In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Technical Oversight Management Committee (TOMC)

Where reference is made to “the Committee” in this Foreword, each of these committees is included individually and collectively.

The Committee’s function is to establish rules of safety relating only to pressure integrity, which govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase engineering judgment refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the

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*The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI’s requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

**Construction, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.**
ARTICLE RG-2
ORGANIZATION

RG-200 ORGANIZATION OF THIS SECTION

RG-201 PARTS

This Section is divided into nine major parts:

(a) Part RG, General Requirements, applying to duties and responsibilities and methods of fabrication;

(b) Part RM, Material Requirements, setting forth rules governing materials applicable to all methods of fabrication;

(c) Part RD, Design Requirements, providing design requirements for all methods of fabrication;

(d) Part RF, Fabrication Requirements, giving rules for permissible methods of fabrication;

(e) Part RQ, Qualification Requirements, used in carrying out the methods of fabrication;

(f) Part RR, Pressure Relief Devices, giving rules for pressure relief devices;

(g) Part RT, Rules Governing Testing, establishing the following:

(1) methods for qualifying designs and procedure specifications, for quality control testing, and for production testing;

(2) methods for determining lamina strength and elastic properties for design criteria and acceptance testing of Class II vessels;

(h) Part RI, Inspection Requirements, setting forth minimum inspection requirements;

(i) Part RS, Marking, Stamping, and Reports, setting forth marking, stamping, and reporting requirements.

RG-202 ARTICLES, PARAGRAPHS, AND SUBPARAGRAPHS

(a) The Parts of this Section are divided into Articles. Each Article is given a number and a title, (e.g., Part RG, Article RG-3, Responsibilities and Duties).

(b) Articles are divided into paragraphs, which are a three- or occasionally a four-digit number, the first of which corresponds to the Article number; thus under Article RG-3 we find paragraph RG-310, User’s Responsibilities.

(c) Paragraphs are divided into subparagraphs. Major subdivisions of paragraphs are designated by suffixing to the above-mentioned three- or four-digit numbers a decimal point followed by a digit or digits. Where necessary, divisions of subparagraphs are indicated by letters and further subdivisions by numbers in parentheses.

(d) Minor subdivisions of paragraphs are indicated by letters instead of decimals followed by digits.

(e) A reference in one of the paragraphs of this Section to another such paragraph includes all of the applicable rules in the referenced paragraph and its subdivisions, unless otherwise stipulated.

(f) Part ROP, Overpressure Protection, giving rules for protection against overpressure.
RD-111 DESIGN PRESSURE

The design pressure is the pressure used in the design of the vessel for the purposes of establishing minimum thickness or minimum laminate requirements of the different zones of the vessel. Static head shall be included in the design pressure to determine the minimum thickness or minimum laminate requirements of any specific zone of the vessel.

For Class I vessels, the design pressure at any point under consideration shall not exceed the lower of 150 psi (1 MPa) for bag-molded, centrifugally cast, and contact-molded vessels, and 1,500 psi (10 MPa) for filament-wound vessels, or one-sixth of the bursting pressure determined in accordance with the rules of Article RT-2. The same design pressure at any point under consideration shall not exceed the lower of 3,000 psi (20 MPa) for filament-wound vessels with polar boss openings or one-fifth of the bursting pressure determined in accordance with the rules of Article RT-2.

For Class II vessels, the design pressure shall not exceed the limits specified in RD-1120.

RD-112 DESIGN TEMPERATURE

RD-112.1 Maximum Design Temperature. For Class I vessels, the maximum design temperature, even though a lower operating temperature is specified in the Design Specification, shall be taken as 150°F (65°C) for design temperatures less than or equal to 150°F (65°C), or at the specified design temperature when the design temperature exceeds 150°F (65°C). When the design temperature exceeds 150°F (65°C) on Class I vessels, the specified design temperature shall not exceed 250°F or 35°F (120°C or 19°C) below the maximum use temperature (see RM-121) of the resin, whichever is lower. The hydrostatic qualification pressure tests used to establish the permissible design pressure shall be conducted at that temperature (see Article RT-2). For Class II vessels, the design temperature shall not be less than the interior laminate wall temperature expected under operating conditions for the part considered and shall not exceed, 250°F or 35°F (120°C or 19°C) below the maximum use temperature (see RM-121) of the resin, whichever is lower.

