psi (20.7 kPa), whichever is greater, during the test. This requirement is often misconstrued to be an operating requirement, which it is not. Blowdown requirements are summarized in Table 2.

3 Selection of Pressure Relieving Devices

When the required relieving capacity has been established and the allowable set pressure and overpressure determined, the pressure-relieving devices can then be selected. The choice of device is limited to those permitted by the particular book section covering the service in question. The first broad category of allowable overpressure protection devices comprises the reclosing pressure relief devices.

The reclosing pressure relief device most widely accepted by the various book sections of the Code is the "spring-loaded pressure relief valve." This valve consists of a nozzle attached to an opening in the protected system with a disk held against the open end of the nozzle by a spring. When the system pressure acting against the disk overcomes the spring force, the disk opens and fluid flows from the system. One particular type of spring-loaded valve is the "balanced valve," sometimes called a "balanced bellows valve," wherein a bellows having an effective area equivalent to the valve seat area is attached to the disk to prevent backpressure in the valve's discharge system from acting on the disk and affecting its opening pressure. A variation on the balanced bellows valve is the "balanced piston design" required by article NB-7511 of Section III, where a redundant piston is provided in addition to the balanced bellows.

Traditionally, spring-loaded valves for boiler or steam application have been called "safety valves;" spring-loaded valves for liquid application have been called "relief valves;" and multi-purpose spring-loaded valves which might be used for steam, other compressible fluids, or liquid, have been called "safety relief valves." None of these terms fully describes the design or function of a "pressure relief valve;" and in many cases, the terms are used interchangeably. The more generic term, pressure relief valve, has replaced the three definitions in some portions of the Code.

A spring-loaded pressure relief valve is permitted by all sections of the Code as an overpressure protection device. Operational and construction requirements, however, vary among the book sections. The popularity of this design is due to the reliability of having few moving parts, the repeatability of an opening point controlled by a spring, and the ability of the valve to close when an overpressure condition is reduced to a safe level. However, systems with unusual piping configurations, a desire to operate at pressures close to valve set

pressure, requirements for on-site testing, and a need for improved seat tightness have led to the development and acceptance of other types of pressure relief valves.

A variation on the spring-loaded valve is the "anti-simmering-type valve" allowed in Section III service only. This valve employs an auxiliary actuator to hold the disk closed under normal operating conditions, using an external source of power such as compressed air. The external loading is limited so that if the device should fail, the valve will still open (despite the external load) and pass its rated flow within the specified overpressure. When the valve is called upon to open, the assisting load is removed automatically and the valve opens. When a safe pressure is restored, the auxiliary actuator assists in closing the valve. Seat tightness is enhanced up to the opening pressure of the valve due to the auxiliary load.

A second type of auxiliary device used on spring-loaded valves is the "anti-chatter device." This is an auxiliary actuator which assists the valve to open and then allows the valve to reseal normally. When the valve is called upon to open, the assist device is actuated, opening the pressure relief valve by mechanical means. When a safe pressure is restored, the assist device is de-actuated and the valve closes normally. If the assist device should fail to operate, there is no interference with the normal operation of the valve.

Section III valves with auxiliary anti-simmer and anti-chatter devices must be constructed so that the failure of the auxiliary device does not interfere with proper operation of the valve. These devices are not specifically addressed by the other sections of the Code. This may be because, in order for them to be effective, the set pressure at which the spring-loaded valve is adjusted to open may be higher than normally allowed, even though the valve with its auxiliary device may be set to open within allowable limits.

