KG-112  INTERNAL PRESSURE PIPING

Internal pressure piping, when failure of such piping will affect the integrity of the pressure boundary.

KG-113  NONPRESSURE PARTS

Nonpressure parts that are welded directly to the internal or external surface of a pressure vessel. For parts beyond this, and for stud-bolted attachments, see Articles KD-6 and KD-7.

KG-114  COVERS AND CLOSURES

Pressure-retaining permanent covers or closures, including seals and bolting, or other mechanical retainers, used in service for vessel openings (see Article KD-6).

KG-115  INSTRUMENT CONNECTIONS

The first sealing surface for small proprietary fittings or instrumentation, such as gages and instruments, for which rules are not provided by this Division (see Article KD-6).

KG-116  OVERPRESSURE PROTECTION

Pressure relief devices shall satisfy the requirements of Part KR.

KG-117  COMBINATION UNITS

When a pressure vessel unit consists of more than one independent pressure chamber, only the parts of chambers which are within the scope of this Division need to be constructed in compliance with its provisions (see Articles KD-1 and KG-3).

KG-120  CLASSIFICATIONS OUTSIDE THE SCOPE OF THIS DIVISION

The following classes of pressure-containing equipment are not within the scope of this Division:

(a) those within the scopes of other Sections of this Code
(b) fired process tubular heaters
(c) pressure-containing equipment that is an integral part or component of a rotating or reciprocating mechanical device, such as
   (1) pumps
   (2) compressors
   (3) turbines
   (4) generators
   (5) engines
   (6) hydraulic or pneumatic cylinders

where the primary design considerations and/or stresses are derived from the functional requirements of the device

(d) structures whose primary function is the transport of fluids from one location to another within a system of which they are integral parts (piping systems)

KG-121  STAMPING OF VESSELS OUTSIDE THE SCOPE OF THIS DIVISION

Any pressure vessel which meets all applicable requirements of this Division may be stamped with the Certification Mark with U3 Designator.

The Certification Mark is an ASME symbol identifying a product as meeting Code requirements. The Designator is a symbol used in conjunction with the Certification Mark for the scope of activity described in a Manufacturer’s Certificate of Authorization.

KG-130  ASSEMBLY AND TESTING OF VESSELS AT FIELD OR INTERMEDIATE SITES

A field site is a location of final permanent installation of the pressure equipment. An intermediate site is a temporary location under the control of the Certificate Holder. The location of an intermediate site is other than that listed on the Certificate of Authorization and other than a field site. All Code activities may be performed at intermediate or field sites by the Certificate Holder provided they comply with all Code requirements, and control of those activities is described in the Certificate Holder’s Quality Control System. Assembly and testing of vessels constructed to this Division at intermediate or field sites shall be performed using one of the following three alternatives:

(a) The Manufacturer of the vessel completes the vessel in the field or at an intermediate site.

(b) The Manufacturer of parts of a vessel to be completed in the field or at an intermediate site by some other party stamps these parts in accordance with Code rules and supplies the Manufacturer’s Data Report Form K-2 to the other party. The other party, who shall also hold a valid U3 Certificate of Authorization, makes the final assembly, required nondestructive examination (NDE), and final pressure test; completes the Manufacturer’s Data Report Form K-1; and stamps the vessel. The Certificate of Authorization is a document issued by the Society that authorizes the use of the ASME Certification Mark and appropriate Designator for a specified time and for a specified scope of activity.

(c) Code work at field or intermediate sites is completed by a Certificate Holder of a valid U3 Certificate of Authorization other than the Manufacturer. The Certificate Holder performing the work is required to supply a Manufacturer’s Data Report Form K-2 covering the portion of the work completed by his organization (including data on the pressure test if conducted by the Certificate Holder performing the fieldwork) to the Manufacturer responsible for the Code vessel. The Manufacturer applies his Certification Mark with U3 Designator in the presence of a representative from his Inspection Agency and completes the Manufacturer’s Data Report Form K-1 with his Inspector.
In all three alternatives, the party completing and signing the Manufacturer's Data Report Form K-1 assumes full Code responsibility for the vessel. In all three cases, each Manufacturer's Quality Control System shall describe the controls to assure compliance for each Certificate holder.

**KG-140 STANDARDS REFERENCED BY THIS DIVISION**

**KG-141 SECTIONS OF THE ASME CODE**

(a) Sections of the ASME Boiler and Pressure Vessel Code referenced in this Division are

- Section I, Rules for Construction of Power Boilers
- Section II, Materials
  - Part A — Ferrous Material Specifications
  - Part B — Nonferrous Material Specifications
  - Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
  - Part D — Properties
- Section V, Nondestructive Examination
- Section VIII, Division 1, Rules for Construction of Pressure Vessels
- Section VIII, Division 2, Alternative Rules for Construction of Pressure Vessels
- Section IX, Welding, Brazing, and Fusing Qualifications
- Section X, Fiber-Reinforced Plastic Pressure Vessels

(b) Throughout this Division references are made to various standards, such as ASME standards, that cover pressure–temperature rating, dimensional, or procedural standards for pressure vessel parts. Specific editions of standards referenced in this Division are shown in Table KG-150.

**KG-142 STANDARD PARTS**

Standard pressure parts which comply with an ASME product standard shall be made of materials permitted by this Division (see Part KM).

**KG-150 UNITS OF MEASUREMENT**

(a) Either U.S. Customary, SI, or any local customary units may be used to demonstrate compliance with requirements of this edition related to materials, fabrication, examination, inspection, testing, certification, and overpressure protection.

(b) A single system of units shall be used for all aspects of design except where otherwise permitted by this Division. When components are manufactured at different locations where local customary units are different than those used for the general design, the local units may be used for the design and documentation of that component, within the limitations given in (c). Similarly, for proprietary components or those uniquely associated with a system of units different than that used for the general design, the alternate units may be used for the design and documentation of that component, within the limitations given in (c).

(c) For any single equation, all variables shall be expressed in a single system of units. Calculations using any material data published in this Division or Section II, Part D (e.g., allowable stresses, physical properties, external pressure design factor B, etc.) shall be carried out in one of the standard units given in Table KG-150. When separate equations are provided for U.S. Customary and SI units, those equations must be executed using variables in the units associated with the specific equation. Data expressed in other units shall be converted to U.S. Customary or SI units for use in these equations. The result obtained from execution of these equations or any other calculations carried out in either U.S. Customary or SI units may be converted to other units.

(d) Production, measurement, and test equipment, drawings, welding procedure specifications, welding procedure and performance qualifications, and other fabrication documents may be in U.S. Customary, SI, or local customary units in accordance with the fabricator’s practice. When values shown in calculations and analysis, fabrication documents, or measurement and test equipment are in different units, any conversions necessary for verification of Code compliance and to ensure that dimensional consistency is maintained shall be in accordance with the following:

(1) Conversion factors shall be accurate to at least four significant figures.

(2) The results of conversions of units shall be expressed to a minimum of three significant figures.

(e) Conversion of units, using the precision specified previously, shall be performed to ensure that dimensional consistency is maintained. Conversion factors between U.S. Customary and SI units may be found in the Nonmandatory Appendix I, Guidance for the Use of U.S. Customary and SI Units, in the ASME Boiler and Pressure Vessel Code. Whenever local customary units are used, the Manufacturer shall provide the source of the conversion factors which shall be subject to verification and acceptance by the Authorized Inspector or Certified Individual.

(f) Dimensions shown in the text, tables, and figures, whether given as a decimal or a fraction, may be taken as a decimal or a fraction and do not imply any manufacturing precision or tolerance on the dimension.

(g) Material that has been manufactured and certified to either the U.S. Customary or SI material specification (e.g., SA-516M) may be used regardless of the unit system used in design. Standard fittings (e.g., flanges and elbows) that have been certified to either U.S. Customary or SI units may be used regardless of the equations or any other calculations carried out in either U.S. Customary or SI units system used in design.

(h) All entries on a Manufacturer’s Data Report and data for Code-required nameplate marking shall be in units consistent with the fabrication drawings for the
component using U.S. Customary, SI, or local customary units. Units may be shown parenthetically (either primary or alternative). Users of this Code are cautioned that the receiving jurisdiction should be contacted to ensure the units are acceptable.

### KG-160 TOLERANCES

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

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Table KG-141
Referenced Standards in This Division and Year of Acceptable Edition

<table>
<thead>
<tr>
<th>Title</th>
<th>Number</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Chemical Plants</td>
<td>API RP 941</td>
<td>2016</td>
</tr>
<tr>
<td>Unified Inch Screw Threads (UN and UNR Thread Form)</td>
<td>ASME B1.1</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Pipe Flanges and Flanged Fittings, NPS ½ Through NPS 24 Metric/Inch Standard</td>
<td>ASME B16.5</td>
<td>2013</td>
</tr>
<tr>
<td>Fitness-For-Service</td>
<td>API 579-1/ASME FFS-1</td>
<td>2016</td>
</tr>
<tr>
<td>Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)</td>
<td>ASME B18.2.2</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Metric Fasteners for Use in Structural Applications</td>
<td>ASME B18.2.6M</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Process Piping</td>
<td>ASME B31.3</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Surface Texture (Surface Roughness, Waviness and Lay)</td>
<td>ASME B46.1</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Conformity Assessment Requirements</td>
<td>ASME CA-1</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Inspection Planning Using Risk-Based Methods</td>
<td>ASME PCC-3</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Pressure Relief Devices</td>
<td>ASME PTC-2S</td>
<td>2014</td>
</tr>
<tr>
<td>Qualifications for Authorized Inspection</td>
<td>ASME QAI-1</td>
<td>Latest edition</td>
</tr>
<tr>
<td>Standard Method for Plane-Strain Fracture Toughness of Metallic Materials</td>
<td>ASTM E399</td>
<td>2012e3</td>
</tr>
<tr>
<td>Standard Test Method for Measurement of Fracture Toughness</td>
<td>ASTM E1820</td>
<td>2015a</td>
</tr>
<tr>
<td>Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures</td>
<td>BS-7910</td>
<td>2013</td>
</tr>
<tr>
<td>Marking and Labeling Systems</td>
<td>ANSI/UL-969</td>
<td>Latest edition</td>
</tr>
</tbody>
</table>

GENERAL NOTE: For product standards, pressure–temperature ratings and cyclic analysis may limit application (see Part KD).

NOTE: (1) See KG-411.
ARTICLE KG-2
ORGANIZATION OF THIS DIVISION

KG-200 ORGANIZATION

KG-210 PARTS OF THIS DIVISION

This Division is divided into eight parts.

(a) Part KG contains the scope of the Division, establishes the extent of its coverage, and sets forth the responsibilities of the User and Manufacturer and the duties of the Inspectors of vessels constructed under these rules.

(b) Part KM contains

(1) the materials which may be utilized

(2) the permissible material specification identification numbers, special requirements, and limitations

(3) mechanical and physical properties upon which the design is based, and other necessary information concerning material properties (see Section II, Part D)

(c) Part KD contains requirements for the design of vessels and vessel parts.

(d) Part KF contains requirements for the fabrication of vessels and vessel parts.

(e) Part KR contains rules for pressure relief devices.

(f) Part KE contains requirements for nondestructive examination and repair of materials, vessels, and vessel parts.

(g) Part KT contains testing requirements and procedures.

(h) Part KS contains requirements for stamping and certifying vessels and vessel parts. It also gives requirements for Manufacturer’s Data Reports and Records to be furnished to the User.

KG-220 APPENDICES

KG-221 Mandatory. The Mandatory Appendices address specific subjects not covered elsewhere in this Division. Their requirements are mandatory when applicable.

KG-222 Nonmandatory. The Nonmandatory Appendices provide information and suggested good practices.

KG-230 ARTICLES AND PARAGRAPHS

KG-231 Articles. The main divisions of the Parts of this Division are designated Articles. These are given numbers and titles such as Article KG-1, Scope and Jurisdiction.

KG-232 Paragraphs and Subparagraphs. The Articles are divided into paragraphs and subparagraphs which are given three-digit numbers, the first of which corresponds to the Article number. Each such paragraph or subparagraph number is prefixed with letters which, with the first digit (hundreds), indicate the Part and Article of this Division in which it is found, such as KD-140, which is a subparagraph of KD-100 in Article KD-1 of Part KD.

(a) Major subdivisions of paragraphs or subparagraphs are indicated by the basic paragraph number followed by a decimal point and one or two digits. Each of these subdivisions are titled and appear in the table of contents.

(b) Minor subdivisions of paragraphs are designated (a), (b), etc.

(c) Where further subdivisions are needed, they are designated by numbers in parentheses [e.g. KG-311.8(b)(1)].

KG-240 REFERENCES

When a Part, Article, or paragraph is referenced in this Division, the reference shall be taken to include all subdivisions under that Part, Article, or paragraph, including subparagraphs.

KG-250 TERMS AND DEFINITIONS

Terms and symbols used in this Division are defined in the various Parts, Articles, or paragraphs where they first apply or are of primary interest. A list of symbols is given in Mandatory Appendix 1.
ARTICLE KG-6
ADDITIONAL GENERAL REQUIREMENTS FOR IMPULSIVELY LOADED VESSELS

KG-600 GENERAL REQUIREMENTS

The following Article provides additional general requirements for the design and manufacture of impulsively loaded vessels.

KG-610 SCOPE

This Article applies to pressure vessels that are subjected to internal impulsive loadings that may consist of blast pressure from a detonation source and mechanical loadings caused by detonation fragments. Impulsive loading is defined in KD-210.

KG-611 CONSTRUCTION RULES

Each pressure vessel to which this Article applies shall comply with the existing rules of Section VIII, Division 3 and the additional requirements given in Article KM-7, KD-240, Article KR-7, KT-350, and KS-102.

KG-612 MATERIALS AND COMBINATIONS OF MATERIALS

Each pressure vessel to which this Article applies shall comply with the requirements of KD-101, except as covered in Article KM-7.

KG-613 OVERPRESSURE PROTECTION

In accordance with KG-311.11, the User, or his designated agent, shall be responsible for the provision in the Design Specification of the administrative or engineered controls that provide overpressure protection as specified in Article KR-7.

KG-614 LOADINGS

The User’s Design Specification (see KG-311) shall provide the following in addition to the required loadings specified in KG-311:

(a) the impulsive loading design basis.
(b) impulse source location within the vessel (i.e., vessel center, off-center, etc.).
(c) the basis for administrative controls limiting the impulse source.
(d) any protective liner requirements, such as for fragment shielding. For vessels without protective liners, such as single-use vessels, guidance for evaluation of postulated localized wall thinning from fragment partial penetration is provided in API-579-1/ASME FFS-1.
ARTICLE KR-1
GENERAL REQUIREMENTS

KR-100 PROTECTION AGAINST OVERPRESSURE

All pressure vessels within the scope of this Division shall be provided with protection against overpressure according to the requirements of this Part. Combination units (such as heat-exchangers with shells designed for lower pressures than the tubes) shall be protected against overpressure from internal failures. The User or his designated agent shall be responsible for establishing a procedure for sizing and/or flow capacity calculations for the device and associated flow paths, as well as changes in fluid conditions and properties as appropriate. These calculations shall be based on the most severe credible combinations of final compositions and resulting temperature. Alternatively, sizing shall be determined on an empirical basis by actual capacity tests with the process in question at expected relieving conditions. The User shall be responsible for providing or approving the assumptions used in all flow capacity calculations. The User is cautioned that some fluids (e.g., ethylene) in the supercritical state behave more like liquids than gases, so liquid or combination liquid/vapor trim values should be considered.

KR-110 DEFINITIONS

Unless otherwise defined in this Division, definitions relating to pressure relief devices in ASME PTC 25, Pressure Relief Devices, Section 2 shall apply.

Assembler: a person or organization who purchases or receives from a Manufacturer the necessary component parts or valves and who assembles, adjusts, tests, seals, and ships pressure relief valves certified under this Division, at a geographical location other than and using facilities other than those used by the Manufacturer. An Assembler may be organizationally independent of a Manufacturer, or may be wholly or partly owned by a Manufacturer.

combination device: one rupture disk in series with one pressure relief valve.

compressibility factor: the ratio of the specific volume of a given fluid at a particular temperature and pressure to the specific volume of that fluid as calculated by ideal gas laws at that temperature and pressure.

gas: for the purpose of Part KR, a gas shall be defined as a fluid that undergoes a significant change in density as it flows through the pressure relief device.

liquid: for the purpose of Part KR, a liquid shall be defined as a fluid that does not undergo a significant change in density through the pressure relief device.

lot of rupture disks: those disks manufactured of the same material, at the same time, of the same size, thickness, type, heat, and manufacturing process including heat treatment.

Manufacturer: within the requirements of Part KR, a Manufacturer is defined as a person or organization who is completely responsible for design, material selection, capacity certification when required, manufacture of all component parts, assembly when required, testing, sealing when required, and shipping of pressure relief devices certified under this Division. The Manufacturer of a rupture disk holder may be different than the Manufacturer of the rupture disk.

Manufacturer’s standard rupture disk holder: the structure that encloses and clamps the rupture disk into position and includes at least one proprietary high-pressure tube fitting connection.

manufacturing design range: a range of pressure within which the marked burst pressure must fall to be acceptable for a particular requirement as agreed upon between the rupture disk Manufacturer and the User or his designated agent. The manufacturing design range must be evaluated in conjunction with the specified burst
pressure to ensure that the marked burst pressure of the rupture disk will always be within the limits of the agreed upon particular requirement.

