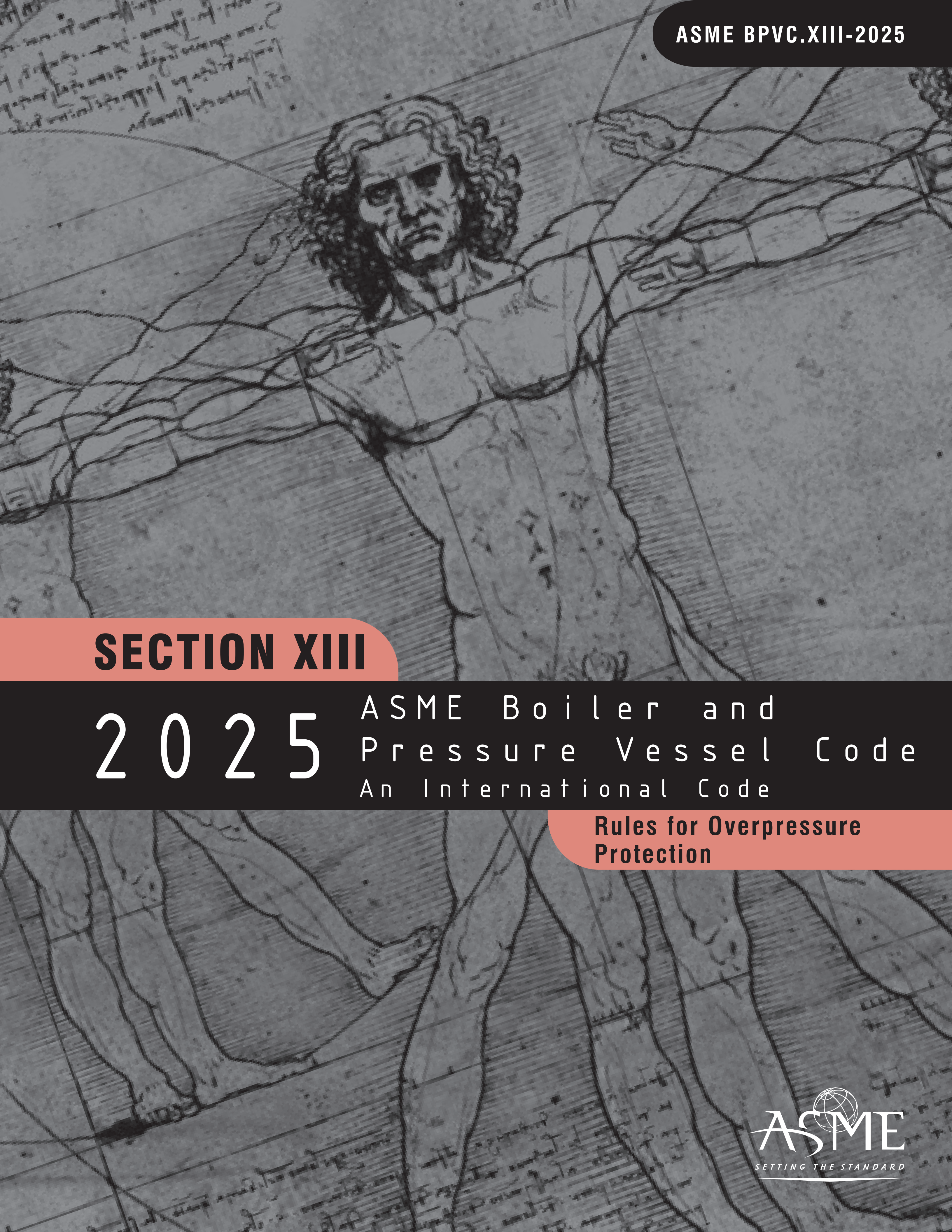

ASME BPVC.XIII-2025

SECTION XIII

2025 ASME Boiler and Pressure Vessel Code

An International Code

Rules for Overpressure Protection

ASME

SETTING THE STANDARD

AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition July 1, 2025

XIII

RULES FOR OVERPRESSURE PROTECTION

ASME Boiler and Pressure Vessel Committee
on Overpressure Protection

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: July 1, 2025

Library of Congress Catalog Card Number: 56-3934

Adopted by the Council of The American Society of Mechanical Engineers, 1914; latest edition 2025.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

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FOREWORD[*]

(25)

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 In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

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

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

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

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

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

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

[**] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of the Code. Requests for revisions, new rules, Code cases, or interpretations shall be addressed to the staff secretary in writing and shall give full particulars in order to receive consideration and action (see the Correspondence With the Committee page). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in the Code, the singular shall be interpreted as the plural, and vice versa.