RD-112.2 Minimum Design Temperature. The minimum permissible temperature to which a vessel constructed under this Section may be subjected is −65°F (−54°C) (see RG-112).

RD-113 MAXIMUM ALLOWABLE WORKING PRESSURE

The Maximum Allowable Working Pressure (MAWP) is the maximum pressure at the top of the vessel in its normal operating position at the coincident laminate temperature. The MAWP for a vessel part is the maximum internal or external pressure including static head thereon.

RD-114 QUALIFICATION PRESSURE

The qualification pressure of a Class I vessel is the maximum hydrostatic pressure that has been attained by a prototype vessel and an optional internal bladder (see Mandatory Appendix 4). This pressure serves as proof of the adequacy of the vessel’s design and fabrication for the specified service conditions (see RT-223).

RD-115 TEST PRESSURE

The test pressure is that pressure applied at the top of the vessel. For Class I vessels see Article RT-4. For Class II vessels see Article RT-6 on acceptance testing.

RD-116 SAFETY VALVE SETTING

The pressure for which safety or safety relief valves shall be set to open is established in RR-120.

RD-120 LOADINGS

The loadings to be included in designing a vessel shall include any expected combination of loads listed below and stipulated in the Design Specification:

(a) internal and/or external design pressure as defined in RD-111;
(b) impact loads;
(c) weight of the vessel and normal contents under operating and test conditions (this includes additional pressure due to static head of liquids);
(d) superimposed loads, such as other vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings, and piping;
(e) live loads due to personnel, which shall be a minimum of 250 lb (1100 N) in a 4 in. (100 mm) circle on the top of the vessel;
(f) snow and ice loads;
(g) wind loads, and earthquake loads where required;
(h) reactions of supporting lugs, rings, saddles, and other types of supports;
(i) loads due to thermal expansion and thermal gradients.

RD-121 STRESS DUE TO COMBINED LOADINGS

The geometry and wall thickness of a vessel designed under this Section shall be such that:

(a) for Class I vessels, the maximum direct (membrane) stress due to all combinations of loadings listed in RD-120 that are expected to occur simultaneously during normal operation of the vessel shall not exceed one-sixth of the maximum membrane stress value, as determined from the qualification pressure test, and considering any additional membrane stresses caused by other test loadings in addition to the pressure loading (see RD-130 and RQ-132);
PART RR
PRESSURE RELIEF DEVICES

ARTICLE RR-1
GENERAL REQUIREMENTS

RR-100 PROTECTION AGAINST OVERPRESSURE

(a) All pressure vessels within the scope of this Section shall be provided with protection against overpressure in accordance with the requirements of this Article.

(b) Heat exchangers and similar vessels shall be protected against overpressure in case of an internal failure.

RR-110 TYPES OF OVERPRESSURE PROTECTION

Protection against overpressure shall be provided by one or a combination of the following devices:

(a) Direct spring-loaded safety or safety relief valves.

(b) Indirectly operated safety or safety relief valves, such as pilot-operated valves. Design of pilot-operated valves or other indirectly operated valves shall be such that the main unloading valve will open automatically at the set pressure and will discharge its full rated capacity if some essential part of the pilot or auxiliary device should fail.

(c) Rupture disks.

(d) Breaking-pin devices.

(e) Open flow paths or vents.

(f) Overpressure protection by system design.

RR-111 PROTECTION AGAINST EXTERNAL PRESSURE

Vessels used for potable water, as described in RG-113 (Section IV application), shall be equipped with a breather valve directly connected to the inside of the vessel.

RR-120 SET PRESSURE

When a single pressure relieving device is used, it shall be set to operate at a pressure not exceeding the design pressure of the vessel. When the required capacity is provided by more than one pressure relieving device, only one device need be set at or below the design pressure, and the additional devices may be set to open at higher pressures but no case at a pressure higher than 105% of the design pressure.

RR-121 PRESSURE EFFECTS TO BE INCLUDED IN SETTING

The pressure at which any device is set to open shall include the effects of static head and back pressure.

RR-130 PERMISSIBLE OVERPRESSURES

The combined capacity of the pressure relief devices shall be sufficient to prevent overpressure in excess of those specified below when the pressure relief devices are discharging at full capacity:

(a) When the overpressure protection is provided by a single pressure relief device, 110% of the design pressure or 3 psi (20 kPa) above design pressure, whichever is greater.

(b) When the overpressure protection is provided by multiple pressure relief devices, 116% of the design pressure or 4 psi (28 kPa) above design pressure, whichever is greater.