**nonreclosing pressure relief device:** a pressure relief device designed to remain open after operation.

**overpressure:** a pressure increase over the set pressure of a pressure relief valve, usually expressed as a percentage of set pressure.

**pressure relief valve:** a passive pressure relief device that is actuated by static inlet pressure. The opening is characterized by a rapid opening (pop action), or by opening in proportion to the difference between the static pressure and the set pressure of the valve, depending on the valve design and the application. A pressure relief valve is also designed to reclose to prevent further discharge of fluid after the inlet pressure decreases below the set pressure of the valve. Also referred to as a safety relief valve, safety valve, relief valve, and pop-off valve.

**pressure relief valve set pressure:** that pressure which causes the valve stem to lift at least 5% of its full travel.

**rupture disk:** the rupture disk is the pressure-retaining and pressure-sensitive element of a rupture disk device. The failure of the rupture disk is the cause of the opening of the rupture disk device. Rupture disks need not be flat round disks, as long as their design configuration meets the design burst pressure and flow capacity requirements.

**rupture disk device:** a nonreclosing differential pressure relief device actuated by inlet static pressure and designed to function by the bursting of a pressure-retaining disk. The rupture disk device includes the rupture disk, the rupture disk holder, and all other components that are required for the device to function in the prescribed manner. The holder is the structure which encloses, clamps, and seals the rupture disk in position.

**specified disk temperature (supplied to the rupture disk manufacturer):** the expected temperature of the disk when a specified overpressure condition exists, and the disk is expected to rupture.

**KR-120 TYPES OF OVERPRESSURE PROTECTION**

Pressure relief valves, rupture disks, flow paths, or vents directly or indirectly open to the atmosphere, or inherent overpressure protection in accordance with KR-125, may be used for overpressure protection. The overpressure limits specified in KR-150 shall apply to these devices.

**KR-121 RUPTURE DISK DEVICES**

Because of the high pressures associated with this Division, it may be impractical to accomplish full-scale flow capacity performance testing and certification of pressure-relieving devices. For this reason, rupture disk devices may be the more commonly used means of over-pressure protection for vessels within the scope of this Division. All rupture disks shall meet the requirements of Article KR-2.

The use of rupture disk devices may be advisable when very rapid rates of pressure rise may be encountered, or where the relief device must have intimate contact with the process stream. Intimate contact may be required to overcome inlet-line fouling problems or to ensure that the temperature of the disk is the same as the interior temperature of the vessel.

**KR-122 PRESSURE RELIEF VALVES**

All pressure relief valves shall meet the requirements of Article KR-3, and shall be flow capacity performance tested and certified in accordance with Article KR-5, except in the case where their opening is not required to satisfy the overpressure limits given in KR-150. See KR-123(c) for further discussion about the use of relief valves in parallel with rupture disks.

**KR-123 COMBINATIONS**

A rupture disk device used in combination with a pressure relief valve may be advisable on vessels containing substances that may render a pressure relief valve inoperative by fouling, or where a loss of valuable material by leakage should be avoided, or where contamination of the atmosphere by leakage of noxious, flammable, or hazardous fluids must be avoided.

(a) Multiple rupture disk devices in parallel shall not be used on the inlet side of a pressure relief valve.

(b) When a combination device is used, both the rupture disk device and the pressure relief valve shall meet the applicable requirements of Part KR. The rupture disk device shall be installed to prevent fragments from the rupture disk from interfering with the proper operation of the pressure relief valve. For additional requirements, see KR-220 and KR-340.

(c) A rupture disk device may be used in parallel with a pressure relief valve whose set pressure is lower than the rupture disk when it is important to limit the quantity of a release or if it is impractical to certify the flow capacity of the pressure relief valve under the rules of this Division. The calculated flow capacity of the rupture disk device acting alone shall be adequate to meet the requirements of KR-150, and the rupture disk device shall meet all the applicable requirements of this Part. With the exception of the flow capacity certification, the pressure relief valve shall meet all the requirements of this Part.
**KR-124 REQUIREMENTS FOR PRESSURE-RETAINING COMPONENTS**

All components subject to the design pressure shall meet the requirements of this Division except as permitted below. Requirements for the pressure relief valve seat, spring, and valve stem are given in Article KR-3, and requirements for the rupture disk component are given in Article KR-2. Components that are subject to pressures lower than the design pressure when the pressure relief device opens shall meet the requirements of this Division or other Divisions of Section VIII.

**KR-125 INHERENT OVERPRESSURE PROTECTION**

Overpressure protection need not be provided when the source of pressure is external to the vessel and when the source of pressure is under such positive control that the pressure in the vessel cannot exceed the design conditions except as permitted in KR-150.

**KR-126 INTENSIFIER SYSTEMS**

In the case where a vessel is pressurized by an intensifier system whose output pressure to the vessel is a fixed multiple of the supply pressure, the pressure relief device may be located on the low-pressure supply side of the intensifier if all the following requirements are met:

(a) There shall be no intervening stop valves or check valves between the driving-chamber(s) and the relief device(s).

(b) Heating of the discharge fluid shall be controlled to prevent further pressure increase which would exceed vessel design conditions.

(c) The discharge fluid shall be stable and nonreactive (water, hydraulic fluid, etc.).

(d) The material being processed in downstream equipment is stable and nonreactive, or is provided with a suitable secondary vent system which will effectively prevent transfer of secondary energy sufficient to overpressure the vessel.

The Designer is cautioned to consider the effects of leaking check valves in such systems.

**KR-130 SIZE OF OPENINGS AND NOZZLES**

The flow characteristics of the entire pressure-relieving system shall be part of the relieving capacity calculations. The size of nozzles and openings shall not adversely affect the proper operation of the pressure-relieving device.

**KR-140 INTERVENING STOP VALVES**

There shall be no intervening stop valves between the vessel and any overpressure protection device associated with the vessel, except as permitted in KR-141.

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 relief devices on 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 shall be so arranged that it can be locked or sealed in either the open or closed position by an authorized person. Under no condition shall this valve be closed while the vessel is in operation.

**KR-141 DUAL OVERPRESSURE PROTECTION**

Where it is desirable to perform maintenance on relief devices without shutting down the process, a full-area three-way transfer valve may be installed on the inlet of the relief device(s). The design of the transfer valve and relief devices must be such that the requirements of KR-150 are met at any position of the transfer valve. Alternatively, the User may elect to install stop valves in each branch, but so controlled that one branch is open at all times and the requirements of KR-150 are always met while the process is in operation.

**KR-150 PERMISSIBLE OVERPRESSURES**

The aggregate capacity of the safety relief devices, open flow paths, or vents shall be sufficient to prevent overpressures in excess of 10% above the design pressure of the vessel when the safety relief devices are discharging.

The Designer shall consider the effects of the pressure drop in the overpressure protection system piping during venting when specifying the set pressures and flow capacities of pressure relief valves and rupture disk devices. When multiple pressure relief devices can discharge through a common stack or vent path, the maximum back pressure that can exist during simultaneous releases at the exit of each pressure relief device shall not impair its operation.

**KR-160 SET PRESSURES**

**KR-161 SINGLE PRESSURE RELIEF DEVICE**

A single safety relief device shall open at a nominal pressure not exceeding the design pressure of the vessel at the operating temperature, except as permitted in KR-162.

Users are cautioned that certain types of rupture disks have manufacturing ranges that can result in a marked burst pressure greater than the specified burst pressure.

**KR-162 MULTIPLE PRESSURE RELIEF DEVICES**

If the required discharging capacity is supplied by more than one device, only one need be set to operate at a pressure not exceeding the design pressure of the vessel.
additional device or devices may be set at a higher pressure but not to exceed 105% of the design pressure of the vessel. The requirements of KR-150 shall also apply.

**KR-163  PRESSURE EFFECTS TO BE INCLUDED IN THE SETTING**

The pressure at which any device is set shall include the effects of superimposed back pressure through the pressure relief device and the vent system (see KR-150).

**KR-164  ALTERNATIVE SET-PRESSURE REQUIREMENTS FOR CRPV IN TRANSPORT SERVICE**

(a) For CRPV in transport service, a single safety-relief device may be set to open at a nominal pressure not exceeding 110% of the design pressure of the vessel at the operating temperature in lieu of the requirements in KR-161.

(b) The requirements of KR-150 apply.
ARTICLE KR-2
REQUIREMENTS FOR RUPTURE DISK DEVICES

KR-200 GENERAL REQUIREMENTS

(a) Rupture disk devices used to meet the requirements of KR-100 shall carry the ASME Certification Mark with the applicable “UD” or “UD3” Designator.

(1) Rupture disk devices certified in accordance with Section VIII, Division 1 may be used, provided the requirements of KR-230 and KR-240 are met and the holder is also marked with “DIV2” to designate that the design and materials comply with these provisions.

(2) Rupture disk devices certified in accordance with this Division may incorporate a Manufacturer’s standard rupture disk holder manufactured by a Manufacturer other than the rupture disk Manufacturer.

(b) Rupture disk devices shall burst within a tolerance of ±5% of the marked burst pressure.

KR-210 CAPACITY REQUIREMENTS

The flow capacity of the rupture disk device shall be demonstrated by calculation to meet the requirements of KR-150.

(a) The calculated capacity rating of a rupture disk device shall not exceed a value based on the applicable theoretical formula multiplied by a coefficient of discharge, $K_D$, where

$$K_D = 0.62$$

(b) The Designer is responsible to evaluate the rupture disk and holder design to determine the applicable area to be used in the theoretical formula. The Designer is cautioned that normal capacity calculations may not be applicable for supercritical fluids and should consider the critical point and nonlinear thermodynamic properties of the fluid used in service. Flow through the entire relieving system shall be analyzed with due consideration for the wide variation in physical properties, which will occur due to the wide range of flowing pressures.

(c) Rupture disks may be certified as to burst pressure provided the test stand has enough volume to provide a complete burst. Flow coefficient ($C_D, K, L_{TEQ},$ percent open area) may be established at a lower pressure using any suitable fluid.

KR-220 RUPTURE DISK DEVICES USED IN COMBINATION WITH FLOW CAPACITY CERTIFIED PRESSURE RELIEF VALVES

KR-221 RUPTURE DISK DEVICES INSTALLED UPSTREAM OF FLOW CAPACITY CERTIFIED PRESSURE RELIEF VALVES

A rupture disk device may be installed between a pressure relief valve and the vessel, provided the requirements of (a) through (g) are met.

(a) The combination of the spring-loaded pressure relief valve and the rupture disk device meets the requirements of KR-150.

(b) The stamped capacity of a pressure relief valve is multiplied by a factor of 0.90 of the rated relieving capacity of the valve alone.

(c) The volume between the rupture disk device and the pressure relief valve is provided with a means to prevent pressure buildup between the rupture disk and the pressure relief valve, or the series combination is provided with a second rupture disk device in parallel whose burst pressure is 116% of design pressure.

(d) The opening provided through the rupture disk after burst is sufficient to permit a flow equal to the capacity of the valve [see (b)], and there is no chance of interference with proper functioning of the pressure relief valve. In addition, the flow area of the burst rupture disk shall not be less than 90% of the area of the inlet of the valve unless the capacity and functioning of the specific combination of rupture disk and valve have been established by test according to KR-560.

(e) The use of a rupture disk device in combination with a pressure relief valve should be carefully evaluated to ensure that the media being handled and the valve operational characteristics will result in opening action of the valve coincident with the bursting of the rupture disk, so that the requirements of KR-150 are met.

(f) The installation shall ensure that solid material will not collect in the inlet or outlet of a rupture disk which could impair the relieving capacity of the vent system.

(g) Fragmenting type rupture disks shall not be used upstream of a pressure relief valve.
KR-222 RUPTURE-DISK-DEVICES-INSTALLED
DOWNSTREAM-OF-FLOW-CAPACITY
CERTIFIED-PRESSURE-RELIEF-VALVES

A rupture disk device may be installed on the outlet side of a pressure relief valve, provided (a) through (g) are met.

(a) The pressure relief valve is designed so that the pressure between the valve outlet and the rupture disk does not affect the valve’s set pressure. This volume should be vented or drained to prevent accumulation of fluid due to a small amount of leakage from the valve.

(b) The valve and disk combination shall meet the requirements of KR-150.

(c) The stamped bursting pressure of the rupture disk at the coincident temperature, plus the additional pressure in the outlet piping that will occur during venting, shall not exceed the design pressure of the outlet portion of the pressure relief device and any pipe or fitting between the pressure relief valve and the rupture disk device. In addition, the stamped bursting pressure of the rupture disk at the coincident disk temperature plus the pressure developed in the outlet piping during venting shall not exceed the set pressure of the pressure relief valve.

(d) The opening provided through the rupture disk after breakage is sufficient to permit a flow capacity greater than or equal to the rated capacity of the pressure relief valve.

(e) Any piping beyond the rupture disk shall be designed so that it will not be obstructed by the rupture disk or its fragments.

(f) The contents of the vessel are clean fluids, free from gumming or clogging matter, so accumulation in the relief system will not interfere with pressure relief valve function.

(g) The design pressure of the pressure relief valve’s bonnet, bellows if any, and exit connection to the rupture disk is greater than or equal to the burst pressure of the disk.

KR-230 MECHANICAL-REQUIREMENTS

(a) The design shall incorporate arrangements necessary to ensure consistent operation and tightness.

(b) Rupture disk devices having threaded inlet or outlet connections shall be designed to allow for normal installation without damaging the rupture disk.

(c) Rupture disk holders shall comply with the applicable requirements of Part KD. Alternatively, it is permissible to design rupture disk holders in accordance with the rules in ASME B31.3, Chapter IX, instead of the requirements in Part KD, provided that

(1) the materials for the holder meet the requirements of this Division

(2) all components of the rupture disk device are outside of the geometric scope of this Division and are part of the external piping as defined in KG-110.

KR-240 MATERIAL-REQUIREMENTS

(a) The rupture disk material is not required to conform to a material specification listed in ASME Section II.

(b) The rupture disk material shall be manufactured to a specification ensuring the control of material properties.

(c) Rupture disks may be fabricated from either ductile or brittle materials.

(d) The materials used in the rupture disk holder pressure-containing and pressure-retaining components shall meet all the requirements of this Division for pressure-boundary components.

KR-250 INSPECTION-OF-MANUFACTURING
OF RUPTURE-DISK-DEVICES

(a) A Manufacturer shall demonstrate to the satisfaction of a representative of an ASME Designated Organization that its manufacturing, production, and testing facilities and quality control procedures will ensure close agreement between the performance of random production samples and the performance of those devices submitted for Certification.

(b) The manufacturing, assembly, inspection, and test operations are subject to inspections at any time by an ASME Designee.

(c) A Manufacturer may be granted permission to apply the Certification Mark with “UD3” Designator to production rupture disk devices, provided the following tests are successfully completed. This permission shall expire on the sixth anniversary of the date it is initially granted. The permission may be extended for 6-yr periods if the following tests are successfully completed within the 6-month period before expiration:

(1) Two production sample rupture disk devices shall be selected by a representative of an ASME Designated Organization.

(2) Burst testing shall be conducted in the presence of a representative of an ASME Designated Organization. When the rupture disk device incorporates a Manufacturer’s standard rupture disk holder from a different Manufacturer, two new rupture disk holders shall be procured by the rupture disk Manufacturer for use in the tests.

(3) Should any device fail to meet the burst pressure requirements of KR-200(b), the test may be repeated at a rate of two replacement disks for each device that failed.

(4) Failure of any of the replacement disks shall be cause for revocation within 60 days of the authorization to use the Certification Mark on that particular type of rupture disk design. During this period, the Manufacturer
shall demonstrate the cause of such deficiency and the action taken to guard against future occurrence, and the requirements of (c) shall apply.

**KR-260 PRODUCTION TESTING BY MANUFACTURERS**

Each rupture disk device to which the Certification Mark with “UD3” Designator is to be applied shall be subject to the tests specified in KR-261 and KR-262 by the Manufacturer. The Manufacturer shall have a documented program for the application, calibration, and maintenance of gages and instruments used during these tests.

**KR-261 HYDROSTATIC TESTING**

The pressure-containing parts of each rupture disk holder shall be hydrostatically tested at a pressure at least 1.25 times the design pressure of the parts and not exceeding the upper limit as defined in KT-312. There shall be no sign of leakage.

(a) Testing may be performed on the individual components or in the assembled condition.

(b) When the outlet of the device is not designed to contain pressure, holder components downstream of the rupture disk are exempt from hydrostatic testing.

(c) Holder components downstream of the rupture disk and fully contained within the holder are exempt from hydrostatic testing.

(d) These tests shall be conducted after all machining and welding operations on the parts have been completed.

**KR-262 BURST PRESSURE TESTING**

Each lot of rupture disks shall be tested in accordance with one of the following methods. All tests of disks for a given lot shall be made in a holder of the same form and pressure area dimensions as that being used in service. Sample rupture disks, selected from each lot of rupture disks, shall be made from the same material and of the same size as those to be used in service. Test results shall only be applicable to rupture disks installed in the Manufacturer’s standard rupture disk holders as specified in the required rupture disk marking.