The words "shall," "should," and "may" are used in the Code as follows:

– *Shall* is used to denote a requirement.
– *Should* is used to denote a recommendation.
– *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

(25)

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CORRESPONDENCE WITH THE COMMITTEE

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NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number to which the proposed case applies

(4) the editions of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition

of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Inquiry Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not “approve,” “certify,” “rate,” or “endorse” any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(25)**, placed next to the affected area.

Page	*Location*	*Change*
x	List of Sections	Title of Section XI, Division 1 revised
xi	Foreword	Third, fourth, seventh, tenth, and eleventh paragraphs editorially revised
xiv	Personnel	Updated
1	1.2	Subparagraph (a)(9) editorially revised
2	1.4	Revised
	Table 1.4-1	Updated
7	Table 2.1-1	(1) In first column, "Spring-loaded non-reclosing valve" revised to "Spring-actuated non-reclosing relief device," and the associated Section VIII Certification Mark Designators revised
		(2) Note (11) revised
9	3.2.3	Subparagraph (a) added and existing paragraph designated as (b)
10	3.2.10	Revised
11	3.3.3	Subparagraph (c) revised
12	3.4.3	In subparas. (a)(1) and (b)(1)(-a), cross-reference revised
13	3.5	First sentence and subpara. (b) revised
14	3.6.1	Subparagraph (a) revised
14	3.6.3	(1) 3.6.3.1(e) revised and 3.6.3.1(f) added;
		(2) 3.6.3.2 revised in its entirety
16	3.9	Subparagraph (e)(1) revised
18	4.1.3.2	First sentence revised
19	4.4.3	First sentence revised
20	4.4.3.2	Last two sentences added
22	5.1.2	First sentence of subpara. (c) revised
22	5.1.3.2	First sentence revised
22	5.2	Subparagraph (k) added and subsequent subparagraph redesignated
24	5.4.2	First sentence revised
24	5.4.2.2	First sentence revised
24	5.4.2.4	Subparagraphs (a)(1), (b)(1)(-a), and (b)(2) revised
26	5.7.1	Revised
26	5.7.3	Subparagraph (a) revised and subpara. (c) deleted
27	Part 6	Revised in its entirety
33	8.3	(1) Subparagraphs (a) and (c) revised
		(2) Subparagraphs (h) and (i) deleted
34	8.5	Deleted
35	9.1	9.1.1(b) and 9.1.2(a) revised
36	9.3	Subparagraphs (b) and (c) revised
36	9.4	Deleted
37	9.7.1	In subpara. (d), equation for capacity added
38	Table 9.7.2-1	Title of third column revised
38	9.7.3	Revised
39	9.7.4	First paragraph revised
39	9.7.5	First paragraph revised
39	9.7.6	Title, first paragraph, 9.7.6.4, and 9.7.6.6 revised
42	9.7.7	(1) First paragraph, 9.7.7.7(d), and 9.7.7.9 (formerly 9.7.7.8) revised
		(2) 9.7.7.8 added and subsequent paragraph redesignated