(c) For Class II vessels, the overpressure protection provision shall be established in the Design Specification.
ARTICLE RR-2
PROVISIONS IN VESSELS FOR INSTALLATION OF PRESSURE RELIEF DEVICES

RR-200 NUMBER, SIZE, AND LOCATION OF CONNECTIONS

RR-201 NUMBER OF CONNECTIONS

Vessels shall have at least one connection for mounting pressure relief devices directly on the vessel, or for connecting piping to pressure relief devices.

RR-202 SIZE OF OPENINGS AND NOZZLES

(a) Openings and nozzles constituting the connections specified in RR-201 shall be designed to provide direct and unobstructed flow between the vessel and its pressure relief devices.

(b) The area through the openings or nozzles and all pipe fittings between a pressure vessel and its pressure relief device shall be at least equal to the area of the pressure relief device(s) inlet and in all cases shall have sufficient area so as not to restrict the flow to the pressure device.

(c) When two or more required pressure relief devices are placed on one connection, the inlet internal cross-sectional area of this connection shall be at least equal to the combined inlet areas of the safety devices connected to it and in all cases shall be sufficient to not restrict the combined flow of the attached devices.

(d) Connections for liquid relief valves shall be at least NPS 1/2 (DN 15).

RR-203 LOCATION OF OPENINGS AND CONNECTIONS

(a) Openings and connections for pressure relief purposes shall be located so that the nature of the vessel’s contents will not hinder flow through such openings and connections.

(b) Connections for vapor pressure relief devices shall be located in the vapor space.

(c) Connections for liquid relief valves shall be below the normal liquid level.

RR-210 STOP VALVES BETWEEN THE VESSEL AND PRESSURE RELIEF DEVICE

There shall be no intervening stop valves between the vessel and its pressure relief device or devices, or between the pressure relief device or devices and the point of discharge, except:

(a) when the stop valves are so constructed or positively controlled that the closing of the maximum number of stop valves possible at one time will not reduce the pressure relief capacity provided by the unaffected relieving devices below the required relieving capacity; or

(b) under the conditions set forth in Nonmandatory Appendix AB.

RR-220 DISCHARGE LINES FROM PRESSURE RELIEF DEVICES

Discharge lines from pressure relief devices shall be designed to facilitate drainage or shall be fitted with an open drain to prevent liquid lodging in the discharge side of the safety device, and such lines shall lead to a safe place of discharge. The size of the discharge lines shall be such that any pressure that may exist or develop shall not reduce the relieving capacity of the relieving devices below that required to protect the vessel (see Mandatory Appendix 2).
PART ROP
OVERPRESSURE PROTECTION

ARTICLE ROP-1
GENERAL REQUIREMENTS

ROP-100 GENERAL

(a) This Part provides the acceptable methods and requirements for overpressure protection for pressure vessels constructed to the requirements of this Division. Acceptable methods include pressure relief devices, open flow paths, and overpressure protection by system design. It establishes the type, quantity and settings of acceptable pressure relief devices and relieving capacity requirements including maximum allowed relieving pressures. Unless otherwise specified, the required pressure relief devices shall be constructed, capacity certified, and bear the ASME Mark in accordance with Section XIII. In addition, this Part provides requirements for installation of pressure relief devices.

(b) All pressure vessels within the scope of this Section shall be provided with protection against overpressure in accordance with the requirements of this Part.

(c) Heat exchangers and similar vessels shall be protected against overpressure in case of an internal failure.

(d) Protection Against External Pressure - Vessels used for potable water, as described in RG-113 (Section IV application), shall be equipped with a breather valve directly connected to the inside of the vessel.

ROP-110 DEFINITIONS

Unless otherwise defined in this Section, the definitions relating to pressure relief devices in Section XIII shall apply.

ROP-120 RESPONSIBILITIES

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

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

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

   (1) Normal operation and upset conditions
   (2) Fluids
   (3) Fluid phases

(d) The overpressure protection system need not be supplied by the vessel manufacturer.

ROP-130 DETERMINATION OF PRESSURE RELIEVING REQUIREMENTS

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

(b) The aggregate capacity of the pressure relief devices connected to any vessel or system of vessels for the release of a liquid, air, steam, or other vapor shall be sufficient to carry off the maximum quantity that can be determined the required relief rate, size and select the device, and design the relief system.
generated or supplied to the attached equipment without permitting a rise in pressure within the vessel of more than that specified in ROP-140.