(a) At least two sample rupture disks from each lot of rupture disks shall be burst at the specified disk temperature. The marked burst pressure shall be determined so that the sample rupture disk burst pressures are within the burst pressure tolerance specified in KR-200.

(b) At least four sample rupture disks, but not less than 5% from each lot of rupture disks, shall be burst at four different temperatures distributed over the applicable temperature range for which the disks will be used. This data shall be used to establish a smooth curve of burst pressure versus temperature for the lot of disks. The burst pressure for each data point shall not deviate from the curve more than the burst pressure tolerance specified in KR-200. At least two disks from each lot of disks, made from this lot of material, shall be burst at the ambient temperature to establish the room temperature rating of the lot of disks. The value for the marked burst pressure shall be derived from the curve for a specified temperature.

(c) For prebulged solid metal disks or graphite disks only, at least four sample rupture disks using one size of disk from one lot of material shall be burst at four different temperatures, distributed over the applicable temperature range for which this lot of material will be used. These data shall be used to establish a smooth curve of percent change of burst pressure versus temperature for the lot of material. The acceptance criteria of the smooth curve shall be as in (b) above. At least two disks from each lot of disks, made from this lot of material and of the same size as those to be used, shall be burst at the ambient temperature to establish the room temperature rating of the lot of disks. The percent change shall be used to establish the marked burst pressure at the specified disk temperature for the lot of disks.

**KR-270 DESIGN REQUIREMENTS**

At the time of the inspection in accordance with KR-250 above, a representative from an ASME Designated Organization has the authority to review the design, prior to testing, for conformity with the requirements of KR-230 and KR-240 and to reject or require modification of designs that do not conform.
ARTICLE KR-3
REQUIREMENTS FOR PRESSURE RELIEF VALVES

KR-300  GENERAL REQUIREMENTS

(a) The requirements of this Article apply to pressure relief valves within the scope of this Division, including those which do not have to be flow capacity tested and certified; see KR-123(c).

(b) Pressure relief valves shall be the direct-acting, spring-loaded type.

(c) The set-pressure tolerance of pressure relief valves shall not exceed ±3%.

(d) Pressure relief valves meeting the requirements of ASME Boiler and Pressure Vessel Code Section VIII, Division 1 or 2, may be used provided all requirements of this Article are met. If the valve is the primary relief device (see KR-123(c)), the requirements of Article KR-5 and ASME CA-1 for accreditation of testing laboratories and acceptance of Authorized Observers shall be met.

KR-310  DESIGN REQUIREMENTS

KR-311  GUIDING

The design shall incorporate guiding arrangements necessary to ensure consistent opening at the set pressure, and reseat when the inlet pressure decreases to some pressure below the set pressure. Consideration shall be given to the effects of galling and friction on the valve operation.

KR-312  SPRING

The spring shall be designed so that the spring compression at full lift of the valve shall not be greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the original free length and the free length measured 10 min after the spring has been compressed to its solid height three times after the valve has been preset at room temperature) shall not exceed 0.5% of the original free length.

For direct spring-loaded valves that have set pressures above the maximum pressure used in the flow capacity certification tests, the spring force ratio shall not exceed 1.1 times the spring force ratio of the valve with the highest set-pressure used in the flow capacity certification tests. For direct spring-loaded valves that have orifices larger than the largest size used in the flow capacity certification tests, the spring force ratio shall not exceed 1.1 times the spring force ratio of the valve with the largest size orifice in the flow capacity certification tests. The spring force ratio, \( R_{sf} \), shall be calculated as follows:

\[
R_{sf} = \frac{F_{so}}{F_{sc}}
\]

where

\( F_{sc} \) = force exerted by the spring when the valve is closed or seated

\( F_{so} \) = force exerted by the spring when the valve is at rated lift

KR-313  SEAT

If the seat is not integral with the relief valve, it shall be secured to the valve body so that there is no possibility of the seat lifting or separating.

The manufacturer shall consider the potential for brinelling and the effects on the performance of the pressure relief valve in the selection of materials for the seating surfaces.

KR-314  BODY AND PRESSURE-RETAINING COMPONENTS

In the design of the valve body, consideration shall be given to minimizing the effects of deposits. See also KR-124 for requirements for all pressure-retaining components.

KR-315  BONNET

The bonnet of the pressure relief valve shall be vented to prevent accumulation of pressure. Sealing/isolation of the bonnet area from the relieving fluid may be required for protection of the spring assembly from corrosion or solids accumulation.

KR-316  INLET FITTINGS

Valves having threaded inlet or outlet connections in accordance with Article KD-6 shall be provided with wrenching surfaces as required to allow for normal installation without damaging operating parts.

KR-317  SEALING OF VALVE SETTINGS

Means shall be provided in the design of all pressure relief valves for use under this Division for sealing all adjustments which can be made without disassembling the valve before or after installation. Seals shall be installed by the Manufacturer at the time of initial shipment.
and after field adjustment of the valves by either the Man-
ufacturer or his authorized representative. Seals shall be
installed in a manner to prevent changing the adjustment
without breaking the seal. For valves larger than NPS ½
(DN 15), the seal shall identify the Manufacturer or As-
sembler making the adjustment.

KR-318 DRAIN REQUIREMENTS

If the design of a pressure relief valve is such that liquid
can collect on the discharge side of the disk, the valve
shall be equipped with a drain at the lowest point where
liquid can collect.

KR-320 MATERIAL SELECTION

KR-321 SEATS AND DISKS

Cast iron seats and disks are not permitted. The seats
and disks of pressure relief valves shall be of suitable ma-
terial to resist corrosion by the fluid to be contained (see
KG-311.7), and meet the requirements of KR-324(a),
KR-324(b), or KR-324(c).

KR-322 GUIDES AND SPRINGS

The materials used for guides and springs shall meet
the requirements of KR-324(a), KR-324(b), or
KR-324(c). Adjacent sliding surfaces such as guides and
disks or disk holders shall both be of corrosion-resistant
and galling-resistant material or shall have a corrosion-
resistant coating applied. Galling resistance shall be de-
monstrated on a prototype valve by popping a valve to
full stem lift ten times with subsequent disassembly and
inspection showing no indication of galling.

KR-323 PRESSURE-RETAINING PARTS

Materials used in pressure-retaining parts shall be
listed in Part KM.

KR-324 NONPRESSURE-RETAINING PARTS

Materials used in nozzles, disks, and other parts con-
tained within the external structure of the pressure relief
valves shall be one of the following categories:
(a) listed in Section II
(b) listed in ASTM specifications
(c) controlled by the Manufacturer of the pressure re-
  lief valve to a specification ensuring control of chemical
  and physical properties and quality at least equivalent
  to ASTM standards

KR-330 INSPECTION OF MANUFACTURING
AND/OR ASSEMBLY OF PRESSURE
RELIEF VALVES

KR-331 QUALITY

A Manufacturer shall demonstrate to the satisfaction of
an ASME designee that manufacturing as applicable; as-
sembling, production, and testing facilities; and quality
control procedures ensure that the valves produced by
the Manufacturer or Assembler meet the requirements
of this Division. For pressure relief valves requiring flow
capacity certification (see Article KR-5), it shall also be
demonstrated to the satisfaction of an ASME Designated Or-
ganization that there will be close agreement between the
performance of random production samples and the per-
formance of those valves submitted for capacity
certification.

KR-332 VERIFICATION

(a) Manufacturing, assembly, inspection, and test op-
erations, including capacity testing as appropriate, are
subject to inspection at any time by an ASME designee.

(b) At the time of the production testing in accordance
with KR-340, or the submission of valves for flow capacity
certification testing in accordance with Article KR-5, as
applicable, the ASME designee and/or its consultants
has the authority to reject or require modification of de-
signs which do not conform with the requirements of this
Part.

KR-340 PRODUCTION TESTING BY
MANUFACTURERS AND
ASSEMBLERS

All pressure relief valves manufactured in accordance
with this Division shall be tested as described below.
Pressure relief valves may be flow capacity tested in ac-
cordance with this Article and Article KR-5 [see
KR-123(c)].

KR-341 HYDROSTATIC TESTING

The primary pressure-retaining parts of each pressure
relief valve to which the Certification Mark with UV3 Des-
ignator is to be applied shall be hydrostatically tested to
not less than 1.25 times the design pressure of the parts.
These tests shall be conducted after all machining oper-
ations on the parts have been completed. There shall be no
visible signs of leakage. The secondary pressure zone of
each closed bonnet valve shall be tested at 1.25 times
the stated design pressure of the secondary pressure zone
but not less than 0.125 times the design pressure of the
primary parts.
KR-342 TEST MEDIA

Each pressure-relief valve to which the Certification Mark is to be applied shall be tested by the Manufacturer or Assembler to demonstrate set pressure of the pressure relief valve and the leak-tightness. Valves intended for compressible fluid service shall be tested with air or other suitable gas, and valves intended for incompressible fluid service shall be tested with water or other suitable incompressible fluid (see KG-311.11).

When the direct spring loaded pressure relief valve is beyond the production test equipment capabilities, an alternative test method presented in KR-342.1 or KR-342.2 may be used, provided all of the following conditions are met:

(a) testing the valve at full pressure may cause damage to the valve;
(b) the valve lift has been mechanically verified to meet or exceed the required lift;
(c) for valves with adjustable blowdown, the blowdown control elements are set to the valve manufacturer's specification; and
(d) the valve design is compatible with the alternative test method selected.

KR-342.1 The valve, with its lift temporarily restricted during the test, if required to prevent valve damage, shall be tested on the appropriate media to demonstrate popping or set pressure.

KR-342.2 The valve may be fitted with a hydraulic or pneumatic lift assist device and tested on the appropriate media at a pressure less than the valve set pressure. The lift assist device and test procedure shall be calibrated to provide the set pressure setting within the tolerance of KR-300(c).

KR-343 LEAK TIGHTNESS

A leak-tightness test shall be conducted at a maximum expected operating pressure, but at a pressure not exceeding the reseating pressure of the valve. When testing with water, a valve exhibiting no visible signs of leakage shall be considered leak-tight. The leak rate of the valve tested with a gas shall meet the criteria specified in the User's Design Specification (see KG-311.11).

KR-344 INSTRUMENTATION

A Manufacturer or Assembler shall have a documented program for the application, calibration, and maintenance of test gages and instruments.

KR-345 SET PRESSURE TOLERANCE

Test fixtures and test drums for pressure relief valves, where applicable, shall be of adequate size and capacity to ensure representative action and response at blowdown ring adjustments intended for installation. Under these conditions, the valve action shall be consistent with the stamped set pressure within a tolerance of ±3%.

KR-346 FLOW CAPACITY TESTING

The following sampling schedule of tests applies to production pressure relief valves that are to be flow capacity certified in accordance with Article KR-5; produced, assembled, tested, sealed, and shipped by the Manufacturer or Assembler; and having a normal scope of size and capacity within the capability of ASME accepted laboratories. Production valves for flow capacity and operational testing shall be selected by an ASME designee and the testing shall be carried out in the presence of a representative of the same organization at an ASME accepted laboratory in accordance with the following:

(a) Initial flow capacity certification shall be valid for 1 year, during which time two production valves shall be tested for operation, and stamped flow capacity verified. Should any valve fail to meet performance requirements, the test shall be repeated at the rate of two valves for each valve that failed. Initial flow capacity verification may be extended for 1 year intervals until the valve is in production. Valves having an adjustable blowdown construction shall be adjusted to the position recommended by the Manufacturer for use in service prior to flow testing. This adjustment may be made on the flow test facility.

(b) Thereafter, two valves shall be tested within each 6 year period of time. The valve Manufacturer shall be notified of the time of the test and may have a witness present during the test. Should any valve fail to relieve at or above its stamped flow capacity, or should it fail to meet performance requirements of this Division, the test shall be repeated at the rate of two valves for each valve that failed. Initial flow capacity verification may be extended for 1 year intervals until the valve is in production. Valves having an adjustable blowdown construction shall be set in accordance with (a). These valves shall be furnished by the Manufacturer. Failure of any valve to meet the stamped flow capacity or the performance requirements of this Division shall be cause for revocation within 60 days of the authorization to use the Certification Mark on that particular type of valve. During this period, the Manufacturer shall demonstrate the cause of such deficiency and the action taken to guard against future occurrence, and the requirements of (a) shall apply.
ARTICLE KR-4
CERTIFICATION MARK

KR-400 MARKING

KR-401 MARKING OF PRESSURE RELIEF VALVES

Each pressure-relief valve shall be plainly marked by the Manufacturer or Assembler with the required data in such a way that the markings will not be obliterated in service. The markings shall be located on the valve or a corrosion-resistant metal plate or plates securely fastened to the valve. Small valves [less than NPS ½ (DN 15) inlet] may have the nameplate attached with a chain or wire. Nameplates may be attached with pressure-sensitive acrylic adhesive systems in accordance with Mandatory Appendix 5. The marking shall include
(a) the name or identifying trademark of the Manufacturer and/or Assembler, as appropriate, preceded by the words “Certified by”
(b) Manufacturer’s or Assembler’s design, type number
(c) valve inlet size, in. (mm)
(d) set-pressure, ksi (MPa)
(e) flow capacity, SCFM (m³/hr) of air (60°F and 14.7 psia) (16°C and 101 kPa), or gal/min (L/min) of water at 70°F (21°C), if the pressure-relief valve is to be tested to have a certified flow capacity; see KR-122 and KR-123(b). If the pressure-relief valve is not flow capacity tested and certified, the flow capacity shall be stamped “NONE.”

NOTE: In addition, the Manufacturer/Assembler may indicate the flow capacity in other fluids (see KR-530).
(f) year built, or alternatively, a coding may be marked on the valve such that the valve Manufacturer/Assembler can identify the year built
(g) Certification Mark with the UV3 Designator placed under the mark shown in Figure KR-401, sketch (a). A marking method other than the stamp issued by the Society may be used, provided it is acceptable to the ASME Designated Organization.
(h) Use of the Certification Mark with UV3 Designator by an Assembler shall indicate the use of original, unmodified parts in strict accordance with instructions of the Manufacturer of the valve. The nameplate marking shall include the name of the Manufacturer and the Assembler, and the Certification Mark with UV3 Designator shall be that of the Assembler.

KR-402 MARKING OF RUPTURE DISK DEVICES

Every rupture disk shall be plainly marked by the Manufacturer in such a way that the marking will not be obliterated in service and will not interfere with the function of the disk. The marking may be placed on the flange of the disk or on a metal tab permanently attached thereto. The marking shall include the following:
(a) the name or identifying trademark of the Manufacturer
(b) Manufacturer’s design, type number, or drawing number
(c) lot number
(d) material
(e) size, in. (mm)
(f) marked burst pressure, ksi (MPa)
(g) specified disk temperature, °F (°C)
(h) Certification Mark with the UD3 Designator placed under the mark shown in Figure KR-401, sketch (b).
(i) year built, or alternatively, a coding may be marked such that the rupture disk device Manufacturer can identify the year the rupture disk device was assembled and tested
(j) design, type number, or drawing number of the intended Manufacturer’s standard rupture disk holder

Item (a), (b), (d), (e), (h), and (i) shall also be marked on the rupture disk holder.

Figure KR-401
Official New Certification Mark to Denote the American Society of Mechanical Engineers’ Standard

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For rupture disks that are fully enclosed in the holder or the system it protects, the disk may be marked only with the lot number and shall be packaged and shipped with an associated metal tag marked in accordance with (a) through (j).

Following installation of the disk into the holder or system, the metal tag shall be sealed to the installation in a manner that will prevent changing the disk without breaking the seal. The seal shall serve as a means of identifying the organization responsible for making the installation.

KR-403 MARKING OF PRESSURE RELIEF VALVES IN COMBINATION WITH RUPTURE DISK DEVICES

Pressure relief valves in combination with rupture disk devices shall be marked with the flow capacity established in accordance to KR-220, in addition to the marking of KR-401 and KR-402. The marking may be placed on the valve or on a plate or plates securely fastened to the valve. The marking shall include the marking required by KR-401(a) through KR-401(g) and the specific details of the rupture disk device so that the rupture disk device is uniquely identified and specified.

KR-410 USE OF CERTIFICATION MARK

Each pressure relief device to which the Certification Mark is to be applied shall be fabricated or assembled by a Manufacturer or Assembler who is in possession of a Certification Mark (see Figure KR-401) and a valid Certificate of Authorization, obtainable when the conditions of Article KS-2 have been met.

A Certified Individual (CI) meeting the current requirements of ASME QAI-1 shall provide oversight to ensure that each use of the Certification Mark is in accordance with the requirements of this Division. In addition, each use of the Certification Mark is to be documented on a Certificate of Conformance Form K-4 or Form K-5 as appropriate.

(a) Requirements for the Certified Individual (CI). The CI shall

1) be qualified in accordance with ASME CA-1 and the requirements of this Division

2) have the following qualifications as a minimum
   (a) knowledge of the requirements of this Division for the application of the Certification Mark and appropriate Designator
   (b) knowledge of the Manufacturer’s or Assembler’s quality program
   (c) training commensurate with the scope, complexity, or special nature of the activities to which oversight is to be provided

3) have a record, maintained and certified by the Manufacturer or Assembler, containing objective evidence of the qualifications of the CI and the training program provided

(b) Duties of the Certified Individual (CI). The CI shall

1) verify that each item to which the Certification Mark is applied meets all applicable requirements of this Division and has a current capacity certification for the Certification Mark with appropriate Designator

2) review documentation for each lot of items to be stamped to verify, for the lot, that requirements of this Division have been completed

3) sign the Certificate of Conformance Form K-4 or Form K-5, as appropriate, prior to release of control of the item

(c) Certificate of Conformance Form K-4 or Form K-5

1) The appropriate Certificate of Conformance shall be filled out by the Manufacturer or Assembler and signed by the CI. Multiple duplicate pressure relief devices shall be recorded on a single entry, provided the devices are identical and produced in the same lot.