Page	*Location*	*Change*
44	9.8	Title and subparas. (a), (a)(2), (b), and (c) revised
45	9.9.1.2	Title revised
46	9.9.2.2	Title revised
48	10.1	Revised
48	10.6	Subparagraphs (c)(1) and (c)(2) revised
49	10.7	Subparagraph (a) revised
51	12.5	Title revised
52	12.8	Title revised
52	12.10	Added
53	13.1	Subparagraphs (a) and (b) revised
53	13.2	Second sentence deleted
53	13.3	Subparagraphs (b) and (c) revised
55	I-2	Definitions added and revised throughout to support addition of Mandatory Appendix V and Nonmandatory Appendices D and E
63	Mandatory Appendix II	II-3 deleted
66	IV-1	In subpara. (b) nomenclature, definition of *A* revised
67	Figure IV-1-1M	Figure corrected by errata to the metric figure
67	Figure IV-1-1	Figure corrected by errata to the U.S. Customary figure
66	IV-2	In subpara. (f), second sentence revised
71	IV-4	Revised in its entirety
72	Mandatory Appendix V	Added
140	Table C-1-1	Type of Certificate of Conformance for Certification Designator HV revised
141	Form HV-1	In Certificate of Shop Compliance, “manufacturer” revised to “Manufacturer”
142	Table C-2-1	Instructions for item (17) revised
144	Form UD-1	Title and line 2B editorially revised
145	Table C-2-2	Instructions for item (18) revised
147	Table C-2-3	Instructions for item (18) revised
149	Table C-2-4	Instructions for item (17) revised
151	Form TD-1	Title and line 2B editorially revised
152	Table C-2-5	Instructions for item (18) revised
153	Nonmandatory Appendix D	Added
160	Nonmandatory Appendix E	Added
170	Nonmandatory Appendix F	Added

CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) *Hierarchy of Subparagraph Breakdowns*

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) *Cross-References to Subparagraph Breakdowns.* Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

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PART 1
GENERAL REQUIREMENTS

1.1 SCOPE

(a) The rules of this Section provide the requirements for the overpressure protection of pressurized equipment such as boilers, pressure vessels, and piping systems. Overpressure protection methods include

(1) releasing excess pressure by use of pressure relief devices

(2) applying controls to prevent an increase in pressure (overpressure protection by system design)

(3) using a combination of (1) and (2)

(b) The referencing Code or Standard specifies the objectives of the overpressure protection and acceptable methods to achieve it. Where a pressure-releasing overpressure protection method is specified, the referencing Code or Standard identifies the permissible devices based on this Section's rules for devices to be marked with the Certification Mark and appropriate Designator (e.g., HV, UV, UD).

(c) This Section includes

(1) requirements relating to pressure integrity and performance governing the construction and installation of pressure relief devices. Construction requirements include materials, design, manufacture, examination, inspection, production testing, and certification. Installation requirements address only the variables that affect the performance and pressure-relieving function of the devices, including the inlet and outlet piping.

(2) requirements for conducting tests and analyses to determine the performance of pressure relief devices. These include rules for device-type certification of relieving capacity and/or flow resistance and production testing for new pressure relief devices.

(3) requirements for the use of overpressure protection by system design.

(4) Mandatory Appendices that address specific subjects not covered elsewhere in this Section.

(5) Nonmandatory Appendices that provide information and suggested best practices.

(d) This Section contains requirements, specific prohibitions, and nonmandatory guidance for the design, materials, manufacture, examination, inspection, testing, assembly, installation, and certification of pressure relief devices. The Code does not address all aspects of overpressure protection, and those aspects that are not specifically addressed should not be considered prohibited. In these situations, engineering judgment shall be applied in a manner consistent with the philosophy of this Section, and such judgments shall never be used to overrule mandatory requirements or specific prohibitions of this Section or the referencing Code or Standard.

(e) The scope of this Section has been established to identify the devices and methods considered in formulating the rules given in this Section. Laws or regulations issued by municipal, state, provincial, federal, or other enforcement or regulatory bodies having jurisdiction at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within their jurisdiction.

(f) In relation to the geometry of pressure-containing and pressure-retaining parts of a device, the scope of this Section shall begin at the inlet connection of the device and end at the outlet connection of the device. The inlet and outlet connections are defined as

(1) the first circumferential joint for welded connections, excluding the connecting weld

(2) the first threaded joint for screwed connections

(3) the face of the flange for bolted, flanged connections, excluding the bolting

(4) the first sealing surface for proprietary connections or fittings

1.2 ORGANIZATION (25)

(a) This Section is divided into 13 Parts.