(c) Vessels connected together by a system of adequate piping not containing valves which can isolate any vessel, and those containing valves in compliance with Section XIII Nonmandatory Appendix B, may be considered as one unit in figuring the required relieving capacity of pressure relief devices to be furnished.

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

(e) The rated pressure-relieving capacity of a pressure relief valve for other than steam or air shall be determined by the method of conversion given in Section XIII Mandatory Appendix IV.

(f) The relieving capacity of a pressure relief device for compressible fluids may be prorated at any relieving pressure greater than $1.10p$, as permitted under ROP-140, by applying a multiplier to the official relieving capacity as follows:

(U.S. Customary Units)

$$\frac{P + 14.7}{1.10p + 14.7}$$

(SI Units)

$$\frac{P + 101}{1.10p + 101}$$

Where

$P =$ relieving pressure, psig (kPa gage)

$p =$ set pressure, psig (kPa gage)

ROP-150 PERMITTED PRESSURE RELIEF DEVICES

Protection against overpressure shall be provided by one or a combination of the following devices and methods in accordance with Section XIII:

(a) direct spring-loaded pressure relief valves bearing the ASME Certification Mark with the UV or HV Designator.

(b) pilot operated pressure relief valves bearing the ASME Certification Mark with the UV Designator.

(c) rupture disks bearing the ASME Certification Mark with the UD Designator.

(d) breaking pin devices bearing the ASME Certification Mark with the UD Designator.

(e) open flow paths or vents.

(f) overpressure protection by system design provided the requirements in ROP-140(b) and Section XIII Part 13 are met.
ROP-160 PRESSURE SETTING AND PERFORMANCE REQUIREMENTS

(a) When a single pressure relieving device is used, it shall have a set pressure at a pressure that does not exceed the design pressure of the vessel. When the required capacity is provided in more than one pressure relieving device, only one device need be set at or below the design pressure, and the additional devices may be set to open at higher pressures but in no case at a pressure higher than 105% of the design pressure.

(b) The pressure at which any device is set to open shall include the effects of static head and back pressure.

(c) Set pressure tolerance for pressure relief valves with the HV Designator shall not exceed 3 psi (20 kPa) for pressure up to and including 60 psi (400 kPa) and 5% for pressures above 60 psi (400 kPa).

(d) The burst pressure tolerance for rupture disk devices with the UD Designator at the specified disk temperature shall not exceed ±2 psi (15 kPa) of marked burst pressure up to and including 40 psi (300 kPa) and ±5% of marked burst pressure above 40 psi (300 kPa).

(e) The set pressure tolerance for pin devices with the UD Designator shall not exceed ±2 psi (15 kPa) of marked set pressure up to and including 40 psi (300 kPa) and ±5% of marked set pressures above 40 psi (300 kPa) at specified pin temperature.

ROP-170 INSTALLATION

(a) Number of Connections

Vessels shall have at least one connection for mounting pressure relief devices directly on the vessel, or for connecting piping to pressure relief devices.

(b) Size of Openings and Nozzles

(1) Openings and nozzles constituting the connections specified in (a) shall be designed to provide direct and unobstructed flow between the vessel and its pressure relief devices.

(2) The area through the opening or nozzles and all pipe fittings between a pressure vessel and its pressure relief device shall be at least equal to the area of the pressure relief device(s) inlet and in all cases shall have sufficient area so as not to restrict the flow to the pressure device.

(3) When two or more required pressure relief devices are placed on one connection, the inlet internal cross-sectional area of this connection shall be at least equal to the combined inlet areas of the pressure relief devices connected to it and in all cases shall be sufficient to not restrict the combined flow of the attached devices.

(4) Connections for liquid relief valves shall be at least NPS 1/2 (DN 15).

(c) Location of Openings and Connections

(1) Openings and connections for pressure relief purposes shall be located so that the nature of the vessel’s contents will not hinder flow through such openings and connections.

(2) Connections for vapor pressure relief devices shall be located in the vapor space.

(3) Connections for liquid relief valves shall be below the normal liquid level.

(d) Stop Valves Between the Vessel and Pressure Relief Device

There shall be no intervening stop valves between the vessel and its pressure relief device or devices, or between the pressure relief device or devices and the point of discharge, except:
(1) when the stop valves are so constructed or positively controlled that the closing of the maximum number of stop valves possible at one time will not reduce the pressure relief capacity provided by the unaffected relieving devices below the required relieving capacity; or

(2) under the conditions set forth in Nonmandatory Appendix AB.