2) The Manufacturer’s or Assembler’s written quality control program shall include requirements for completion of Certificates of Conformance forms and retention by the Manufacturer or Assembler for a minimum of 6 years.
ARTICLE KR-5
CERTIFICATION OF FLOW CAPACITY OF PRESSURE RELIEF VALVES

KR-500 FLOW CAPACITY CERTIFICATION TESTS

KR-501 FLUID MEDIA

Flow-capacity certification tests shall be conducted with liquids, or vapors as appropriate. For fluids which are to be handled near their critical point, or in any region where their thermodynamic properties are significantly nonlinear, or where a change of phase may occur in the valve (flashing), the flow capacity shall be determined from the vapor and liquid capacity data using appropriate correlations and procedures. Saturated water service is addressed in KR-532(a). Alternatively, the flow capacity and design of the overpressure protection system may be specified by the User or his Agent, based on basic data, testing, and demonstration on such actual fluids at expected operating conditions. This information is stated in the User’s Design Specification; see KG-311.11.

For relief valves intended for use with supercritical fluids relieving at or above the critical point, tests shall be conducted on both liquid and vapor. The ASME accreditied testing laboratory shall measure and report the stem lift at the stated capacity for both liquid and vapor.

KR-502 TEST PRESSURES

Flow capacity certification tests shall be conducted at a pressure not to exceed 110% of the set pressure of the pressure relief valve. The reseating pressure shall be noted and recorded. Valves having an adjustable blowdown construction shall be adjusted prior to testing so that the blowdown does not exceed 5% of the set pressure. Flow tests to certify flow capacity tested at a given pressure shall not be extrapolated to a higher pressure.

KR-510 RECERTIFICATION TESTING

When changes are made in the design of a pressure relief valve that affect the flow path, lift, or may affect other performance characteristics of the pressure relief valve, new tests shall be performed in accordance with this Division.

KR-520 PROCEDURES FOR FLOW CAPACITY CERTIFICATION TESTS

KR-521 THREE-VALVE METHOD

A flow capacity certification test is required on a set of three valves for each combination of size, design and pressure setting. The stamped flow capacity rating for each combination of design, size, and test pressure shall not exceed 90% of the average flow capacity of the three valves tested. Test valves must be installed with an adequate vent system that will not affect the flow capacity of the valves or cause chatter. The flow capacity of any one of a set of three valves shall fall within a range of ±5% of the average flow capacity. Failure to meet this requirement shall be cause to refuse certification of a particular safety valve design.

KR-522 SLOPE METHOD

If a Manufacturer wishes to apply the Certification Mark to a design of pressure relief valves, four valves of each combination of pipe size and orifice size shall be tested. These four valves shall be set at pressures that cover the approximate range of pressures for which the valve will be used or covering the range available at the certified test facility, which shall conduct the tests. The capacities based on these four tests shall be as follows:

(a) For compressible fluids, the slope \( W/P \) of the actual measured capacity versus the flow pressure for each test point shall be calculated and averaged:

\[
\text{Slope} = \frac{W}{P} = \frac{\text{measured capacity}}{\text{absolute flow pressure}}
\]

All values derived from the testing must fall within ±5% of the average value:

- Minimum slope = 0.95 x average slope
- Maximum slope = 1.05 x average slope

If the values derived from the testing do not fall between the minimum and maximum slope values, the authorized observer shall require that additional valves be tested at the rate of two or each valve beyond the maximum and minimum values, with a limit of four additional valves.
The relieving capacity to be stamped on the valve shall not exceed 90% of the average slope times the absolute accumulation pressure:

\[ \text{Rated slope} = 0.90 \times \text{average slope} \]

Stamped capacity ≤ rated slope \((\text{set pressure } \times 1.10 + 14.7) \text{ psi, } (\text{set pressure } \times 1.10 + 101) \text{ kPa}\)

(b) For incompressible fluids, the capacities shall be plotted on log-log paper against the differential (inlet minus discharge pressure) test pressure and a straight line drawn through these four points. If the four points do not establish a straight line, two additional valves shall be tested for each unsatisfactory point, with a limit of two unsatisfactory points. Any point that departs from the straight line by more than 5% should be considered an unsatisfactory point. The relieving capacity shall be determined from this line. The certified capacity shall not exceed 90% of the capacity taken from the line.

**KR-523 COEFFICIENT OF DISCHARGE METHOD**

**KR-523.1 Procedure.** Instead of individual flow capacity certification, as provided in KR-521 and KR-522, a coefficient of discharge \(K_D\) may be established for a specific pressure relief valve design according to the procedure in KR-523.2 and KR-523.3. This procedure will not be applicable to fluids handled near their critical point, or in any region where their thermodynamic properties are nonlinear. Refer to KR-501.

**KR-523.2 Number of Valves.** For each design, the pressure relief valve Manufacturer shall submit for test at least three valves for each of three different sizes (a total of nine valves) together with detailed drawings showing the valve construction. Each valve of a given size shall be set at a different pressure.

**KR-523.3 Calculation Method.** Tests shall be made on each pressure relief valve to determine its flow capacity, lift, popping, and blowdown pressures and actual flow capacity in terms of the fluid used in the test. A coefficient of discharge \(K_D\) shall be established for each test run as follows:

\[
K_D = \frac{\text{actual flow}}{\text{theoretical flow}} = \frac{W_T}{W_T}
\]

where actual flow is determined quantitatively by testing, and theoretical flow is calculated by the appropriate equation which follows:

For tests with air

\[ W_T = 27.14P\left[\frac{M}{ZT}\right]^{0.5} \text{ kg/hr} \]

For tests with other gases:

\[ W_T = C\left[\frac{M}{ZT}\right]^{0.5} \]

For tests with water or other incompressible fluids:

\[ W_T = 3.87A\sqrt{\rho(P - P_B)} \text{ kg/hr} \]

where

\[
A = \text{actual discharge area through the device during venting, in.}^2 \text{ (mm}^2\text{)}
\]

\[
C = \text{constant for gas or vapor based on } \kappa, \text{ the ratio of specific heats } C_P/C_V \text{ (refer to Figure KR-523.3)}
\]

**KR-523.4 Determining Coefficients.** The average of the coefficients \(K_D\) of all nine tests required shall be multiplied by 0.90, and this product shall be taken as the coefficient \(K_D\) of that design. All experimentally determined coefficients \(K_D\) shall fall within a range of ±5% of the average \(K_D\) found. Failure to meet this requirement shall
be cause to refuse certification of that particular valve design. The coefficient shall not be applied to valves with springs that do not meet the requirements of KR-312.

**KR-523.5 Flow Capacity**. The certified relieving flow capacity of all sizes and pressures of a given design, for which $K_D$ has been established under the provisions of KR-523.3, that are manufactured subsequently shall not exceed the value calculated by the appropriate equation in KR-523.3 multiplied by the coefficient $K_D$ (see KR-530). For direct spring loaded valves, the flow capacity may be extrapolated to valves with set pressures higher than the highest set pressure used in the flow capacity certification tests, if the spring in the valve with the higher set pressure meets the requirements of KR-312.

The results may be extrapolated to valves larger or smaller than the valves used in the flow capacity certification tests providing that all dimensions of the flow path and all dimensions of the parts that can affect the overall thrust exercised by the medium on the moving parts are scaled with the corresponding dimensions of the valves used in the flow capacity.

**KR-530 Flow Capacity Conversions**

**KR-531 Gas and Air Service**

For low pressure gases (gases at pressures less than two-thirds of their critical pressure), the capacity of the relief valve in terms of a gas other than that for which its rating was certified shall be determined as follows:

(a) For air:

\[
W_a = C K_D A P (\frac{M}{T Z})^{0.5}
\]

where:

- \(C = 356,000\) (U.S. Customary Units) or \(27.1\) (SI Units)
- \(M = 28.97\)
- \(T = 520°R\) (289 K) when \(W_a\) is the rated capacity.
For any gas or vapor with linear thermodynamic properties through the valve:

\[ W = C K D A^0.5 \]  

where

- \( A \) = actual discharge area of the relief valve, in.\(^2\) (mm\(^2\))
- \( C \) = constant for gas which is a function of the ratio of specific heats; see Figure KR-523.3
- \( K_D \) = coefficient of discharge; see KR-523
- \( M \) = molecular weight
- \( P \) = 110% of set pressure plus atmospheric pressure
- \( T \) = absolute gas temperature at the inlet, \( ^\circ R = ^\circ F + 460 \) (K = \( ^\circ C + 273 \))
- \( W \) = capacity of any gas in lbm/hr (kg/hr)
- \( W_a \) = rated capacity, converted to lbm/hr (kg/hr) of air at 60\(^\circ\)F (16\(^\circ\)C), inlet temperature
- \( Z \) = compressibility factor

Knowing the certified capacity rating of a relief valve including the gas and conditions of the gas for which it is certified, it is possible to determine the overall value of the product of \( K_D A \) for that given valve by solving the above equations for \( K_D A \). This value of \( K_D A \) can then be used to solve for \( W \) or \( W_a \) at a new set of conditions. For hydrocarbons and other gases where the value of \( k = (C_p/C_v) \) is not known, assume a value of \( k = 1.001 \) and a corresponding value of \( C \approx 315,000 \) (U.S. Customary Units) or 24.0 (SI Units)(see Figure KR-523.3).

**KR-532 LIQUID AND HIGH-PRESSURE GAS SERVICE**

For gas pressure service above the pressure limits given in KR-531, and for liquid service, additional consideration shall be given to the fact that the actual flow capacity of a given valve may be influenced by any of the following:

- (a) fluid conditions close to or above the critical point
- (b) liquid flashing to vapor and other phase changes that may occur causing a two-phase or multi-phase flow regime in the valve
- (c) conditions in which decomposition reactions occur and the chemical composition of the resulting fluid cannot be definitively established

The User or his designated agent shall be responsible for establishing a procedure for sizing and flow capacity conversion based on device geometry, as well as the change in fluid conditions and fluid properties during flow through the valve and all associated piping. This procedure shall address the effects of phase changes at particular points in the device as appropriate. If necessary, sizing may be determined on an empirical basis by actual capacity tests with the process in question at expected relieving conditions. The User shall be responsible for providing or approving the assumptions and calculations used in all flow capacity conversions.
KR-540  FLOW-CAPACITY CERTIFICATION TESTING REQUIREMENTS FOR TEST FACILITIES

Capacity and flow resistance certification shall be conducted in accordance with ASME PTC 25. Testing shall be conducted by an accredited testing laboratory with Authorized Observers. Testing laboratories shall be accredited, and test supervisors shall have been accepted as Authorized Observers, in accordance with the rules of ASME-CA-1.

KR-550  TEST-DATA REPORTS

Flow capacity test Data Reports for each valve model, type, and size signed by the Manufacturer and the Authorized Observer witnessing the tests shall be submitted to an ASME designee for certification. Where changes are made in the design, flow capacity certification tests shall be repeated.

KR-560  CERTIFICATION OF FLOW CAPACITY OF PRESSURE RELIEF VALVES IN COMBINATION WITH RUPTURE DISK DEVICES

For each combination of pressure relief valve design and rupture disk device design, the pressure relief valve Manufacturer or the rupture disk device Manufacturer may have the flow capacity of the combination certified as prescribed in KR-561 through KR-563.

KR-561  TEST MEDIA AND TEST PRESSURES

The test media and test pressure requirements are the same as those stated in KR-501 and KR-502.

KR-562  SIZES OF TEST UNITS

The valve Manufacturer or the rupture disk device Manufacturer may submit for tests the smallest rupture disk device size with the equivalent size of pressure relief valve that is intended to be used as a combination device. The pressure relief valve to be tested shall have the largest orifice used in that particular pressure relief valve inlet size.

KR-563  TESTING METHOD

Tests may be performed in accordance with the following:

(a) The pressure-relief valve (one valve) shall be tested for flow capacity as an individual valve, without the rupture disk device, at a pressure 10% above the valve set pressure. The rupture disk device shall then be installed ahead of the pressure relief valve and the disk burst to operate the valve. The flow capacity test shall be performed on the combination at 10% above the valve set pressure duplicating the individual pressure relief valve flow capacity test.

(b) Tests shall be repeated with two additional rupture disks of the same nominal rating for a total of three rupture disks to be tested with the single valve. The results of the flow capacity tests shall fall within a range of ±10% of the average flow capacity of the three tests. Failure to meet this requirement shall be cause to require retest for determination of cause of the discrepancies.

(c) From the results of the tests, a combination flow capacity factor shall be determined. The combination flow capacity factor is the ratio of the average flow capacity determined by the combination tests to the flow capacity determined on the individual valve. The combination flow capacity factor shall be used as a multiplier to make appropriate changes in the ASME rated relieving flow capacity of the pressure relief valve in all sizes of the design. The value of the combination flow capacity factor shall not be greater than one. The combination flow capacity factor shall apply only to combinations of the same design of pressure relief valve and the same design of rupture disk device as those tested.

(d) The test laboratory shall meet the requirements of KR-540 and shall submit to an ASME designee the test results for approval of the combination flow capacity factor for certification.

KR-570  OPTIONAL TESTING OF RUPTURE DISK DEVICES AND PRESSURE RELIEF VALVES

KR-571  LARGER-SIZES

If desired, a valve Manufacturer or a rupture disk device Manufacturer may conduct tests in the same manner as outlined in KR-550 using a rupture disk device larger than the inlet of the pressure relief valve to determine a combination flow capacity factor applicable to larger sizes. If a greater combination flow capacity factor is established and can be certified by a test facility that meets the requirements of KR-540, it may be used for all disks larger than the combination tested, but shall not be greater than one.

KR-572  HIGHER-PRESSURES

If desired, additional tests may be conducted at higher pressures in accordance with KR-560 to establish a maximum combination flow capacity factor for all pressures higher than the highest tested, but it shall be not greater than one.
ARTICLE KR-6
REQUIREMENTS FOR POWER-ACTUATED PRESSURE RELIEF SYSTEMS

KR-600 GENERAL REQUIREMENTS

(a) In accordance with the rules provided in this Article, a power-actuated pressure relief system may be used instead of a relief valve or rupture disk on high-pressure vessels equipped with an external yoke to support end-closures.

(b) A pressure vessel may also be provided with overpressure protection by a power-actuated pressure relief system by design in lieu of a pressure relief valve, rupture disk, or other pressure relief devices if all provisions of Section VIII, Division 1, UG-140 are satisfied.

KR-601 USER RESPONSIBILITIES

The User’s Design Specification shall

(a) require overpressure protection by a power-actuated pressure relief system

(b) certify that the User will demonstrate the functioning of the system prior to initial operation and at least four times per year

KR-602 MANUFACTURER’S RESPONSIBILITIES

(a) The Manufacturer’s Design Report shall contain instructions for demonstration of the functioning of the system.

(b) The Manufacturer shall ensure that the Authorized Inspector witnesses the initial setting and verification of the functionality of each power-actuated pressure relief device.

(c) Overpressure protection provided by this Article shall be shown in the Manufacturer’s Data Report.

(d) A detailed schematic of the control system shall be supplied with the vessel documentation.

KR-610 SYSTEM REQUIREMENTS

(a) The output from three independent devices shall be processed by an automated system. These devices shall be a combination of pressure transducers and elongation (strain) measuring devices as described in (1) and (2) below.

(1) Two pressure transducers and one elongation measuring device.

(2) Two elongation measuring devices and one pressure transducer.

(b) Any elongation measuring device shall be continuously indicative of the elongation (strain) of the yoke in a location where the elastic elongation (strain) of the yoke is linearly proportional to the pressure.

(1) Any elongation (strain) measuring device shall be designed and installed such that temperature does not affect the results.

(2) Means shall be provided to automatically reset the zero of the elongation measuring device(s) at the beginning of each pressurization cycle to maintain calibration.

(c) The pressure vessel shall be automatically depressurized under any of the following conditions:

(1) Any outputs (pressure transducer or elongation device) indicate that the pressure exceeds the limits in KR-160.

(2) Any of the three input signals are lost or fail for duration of 2 sec or more.

(3) Any pressure or elongation output deviates from any other output by more than 5%.

(d) There shall be at least two normally opened (NO) valves that are kept closed by the use of hydraulic or pneumatic pressure, so that both valves open (thereby lowering the vessel pressure) when the electrical signal to the valve is lost.

(e) The power-actuated pressure relief valves shall be designed to fail open, relieving the pressure in the pressure vessel in case of an electric, hydraulic, or pneumatic failure.

(f) The set pressure tolerance for the power-actuated pressure relief valves shall not exceed ±5% of the set pressure.

(g) The material for the portion of the valve that is exposed to the high-pressure fluid shall meet the material requirements in Part KR.