Another type of pressure relief valve is the "pilot-operated pressure relief valve." This is a valve in which the major relieving device or main valve is combined with and controlled by a self-actuated auxiliary pressure relief valve or pilot. The main valve consists of a nozzle and a disk similar to the spring-loaded valve, except that the disk is held in place by system pressure. When system pressure rises above the set pressure of the valve, the pilot senses that pressure and vents the pressure above the disk, allowing the main valve to open. As with spring-loaded valves, the pilot-operated pressure relief valve is self-operated using only system fluid as the operating medium. Pilot-operated pressure relief valves have the advantage that their operation is less influenced by fluid conditions at the valve inlet; they generally can be tested in situ, and a high seating load is maintained up to the opening point of the valve. The valve has more operating parts, however, and because of typically small passages in the pilot, the cleanliness of the fluids on which the pilot-operated pressure relief valve operates could become a concern. Pilot-operated pressure relief valves are permitted by Sections III, VIII, and X.

A third type of pressure relief valve is the "power-actuated pressure relief valve." These valves differ from pilot-operated pressure relief valves in that they require an external energy source provided by electrical, pneumatic or hydraulic systems and generally operate in response to signals from pressure or temperature-sensing devices. These types of pressure relief valves offer the benefits of a wide variety of control systems, but have the disadvantage of relying on an external source of power which may fail under emergency conditions. Power-actuated relieving valves are often furnished on drum-type boilers as a convenience to the operators, even though for that type of boiler Section I permits no credit for their relieving capacity. Power-actuated pressure relief valves are permitted by Sections I and III, provided they are used in addition to self-actuated pressure relief valves in Section I

service, and provided redundant controls and energy sources are included for Section III service.

The second broad category of allowable overpressure protection devices comprises the nonreclosing devices. The most common nonreclosing device is a rupture disk device, which is designed to function by the bursting of a pressure containing disk. The rupture disk is the pressure containing and pressure sensitive element of the rupture disk device. Rupture disks may be designed in several configurations, such as plain flat, prebulged, or reverse buckling, and can be made of either ductile or brittle material.

A rupture disk is a relatively inexpensive device which, once opened, is not subject to conditions of instability. Also, rupture disks themselves are less likely to leak prior to opening. However, they do not reclose after opening and must be replaced after each overpressure event. In some circumstances, the operating point of some types of disk may be affected by pressure pulsations.

Rupture disks are permitted by Sections I, III, VIII, and X. Sections VIII, X, and subsections NC and ND of Section III, permit rupture disks to be used as the sole relieving device. In other sections, their application is limited; for example, Section I allows use of rupture disks only in combination with safety valves installed on organic fluid vapor generators. The rupture disk helps prevent leakage to the environment and protects the valve from the organic fluid, which can polymerize in service and cause valve malfunction. In some installations, rupture disks may be installed on the inlet and/or outlet of a pressure relief valve. When rupture disks are used in combination with pressure relief valves, an overpressure event causes rupture of the disk followed by opening of the valve, or vice versa, depending on which element is upstream. When pressure returns to normal, the pressure relief valve closes and prevents further loss of system fluid. The space between the rupture disk and the valve must be provided with a pressure gage, a try cock, a drain, a free vent with an excess flow check valve, or a telltale indicator, so that pressure cannot build up undetected in these spaces. A buildup of pressure between the rupture disk and the valve inlet will alter the bursting pressure of the rupture disk. Similarly, any buildup of pressure in the space between a pressure relief valve and a rupture disk on the valve outlet may alter the opening pressure of the valve.

Other types of nonreclosing devices are permitted, but for Section VIII use only. These devices are "nonreclosing spring-loaded pressure relief valves, breaking pins," and the relatively new "buckling pin device" recently allowed for Section VIII, Div. 1 use by Code Case 2091.

The nonreclosing spring-loaded pressure relief valve is designed so that the spring-loaded portion of the device opens at the specified set pressure, and remains open, until manually reset. Such a device may not be used in combination with any other type of pressure relief device.

A breaking pin device is a nonreclosing pressure relief device actuated by inlet static pressure. It functions by the failure in tension of a breaking pin which supports a pressure containing or closure member within the breaking pin device. When set pressure is reached, the breaking pin breaks, allowing the device to open and flow its rated capacity. The pin must be replaced before the device can be reclosed. Breaking pin devices may not be used alone, but only in combination with a spring-loaded pressure relief valve. Like rupture disks, they may be used to protect the valve from potentially harmful fluids or to reduce the likelihood of valve leakage.