(e) Discharge Lines from Pressure Relief Devices

Discharge lines from pressure relief devices shall be designed to facilitate drainage or shall be fitted with an open drain to prevent liquid lodging in the discharge side of the pressure relief device, and such lines shall lead to a safe place of discharge. The size of the discharge lines shall be such that any pressure that may exist or develop shall not reduce the relieving capacity of the relieving devices below that are required to protect the vessel (see Nonmandatory Appendix AB).
MANDATORY APPENDIX 2  
CAPACITY CONVERSIONS FOR SAFETY VALVES

This Appendix has moved to Section XIII, Mandatory Appendix IV

2-100 REQUIREMENTS FOR CAPACITY CONVERSIONS

(a) The capacity of a safety or relief valve in terms of a gas or vapor other than the medium for which the valve was officially rated may be determined by application of the following equations.\(^{24}\)

For steam:

\[ W_s = C_N KAP \]

where

- \( C_N = 51.5 \) for calculations of U.S. Customary units
- \( x = 5.25 \) for SI units calculations
- \( P \) (MPa)

For air:

\[ W_a = CKAP \sqrt{\frac{M}{T}} \]

where

- \( C = 356 \) for U.S. Customary units calculations
- \( x = 27.03 \) for SI units calculations
- \( M = 28.97 \) mol. wt. for both U.S. Customary and SI units calculations
- \( T = 520 \) when \( W_a \) is the rated capacity for U.S. Customary units calculations
- \( T = 288 \) when \( W_a \) is the rated capacity for SI units calculations

For any gas or vapor:

\[ W = CKAP \sqrt{\frac{M}{T}} \]

where

- \( A = \) actual discharge area of the safety valve, in.\(^2\) (mm\(^2\))
- \( C = \) constant for gas or vapor which is a function of the ratio of specific heats \( k = \frac{c_p}{c_v} \) [see Figure 2-100.1 (Figure 2-100.1M)]
- \( K = \) coefficient of discharge (see RR-112)
- \( M = \) molecular weight
- \( P = \) (set pressure \( \times 1.10 \)) plus atmospheric pressure, psia [MPA (absolute)]
- \( T = \) absolute temperature at inlet, °F plus 460 (K)
- \( W = \) flow of any gas or vapor, lb/hr (kg/h)
- \( W_a = \) rated capacity, converted to lb of air/hr at 60°F (20°C), inlet temperature
- \( W_s = \) rated capacity, lb of steam/hr

(b) Molecular weights of some of the common gases and vapors are given in Table 2-100.1.

(c) For hydrocarbon vapors, where the actual value of \( k \) is not known, the conservative value \( k = 1.001 \) has been commonly used and the equation becomes:

\[ W = CKAP \sqrt{\frac{M}{T}} \]

where

- \( C = 315 \) for U.S. Customary units calculations
- \( x = 23.95 \) for SI units calculations

(d) When desired, as in the case of light hydrocarbons, the compressibility factor \( Z \) may be included in the equations for gases and vapors as follows:

\[ W = CKAP \sqrt{\frac{M}{T}} Z \]

Example 1:

**Given:** A safety valve bears a certified capacity rating of 3,020 lb of steam/hr for a pressure setting of 200 psi.

**Problem:** What is the relieving capacity of that valve in terms of air at 100°F for the same pressure setting?

**Solution:**

For steam:

\[ W_s = 3,020 \times 51.5 = 156,330 \text{ lb/hr} \]

For air:

\[ W_a = 3,020 \times 356 \sqrt{\frac{28.97}{520}} = 4,750 \text{ lb/hr} \]

These equations may also be used when the required flow of any gas or vapor is known and it is necessary to compute the rated capacity of steam or air.

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FOR ASME COMMITTEE USE ONLY
Figure 2-100.1
Constant C for Gas or Vapor Related to Ratio of Specific Heats
\( (k = \frac{c_p}{c_v}) \)

Flow Formula Calculations

\[ W = K \left( \frac{\text{CAP}}{\sqrt{\text{M/T}}} \right) \]

\[ C = \left( \frac{2}{k + 1} \right) \frac{2}{k + 1} \]

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Figure 2-100.1M
Constant C for Gas or Vapor Related to Ratio of Specific Heats
\( (k = \frac{c_p}{c_v}) \)

Flow Formula Calculations

\[ W = K \left( \frac{\text{CAP}}{\sqrt{\text{M/T}}} \right) \]

\[ C = 39.48 \left( \frac{2}{k + 1} \right) \frac{2}{k + 1} \]

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**Example 2:**

Given: It is required to relieve 5,000 lb of propane/hr from a pressure vessel through a safety valve set to relieve at a pressure of $P_s$ psi, and with an inlet temperature of 125°F.