KR-620 FLOW CAPACITY TESTING

(a) As an alternative to the flow capacity testing requirements of Article KR-5 and KR-346, the capacity of the power-actuated pressure relief valve may be demonstrated by tests on a prototype system. If any of the essential system design variables change, a new demonstration shall be required. The essential variables are

(1) an increase in vessel volume

(2) an increase in heating capacity
(3) an increase in pressure generator capacity
(4) a change in the relief flow path configuration that could reduce the flow capacity
(5) a change in the valve size or model number
(6) a change in any other variables that could increase the required relief capacity or reduce the furnished relief capacity of the system

The system shall be tested using most severe identifiable conditions in such a way that it can be demonstrated that the pressure will be limited to the overpressure required by KR-150. The demonstration shall be witnessed by the Authorized Inspector.

(b) The results of the flow capacity demonstration and the setting and verification tests shall be documented in the Manufacturer's Design Report.

(c) Because the actual flow capacity test is performed on the entire system, the 10% derating factor required in KR-522 shall not apply.
ARTICLE KR-7
OVERPRESSURE PROTECTION FOR IMPULSIVELY LOADED VESSELS

KR-700 GENERAL

Since impulsive pressure loading durations are short in comparison to the reaction time of overpressure protection systems, overpressure protection requirements for impulsively loaded vessels are provided in the following paragraphs. The User, or his designated agent, shall specify overpressure protection by administrative controls and system design, and shall reference this Article in writing in the purchase documents. The Manufacturer is responsible only for verifying that the User or his designated agent has specified overpressure protection by administrative controls and system design, and for listing this Article on the Manufacturer’s Data Report.

(a) The User, or his designated agent, shall conduct a detailed analysis that examines all credible scenarios that could result in an overpressure condition. The “Causes of Overpressure” described in Section 4 of API Standard 521, “Pressure-Relieving and Depressurizing Systems” shall be considered. An organized, systematic approach by a multidisciplinary team employing one or more of the following methodologies shall be used:

1. Hazards and Operability Analysis (HazOp)
2. Failure Modes, Effects, and Criticality Analysis (FMECA)
3. Fault Tree Analysis
4. Event Tree Analysis
5. “What-If” Analysis

In all cases, the User or his designated agent shall determine the potential for overpressure due to all credible operating and upset conditions, including equipment and instrumentation malfunctions.

(b) The analysis described in (a) shall be conducted by an engineer experienced in the applicable analysis methodology. Any overpressure concerns that are identified shall be evaluated by an engineer experienced in pressure vessel design and analysis. The results of the analysis shall be documented and signed by the individual in charge of operation of the vessel. The documentation shall include:

1. detailed Process and Instrument Flow Diagrams (P&IDs), showing all pertinent elements of the system associated with the vessel
2. a description of all credible operating and upset scenarios, including scenarios involving fire, and those that result from equipment and instrumentation failures
3. an analysis showing the maximum short-term impulsive loading and long-term pressure that can result from each of the scenarios examined in (2) above
4. a detailed description of any administrative controls and/or instrumentation and control system that is used to limit the impulsive loading and long-term pressure to the system, including the identification of all truly independent redundancies and a reliability evaluation (qualitative or quantitative) of the overall safety system

(c) The documentation shall be made available to the regulatory and enforcement authorities having jurisdiction at the site where the vessel will be installed. The User of this Article is cautioned that prior jurisdictional acceptance may be required.

(d) This Article shall be shown on the Manufacturer’s Data Report for pressure vessels that will be provided with overpressure protection by administrative controls and system design, and it shall be noted on the Data Report that prior jurisdictional acceptance may be required.
PART KOP
OVERPRESSURE PROTECTION
ARTICLE KOP-1
GENERAL REQUIREMENTS

KOP-100 GENERAL REQUIREMENTS

(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 inherent overpressure protection. 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 Division shall be provided with protection against overpressure according to the requirements of this Part. Combination units (such as heat exchangers with shells designed for lower pressures than the tubes) shall be protected against overpressure from internal failures.

(c) Overpressure protection need not be provided when the source of pressure is external to the vessel and when the source of pressure is under such positive control that the pressure in the vessel cannot exceed the design conditions except as permitted in KOP-140.

(d) In the case where a vessel is pressurized by an intensifier system whose output pressure to the vessel is a fixed multiple of the supply pressure, the pressure relief device may be located on the low pressure supply side of the intensifier if all the following requirements are met:

1. There shall be no intervening stop valves or check valves between the driving chamber(s) and the relief device(s).
2. Heating of the discharge fluid shall be controlled to prevent further pressure increase which would exceed vessel design conditions.
3. The discharge fluid shall be stable and nonreactive (water, hydraulic fluid, etc.).
4. The material being processed in downstream equipment is stable and nonreactive or is provided with a suitable secondary vent system which will effectively prevent transfer of secondary energy sufficient to overpressure the vessel.

The Designer is cautioned to consider the effects of leaking check valves in such systems.

KOP-110 - DEFINITIONS

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

KOP-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 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 operating and upset conditions
(2) fluids
(3) fluid phases
(4) The overpressure protection system need not be supplied by the vessel Manufacturer.
(5) The User or his designated agent shall be responsible for establishing a procedure for sizing and/or flow capacity calculations for the device and associated flow paths, as well as changes in fluid conditions and properties as appropriate. These calculations shall be based on the most severe credible combinations of final compositions and resulting temperature. Alternatively, sizing shall be determined on an empirical basis by actual capacity tests with the process in question at expected relieving conditions. The User shall be responsible for providing or approving the assumptions used in all flow capacity calculations. The User is cautioned that some fluids (e.g., ethylene) in the supercritical state behave more like liquids than gasses, so liquid or combination liquid/vapor trim values should be considered.

**KOP-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 remove the maximum quantity that can be generated or supplied to the attached equipment without permitting a rise in pressure within the vessel of more than that specified in KOP-140.
(c) 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.

**KOP-140 OVERPRESSURE LIMITS**

The aggregate capacity of the safety relief devices, open flow paths, or vents shall be sufficient to prevent overpressures in excess of 10% above the design pressure of the vessel when the safety relief devices are discharging. The Designer shall consider the effects of the pressure drop in the overpressure protection system piping during venting when specifying the set pressures and flow capacities of pressure relief valves and rupture disk devices. When multiple pressure relief devices can discharge through a common stack or vent path, the maximum back pressure that can exist during simultaneous releases at the exit of each pressure relief device shall not impair its operation.

**KOP-150 PERMITTED PRESSURE RELIEF DEVICES AND METHODS**

**KOP-151 General**
Pressure relief valves, rupture disk devices, open flow paths and/or inherent overpressure protection may be used to protect against overpressure.

**KOP-152 Rupture Disk Devices**
(a) Because of the high pressures associated with this Division, it may be impractical to accomplish full-scale flow capacity performance testing and certification of pressure-relieving devices. For this reason,
rupture disk devices may be the more commonly used means of overpressure protection for vessels within the scope of this Division.

The use of rupture disk devices may be advisable when very rapid rates of pressure rise could be encountered, or where the relief device must have intimate contact with the process stream. Intimate contact may be required to overcome inlet line fouling problems or to ensure that the temperature of the disk is the same as the interior temperature of the vessel.

(b) Rupture disk devices bearing the Certification Mark with the UD3 Designator in accordance with Section XIII may be used.
(c) Rupture disk devices bearing the Certification Mark with the UD Designator in accordance with Section XIII may be used, provided the applicable requirements of Section XIII, Part 4 are met, including the specific requirements for Section VIII, Division 3.
(d) Rupture disk devices bearing the Certification Mark with the UD3 Designator in accordance with Section XIII may incorporate a Manufacturer’s standard rupture disk holder manufactured by a Manufacturer other than the rupture disk Manufacturer.
(e) The flow capacity of the rupture disk device shall be demonstrated by calculation to meet the requirements of KOP-140.
(1) The calculated capacity rating of the rupture disk device shall not exceed a value based on the applicable theoretical formula multiplied by a coefficient of discharge, KD, where KD = 0.62
(2) The Designer is responsible to evaluate the rupture disk and holder design to determine the applicable area to be used in the theoretical formula. The Designer is cautioned that normal capacity calculations may not be applicable for supercritical fluids and should consider the critical point and nonlinear thermodynamic properties of the fluid used in service. Flow through the entire relieving system shall be analyzed with due consideration for the wide variation in physical properties, which will occur due to the wide range of flowing pressures.
(3) Rupture disks may be certified as to burst pressure provided the test stand has enough volume to provide a complete burst. Flow coefficient (Cp, K, LEQ, percent open area) may be established at a lower pressure using any suitable fluid.

KOP-153 Pressure Relief Valves

(a) Pressure relief valves bearing the Certification Mark with the UV3 Designator in accordance with Section XIII may be used. Pressure relief valves bearing the Certification Mark with the UV Designator in accordance with Section XIII may be used, provided the applicable requirements of Section XIII, Part 4 are met, including specific requirements for Section VIII, Division 3. If the valve is the primary relief device [see KOP-154(c)], the requirements of Section XIII, Parts 9 and 10 for accreditation of testing laboratories and acceptance of Authorized Observers shall be met.
(b) All pressure relief valves shall meet the requirements of Section XIII, and shall be flow capacity performance tested and certified in accordance with Section XIII, Part 9, except in the case where their opening is not required to satisfy the overpressure limits given in KOP-140. See KOP-154(c) for further discussion about the use of relief valves in parallel with rupture disks.
(c) Pressure relief valves shall be the direct spring-loaded type.

KOP-154 Combination Devices

A rupture disk device used in combination with a pressure relief valve may be advisable on vessels containing substances that may render a pressure relief valve inoperative by fouling, or where a loss of valuable material by leakage should be avoided, or where contamination of the atmosphere by leakage
of noxious, flammable, or hazardous fluids must be avoided.

(a) Multiple rupture disk devices in parallel shall not be used on the inlet side of a pressure relief valve.

(b) When a combination device is used, both the rupture disk device and the pressure relief valve shall meet the applicable requirements of Part KOP and Section XIII. The rupture disk device shall be installed to prevent fragments from the rupture disk from interfering with the proper operation of the pressure relief valve. For additional requirements, see Section XIII, Part 8.

(c) A rupture disk device may be used in parallel with a pressure relief valve whose set pressure is lower than the rupture disk when it is important to limit the quantity of a release or it is impractical to certify the flow capacity of the pressure relief valve under the rules of this Division. The calculated flow capacity of the rupture disk device acting alone shall be adequate to meet the requirements of KOP-140, and the rupture disk device shall meet all the applicable requirements of this Part. With the exception of the flow capacity certification, the pressure relief valve shall meet all the requirements of this Part.

KOP-155 Power-Actuated Pressure Relief Systems

Power actuated pressure relief systems may be used in accordance with Article KOP-2.

KOP-156 Inherent Overpressure Protection

Inherent overpressure protection is permitted, provided the requirements of KOP-100(c) are met.

KOP-160 PRESSURE SETTINGS AND PERFORMANCE REQUIREMENTS

(a) A single safety relief device shall open at a nominal pressure not exceeding the design pressure of the vessel at the operating temperature, except as permitted in (b) below.

Users are cautioned that certain types of rupture disks have manufacturing ranges that can result in a marked burst pressure greater than the specified burst pressure.

(b) If the required discharging capacity is supplied by more than one device, only one need be set to operate at a pressure not exceeding the design pressure of the vessel. The additional device or devices may be set at a higher pressure but not to exceed 105% of the design pressure of the vessel. The requirements of KOP-140 shall also apply.

(c) For CRPV in transport service, a single safety relief device may be set to open at a nominal pressure not exceeding 110% of the design pressure of the vessel at the operating temperature in lieu of the requirements in (a) above. The requirements of KOP-140 shall also apply.

(d) The pressure at which any device is set shall include the effects of superimposed back pressure through the pressure relief device and the vent system (see KOP-140).

(e) The set pressure tolerance of pressure relief valves shall not exceed ±3%.

(f) Rupture disk devices shall burst within a tolerance of ±5% of the marked burst pressure.

KOP-170 INSTALLATION

KOP-171 Size of Openings and Nozzles

The flow characteristics of the entire pressure-relieving system shall be part of the relieving capacity calculations. The size of nozzles and openings shall not adversely affect the proper operation of the pressure-relieving device.
KOP-172 Intervening Stop Valves

There shall be no intervening stop valves between the vessel and any overpressure protection device associated with the vessel, except as permitted in KOP-173.

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 relief devices on 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 shall be so arranged that it can be locked or sealed in either the open or closed position by an authorized person. Under no condition shall this valve be closed while the vessel is in operation.

KOP-173 Dual Overpressure Protection

Where it is desirable to perform maintenance on pressure relief devices without shutting down the process, a full-area three-way transfer valve may be installed on the inlet of the pressure relief device(s). The design of the transfer valve and pressure relief devices must be such that the requirements of KOP-140 are met at any position of the transfer valve. Alternatively, the User may elect to install stop valves in each branch, but so controlled that one branch is open at all times and the requirements of KOP-140 are always met while the process is in operation.
**ARTICLE KR-6**

**REQUIREMENTS FOR POWER-ACTUATED PRESSURE RELIEF SYSTEMS**

**KR-600 GENERAL REQUIREMENTS**

(a) In accordance with the rules provided in this Article, a power-actuated pressure relief system may be used instead of a relief valve or rupture disk on high pressure vessels equipped with an external yoke to support end closures.

(b) A pressure vessel may also be provided with over-pressure protection by a power-actuated pressure relief system by design in lieu of a pressure relief valve, rupture disk, or other pressure relief devices if all provisions of Section VIII, Division 1, UG-140 are satisfied.

**KR-601 USER RESPONSIBILITIES**

The User’s Design Specification shall

(a) require overpressure protection by a power-actuated pressure relief system

(b) certify that the User will demonstrate the functioning of the system prior to initial operation and at least four times per year

**KR-602 MANUFACTURER’S RESPONSIBILITIES**

(a) The Manufacturer’s Design Report shall contain instructions for demonstration of the functioning of the system.

(b) The Manufacturer shall ensure that the Authorized Inspector witnesses the initial setting and verification of the functionality of each power-actuated pressure relief device.

(c) Overpressure protection provided by this Article shall be shown in the Manufacturer’s Data Report.

(d) A detailed schematic of the control system shall be supplied with the vessel documentation.

**KR-610 SYSTEM REQUIREMENTS**

(a) The output from three independent devices shall be processed by an automated system. These devices shall be a combination of pressure transducers and elongation (strain) measuring devices as described in (1) and (2) below.

(1) Two pressure transducers and one elongation measuring device.

(2) Two elongation measuring devices and one pressure transducer.

(b) Any elongation measuring device shall be provided to continuously indicate the elongation (strain) of the yoke in a location where the elastic elongation (strain) of the yoke is linearly proportional to the pressure.

(1) Any elongation (strain) measuring device shall be designed and installed such that temperature does not affect the results.

(2) Means shall be provided to automatically reset the zero of the elongation measuring device(s) at the beginning of each pressurization cycle to maintain calibration.

(c) The pressure vessel shall be automatically depressurized under any of the following conditions:

(1) Any outputs (pressure transducer or elongation device) indicate that the pressure exceeds the limits in KR-160.

(2) Any of the three input signals are lost or fail for duration of 2 sec or more.

(3) Any pressure or elongation output deviates from any other output by more than 5%.

(d) There shall be at least two normally opened (NO) valves that are kept closed by the use of hydraulic or pneumatic pressure, so that both valves open (thereby lowering the vessel pressure) when the electrical signal to the valve is lost.

(e) The power-actuated pressure relief valves shall be designed to fail open, relieving the pressure in the pressure vessel in case of an electric, hydraulic, or pneumatic failure.

(f) The set pressure tolerance for the power-actuated pressure relief valves shall not exceed ±5% of the set pressure.

(g) The material for the portion of the valve that is exposed to the high-pressure fluid shall meet the material requirements in Part KR.

**KR-620 FLOW CAPACITY TESTING**

(a) As an alternative to the flow capacity testing requirements of Article KR-5 and KR-346, the capacity of the power-actuated pressure relief valve may be demonstrated by tests on a prototype system. If any of the essential system design variables change, a new demonstration shall be required. The essential variables are

(1) an increase in vessel volume

(2) an increase in heating capacity
(3) an increase in pressure generator capacity
(4) a change in the relief flow path configuration that could reduce the flow capacity
(5) a change in the valve size or model number
(6) a change in any other variables that could increase the required relief capacity or reduce the furnished relief capacity of the system

The system shall be tested using most severe identifiable conditions in such a way that it can be demonstrated that the pressure will be limited to the overpressure required by KR-150. The demonstration shall be witnessed by the Authorized Inspector.

(b) The results of the flow capacity demonstration and the setting and verification tests shall be documented in the Manufacturer’s Design Report.

(c) Because the actual flow capacity test is performed on the entire system, the 10% derating factor required in KR-522 shall not apply.
Since impulsive pressure loading durations are short in comparison to the reaction time of overpressure protection systems, overpressure protection requirements for impulsively loaded vessels are provided in the following paragraphs. The User, or his designated agent, shall specify overpressure protection by administrative controls and system design, and shall reference this Article in writing in the purchase documents. The Manufacturer is responsible only for verifying that the User or his designated agent has specified overpressure protection by administrative controls and system design, and for listing this Article on the Manufacturer’s Data Report.