A buckling pin device is one in which a piston resisting the vessel pressure is held in place by a slender pin in compression. The length and diameter of the pin are closely controlled so that its elastic buckling load in compression can be accurately predicted. When pressure in the vessel reaches set

pressure, the pin buckles, allowing the piston to move sufficiently to open a discharge port, thereby relieving the pressure. The pin must be replaced before the device can be returned to service.

One additional device found only in Section III for Class 2 and Class 3 applications is the "vacuum relief valve." Vacuum relief valves may be balanced, self-actuating, horizontally installed swing disk valves or vertically installed disk or pallet type valves. All vacuum relief valves must have provisions for adjustment of the differential pressure at which they open. These valves may employ an external source of energy such as electrical, pneumatic or hydraulic only if at least two independent external power-operated valve and control systems are employed so that the required relieving capacity is still available even if one of the valve systems should fail to operate.

The ASME Code normally does not prohibit specific designs. One exception to this rule, however, is the stipulation that a weight-loaded (as opposed to spring-loaded) valve may not be used for pressure relief. A weight-loaded pressure relief valve is similar to a spring-loaded valve, except that the spring is replaced by a weight. The problem with this type of valve is that any mechanical interference in the valve or tampering with the weight can compromise its pressure-relieving capability. However, such valves are not prohibited internationally, and are used for low pressure vents in the U.S. and elsewhere. A second prohibited type, in Section IV, is a bottom-guided or wing-guided disk design in which the guidance is provided on the process side of the disk. The concern in this case is possible fouling or sticking of the guide due to the process fluid.

The types of pressure relieving devices allowed by each book section of the Code are summarized in Table 1.

4 Design of Pressure Relief Valves

Although the primary emphasis of the ASME Code is on the design of boilers and pressure vessels, pressure relief devices are recognized as important appurtenances of the vessels. The Code provides guidance for the operational integrity of these devices, but with the exception of Section III, provides only limited design guidance for them. Most notably (again with the exception of Section III), design rules are not provided for determining wall thickness of pressure relief valves. Consequently, the manufacturers must look elsewhere: to the design basis published in such standards as ASME/ANSI B16.34 *Valves—Flanged, Threaded, and Welding End* and ASME/ANSI B16.5 *Pipe Flanges & Flanged Fittings*, or to other methods, from proof testing to design-by-analysis using finite element methods, to establish pressure and temperature ratings.

Design guidance for nonreclosing devices is even more limited, to what materials may be used for rupture disk holders, and what sampling and testing methods must be used to verify the stamped bursting pressure at coincident temperature.

4.1 Mechanical Requirements. The mechanical design rules focus on the operability and reliability of the valve. To insure the integrity of the spring, for example, the designer must limit the full lift spring compression to no greater than 80 percent of nominal solid deflection. As an added safeguard, the spring must not exhibit a permanent set of more than 0.5 percent of free height after being compressed to solid height three times. These rules are intended to ensure that the spring does not relax under load, causing a variation in valve set pressure.

The operating or moving parts of a valve must be free at all times. Thus, drains are generally required below valve seats, to avoid collection of liquids or deposits which might

inhibit free operation. Sections I, IV, VIII, and X also require lifting levers which allow a valve to be mechanically operated from time to time to verify that it is free to operate. Except for Section IV valves, the lever must be able to lift the disk when inlet pressure is above 75 percent of set pressure. Levers on Section IV valves must be able to lift the disk at least 1/16 in. with no pressure in the boiler. Levers are required for all Section I and IV valves, and for Section VIII and X valves in steam, air, and hot water (over 140°F (60°C)) service. Many users are concerned about the release of undesirable fluids into the atmosphere, so levers are not generally used for fluids other than steam, air, and water. The requirement for a lifting device on a pilot operated pressure relief valve may be satisfied by providing a connection for applying pressure to the pilot to verify that the critical moving parts are free to move.