Problem: What total capacity in lb of steam/hr in safety valves must be furnished?

Solution:

For propane:

$$W' = CK_{AP} \sqrt{M/T}$$

Value of $C$ is not definitely known. Use the conservative value $C = 315$:

$$5,000 = 315K_{AP} \sqrt{44.09/(460 + 25)}$$

$$K_{AP} = 57.7$$

For steam:

$$W_s' = 0.515K_{AP} = (0.515)(57.7)$$

$$= 2,790 \text{ lb/hr set to relieve at } P_s$$

**Example 3:**

Given: It is required to relieve 1,000 lb of ammonia/hr from a pressure vessel at 150°F.

Problem: What is the required total capacity in lb of steam/hr at the same pressure setting?

Solution:

For ammonia:

$$W' = CK_{AP} \sqrt{M/T}$$

Manufacturer and User agree to use $k = 1.33$. From Figure 2-100.1, $C = 350$:

$$4,000 = 350K_{AP} \sqrt{17.03/(460 + 150)}$$

$$K_{AP} = 17.10$$

For steam:

$$W_s' = 0.515K_{AP} = (0.515)(17.10)$$

$$= 880 \text{ lb/hr}$$

**Example 4:**

Given: A safety valve bearing a certified rating of 10,000 ft³/min of air at 60°F and 14.7 psia (atmospheric pressure).

Problem: What is the flow capacity of this safety valve in lb of saturated steam/hr for the same pressure setting?

Solution:

For air, weight of dry air at 60°F and 14.7 psia is 0.0766 lb/ft³:

$$W_a = (10,000)(0.0766)(60) = 45,960 \text{ lb/hr}$$

$$45,960 = 356K_{AP} \sqrt{28.97/(460 + 60)}$$

$$K_{AP} = 546$$

For steam:

$$W_s' = 0.515K_{AP} = (0.515)(546)$$

$$= 28,200 \text{ lb/hr}$$
NONMANDATORY APPENDIX AB
INSTALLATION AND OPERATION

AB-100 INTRODUCTION

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

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

AB-101 ACCESS FOR INSPECTION

(a) Vessels subject to external degradation (see RD-140) should be so installed that there is sufficient access to all parts of the exterior to permit proper inspection of the exterior, unless adequate protection against degradation is provided or unless the vessel is of such size and is so connected that it may be readily removed from its permanent location for inspection.

(b) Vessels having manholes, handholes, or cover plates to permit inspection of the interior should be so installed that these openings are accessible.

(c) In vertical cylindrical vessels subject to chemical degradation from their contents, the bottom head, if dished, should preferably be concave to pressure to ensure complete drainage.

AB-102 MARKING ON THE VESSEL

The marking required by the Code should be so located that it will be accessible after installation, and when installed should not be covered with insulation or other material that is not readily removable (see Article RS-1).

AB-103 PRESSURE RELIEVING SAFETY DEVICES

The general provisions for the installation of pressure relieving devices are fully covered in Part RR. The following paragraphs contain details in arrangement of stop valves for shutoff control of pressure relief devices that are sometimes necessary for the continuous operation of processing equipment of such a complex nature that the shutdown of any part of it is not feasible. There are also rules in regard to the design of discharge piping from safety and relief valves, which can only be general in nature because the Design Engineer must fit the arrangement and proportions of such a system to the particular requirements of the operation of the equipment involved.

AB-104 STOP VALVES BETWEEN PRESSURE RELIEVING DEVICE AND VESSEL

(a) A vessel, in which pressure can be generated because of service conditions, may have a full-area stop valve between it and its pressure relieving device for inspection and repair purposes only. When such a stop valve is provided, it should be so arranged that it can be locked or sealed open, and it should not be closed except by an authorized person who should remain stationed there during that period of the vessel’s operation within which the valve remains closed, and who should again lock or seal the stop valve in the open position before leaving the station.