(1) Part 1 contains the scope and general requirements of this Section.

(2) Part 2 contains the responsibilities for providing overpressure protection.

(3) Part 3 contains requirements for the design, materials, inspection, testing, welding, and marking of pressure relief valves.

(4) Part 4 contains requirements for the design, materials, inspection, testing, welding, and marking of rupture disk devices.

(5) Part 5 contains requirements for the design, materials, inspection, testing, welding, and marking of pin devices.

(6) Part 6 contains requirements for the design, materials, inspection, testing, welding, and marking of spring-actuated non-reclosing devices.

(7) Part 7 contains requirements for the design, materials, inspection, testing, welding, and marking of temperature and pressure relief valves.

(8) Part 8 contains requirements for the use and marking of devices in combination.

(9) Part 9 contains requirements for capacity and flow resistance certification of pressure relief devices.

(10) Part 10 contains requirements concerning the use of the Certification Mark.

(11) Part 11 contains requirements for open flow paths and vents.

(12) Part 12 contains requirements and guidelines for the installation of pressure relief devices; these requirements and guidelines address only the variables that affect the performance and pressure-relieving function of the devices.

(13) Part 13 contains requirements for overpressure protection by system design.

(b) The Mandatory Appendices contain specific rules that are not covered elsewhere in this Section. Their requirements are mandatory, when applicable.

(c) The Nonmandatory Appendices provide information and suggested best practices. The information provided is not mandatory; however, if guidance in a Nonmandatory Appendix is used, it shall be used in its entirety.

(d) When a Part, Article, or paragraph is referenced in this Section, the reference shall be taken to include all subdivisions under that Part, Article, or paragraph (including all subparagraphs) and any tables, charts, or figures referenced by that paragraph.

(e) Figures and tables providing relevant illustrations or supporting information for text passages have been designated based on the paragraph they illustrate or support. For a single figure or table, the designator consists of the relevant paragraph designator followed by "-1" (e.g., "10.1-1"). For multiple figures or tables referenced by the same paragraph, each designator consists of the paragraph number followed by a hyphenated numerical suffix that reflects the order of reference.

1.3 DEFINITIONS

The definitions for the terminology used in this Section are contained in Mandatory Appendix I.

(25) 1.4 REFERENCES

(a) Referenced Standards. Throughout this Section, references are made to various standards, such as ASME standards. These standards, with the year of the acceptable edition, are listed in Table 1.4-1. Rules for the use of these standards are stated elsewhere in this Section.

The publishers of the referenced standards are as follows:

American National Standards Institute (ANSI), www.ansi.org

American Petroleum Institute (API), www.api.org

The American Society of Mechanical Engineers (ASME), www. ASME.org

ASTM International, www.astm.org

National Board of Boiler and Pressure Vessel Inspectors (NBBI), www.nationalboard.org

UL Solutions (UL) (formerly Underwriters Laboratories), www.ul.com

Welding Research Council (WRC) (website unavailable)

(b) Additional References. The following references are cited in this Section:

ASME Steam Tables (6th ed.) (1993). The American Society of Mechanical Engineers.

Bean, H. S. (Ed.) (1971). Fluid Meters, Their Theory and Application: Report of ASME Research Committee on Fluid Meters (6th ed.). The American Society of Mechanical Engineers.

Benedict, R. P. (1977). Fundamentals of Temperature, Pressure, and Flow Measurement (2nd ed., Chapters 10, 24). John Wiley & Sons.

Lapple, C. E. (1943). "Isothermal and Adiabatic Flow of Compressible Fluids." Transactions of the American Institute of Chemical Engineers, 39, 385–432.

Levenspiel, O. (1977, May). "The Discharge of Gases From a Reservoir Through a Pipe." AIChE Journal, 23(3), 402–403.

Perry, R. H., and Green, D. W. (Eds.) (1984). Perry's Chemical Engineers' Handbook (6th ed.). McGraw-Hill Book Co.

Taylor, J. L. (1988). Fundamentals of Measurement Error (1st ed.). NEFF Instrument Corp.