Other rules relate to the integrity of external adjustments. After a manufacturer, assembler, or other authorized agent adjusts a pressure relief valve, the adjustment must be sealed, generally with a lead seal on wire. Except for Section IV valves, the seal must be marked to identify the organization making the adjustment, and the design must be such that the seal has to be broken to change the adjustment.

The structural integrity of most pressure relief valves is further assured by a Code requirement for the manufacturer to hydrostatically test the primary side of the valves.

4.2 Materials. Sections I, IV, VIII, and X of the Code define two categories of materials acceptable for pressure relief valve construction: one for external pressure-containing parts of the device (e.g., the body and bonnet of the valve), and a second for internal parts, such as valve nozzles and disks. In the first category, materials are limited to those normally used for vessel construction, which are listed in the governing book section. The chemical composition, physical properties, allowable stresses, and weldability of these materials are well known. However, the designer of pressure relief valves must also consider other properties important for proper valve function, such as corrosion resistance of seats, disks, springs, and adjacent sliding surfaces; anti-galling characteristics for sliding surfaces; high strength for valve springs; and erosion resistance for valve seating.

Section I, Section VIII Div. 1, and Section X also permit the use of some eighteen other material specifications for pressure containing valve parts, under Code Case 1750. This case has evolved as a means of permitting the use of new materials without requiring the valve manufacturer to undertake the extensive and burdensome procedures normally required to qualify material for vessel construction, and normally used by the appropriate Code committee to establish allowable design stresses as a function of temperature. Case 1750 thus includes no allowable stresses, leaving the designer to choose his own, presumably using book section criteria.

In the second category of materials, (for internal parts), the Code permits a much wider latitude, limiting materials to those listed in Section II, listed in ASTM specifications, or controlled by a specification which provides "control of chemical and physical properties and quality at least equivalent to ASTM standards." The purpose of this requirement is to help assure consistent quality of these components.

Section III of the Code generally requires that pressure retaining materials be limited to those normally used for vessel construction, which are listed in Section II, Part D. The valve manufacturer is allowed a broader latitude for section of materials for internal parts.

5 Establishing and Certifying Relieving Capacities

Many codes and standards applicable to pressure relief valves worldwide specify performance requirements similar

to those found in the ASME Code and regulatory bodies may require capacity certification and testing of valves. However, only the ASME Code requires the pressure relief valve manufacturer to demonstrate performance and relieving capacity of production pressure relief valves, by a test performed at an ASME accepted test facility, supervised by an ASME Authorized Observer, and witnessed by a qualified third party designated by the ASME. Performance and capacity testing of pressure relief valves was first mandated (by Section I of the Code) in 1937, following a program of valve testing sponsored by the National Board of Boiler & Pressure Vessel Inspectors. These tests, conducted in 1935 and 1936, in some cases showed actual discharge capacities significantly less than those claimed by the valve manufacturer [2].

The procedures used for capacity testing, and the formulas used to determine capacity are based on the assumption that compressible flow through the valve is critical (acoustically choked), i.e., it is essentially a function of inlet pressure. For steam flow, the capacity is assumed to follow Napier's formula which also states that flow is proportional to inlet pressure. For dry saturated steam above 1500 psi, the Code specifies a correction factor for Napier's formula. For incompressible flow of nonflashing (sub-cooled) liquids, the capacity is assumed proportional to the square root of the pressure drop across the valve. Pressure relief valve capacity certification tests conducted at the relatively low pressures available at test laboratories in the 1930s are still valid today. Extrapolation of valve capacities based on low-pressure tests of small valves to higher pressures and larger sizes continues to be acceptable Code practice.