(b) A vessel or system (see RR-111) for which the pressure originates from an outside source exclusively may have individual pressure relieving devices on each vessel, or connected to any point on the connecting piping, or on any one of the vessels to be protected. Under such an arrangement, there may be a stop valve between any vessel and the pressure relieving devices, and this stop valve need not be locked open, provided it also closes off that vessel from the source of pressure.

AB-105 STOP VALVES ON THE DISCHARGE SIDE OF A PRESSURE RELIEVING DEVICE (SEE RR-210)

A full-area stop valve may be placed on the discharge side of a pressure relieving device when its discharge is connected to a common header with other discharge lines from other pressure relieving devices on nearby vessels that are in operation, so that this stop valve when closed will prevent a discharge from any connected operating vessels from backing up beyond the valve so closed. Such a stop valve should be so arranged that it can be locked or sealed in either the open or closed position, and it should be locked or sealed in either position only by an authorized person. When it is to be closed while the vessel is in operation, an authorized person should be present, and he should remain stationed...
there; he should again lock or seal the stop valve in the open position before leaving the station. Under no condition should this valve be closed while the vessel is in operation, except when a stop valve on the inlet side of the relief device is installed and is first closed.

**AB-106 DISCHARGE LINES FROM SAFETY DEVICES**

(a) Where it is feasible, the use of a short discharge pipe or vertical riser, connected through long-radius elbows from each individual device, blowing directly to the atmosphere, is recommended. Such discharge pipes should be at least of the same size as the valve outlet. Where the nature of the discharge permits, telescopic (sometimes called “broken”) discharge lines, whereby condensed vapor in the discharge line, or rain, is collected in a drip pan and piped to a drain, are recommended.

(b) When discharge lines are long, or where outlets of two or more valves having set pressures within a comparable range are connected into a common line, the effect of the back pressure that may be developed therein when certain valves operate must be considered (see RR-220). The sizing of any section of a common-discharge header downstream from each of the two or more pressure-relieving devices that may reasonably be expected to discharge simultaneously should be based on the total of their outlet areas, with due allowance for the pressure drop in all downstream sections. Use of specially designed valves suitable for use on high or variable back-pressure service should be considered.

(c) All discharge lines should be run as direct as is practicable to the point of final release for disposal. For the longer lines, due consideration should be given to the advantage of long-radius elbows, avoidance of close-up fittings, and the minimizing of excessive line strains by expansion joints and well-known means of support to minimize line-sway and vibration under operating conditions.

NOTE: It is recognized that no simple rule can be applied generally to fit the many installation requirements, which vary from simple short lines that discharge directly into the atmosphere to the extensive manifolded discharge piping systems where the quantity and rate of the product to be disposed of requires piping to a distant safe place.

**AB-107 GENERAL ADVISORY INFORMATION ON THE CHARACTERISTICS OF SAFETY RELIEF VALVES DISCHARGING INTO A COMMON HEADER**

Because of the wide variety of types and kinds of relief valves, it is not considered advisable to attempt a description in this Appendix of the effects produced by discharging them into a common header. Several different types of valves may conceivably be connected to the same discharge header, and the effect of back pressure on each type may be radically different. Data compiled by the Manufacturers of each type of valve used should be consulted for information relative to its performance under the conditions anticipated.
ENDNOTES

1 By **lethal fluids** is meant poisonous gases or liquids of such a nature that a very small amount of the gas or of the vapor of the liquid, mixed or unmixed with air, is dangerous to life when inhaled. For purposes of the Code, this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel.

2 Requirements for pressure vessels for human occupancy are covered by ASME PVHO-1.

3 Wherever the word **User** appears in this Section, it shall be considered to include an agent acting in his behalf. The **agent** may be the Fabricator when multiple duplicate vessels are being fabricated.

4 A glossary of terms used in fiber-reinforced plastic pressure vessel fabrication is given in Mandatory Appendix 4.

5 Matched-die-method parts are acceptable under this Section as being equivalent to bag-molded parts when using the same type of fiber reinforcement and the same resin system.

6 Sudden cyclic changes in temperature shall be part of the design consideration.

7 An exception to this one-sixth value is permitted for vessels per **RG-404.2** (Filament Winding — With Uncut Filaments), where the maximum combined stress value may be one-fifth of maximum membrane stress.

8 **Nominal pipe size (NPS)** is a designation assigned for the purpose of convenient specification of pipe size. The actual inside and outside dimensions are listed in ANSI B36.10M.