1.5 UNITS OF MEASURE

(a) Either U.S. Customary, SI, or any local customary units may be used to demonstrate compliance with requirements of this Section. However, one system of units shall be used consistently throughout the construction cycle for each individual relief device.

(b) For any single equation, all variables shall be expressed in a single system of units. When separate equations are provided for U.S. Customary and SI units, those equations shall be executed using variables in the units associated with the specific equation. Data expressed in other units shall be converted to U.S. Customary units 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.

(c) Production, measurement and test equipment, drawings, welding procedure specifications, welding procedure and performance qualifications, and other manufacturing documents may be in U.S. Customary, SI, or local customary units in accordance with the Manufacturer's or Assembler's practice. When values shown in

calculations and analysis, manufacturing documents, or measurement and test equipment are in different units, any conversions necessary to verify Code compliance and 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.

(d) Conversion of units to the level of precision specified in (c) 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 A. 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 Certified Individual.

(e) 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.

(f) 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 (flanges, elbows, etc.) that have been certified to either U.S. Customary units or SI units may be used regardless of the unit system used in design.

(g) It is acceptable to show alternative units parenthetically.

1.6 TOLERANCES

This Section 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.

Table 1.4-1
Acceptable Edition of Standards Referenced in This Section

Designator	Title	Acceptable Edition
ANSI Z21.22/CSA 4.4	Relief Valves for Hot Water Supply Systems	2015
API 6A	Specification for Wellhead and Tree Equipment	2018, 21st ed.
API 527	Seat Tightness of Pressure Relief Valves	2020, 5th ed.
API Standard 521	Pressure-Relieving and Depressuring Systems	2020, 7th edition [Note (1)]
ASME B16.5	Pipe Flanges and Flanged Fittings	Latest edition
ASME B16.34	Valves — Flanged, Threaded, and Welding End	Latest edition
ASME B31.1	Power Piping	Latest edition
ASME B31.3	Process Piping	Latest edition
ASME BPVC, Section I	Rules for Construction of Power Boilers	Latest edition
ASME BPVC, Section II	Materials	Latest edition
ASME BPVC, Section III, Subsection NB	Rules for Construction of Nuclear Facility Components — Class 1 Components	Latest edition
ASME BPVC, Section III, Subsection NCD	Rules for Construction of Nuclear Facility Components — Class 2 and Class 3 Components	Latest edition
ASME BPVC, Section III, Subsection NE	Rules for Construction of Nuclear Facility Components — Class MC Components	Latest edition
ASME BPVC, Section IV	Rules for Construction of Heating Boilers	Latest edition
ASME BPVC, Section V	Nondestructive Examination	Latest edition
ASME BPVC, Section VIII, Division 1	Rules for Construction of Pressure Vessels	Latest edition
ASME BPVC, Section VIII, Division 2	Rules for Construction of Pressure Vessels — Alternative Rules	Latest edition
ASME BPVC, Section VIII, Division 3	Rules for Construction of Pressure Vessels — Alternative Rules for Construction of High Pressure Vessels	Latest edition
ASME BPVC, Section IX	Welding, Brazing, and Fusing Qualifications	Latest edition
ASME BPVC, Section X	Fiber-Reinforced Plastic Pressure Vessels	Latest edition
ASME BPVC, Section XII	Rules for Construction and Continued Service of Transport Tanks	Latest edition
ASME CA-1	Conformity Assessment Requirements	Latest edition
ASME MFC-3M	Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi	Latest edition
ASME PTC 19.1	Test Uncertainty	Latest edition
ASME PTC 19.2	Pressure Measurement	Latest edition
ASME PTC 19.3	Temperature Measurement	Latest edition
ASME PTC 19.5	Flow Measurement	Latest edition
ASME PTC 19.11	Steam and Water Sampling, Conditioning, and Analysis in the Power Cycle	Latest edition
ASME QAI-1	Qualifications for Authorized Inspection	Latest edition
ASME SI-1	Orientation and Guide for Use of SI (Metric) Units	Latest edition
ASTM D1070	Standard Test Methods for Relative Density of Gaseous Fuels	Latest edition
ASTM D1298	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method	Latest edition
ASTM E380	Metric Practice Guide	Latest edition
NBBI NB-18	Pressure-Relief Device Certification	Latest edition
UL-969	Standard for Marking and Labeling Systems	Latest edition
WRC Bulletin 498	Guidance on the Application of Code Case 2211 — Overpressure Protection by Systems Design	2005