All ASME pressure relief valves must be marked by the manufacturer with an ASME Code symbol. Before the ASME Code symbol may be applied to a pressure relief valve, its relieving capacity must first be certified, and then confirmed by tests of randomly selected production valves. This process generally involves an initial or "provisional test" whereby a number of valves are tested to determine the "rated relieving capacity," and to demonstrate consistency of valve relieving performance, in accordance with the requirements of the applicable book section. This is followed by periodic testing (initially, and at least every 5 yr thereafter) of randomly selected production valves in the presence of a representative of the National Board who serves as an ASME designee. This ongoing testing verifies that production valves continue to perform as originally certified.

The initial or provisional testing of valves which are to be used on compressible fluids is performed on dry saturated steam, air, or natural gas. For Section VIII use, if the valve is intended for use on steam, at least one of the certification valves must be tested on steam. Valves which are to be used for incompressible fluid service must be tested on water.

Before each test is performed, valve set pressure must be checked for compliance with the applicable book section (i.e., it must meet the opening pressure tolerance). The capacity test is then performed at the "allowable overpressure above set pressure" specified in that same book section.

The book sections specify various operational and performance requirements for pressure relief valves; some apply during testing and service, others apply only during testing. For example, Section VIII imposes a 10 percent overpressure limit during testing and service, but its 5 percent blowdown requirement only applies during provisional testing on compressible fluids, and then only if the blowdown is adjustable. There is some minor variation in test procedure among the various book sections.

There are three different methods used for certification testing: the Three Valve Method, the Four Valve Method, and the Coefficient of Discharge Method.

The Three Valve Method. If it is intended to test a *single*

valve design at a single set pressure, three identical valves, all set at the same pressure, are tested to determine capacity. Each of the measured capacities must fall within ± 5 percent of the average of three capacities. This average capacity is then multiplied by 0.9 to determine the official certified capacity to be stamped on the valve, for this valve design at the particular pressure chosen.

The Four Valve Method. This method is used to determine the capacity of a *single valve design over a range of set pressures*. The four valve method is also known as the slope method, since there is a straight line relationship between capacity and absolute inlet pressure for compressible fluids, and between the log of capacity and the log of pressure drop across the valve for incompressible fluids. In this method, four valves of the same size are set at four different pressures, and the capacity of each valve is determined by test. For *compressible fluids*, each measured capacity is divided by the absolute flowing pressure to determine a slope, in lb per hr per psi (kg per hr per Pa). The slope derived from each individual test must fall within 5 percent of the average value of slope calculated from the result of all four tests. The rated, or certified, relieving capacity is then determined as 0.9 times the product of the average slope times the (absolute) set pressure plus allowable overpressure. For example, the certified capacity to be stamped on a Section I valve would be $0.9 \times \text{average slope} \times (1.03 \times \text{set pressure} + 14.7)$. For *incompressible fluids*, the capacities determined from the four tests are plotted on log paper against the differential test pressure (inlet pressure minus discharge pressure) and a straight line drawn through the four points. Individual points may not depart more than 5 percent from the straight line. The relieving capacity is then determined from this plotted line. The certified capacity may not exceed 0.9 times the capacity taken from the line. The results of the four valve method may be extrapolated to cover a larger range of pressures.

When a *complete line of valves* consisting of various inlet sizes, orifice sizes, and set pressures is to be certified, the "coefficient of discharge method" is used. In this case, three valves of each of three different sizes (a total of 9 valves) are tested, with each valve of a given size set at a different pressure. From each test, a coefficient of discharge is calculated equal to the actual flow measured divided by a theoretical flow determined from formulas appropriate to the fluid being used. Each of the calculated coefficients of discharge must fall within ± 5 percent of an average coefficient of discharge calculated from the results of the nine tests. For Sections III and VIII the average coefficient of discharge is then multiplied by 0.9 to determine the rated coefficient of discharge to be used for calculating the rated relieving capacity of that line of valves. For valves certified per the rules of Sections I and IV, the average coefficient is used directly and the 0.9 factor is included in the formula used for calculating the relieving capacity.