9 Diameters of vessels and sizes of openings are nominal.

10 The governing principle in the design and fabrication of a Class II vessel is the establishment of the Procedure Specification (**Form Q-120**) at the time of design and the strict observance of the Procedure Specification during fabrication. The engineering constants of laminate materials upon which the design is based, and from which fabrication will occur, are determined using a mathematical treatment known as laminate theory. Laminate theory utilizes the orthotropic properties of the individual lamina (based on the specific resin–fiber combination), ply sequence, and ply orientations identified in the Procedure Specification to determine the stiffness coefficients and effective elastic properties of the resultant laminate.

The Procedure Specification is qualified by observance of the mandatory design rules of this Article and strict observance of the Procedure Specification during fabrication (as documented by quality control records) to assure that the combinations of resin, reinforcement, ply sequence, and ply orientation upon which the design was based are followed during fabrication.

The structural integrity of the vessel is confirmed by individual acceptance testing of each vessel using acoustic emission monitoring.

11 An example of these calculations appears in **Nonmandatory Appendix AD**.

12 Random short length is that produced by cutter blades with not less than 1 in. (25 mm) nor more than 4 in. (100 mm) spacing.

13 See **Article RT-2** for detailed requirements governing the conducting of these checks and tests.

14 Essential variables shall be held within tolerances established in the Procedure Specification.

15 Essential variables shall be held within tolerances established elsewhere in this Section.

16 **Set to operate** means the set pressure of a pressure relief valve or a spring-loaded non-reclosing device, the bursting pressure of a rupture disk device, or the breaking pressure of a breaking pin device.


18 The water jacket method described in pamphlet C-1, published by the Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202, may be used.

19 In the case of vessel designs that have not been previously qualified, it is recommended that a preliminary hydrostatic qualification pressure test in accordance with **RT-223.1(a)(3)** be carried out before the cyclic pressure and qualification pressure test of a prototype vessel is conducted.

20 During the cyclic pressure test, the minimum pressure shall be the lower of 20% of design pressure or 30 psig (0.270 MPa).

21 If polyester is being used, the surface of the repaired area may be covered with cellophane or other suitable nonpermeable film to retard evaporation of monomer.

22 The maximum allowable external working pressure is required only when specified as a design condition.
23 Wherever the word "stamp" or "stamping," referring to the Certification Mark to be applied to the vessel (but not to safety or safety relief devices), appears in this Section, it may be construed to mean marking the vessel nameplate with the Certification Mark with RP Designator by means other than a steel stamp (see RS-130 and RS-131).

24 Knowing the official rating capacity of a safety valve that is stamped on the valve, it is possible to determine the overall value of $K_A$ in either of the following equations in cases where the value of these individual terms is not known:

$$K_A = \frac{W_s}{51.5 P}$$

$$K_A = \left(\frac{W_s}{C P}\right)^{1/2}\frac{T}{M}$$

This value for $K_A$ is then substituted in the above equations to determine the capacity of the safety valve in terms of the new gas or vapor.

25 Holiday is defined as a discontinuity, such as a pinhole, void, crack, thin spot, foreign inclusion, or contaminant in the laminate.

26 Yield is measured in yards per pound and is furnished by the fiber producer. The constant (1.125) in the equation is a function of the reinforcement content and the resin specific gravity. The normal variation of fiberglass content in filament winding is from 60% to 75% by weight.

27 The equations in Article AA-2 are for isotropic materials only. Any deviation from such materials will require modifications of the equations.

28 This construction has the further advantage of not transmitting discharge-pipe strains to the valve. In these types of installations, the back-pressure effect will be negligible, and no undue influence upon normal valve operation can result.

29 Note that $3/\beta = 9.07$ in., which is less than the length $L = 10$ in.; by AC-231(b), $B_{11} = B_{12} = 1$, $B_{22} = 2$, and $G_{11} = G_{12} = G_{22} = 0$, which have been used above.
AM-1 GENERAL

(a) The 2021 Edition of this Section adopts the new BVPC Section XIII, Rules for Overpressure Protection. This includes the transfer of all pressure relief device requirements from Section X to Section XIII and the restructuring the remaining Section X overpressure protection requirements to a new Part ROP. This nonmandatory appendix is a cross reference table that shows the new location for all Part RR requirements.

(b) Part RR and this nonmandatory appendix will only be published in the 2021 Edition.

(c) Table AM-1 can also be obtained in a spreadsheet format at the following web site:

https://cstools.asme.org/??????

Note - Link address is example only and to be specified by ASME Staff.