(a) The User, or his designated agent, shall conduct a detailed analysis that examines all credible scenarios that could result in an overpressure condition. The “Causes of Overpressure” described in Section 4 of API Standard 521, “Pressure-Relieving and Depressurizing Systems” shall be considered. An organized, systematic approach by a multidisciplinary team employing one or more of the following methodologies shall be used:

1. Hazards and Operability Analysis (HazOp)
2. Failure Modes, Effects, and Criticality Analysis (FMECA)
3. Fault Tree Analysis
4. Event Tree Analysis
5. “What-If” Analysis

In all cases, the User or his designated agent shall determine the potential for overpressure due to all credible operating and upset conditions, including equipment and instrumentation malfunctions.

(b) The analysis described in (a) shall be conducted by an engineer experienced in the applicable analysis methodology. Any overpressure concerns that are identified shall be evaluated by an engineer experienced in pressure vessel design and analysis. The results of the analysis shall be documented and signed by the individual in charge of operation of the vessel. The documentation shall include:

1. detailed Process and Instrument Flow Diagrams (P&IDs), showing all pertinent elements of the system associated with the vessel
2. a description of all credible operating and upset scenarios, including scenarios involving fire, and those that result from equipment and instrumentation malfunctions
3. an analysis showing the maximum short-term impulsive loading and long-term pressure that can result from each of the scenarios examined in (2) above
4. a detailed description of any administrative controls and/or instrumentation and control system that is used to limit the impulsive loading and long-term pressure to the system, including the identification of all truly independent redundancies and a reliability evaluation (qualitative or quantitative) of the overall safety system

(c) The documentation shall be made available to the regulatory and enforcement authorities having jurisdiction at the site where the vessel will be installed. The User of this Article is cautioned that prior jurisdictional acceptance may be required.

(d) This Article shall be shown on the Manufacturer’s Data Report for pressure vessels that will be provided with overpressure protection by administrative controls and system design, and it shall be noted on the Data Report that prior jurisdictional acceptance may be required.
applicable to each chamber, including the maximum differential pressure for the common elements, when this pressure is less than the higher pressure in the adjacent chambers.

**KS-101.2 If Each Independent Chamber Is Marked.** The complete required marking may be applied to each independent pressure chamber, provided additional marking, such as name of principal chamber (e.g., process chamber, jacket, tubes) is used to indicate clearly to which chamber the data apply.

(19) **KS-102 MARKING OF IMPULSIVELY LOADED VESSELS**

Impulsively loaded vessel marking shall follow KS-100(a) using the QSP as the design pressure. In addition, the vessel shall be marked with

(a) the central equivalent impulsive load (CEIL) which may be expressed as the maximum allowable TNT-equivalent spherical explosive charge weight with its center placed at a distance of at least the vessel inside radius from any vessel boundary, or

(b) the design basis impulse loading (DBIL) which may be expressed as the TNT-equivalent explosive charge for the limting configuration as given in the User’s Design Specification. Limitations on the placement of the charge(s) should be defined in that document and should also be in the Manufacturer’s Design Report

**KS-110 APPLICATION OF CERTIFICATION MARK**

The Certification Mark with U3 Designator shall be applied by the Manufacturer only with the approval of the Inspector, and after the hydrostatic test has been satisfactorily made and all other required inspection and testing have been satisfactorily completed. Such application of the Certification Mark with U3 Designator, together with final certification in accordance with the rules of this Division, shall confirm that all applicable requirements of this Division and the User’s Design Specification have been fulfilled.

**KS-120 PART MARKING**

(a) See below.

(1) Parts of pressure vessels for which Partial Data Reports with a nameplate or stamping are required shall be marked by the Parts Manufacturer with the following:

(-a) the Certification Mark with appropriate Designator shown in Figure KS-100 above the word "PART"

(-b) the name of the manufacturer of the part, preceded by the words "Certified by"

(-c) the manufacturer’s serial number assigned to the part

(-d) design pressure(s) and coincident design metal temperature(s) [see KG-311.4(a) and KG-311.4(b)]

(-e) minimum design metal temperature at the maximum design pressure

Parts may be stamped with the Certification Mark without being pressure tested prior to shipment. If testing was not performed, this shall be indicated in the Remarks section of the K-2 Manufacturer’s Partial Data Reports. (See Nonmandatory Appendix A Form K-2.)

(2) No accessory or part of a pressure vessel may be marked “ASME” or “ASME Std.” unless so specified in this Division.

(b) The requirements for part marking in accordance with (a)(1)(-d) and (a)(1)(-e) do not apply for the following conditions:

(1) for parts for which the Parts Manufacturer does not prepare a Manufacturer’s Design Report

(2) for overpressure relief devices, which are covered in Part KR

(c) Parts may be stamped with the Certification Mark on the part, located on an area designated as a low stress area by the Designer (see KG-330) in the Manufacturer’s Design Report (see KG-330). Markings made directly on the vessel shall not be made by the electro-etch method.

**KS-130 APPLICATION OF MARKINGS**

Markings required in KS-100 through KS-120 shall be applied by one of the following methods.

**KS-130.1 Nameplate.** A separate corrosion-resistant nameplate, at least 0.02 in. (0.5 mm) thick, shall be permanently attached to the vessel or to an intervening support bracket. The attachment weld to the vessel shall not adversely affect the integrity of the vessel. Attachment by welding shall not be permitted on materials enhanced by heat treatment or on vessels that have been prestressed.

(a) Only the Certification Mark need be stamped on the nameplate.

(b) All other data may be stamped, etched, or engraved on the nameplate. See KS-132.

**KS-130.2 Directly on Vessel Shell.** Markings shall be stamped, with low stress type stamps, directly on the vessel, located on an area designated as a low stress area by the Designer (see KG-330) in the Manufacturer’s Design Report (see KG-330). Markings made directly on the vessel shall not be made by the electro-etch method.

**KS-130.3 Permanently Attached Tag.** When the surface area of small parts is too small to permit the attachment of a nameplate or bracket, or by stamping directly on the part, the required markings shall be located on a permanently attached tag, subject to the prior agreement of the Inspector and the User. The method of attachment shall be described in the Manufacturer’s Design Report and traceable to the Form K-2 Manufacturer’s Partial Data Report. Such marking shall be of a type that will remain visible until the parts are installed. The Certification Mark is not required.
ARTICLE KS-2
OBTAINING AND USING CERTIFICATION MARKS

KS-200 CERTIFICATION MARK BEARING OFFICIAL SYMBOL

A Certificate of Authorization to use the Certification Mark with U3, UV3, or UD3 Designators (see https://www.asme.org/shop/certification-accreditation) shown in Figure KS-100 and Figure KR-401 will be granted by the Society pursuant to the provisions of the following paragraphs. Stamps for applying the Certification Mark shall be obtained from the Society.

KS-210 APPLICATION FOR CERTIFICATE OF AUTHORIZATION

Any organization desiring a Certificate of Authorization shall apply to ASME in accordance with the certification process of ASME CA-1. Authorization to use Certification Marks may be granted, renewed, suspended, or withdrawn as specified in ASME CA-1.

KS-220 ISSUANCE OF AUTHORIZATION

Certificate of Authorization shall be issued in accordance with ASME CA-1 (see https://www.asme.org/shop/certification-accreditation).

KS-230 DESIGNATED OVERSIGHT

The Manufacturer shall comply with the requirements of ASME CA-1 for designated oversight by use of an Authorized Inspection Agency or Certified Individual, as applicable.

KS-240 QUALITY CONTROL SYSTEM

Any Manufacturer or Assembler holding or applying for a Certificate of Authorization shall demonstrate a Quality Control System that meets the requirements of ASME CA-1 and Mandatory Appendix 2.

KS-250 EVALUATION OF THE QUALITY CONTROL SYSTEM

(a) The issuance or renewal of a Certificate of Authorization is based upon ASME’s evaluation and approval of the Quality Control System, and shall be in accordance with ASME CA-1.

(b) Before issuance or renewal of a Certificate of Authorization for use of the Certification Mark with U3 Designator, the Manufacturer’s facilities and organization are subject to a joint review by a representative of his Authorized Inspection Agency and an individual certified as an ASME designee who is selected by the concerned legal jurisdiction.

(c) Before issuance or renewal of a Certificate of Authorization for use of the Certification Mark with UV3 or UD3 Designator, the Manufacturer’s or Assembler’s facilities and organization are subject to a review by an ASME designee.

(d) For those areas where there is no jurisdiction or where a jurisdiction does not choose to select an ASME designee to review a Manufacturer’s facility, that function shall be performed by an ASME designee selected by ASME. Where the jurisdiction is the Manufacturer’s inspection agency, the joint review and joint report shall be made by the jurisdiction and the ASME designee.

KS-260 CODE CONSTRUCTION BEFORE RECEIPT OF CERTIFICATE OF AUTHORIZATION

When used to demonstrate his Quality Control System, a Manufacturer may start fabricating Code items before receipt of a Certificate of Authorization to use a Certification Mark under the conditions specified in ASME CA-1.

KS-270 SPECIAL REQUIREMENTS REGARDING MANUFACTURER’S CERTIFICATES FOR MANUFACTURE OF COMPOSITE REINFORCED PRESSURE VESSELS (CRPV)

The Manufacturer shall prepare, implement, and use a quality program that includes the specific technical issues related to the manufacture of CRPV. The level of detail shall be sufficient to satisfy all requirements listed in Mandatory Appendix 2 of this Division, and Section X, Appendix 1.
MANDATORY APPENDIX 1
NOMENCLATURE

(A) 1-100 NOMENCLATURE

\( A \) = interference pressure factor (KD-811)
\( D_1 \) = actual discharge area of relief device
\( (KR-531) \)
\( D_2 \) = nozzle or opening reinforcement area
\( (H-120) \)
\( D_3 \) = cross-sectional area of a vessel normal to
the vessel axis through female threads
\( (E-210) \)
\( D_4 \) = total cross-sectional area of the bolts per
clamp lug (G-300)
\( D_5 \) = cross-sectional area of a closure normal to
the vessel axis through female threads
\( (E-210) \)
\( D_6 \) = total cross-sectional area of the clamp
\( (G-300) \)
\( D_7 \) = partial clamp area (G-300)
\( D_8 \) = partial clamp area (G-300)
\( D_9 \) = partial clamp area (G-300)
\( D_{10} \) = cross-sectional area (KD-502)
\( D_{11} \) = gap area (Figure KF-826)
\( D_{12} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{13} \) = partial clamp area (G-300)
\( D_{14} \) = partial clamp area (G-300)
\( D_{15} \) = partial clamp area (G-300)
\( D_{16} \) = cross-sectional area of the bolts, gasket
seating (G-300)
\( D_{17} \) = cross-sectional area of the bolts, operating
\( (G-300) \)
\( D_{18} \) = outside diameter of the hub (G-300)
\( D_{19} \) = outside bearing diameter of the hub
\( (G-300) \)
\( D_{20} \) = curve fitting constant for the elastic region
of the stress–strain curve (KM-620)
\( D_{21} \) = curve fitting constant for the plastic region
of the stress–strain curve (KM-620)
\( D_{22} \) = lesser of \( D_{23} \) and \( D_{24} \) (G-300)
\( D_{23} \) = hub longitudinal shear area based on
straight shear (G-300)
\( D_{24} \) = hub longitudinal shear area based on
45 deg conical (G-300)
\( D_{25} \) = minimum clamp cross-sectional area,
tangential-longitudinal (G-300)
\( D_{26} \) = maximum clamp bolt hole cutout area
\( (G-300) \)
\( D_{27} \) = individual clamp bolt hole cutout area
\( (G-300) \)
\( D_{28} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{29} \) = partial clamp area (G-300)
\( D_{30} \) = partial clamp area (G-300)
\( D_{31} \) = partial clamp area (G-300)
\( D_{32} \) = cross-sectional area (KD-502)
\( D_{33} \) = gap area (Figure KF-826)
\( D_{34} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{35} \) = partial clamp area (G-300)
\( D_{36} \) = partial clamp area (G-300)
\( D_{37} \) = partial clamp area (G-300)
\( D_{38} \) = cross-sectional area of the bolts, gasket
seating (G-300)
\( D_{39} \) = cross-sectional area of the bolts, operating
\( (G-300) \)
\( D_{40} \) = outside diameter of the hub (G-300)
\( D_{41} \) = outside bearing diameter of the hub
\( (G-300) \)
\( D_{42} \) = curve fitting constant for the elastic region
of the stress–strain curve (KM-620)
\( D_{43} \) = curve fitting constant for the plastic region
of the stress–strain curve (KM-620)
\( D_{44} \) = lesser of \( D_{45} \) and \( D_{46} \) (G-300)
\( D_{45} \) = hub longitudinal shear area based on
straight shear (G-300)
\( D_{46} \) = hub longitudinal shear area based on
45 deg conical (G-300)
\( D_{47} \) = minimum clamp cross-sectional area,
tangential-longitudinal (G-300)
\( D_{48} \) = maximum clamp bolt hole cutout area
\( (G-300) \)
\( D_{49} \) = individual clamp bolt hole cutout area
\( (G-300) \)
\( D_{50} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{51} \) = partial clamp area (G-300)
\( D_{52} \) = partial clamp area (G-300)
\( D_{53} \) = partial clamp area (G-300)
\( D_{54} \) = cross-sectional area (KD-502)
\( D_{55} \) = gap area (Figure KF-826)
\( D_{56} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{57} \) = partial clamp area (G-300)
\( D_{58} \) = partial clamp area (G-300)
\( D_{59} \) = partial clamp area (G-300)
\( D_{60} \) = cross-sectional area of the bolts, gasket
seating (G-300)
\( D_{61} \) = cross-sectional area of the bolts, operating
\( (G-300) \)
\( D_{62} \) = outside diameter of the hub (G-300)
\( D_{63} \) = outside bearing diameter of the hub
\( (G-300) \)
\( D_{64} \) = curve fitting constant for the elastic region
of the stress–strain curve (KM-620)
\( D_{65} \) = curve fitting constant for the plastic region
of the stress–strain curve (KM-620)
\( D_{66} \) = lesser of \( D_{67} \) and \( D_{68} \) (G-300)
\( D_{67} \) = hub longitudinal shear area based on
straight shear (G-300)
\( D_{68} \) = hub longitudinal shear area based on
45 deg conical (G-300)
\( D_{69} \) = minimum clamp cross-sectional area,
tangential-longitudinal (G-300)
\( D_{70} \) = maximum clamp bolt hole cutout area
\( (G-300) \)
\( D_{71} \) = individual clamp bolt hole cutout area
\( (G-300) \)
\( D_{72} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{73} \) = partial clamp area (G-300)
\( D_{74} \) = partial clamp area (G-300)
\( D_{75} \) = partial clamp area (G-300)
\( D_{76} \) = cross-sectional area (KD-502)
\( D_{77} \) = gap area (Figure KF-826)
\( D_{78} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{79} \) = partial clamp area (G-300)
\( D_{80} \) = partial clamp area (G-300)
\( D_{81} \) = partial clamp area (G-300)
\( D_{82} \) = cross-sectional area of the bolts, gasket
seating (G-300)
\( D_{83} \) = cross-sectional area of the bolts, operating
\( (G-300) \)
\( D_{84} \) = outside diameter of the hub (G-300)
\( D_{85} \) = outside bearing diameter of the hub
\( (G-300) \)
\( D_{86} \) = curve fitting constant for the elastic region
of the stress–strain curve (KM-620)
\( D_{87} \) = curve fitting constant for the plastic region
of the stress–strain curve (KM-620)
\( D_{88} \) = lesser of \( D_{89} \) and \( D_{90} \) (G-300)
\( D_{89} \) = hub longitudinal shear area based on
straight shear (G-300)
\( D_{90} \) = hub longitudinal shear area based on
45 deg conical (G-300)
\( D_{91} \) = minimum clamp cross-sectional area,
tangential-longitudinal (G-300)
\( D_{92} \) = maximum clamp bolt hole cutout area
\( (G-300) \)
\( D_{93} \) = individual clamp bolt hole cutout area
\( (G-300) \)
\( D_{94} \) = required cross-sectional area of the bolts
\( (G-300) \)
\( D_{95} \) = partial clamp area (G-300)
\( D_{96} \) = partial clamp area (G-300)
\( D_{97} \) = partial clamp area (G-300)
\( D_{98} \) = cross-sectional area (KD-502)
\( D_{99} \) = gap area (Figure KF-826)
\( D_{100} \) = required cross-sectional area of the bolts
\( (G-300) \)
\[ H_2 = \text{correction factor for bending stress (D-401)} \]

\[ h = \text{distance from flange face to end of skirt [Figure KD-830.3, sketch (c)] = gap between two layers (KF-826)} \]

\[ h_D = \text{radial distance clamp–hub reaction circle to } H_D (G-300) \]

\[ h_G = \text{radial distance clamp–hub reaction circle to } H_G (G-300) \]

\[ h_n = \text{hub neck length (G-300)} \]

\[ h_T = \text{radial distance clamp–hub reaction circle to } H_T (G-300) \]

\[ h_2 = \text{average thickness of hub shoulder (G-300)} \]

\[ I = \text{material property (KD-430 = correction factor used in the structural stress evaluation)} \]

\[ I_{c} = \text{moment of inertia of clamp (G-300)} \]