All provisional tests must be performed at an ASME accepted test facility which meets the requirements of reference [3], and must be supervised by an individual (Authorized Observer) whose qualifications must also meet the requirements of [3]. The facilities, procedures, and qualifications of the Authorized Observer must be accepted by ASME on the recommendations of an ASME designee. (The National Board is the ASME designee when pressure relief devices are involved.) Continued acceptance of the testing facility is subject to review by an ASME designee within each 5-yr period.

The valves selected for testing must fall within the capacity of the accepted test facility. Valves larger than those actually tested are therefore designed with flow paths geometrically similar to those of the valves actually tested. The results of

capacity testing can thus be extrapolated for the stamping of larger valves.

Once the pressure relief valve capacity has been determined and certified, and before the Code symbol stamp can be applied, two production valves must be selected by an ASME designee and tested to verify operation and stamped capacity. These tests are performed at an ASME accepted facility supervised by an Authorized Observer and witnessed by a designated representative of the ASME. Thereafter, two more production valves must be selected and tested within each 5-yr period. Should any valve fail to meet specified performance requirements or the stamped capacity, additional valves must be selected and tested. Two valves are selected and tested for each valve which failed. Continued or unexplained failure may cause the revocation of the manufacturer's or assembler's authorization to use the Code symbol stamp on that particular design of valve.

Test data from the initial or provisional test and the subsequent production test are signed by the manufacturer and Authorized Observer and submitted to the ASME designee for review and acceptance. The rated capacities at various pressures, the rated capacity slope, or coefficient of discharge, as applicable for each valve design are then listed in a book entitled *Pressure Relief Device Certifications*, published annually by the National Board of Boiler and Pressure Vessel Inspectors of Columbus, Ohio. Over the years the National Board has issued over 1100 valve capacity certifications to more than 80 manufacturers worldwide, covering air, gas, steam, and liquid service.

The capacity certification requirements for each of the book sections of the Code are similar with the exception of Section III. That section requires initial or provisional certification testing only; it does not require subsequent and periodic retesting of valves selected from production. There are other requirements in each of the book sections for pressure relief devices other than valves (e.g., rupture disks), and those devices in combination with valves. These requirements are similar to those described for valves.

Questions are sometimes asked about the so-called derating factor applied to certification test results to determine stamped capacity. There is a perception that a pressure relief valve could actually pass considerably more fluid than the stamped capacity would indicate. In fact, valves supplied as "non-Code" valves are sometimes stamped with capacities which do not include the derating factor. Nevertheless, there are several reasons to require the use of the 0.9 factor. Individual valves which have been tested as part of the capacity certification program may have demonstrated capacities up to 5 percent below the average used as the reported test value. This reduces the potential difference between the stamped capacity and the tested capacity of those valves to only 5 percent. Moreover, it is reasonable to expect that further variation may occur due to normal manufacturing tolerances. Considering the importance of adequate pressure relieving capacity, the concerned committees chose to apply a conservative derating factor to the reported test value, to assure that actual flow through the device at specified overpressure will always equal or exceed its stamped capacity. However, the designer of the valve discharge system should recognize the possibility of flow (and resulting discharge forces) larger than those based on rated capacities.

6 The Qualification of Pressure Relief Valve Manufacturers

A unique aspect of the ASME Code is a requirement for the manufacturer of pressure relief valves to demonstrate, to the satisfaction of a designated representative of the ASME, that his manufacturing, production, and test facilities, and his quality control system, will insure close agreement between