NOTE: (1) API Standard 521, 2020, 7th edition shall be used as referenced except for the following paragraphs:
(a) 4.4.9.3, Check Valve Leakage
(b) 4.4.14.2.1, Pressure Considerations for Heat Exchanger Tube Failure
(c) 4.4.14.4, Plate-and-Frame, Spiral-Plate, and Welded-Block Heat Exchangers

Table 1.4-1
Acceptable Edition of Standards Referenced in This Section (Cont'd)

NOTE: (Cont'd)

(d) 4.4.14.5.2, Sulfur Recovery Unit Thermal Reactor Waste Heat Steam Generators

The listed paragraphs shall be used with the following clarification: The overpressure protection requirements, including for maximum relief pressure and maximum pressure for overpressure protection by system design, shall be in accordance with the vessel code of construction.

For example, Section VIII, Division 1, UG-154 requires all vessels to be protected by a pressure relief device, open flow path, or overpressure protection by system design. Section VIII, Division 1, UG-153 provides the maximum relief pressure when pressure relief devices or open flow paths are used, and UG-154(e) provides the maximum pressure for overpressure protection by system design. Section VIII, Division 1, UG-152(d) specifically requires heat exchangers and similar vessels be protected with a pressure relief device of sufficient capacity to avoid overpressure in case of an internal failure.

PART 2
PROTECTION AGAINST OVERPRESSURE

2.1 GENERAL

(a) The requirements of this Section, including the Certification Mark and Designators, must be referenced by an ASME Boiler and Pressure Vessel Code (BPVC) Section or other Standard for pressurized equipment before this Section becomes effective for that Code or Standard.

(b) The referencing Code or Standard specifies the objectives of the overpressure protection.

(c) The referencing Code or Standard provides the required performance of the relief system, including maximum relieving pressure and maximum set pressure. The pressure relief devices provided in accordance with this Section are designed to meet the performance requirements of the referencing Code or Standard.

(d) The referencing Code or Standard provides basic installation requirements for the protection of the pressurized equipment. This Section provides additional installation requirements that will affect the performance and safety function of the devices.

(e) The referencing Code or Standard identifies the permissible device types or methods. This Section provides specific requirements for pressure relief devices and methods.

(f) The referencing Code or Standard may specify portions of this Section. In this case, only the referenced portions of this Section shall apply, and the remaining requirements shall come from the referencing Code or Standard.

EXAMPLE: ASME Boiler and Pressure Vessel Code (BPVC) Sections I and III currently refer to this Section for capacity certification only. Materials, design, fabrication, nondestructive examination, pressure testing, and Certification by the Manufacturer shall meet the requirements of Section I or Section III. The V and NV Designators are used in this Section only to highlight requirements specific to pressure relief devices for Section I and Section III service, respectively.

(g) If there is a conflict between Section XIII and the referencing Code or Standard, the referencing Code or Standard takes precedence.

(h) Table 2.1-1 summarizes the pressure relief devices and methods permitted by ASME BPVC Sections. If there is a difference between the information in Table 2.1-1 and the provisions of the ASME BPVC Section, the ASME BPVC Section shall apply.

2.2 RESPONSIBILITIES

(a) The referencing Code or Standard defines the duties required for Code compliance and the parties responsible for performing those duties. The duties include, but are not limited to, the following:

(1) design, construction, and installation of the pressure relief system other than the pressure relief device

(2) determination of all potential overpressure scenarios and of the method of overpressure protection used to mitigate each scenario

(3) selection of the type of overpressure protection as described in this Section

(4) sizing and selection of the pressure relief device(s) based on the intended service

(5) installation of the pressure-relieving device prior to operation

(b) The Manufacturer or Assembler of the pressure relief device to which the Certification Mark will be applied shall be responsible for complying with all of the requirements of this Section. A Certified Individual (CI) shall provide oversight as required by 10.6. The Manufacturer or Assembler is not responsible for the requirements or guidance for installation of pressure relief devices provided in this Section.