\[ I_{h} = \text{moment of inertia of hub shoulder (G-300)} \]

\[ I_{5} = \text{minimum clamp moment of inertia in any radial–tangential plane (G-300)} \]

\[ I_{5h} = \text{maximum reduction clamp moment of inertia bolt holes (G-300)} \]

\[ I_{6} = \text{minimum clamp moment of inertia in any tangential–longitudinal plane (G-300)} \]

\[ I_{6h} = \text{maximum reduction clamp moment of inertia bolt holes (G-300)} \]

\[ I_{r} = \text{correction factor used in the structural shear stress evaluation}} \]

\[ J_{ic} = \text{critical stress intensity for plane stress (KM-250, D-600)} \]

\[ K = \text{stress concentration factor (Figure 9-200-1 = 0.73 times transition radius } r_2 \text{ (H-142))} \]

\[ K_{css} = \text{material parameter for the cyclic stress–strain curve model} \]

\[ K_{ps} = \text{relief device discharge coefficient (KR-523, Figure KR-523.3, KR-531)} \]

\[ K_f = \text{fatigue strength reduction factor used to compute the cyclic stress amplitude or range} \]

\[ K_{t} = \text{stress intensity factors in a crack (KD-420, KD-440)} \]

\[ K_{tmax} = \text{maximum stress intensity factor in a crack (KD-430)} \]

\[ K_{tmin} = \text{minimum stress intensity factor in a crack (KD-430)} \]

\[ K_{ires} = \text{residual stress intensity in a crack (KD-420, KD-430)} \]

\[ K_{ic} = \text{critical stress intensity factor for crack (KM-250, D-601)} \]

\[ K_{fract} = \text{fracture toughness (KD-401)} \]

\[ K_{jref} = \text{crack tip stress intensity factor (D-405)} \]

\[ K_{n} = \text{wire factor (KD-932)} \]

\[ K_{sr} = \text{greater of } 2.6 \text{ or } (K_r)^{4.3} (KD-1262) \]

\[ K_{s} = \text{surface roughness factor (KD-322)} \]

\[ K_{w} = \text{wire factor (KD-932)} \]

\[ K_{sl} = \text{wire factor (KD-932)} \]

\[ K_{ss} = \text{factor for size of highly stressed fatigue area (KD-1262)} \]

\[ K_{sc} = \text{factor for fatigue curves at varying temperatures (KD-1262)} \]

\[ K_{sf} = \text{factor for fatigue surface finish (KD-1262)} \]

\[ K_{st} = \text{factor for statistical variation in fatigue tests (KD-1262)} \]

\[ K_{st} = \text{factor for fatigue test temperature (KD-1262)} \]

\[ K_{th} = \text{threshold stress intensity (KD-430)} \]

\[ K_T = \text{hoop stress concentration factor for cross-bored holes (J-110)} \]

\[ K_{TN} = \text{test life ratio (KD-1262)} \]

\[ K_{TS} = \text{test stress ratio (KD-1262 = length along nozzle with thickness } t_n \text{ plus transition (H-142))} \]

\[ K_u = \text{factor of upper limit of hydrostatic test pressure (KD-221, KT-312)} \]

\[ K_{uteq} = \text{equivalent factor of upper limit of hydrostatic test pressure for layered construction (KD-231.2)} \]

\[ K_{uteq} = \text{factor of upper limit of hydrostatic test pressure for each individual layer (KD-221, KT-312)} \]

\[ k = \text{ratio of specific heats} \]

\[ L = \text{appurtenance live loading (KD-230)} \]

\[ L_A = \text{floating transporter acceleration loads due to spectral motion response determined in KD-237} \]

\[ t_n = \text{distance from clamp bolt centerline to where clamp lug joins body (G-300)} \]

\[ L_d = \text{design fatigue life (KD-330)} \]

\[ L_h = \text{clamp lug height (G-300)} \]

\[ L_T = \text{length of wire pieces in fatigue test (KD-932.3)} \]

\[ L_w = \text{average distance between wire cracks (KD-932.3)} \]

\[ L_{w} = \text{clamp lug width (G-300)} \]

\[ L_{A} = \text{measured length of vessel at test pressure (KD-1121)} \]

\[ L_{e} = \text{length of required taper (Figure KD-1121)} \]

\[ L_{e} = \text{surface length of crack (D-401)} \]

\[ L_{e} = \text{effective clamp lip length (G-300)} \]

\[ L_{e} = \text{circumferential separation of nozzle centerlines (H-101)} \]

\[ L_{e} = \text{longitudinal separation of nozzle centerlines (H-101)} \]

\[ L_{e} = \text{effective clamp lip moment arm (G-300)} \]

\[ M = \text{molecular weight (KR-523.3, KR-531)} \]

\[ M_{D} = \text{moment due to } H_D \text{ (G-300)} \]

\[ M_{R} = \text{offset moment (G-300)} \]

\[ M_{G} = \text{moment due to } H_G \text{ (G-300)} \]
\( n_t \) = time point under consideration that forms a range with time point \( n' t \)

\( n^o_{b,k} \) = elastically calculated bending stress at the point under evaluation for the \( k \)th cycle at the \( n \) point

\( n^o_{m,k} \) = elastically calculated membrane stress at the point under evaluation for the \( k \)th cycle at the \( n \) point

\( n^o_{ij} \) = stress tensor at the point under evaluation at time point \( n' t \)

\( n^e_{b,k} \) = elastically calculated bending component of shear stress distribution at the point under evaluation for the \( k \)th cycle at the \( n \) point

\( n^e_{m,k} \) = elastically calculated membrane component of shear stress distribution at the point under evaluation for the \( k \)th cycle at the \( n \) point

\( P \) = design pressure (KD-802, G-300)

\( P_m \) = fluid pressure acting in a crack (D-401)

\( P_D \) = maximum autofrettage pressure (KD-502)

\( P_{a} \) = back pressure on relief device (KR-520)

\( P_b \) = bending stress (9-200, Figure 9-200-1)

\( P_D \) = design pressure (KD-220)

\( P_{if} \) = interface pressure (KD-802)

\( P_L \) = local membrane stress (KD-210, 9-200)

\( P_m \) = general membrane stress (9-200)

\( P_n \) = pressure at layer interface (KD-802)

\( P_s \) = static head from liquid or bulk materials (e.g., catalyst) (KD-230)

\( P_T \) = cyclic test loading (KD-1262)

\( P_t \) = hydrostatic test pressure (KD-231, KD-824, KT-312)

\( Q \) = secondary membrane plus bending stress (9-200, Figure 9-200-1)

\( Q_c \) = reaction shear force at hub neck (G-300)

\( Q_e \) = percent of theoretical circumferential growth measured on outside (KD-802)

\( R_{b,k} \) = ratio of the bending stress to the membrane plus bending stress

\( R_{b,l,k} \) = ratio of the bending component of the shear stress to the membrane plus bending component of the shear stress

\( R_c \) = corner radius (E-110)

\( R_f \) = final centerline radius of formed head (KF-602)

\( R_g \) = outside radius of layer below gap (Figure KF-826)

\( R_I \) = radius to inside surface of innermost layer (KF-826)

\( R_{k} \) = stress intensity factor ratio (KD-430)

\( R_k \) = stress ratio for the \( k \)th cycle

\( R_m \) = radius of midsurface of head or shell (9-220, KD-721, KE-211)

\( R_o \) = outside radius of vessel (KF-826)

\( R_a \) = original centerline radius of formed plate (KF-602)

\( r \) = radius between flat head and shell (Figure KD-830.3, KD-1112)

\( r_c \) = clamp or hub cross-section corner radius (G-300)

\( r_h \) = hub outside corner radius (G-300)

\( r_j \) = radial coordinate of node \( j \) for an axisymmetric element

\( r_m \) = mean radius of nozzle (H-142)

\( r_z \) = transition radius inside nozzle to vessel wall (H-142)

\( S \) = stress intensity (KD-210)

\( S_a \) = allowable fatigue strength (KD-120)

\( S_a \) = allowable bolt stress, room temperature (G-300)

\( S_{a10^4} \) = stress intensity at design load (KD-1262)

\( S_Q \) = allowable amplitude of alternating stress (KD-312.4)

\( S_{qD} \) = design stress, allowable (KD-1262)

\( S_{alt} \) = alternating stress intensity (KD-302)

\( S_b \) = allowable bolt stress, design temperature (G-300)

\( S_e \) = computed equivalent stress

\( S_{eq} \) = equivalent calculated alternating stress intensity (KD-312.4)

\( S_{f} \) = snow loads (KD-230)

\( S_w \) = ultimate tensile strength (Section II, Part D, Table U)

\( S_{uf} \) = tensile strength for each layer (Section II, Part D, Table U)

\( S_{w(x)} \) = stress in wire (KD-911)

\( S_y \) = yield strength (KD-120, KD-221, KD-1254)

\( S_{y,k} \) = yield strength of the material evaluated at the mean temperature of the \( k \)th cycle

\( S_{yf} \) = yield strength for each layer (Section II, Part D, Table Y-1)

\( S_{act} \) = actual yield stress (KD-1254)

\( S_{yms} \) = actual yield strength per material specification (KD-1254)

\( S_{YAC} \) = yield stress for clamp material, room temperature (G-300)

\( S_{YAH} \) = yield stress for hub material, room temperature (G-300)

\( S_{YOC} \) = yield stress for clamp material, design temperature (G-300)

\( S_{YOH} \) = yield stress for hub material, design temperature (G-300)

\( S_1 \) = hub longitudinal stress on outside hub neck (G-300)
\[ S_2 \] = maximum Lamé hoop stress at hub bore (G-300)  
\[ S_3 \] = hub shear stress at shoulder (G-300)  
\[ S_4 \] = hub radial stress in hub neck (G-300)  
\[ S_5 \] = clamp longitudinal stress at clamp body inner diameter (G-300)  
\[ S_6 \] = clamp tangential stress at clamp body outer diameter (G-300)  
\[ S_7 \] = maximum shear stress in clamp lips (G-300)  
\[ S_8 \] = clamp lip bending stress (G-300)  
\[ S_9 \] = clamp lug bending stress (G-300)  
\[ S_{10} \] = maximum clamp lug shear stress (G-300)  
\[ S_{11} \] = effective bearing stress between clamp and hub (G-300)  
\[ S_j \] = local coordinate, parallel to the stress classification line, that defines the location of nodal force \( N_{F_j} \) relative to the mid-thickness of the section  
\[ T \] = absolute temperature  
\[ T_{c} \] = critical temperature (KD-1262)  
\[ T_{h} \] = hub shoulder thickness below inside edge hub (G-300)  
\[ T_{t} \] = test temperature (KD-1262)  
\[ T_{b} \] = thickness of blind end (E-110)  
\[ t_{ess} \] = structural stress effective thickness  
\[ t_H \] = thickness of head at joint (Figure KD-830.2)  
\[ t_j \] = thickness of each layer (KD-221)  
\[ t_L \] = thickness of layer at joint (Figure KD-830.2)  
\[ t_n \] = thickness of layer \( n \) (KD-802)  
\[ t_p \] = thickness of attached pipe wall (H-142)  
\[ t_r \] = minimum wall thickness without opening (H-120)  
\[ t_{rn} \] = required thickness of seamless nozzle wall (Figure KD-1122)  
\[ t_S \] = shell thickness (Figure KD-830.2)  
\[ t_w \] = thickness of vessel wall (E-110)  
\[ U \] = cumulative usage factor (KD-330)  
\[ V_{REF} \] = longitudinal crack displacement (D-405)  
\[ W \] = wind load (KD-230)  
\[ W_A \] = assembly loads (e.g., shrink fit, wire winding, sealing preload) (KD-230)  
\[ W_g \] = rated air flow for relief device (KR-531)  
\[ W_c \] = total effective clamping preload on one lip (G-300)  
\[ W_{m1} \] = minimum operating bolt load (G-300)  
\[ W_{m2} \] = minimum gasket seating bolt load (G-300)  
\[ W_{pt} \] = pressure test wind load case (KD-230)  
\[ W_T \] = theoretical mass flow (KR-523.3)  
\[ W \] = width of the element to determine structural stresses from Finite Element Analysis  
\[ X \] = absolute value of the range (load or stress) under consideration using the Rainflow Cycle Counting Method  
\[ X_{b} \] = basic clamp dimension to neutral axis (G-300)  
\[ X_{g} \] = global \( X \) axis  
\[ X_i \] = average radial distance from bolt cutout area (G-300)  
\[ X_L \] = local \( X \) axis, oriented parallel to the stress classification line  
\[ X_{5} \] = modified clamp dimension to neutral axis (G-300)  
\[ X_{6} \] = modified clamp dimension to neutral axis (G-300)  
\[ x \] = diameter at any point (KD-911)  
\[ x_1 \] = through-wall thickness coordinate  
\[ X_{1} \] = any diameter of cylinder (KD-911)  
\[ x_2 \] = any diameter of winding (KD-911)  
\[ Y \] = wall ratio or \( DO/DI \) of a shell (KD-220, KT-312)  
\[ Y_{g} \] = global \( Y \) axis  
\[ Y_{i} \] = ratio of outside diameter to inside diameter of inner layer (KD-802)  
\[ Y_{f} \] = ratio of outside diameter to inside diameter of each layer (KD-220, KT-312)  
\[ Y_L \] = local \( Y \) axis, oriented normal to the stress classification line  
\[ Y_o \] = ratio of outside diameter to inside diameter of outer layer (KD-802)  
\[ y \] = radial offset in buttwelding of unequal section thicknesses (Figure KD-1121)  
\[ Z \] = \( D_o/D \), where \( D \) can be any point in the wall (KD-220)  
\[ Y_{o} \] = ratio of outside diameter to inside diameter of outer layer (KD-802)  
\[ Z \] = \( D_o/D \), where \( D \) can be any point in the wall (KD-220)  
\[ w \] = width of the element to determine structural stresses from Finite Element Analysis  
\[ X \] = absolute value of the range (load or stress) under consideration using the Rainflow Cycle Counting Method  
\[ Y_{g} \] = global \( Y \) axis  
\[ Y_{i} \] = ratio of outside diameter to inside diameter of inner layer (KD-802)  
\[ Y_{f} \] = ratio of outside diameter to inside diameter of each layer (KD-220, KT-312)  
\[ Y_L \] = local \( Y \) axis, oriented normal to the stress classification line  
\[ Y_o \] = ratio of outside diameter to inside diameter of outer layer (KD-802)  
\[ y \] = radial offset in buttwelding of unequal section thicknesses (Figure KD-1121)  
\[ Z \] = \( D_o/D \), where \( D \) can be any point in the wall (KD-220)  
\[ w \] = width of the element to determine structural stresses from Finite Element Analysis  
\[ X \] = absolute value of the range (load or stress) under consideration using the Rainflow Cycle Counting Method  
\[ Y_{g} \] = global \( Y \) axis  
\[ Y_{i} \] = ratio of outside diameter to inside diameter of inner layer (KD-802)  
\[ Y_{f} \] = ratio of outside diameter to inside diameter of each layer (KD-220, KT-312)  
\[ Y_L \] = local \( Y \) axis, oriented normal to the stress classification line  
\[ Y_o \] = ratio of outside diameter to inside diameter of outer layer (KD-802)  
\[ y \] = radial offset in buttwelding of unequal section thicknesses (Figure KD-1121)  
\[ Z \] = \( D_o/D \), where \( D \) can be any point in the wall (KD-220)
\[ \Delta = \text{shape factor (KD-210, Figure 9-200-1, 9-100)} \]
\[ \gamma_1 = \text{true strain in the micro-strain region of the stress–strain curve (KM-620)} \]
\[ \gamma_2 = \text{true strain in the macro-strain region of the stress–strain curve (KM-620)} \]
\[ \Delta = \text{difference, increment} \]
\[ \Delta K = \text{range of stress intensity factor (KD-430)} \]
\[ \Delta S_{ess,k} = \text{equivalent structural stress range parameter for the kth cycle} \]
\[ \Delta \bar{\sigma} = \text{average relative standard deviation of fatigue strength (KD-932.3)} \]
\[ \Delta T = \text{operating temperature range (H-150)} \]
\[ \Delta \varepsilon_k = \text{local nonlinear structural strain range at the point under evaluation for the kth cycle} \]
\[ \Delta \varepsilon_{p,ij} = \text{the range of plastic strain component, ij, at the point under evaluation for the kth cycle under evaluation. Note that the shear strains are the engineering strain values that are typically output from a finite element analysis (i.e., not tensor strains) (KD-323)} \]
\[ \Delta \varepsilon_{p,ij,k} = \text{the range of plastic strain component, ij, at the point under evaluation for the kth loading condition or cycle. Note that the shear strains are the engineering strain values that are typically output from a finite element analysis (i.e., not tensor strains) (KD-323)} \]
\[ \Delta \sigma_k = \text{local nonlinear structural stress range at the point under evaluation for the kth cycle} \]
\[ \Delta \sigma_e = \text{structural stress range} \]
\[ \Delta \sigma_{b,k} = \text{elastically calculated structural bending stress range at the point under evaluation for the kth cycle} \]
\[ \Delta \sigma_{e,b,k} = \text{elastically calculated structural bending component of the structural shear stress range at the point under evaluation for the kth cycle} \]
\[ \Delta \sigma_{m,k} = \text{elastically calculated structural membrane component of the structural shear stress range at the point under evaluation for the kth cycle} \]
\[ \Delta \tau_k = \text{structural shear stress range at the point under evaluation for the kth cycle} \]
\[ \Delta \tau_{b,k} = \text{elastically calculated bending component of the structural shear stress range at the point under evaluation for the kth cycle} \]
\[ \Delta \tau_{m,k} = \text{elastically calculated membrane component of the structural shear stress range at the point under evaluation for the kth cycle} \]
\[ \delta = \text{any difference, diametral interference (KD-802)} \]
\[ \epsilon_m = \text{average tangential strain, autofrettaged outside diameter (KD-502)} \]
\[ \epsilon_p = \text{average tangential strain, autofrettaged bore (KD-502)} \]
\[ \epsilon_{rs} = \text{true plastic strain in the micro-strain region of the stress–strain curve (KM-620)} \]
\[ \epsilon_2 = \text{true plastic strain in the macro-strain region of the stress–strain curve (KM-620)} \]
\[ \mu = \text{viscosity} \]
\[ \nu = \text{friction angle (G-300)} \]
\[ \nu = \text{Poisson’s ratio (KD-802); also sometimes viscosity} \]
\[ \nu_i = \text{inner layer Poisson’s ratio (KD-802)} \]
\[ \nu_o = \text{outer layer Poisson’s ratio (KD-802)} \]
\[ \pi = \text{constant} = 3.14159 \]
\[ \rho = \text{mass density (KR-523)} \]
\[ \Sigma = \text{summation} \]
\[ \sigma = \text{normal or principal stresses, with various subscripts} \]
\[ \sigma_{AD} = \text{value of } \sigma_{1,k} \text{ at } D = D_i \text{ (KD-502)} \]
\[ \sigma_{a} = \text{total stress amplitude} \]
\[ \sigma_{b} = \text{bending stress} \]
\[ \sigma_{b,i} = \text{bending stress for element location position } i \]
\[ \sigma_{CD} = \text{residual tangential stress at bore, including the Bauschinger effect (KD-502)} \]
\[ \sigma_{e} = \text{von Mises stress} \]
\[ \sigma_{ij} = \text{stress tensor at the point under evaluation} \]
\[ \sigma_{ij,b} = \text{bending stress tensor at the point under evaluation} \]
\[ \sigma_{ij,F} = \text{peak stress component} \]
\[ \sigma_{ij,IN} = \text{stress tensor on the inside surface of the shell} \]
\[ \sigma_{ij,m} = \text{membrane stress tensor at the point under evaluation} \]
\[ \sigma_{ij,out} = \text{stress tensor on the outside surface of the shell} \]
\[ \sigma_{m} = \text{membrane stress} \]
\[ \sigma_{ml} = \text{membrane stress for element location position } i \]
MANDATORY APPENDIX 2
QUALITY CONTROL SYSTEM