the performance of production valves and the performance of the valves submitted for certification. The valve manufacturing control systems must be documented in the manufacturer's quality control manual. That manual is reviewed by an ASME designee to insure compliance with ASME Code requirements. At the present time, the ASME designates the National Board of Boiler & Pressure Vessel Inspectors to review the manufacturer's facilities and operations. When the ASME is satisfied with a manufacturer's qualifications, a Certificate of Authorization is issued to the manufacturer, good for three years, allowing him to use a Code symbol stamp to mark pressure relief devices he manufactures, as evidence of ASME Code compliance. The review of a manufacturer's manual and system is repeated every three years, before his certificate can be renewed. This periodic review of pressure relief device manufacturers differs from the usual ASME third party inspection system, in which an Authorized Inspector monitors boiler and pressure vessel manufacturers on an ongoing basis to assure Code compliance. However, the relief device manufacturer's operations are subject to inspections at any time by an ASME designee, although unannounced inspections are rare in the absence of a specific complaint.

The manufacturer must perform a series of production tests on each pressure relief valve. Each valve is tested to verify that set pressure, seat tightness, and in some cases (Sections I and IV steam valves) blowdown, meet the requirements specified in the applicable book section. The acceptance standard for seat tightness on steam and water is generally expressed as "no visible leakage." Seat leak tests performed on air must generally meet industry accepted standards.

Production testing of nonreclosing devices in which a component is required to break cannot be used to demonstrate opening of the actual component. Instead, duplicate parts, such as disks for a rupture disk device or pins for a breaking pin device, are manufactured from the same lot of material as the part to be supplied. These duplicates are tested to failure to verify proper operation of the device to be shipped.

Since the mid-1970s, the ASME has also recognized and authorized organizations known as assemblers to assemble and Code stamp pressure relief valves using only original unmodified parts obtained from a valve manufacturer. The assembler must assemble, adjust, test, and seal the valves under the same ASME system of oversight and quality control as the original valve manufacturer.

7 Installation Guidelines

The safety valve rules of the ASME Code deal primarily with design and functional requirements of pressure relief devices, while providing only limited guidance on their installation. However, a few key installation requirements are provided for pressure relief devices in each of the book sections. For example:

1 A pressure relief valve must be installed as close as possible to the vessel or system being protected. This is to minimize inlet pressure drop, which can lead to valve malfunction such as chatter.

2 The opening through all pipe and fittings between a pressure vessel and its pressure relieving device must have at least the area of the inlet to the pressure relieving device. This, too, is to minimize inlet pressure drop.

3 A pressure relief valve must generally be mounted in a vertical position to minimize any potential rescating problems caused by lateral gravity loading.

4 Discharge lines, and in many cases valve bodies, must be

provided with drains to prevent any accumulation of liquid or sediment which could interfere with proper operation.

5 With some few exceptions, no valves may be placed between a pressure relief device and the vessel it is protecting, or on the discharge side, between the device and the atmosphere, since such valves could be inadvertently left in the closed position and thus nullify the overpressure protection.

6 Section I of the Code invokes the use of ASME B31.1 *Power Piping* for the design of certain boiler piping known as boiler external piping. *Power Piping* contains Appendix II, *Nonmandatory Rules for the Design of Safety Valve Installations*. This appendix provides advice on determining loads due to valve discharge and loads on vent stacks, on sizing vents to prevent blowback, and allowable stress criteria for various combinations of loads. It also includes guidance on locating safety valves away from pipe bends, to avoid flow induced vibrations.

7 Both divisions of Section VIII contain nonmandatory appendices (M and A, respectively), *Installation and Operations*, which provide useful supplementary information and guidance regarding pressure relief devices. (Section X has a similar but shorter appendix). In some instances suggested alternatives differ from the mandatory rules of Section VIII; these alternative rules may be used only with permission of the local jurisdictional authorities where the vessel is installed. Among the topics covered are the use of stop valves between a pressure relieving device and the vessel being protected or on the discharge side of the device, a suggested limit on pressure drop between a vessel and the relief device, design considerations for discharge piping, the use of common discharge headers, advice on differentials between operating and set pressure, the effects of relief valve reaction forces, and guidance on the sizing of pressure relief devices for fire conditions. A useful list of references is also provided. Both divisions of Section VIII also contain identical mandatory appendices (11 and 10, respectively), which provide methods for determining the capacity of pressure relief valves on fluids other than the one on which the valve was officially rated.

8 Concluding Remarks

Since the ASME Code with few exceptions applies to *new construction only*, once new pressure relief devices are installed on a boiler or pressure vessel, adjusted, set, and sealed by the device manufacturer or an assembler, the Code rules no longer directly apply. However, although any subsequent work on these devices is not directly covered by the Code, the local jurisdictional authorities refer to and use the Code rules as guidelines. For example, the National Board under its VR (valve repair) program authorizes organizations of proven capability to service, repair, adjust, set, and seal pressure relief valves that have been in service. The objective is to restore and maintain the valves so they will continue to function as when new and thus continue to meet the Code rules for newly installed safety valves on new vessels.

A word of caution is appropriate here. Pressure relief valves are tested for operation and capacity under optimum conditions: inlet pressure drop and back pressure are minimal; all adjustments on the valve are set and sealed by the manufacturer or an assembler, who is qualified to make these adjustments. When any of these conditions is not as it should be, the relieving capacity and proper operation of the valve

can be compromised. That is why the Code requires that all piping and fittings leading to and from pressure relief valves be adequate to minimize inlet pressure drop and buildup of back pressure. Excessive inlet pressure drop can lead to valve chatter and damage; excessive back pressure may reduce capacity. Tampering with adjustments by unqualified persons can cause failure to open at set pressure, failure to achieve full lift (and certified capacity), failure to reseal properly, and the possibility of damage due to unstable operation. For all these reasons, the concerned committees recently revised the rules to permit valve adjustment only by the manufacturer or assembler of the valve. However, since these rules apply to new construction only, they do not assure that only qualified individuals will be allowed to adjust these valves in service. It is important that valves in service be maintained so that they will perform as when originally manufactured.

The minimum design pressure of equipment covered by the ASME Code is for practical purposes 15 psi (103 kPa). Thus, the ASME rules do not generally apply to pressure relief valves for lower pressures. However, there is a Section III Code Case, N-410, which permits certification of relieving capacities for set pressures as low as 3 psi (20.7 kPa).

8.1 Summary. The overpressure protection rules of the ASME Code are based on an integrated system of accreditation and certification which applies to the different parties involved: manufacturers of boilers or pressure vessels, manufacturers of pressure relief devices, testing laboratories, Authorized Observers who supervise the testing, and an ASME designee (a representative of the National Board) who reviews the facilities, quality control systems, and activities of organizations involved in Code construction. Overpressure protection of boilers and pressure vessels may be provided only by use of devices allowed by the section of the Code applicable to the vessel or system being protected.

The ASME overpressure protection rules, with their integrated system of oversight and quality control, have achieved an outstanding safety record. Confirmation of this record is evidenced by the adoption of similar rules in the standards of many other countries, including the draft standards currently being considered by the International Standards Organization and the European Committee for Standardization.

References

- 1 ASME N626.3, *Qualifications and Duties of Specialized Professional Engineers*, 1993. (Note: Soon to be incorporated into Section III.)
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- 3 *Pressure Relief Devices*, ASME Performance Test Code PTC 25, 1994.
- 4 ASME Boiler & Pressure Vessel Code, 1992 Edition with 1993 Addenda.
- 5 *Pressure Relief Device Certifications*, National Board of Boiler & Pressure Vessel Inspectors, Columbus, Ohio.
- 6 *Power Piping*, ASME B31.1, 1992 Edition.
- 7 National Board "VR" Repair Symbol Administrative Rules and Procedures, Repair of ASME and National Board Stamped Pressure Relief Valves, NB-65, National Board of Boiler & Pressure Vessel Inspectors. (Note: Soon to be incorporated into National Board Inspection Code, ANSI/NB-23.)
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