2-100 GENERAL

The Manufacturer or Assembler shall have and maintain a Quality Control System which will establish that all Code requirements, including material, design, fabrication, examination (by the Manufacturer or Assembler), and inspection of vessels and vessel parts (by the Inspector), will be met. The Manufacturer or Assembler shall include duties of a Certified Individual, as required by this Division. The Certified Individual authorized to provide oversight may also serve as the Certificate Holder’s authorized representative responsible for signing data reports or certificates of conformance. Provided that Code requirements are suitably identified, the system may include provisions for satisfying any requirements by the Manufacturer or Assembler or user which exceed minimum Code requirements and may include provisions for quality control of non-Code work. In such systems, the Manufacturer of vessels and vessel parts may make changes in parts of the system which do not affect the Code requirements without securing acceptance by the Inspector (see KG-300). Before implementation, revisions to Quality Control Systems of Manufacturers and Assemblers of pressure relief valves shall have been found acceptable by an ASME designee if such revisions affect Code requirements. The system that the Manufacturer or Assembler uses to meet the requirements of this Division must be one suitable for his own circumstances. The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the Manufacturer’s organization. A written description of the system the Manufacturer or Assembler will use to produce a Code item shall be available for review. Depending upon the circumstances, the description may be brief or voluminous. The written description may contain information of a proprietary nature relating to the Manufacturer’s processes. Therefore, the Code does not require any distribution of this information except for the Inspector’s or ASME designee’s copy as covered by 2-123(c) and 2-124(c). It is intended that information learned about the system in connection with the evaluation will be treated as confidential and that all loaned descriptions will be returned to the Manufacturer or Assembler upon completion of the evaluation.

2-110 OUTLINE OF FEATURES TO BE INCLUDED IN THE WRITTEN DESCRIPTION OF THE QUALITY CONTROL SYSTEM

The following is a guide to some of the features which should be covered in the written description of the Quality Control System and is equally applicable to work performed at the shop or field or intermediate sites.

(a) See Article KE-1.

(b) The complexity of the work includes factors such as design simplicity versus complexity, the types of materials and welding procedures used, the thickness of materials, the types of nondestructive examinations applied, and whether heat treatments are applied.

(c) The size and complexity of the Manufacturer’s or Assembler’s organization includes factors such as the number of employees, the experience level of employees, the number of vessels produced, and whether the factors defining the complexity of the work cover a wide or narrow range.

2-111 AUTHORITY AND RESPONSIBILITY

The authority and responsibility of those in charge of the Quality Control System shall be clearly established. Persons performing quality control functions shall have sufficient and well-defined responsibility, the authority, and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

2-112 ORGANIZATION

An organization chart showing the relationship between management and engineering, purchasing, manufacturing, field construction, inspection, and quality control is required to reflect the actual organization. The purpose of this chart is to identify and associate the various organizational groups with the particular function for which they are responsible. The Code does not intend to encroach on the Manufacturer’s or Assembler’s right to establish, and from time to time to alter, whatever form of organization the Manufacturer or Assembler considers appropriate for its Code work.
2-113 DRAWINGS, DESIGN CALCULATIONS, AND SPECIFICATION CONTROL

The Manufacturer's or Assembler's Quality Control System shall provide procedures which will assure that the latest applicable drawings, design calculations, specifications, and instructions, required by the Code, as well as authorized changes, are used for manufacture, examination, inspection, and testing. The system shall insure that authorized changes are included, when appropriate, in the User's Design Specification and/or in the Manufacturer's Design Report.

2-114 MATERIAL CONTROL

The Manufacturer or Assembler shall include a system of receiving control which will insure that the material received is properly identified and has documentation including required material certifications or material test reports to satisfy Code requirements as ordered. The system material control shall insure that only the intended material is used in Code construction.

2-115 EXAMINATION AND INSPECTION PROGRAM

The Manufacturer's or Assembler's Quality Control System shall describe the fabrication operations, including examination, sufficiently to permit the Inspector or ASME designee to determine at what stages specific inspections are to be performed.

2-116 CORRECTION OF NONCONFORMITIES

There shall be a system agreed upon with the Inspector for correction of nonconformities. A nonconformity is any condition which does not comply with the applicable rules of this Division. Nonconformities must be corrected or eliminated in some way before the completed component can be considered to comply with this Division.

2-117 WELDING

The Quality Control System shall include provisions for indicating that welding conforms to requirements of Section IX as supplemented by this Division.

2-118 NONDESTRUCTIVE EXAMINATION

The Quality Control System shall include provisions for identifying nondestructive examination procedures the Manufacturer or Assembler will apply to conform with the requirements of this Division.

2-119 HEAT TREATMENT

The Quality Control System shall provide controls to ensure that heat treatments as required by the rules of this Division are applied. Means shall be indicated by which the Inspector or ASME designee can satisfy himself that these Code heat treatment requirements are met. This may be by review of furnace time-temperature records or by other methods as appropriate.

2-120 CALIBRATION OF MEASUREMENT AND TEST EQUIPMENT

The Manufacturer or Assembler shall have a system for the calibration of examination, measuring, and test equipment used in fulfillment of requirements of this Division.

2-121 RECORDS RETENTION

The Manufacturer or Assembler shall have a system for the maintenance of Data Reports and records as required by this Division.

2-122 SAMPLE FORMS

The forms used in this Quality Control System and any detailed procedures for their use shall be available for review. The written description shall make necessary references to these forms.

2-123 INSPECTION OF VESSELS AND VESSEL PARTS

(a) Inspection of vessels and vessel parts shall be by the Inspector as defined in Article KG-4.
(b) The written description of the Quality Control System shall include reference to the Inspector.
(c) The Manufacturer shall make available to the Inspector, at the Manufacturer's plant or construction site, a current copy of the written description of the Quality Control System.
(d) The Manufacturer's Quality Control System shall provide for the Inspector at the Manufacturer's plant to have access to the User's Design Specification, the Manufacturer's Design Report, and all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the Inspector to perform his duties in accordance with this Division. The Manufacturer may provide such access either to his own files of such documents or by providing copies to the Inspector.
2-124  INSPECTION OF PRESSURE RELIEF DEVICES

(a) Inspection of pressure relief devices shall be by a designated representative of ASME, as described in KR-331 or KR-250, as applicable.

(b) The written description of the Quality Control System shall include reference to the ASME designee.

(c) The Manufacturer or Assembler shall make available to the ASME designee, at the Manufacturer’s or Assembler’s plant, a current copy of the written description of the applicable Quality Control System.

(d) The device Manufacturer’s or Assembler’s Quality Control System shall provide for the ASME designee to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the designee to perform his duties in accordance with this Division. The Manufacturer may provide such access either to his own files of such documents or by providing copies to the designee.

2-125  CERTIFICATIONS

(a) Methods other than written signature may be used for indicating certifications, authorizations, and approvals where allowed and as described elsewhere in this Division.

(b) Where other methods are employed, controls and safeguards shall be provided and described to ensure the integrity of the certification, authorization, and approval.
FORM K-4  MANUFACTURER’S OR ASSEMBLER’S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 3

1. Manufactured (or assembled) by

2. Table of Certification Marked items:

<table>
<thead>
<tr>
<th>I.D. #</th>
<th>Date</th>
<th>Cert. #</th>
<th>Qty.</th>
<th>Type</th>
<th>Size</th>
<th>Set Pressure</th>
<th>Capacity</th>
<th>Test Fluid</th>
<th>Date Code</th>
<th>Cl Name</th>
<th>Cl Signature</th>
</tr>
</thead>
</table>

3. Remarks

CERTIFICATE OF SHOP COMPLIANCE

By the signature of the Certified Individual (CI) noted above, we certify that the statements made in this report are correct and that all details for design, material, construction, and workmanship of the pressure relief valves conform with the requirements of Section VIII, Division 3 of the ASME Boiler and Pressure Vessel Code.

UV3 Certificate of Authorization No. Expires

Date Signed Name (responsible representative) (Manufacturer or Assembler)
Table A-100.2
Supplementary Instructions for the Preparation of Manufacturer’s or Assembler’s Certificate of Conformance Form K-4

<table>
<thead>
<tr>
<th>Reference to Circed Nos. in the Form</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Name and address of Manufacturer or Assembler.</td>
<td></td>
</tr>
<tr>
<td>(2) Pressure relief valve Manufacturer’s or Assembler’s unique number, such as serial number, work order number, or lot number.</td>
<td></td>
</tr>
<tr>
<td>(3) The date of completion of production of the pressure relief valve.</td>
<td></td>
</tr>
<tr>
<td>(4) The NB Certification Number.</td>
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<tr>
<td>(5) The quantity of identical valves for this line item.</td>
<td></td>
</tr>
<tr>
<td>(6) The Manufacturer’s Design or Type Number as marked on the nameplate.</td>
<td></td>
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<tr>
<td>(7) The inlet size of the pressure relief valve.</td>
<td></td>
</tr>
<tr>
<td>(8) The nameplate set pressure of the pressure relief valve.</td>
<td></td>
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<tr>
<td>(9) The nameplate capacity of the pressure relief valve.</td>
<td></td>
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<tr>
<td>(10) The fluid used for testing the pressure relief valve.</td>
<td></td>
</tr>
<tr>
<td>(11) The year built or the pressure relief valve Manufacturer’s or Assembler’s date code.</td>
<td></td>
</tr>
<tr>
<td>(12) The name of the Certified Individual.</td>
<td></td>
</tr>
<tr>
<td>(13) The signature of the Certified Individual. Required for each line item.</td>
<td></td>
</tr>
<tr>
<td>(14) Include any applicable remarks (referencing the identification number) that may pertain, such as identification of a Code Case that requires marking on the device.</td>
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<tr>
<td>(15) The number of the pressure relief valve Manufacturer’s Certificate of Authorization.</td>
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<tr>
<td>(16) Expiration date of the pressure relief valve Manufacturer’s Certificate of Authorization.</td>
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<tr>
<td>(17) Date signed by the pressure relief valve Manufacturer or Assembler’s authorized representative.</td>
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</tr>
<tr>
<td>(18) The Certificate of Compliance block is to show the name of the Manufacturer or Assembler as shown on his/her ASME Code Certificate of Authorization. This shall be signed in accordance with organizational authority defined in the Quality Control System (see Mandatory Appendix 2).</td>
<td></td>
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</table>

GENERAL NOTE: Any quantity to which units apply shall be entered on the Manufacturer’s Data Report with the chosen units.
FORM K-5  MANUFACTURER’S CERTIFICATE OF CONFORMANCE FOR RUPTURE DISK DEVICES
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 3

1. Manufactured by ____________________________

2A. Table of Certification Marked rupture disks:

<table>
<thead>
<tr>
<th>Lot #</th>
<th>Year Built</th>
<th>NB Cert. #</th>
<th>Qty.</th>
<th>Disk Material</th>
<th>Type</th>
<th>Size</th>
<th>Marked Burst Pressure</th>
<th>Specified Disk Temp.</th>
<th>Holder Type</th>
<th>Date</th>
<th>CI Name</th>
<th>CI Signature</th>
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</table>

2B. Table of Certification Marked rupture disk holders:

<table>
<thead>
<tr>
<th>Year Built</th>
<th>NB Cert. #</th>
<th>Qty.</th>
<th>Holder Material</th>
<th>Type</th>
<th>Size</th>
<th>Date</th>
<th>CI Name</th>
<th>CI Signature</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

3. Remarks ____________________________________________________________

CERTIFICATE OF SHOP COMPLIANCE

By the signature of the Certified Individual (CI) noted above, we certify that the statements made in this report are correct and that all details for design, material, construction, and workmanship of the rupture disk devices conform with the requirements of Section VIII, Division 3 of the ASME Boiler and Pressure Vessel Code.

UD3 Certificate of Authorization No. ____________________________ Expires ____________________________

Date ____________________________ Signed ____________________________ Name ____________________________
## Table A-100.3

**Supplementary Instructions for the Preparation of Manufacturer’s Certificate of Conformance**

*Form K-5*

<table>
<thead>
<tr>
<th>Reference to Circled Nos. in the Form</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Name and address of Manufacturer.</td>
<td></td>
</tr>
<tr>
<td>(2) Pressure relief device Manufacturer’s unique number, such as serial number, work order number, or lot number.</td>
<td></td>
</tr>
<tr>
<td>(3) The year built or the device Manufacturer’s date code.</td>
<td></td>
</tr>
<tr>
<td>(4) The NB Certification Number.</td>
<td></td>
</tr>
<tr>
<td>(5) The quantity of identical devices for this line item.</td>
<td></td>
</tr>
<tr>
<td>(6) The Manufacturer’s Design or Type Number as marked on the nameplate.</td>
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<td>(7) The inlet size of the device.</td>
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<td>(8) The marked burst pressure of the device.</td>
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<td>(9) The specified disk temperature.</td>
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<td>(10) The date of completion of production of the pressure relief device.</td>
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<tr>
<td>(11) The name or unique ID stamp of the Certified Individual.</td>
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<td>(12) The signature of the Certified Individual. Required for each line item.</td>
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<td>(13) Include any applicable remarks (referencing the identification number) that may pertain, such as identification of a Code Case that requires marking on the device.</td>
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<tr>
<td>(14) The number of the pressure relief device Manufacturer’s Certificate of Authorization.</td>
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<td>(15) Expiration date of the pressure relief device Manufacturer’s Certificate of Authorization.</td>
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<tr>
<td>(16) Date signed by the pressure relief device Manufacturer’s authorized representative.</td>
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<td>(17) The Certificate of Compliance block is to show the name of the Manufacturer as shown on his/her ASME Code Certificate of Authorization. This shall be signed in accordance with organizational authority defined in the Quality Control System (see Mandatory Appendix 2).</td>
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<td>(18) The material of the rupture disk and/or holder, as applicable.</td>
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**GENERAL NOTE:** Any quantity to which units apply shall be entered on the Manufacturer’s Data Report with the chosen units.
M-1 GENERAL

(a) The 2021 Edition of this Division adopts the new Boiler and Pressure Vessel Code Section XIII, Rules for Overpressure Protection. All Section VIII Division 3 pressure relief device requirements have been transferred from Part KR to Section XIII, and the remaining Section VIII Division 3 overpressure protection requirements have been restructured within the new Part KOP. Table M-1-1 lists the new locations for all requirements formally located in Part KR.

(b) Part KR has been revised to reference this Appendix. Part KR and this Appendix will be deleted from the next Edition of this Division.

(c) Table M-1-1 may also be obtained in a spreadsheet format from:

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

Table M-1-1 Cross-Reference List

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