(c) Some types of work performed on devices (e.g., machining, forming, nondestructive examination, and heat treating) may be performed by parties other than the Manufacturer. It is the Manufacturer's responsibility to ensure that all work so performed complies with all the applicable requirements of this Section.

2.3 SET PRESSURE

The range of allowable set pressures for each pressure relief device is defined by the referencing Code or Standard.

2.4 OVERPRESSURE

The maximum allowable overpressure for each pressure relief device is defined by the referencing Code or Standard.

Table 2.1-1
Permitted Pressure Relief Devices or Methods by ASME BPVC Section (25)

Device or Method	I	III			IV	VIII			X	XII
		NB	NCD	NE		Division 1	Division 2 [(1)]	Division 3		
Direct spring-loaded pressure relief valve	V	NV-1	NV-2, NV-3	NV-1, NV-2 [(2)]	HV, V	UV, V [(3)]	UV, V [(3)]	UV3, UV [(4)]	UV, HV, V [(3)]	TV, UV [(5), (6)]
Pilot-operated pressure relief valve	V	NV-1	NV-2, NV-3	. . .	. . .	UV	UV, V [(3)]	. . .	UV	. . .
Power-actuated relief valve	V	NV-1	NV-2, NV-3	P	. . .	. . .	. . .	P [(7)]	. . .	. . .
Rupture disk	. . .	P	P	[(8)]	. . .	UD	UD	UD3, UD [(9)]	UD	TD, UD [(5), (6)]
Pin device	. . .	. . .	. . .	[(8)]	. . .	UD	UD	. . .	UD	TD, UD [(5), (6)]
Spring-actuated non-reclosing pressure relief device	. . .	. . .	. . .	[(8)]	. . .	UD	UD	. . .	. . .	. . .
Temperature and pressure relief valves	. . .	. . .	. . .	. . .	HV	. . .	. . .	. . .	. . .	. . .
Rupture disk upstream of pressure relief valve (see 8.2) [(10)]	P [(11)]	. . .	P	. . .	. . .	P	P	P	. . .	P [(12)]
Rupture disk downstream of pressure relief valve (see 8.3) [(10)]	. . .	P	P	. . .	. . .	P	P	P	. . .	. . .
Pin device upstream of pressure relief valve (see 8.4) [(10)]	. . .	. . .	. . .	. . .	. . .	P	P	. . .	. . .	P [(12)]
Open flow paths or vents	. . .	. . .	. . .	. . .	. . .	P	P	P	P	. . .
Fusible plugs	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	P [(13)]
Overpressure protection by system design	. . .	. . .	. . .	. . .	. . .	P	P	. . .	P	. . .
Vacuum relief devices	. . .	. . .	NV-2, NV-3	NV-2	. . .	. . .	. . .	. . .	. . .	. . .

GENERAL NOTES:

(a) If there is a difference between the information in Table 2.1-1 and the provisions of the ASME BPVC Section, the ASME BPVC Section shall apply.

(b) Allowable devices and methods are indicated by either the letter P (permitted) or one or more of the following Certification Mark Designators:

HV = heating boiler pressure relief valve
NV-1 = nuclear Class 1 pressure relief valve
NV-2 = nuclear Class 2 pressure relief valve
NV-3 = nuclear Class 3 pressure relief valve
TV = transport tank pressure relief valve
UD = pressure vessel pressure relief device
UD3 = high pressure vessel pressure relief device, Section VIII, Division 3
UV = pressure vessel pressure relief valve
UV3 = high pressure vessel pressure relief valve, Section VIII, Division 3
V = power boiler safety relief valve

Table 2.1-1
Permitted Pressure Relief Devices or Methods by ASME BPVC Section (Cont'd)

NOTES:

(1) All pressure relief devices permitted in Section VIII, Division 1 and bearing the Certification Mark and either the UV or UD Designator may be used on pressure vessels constructed to Section VIII, Division 2.

(2) A pressure relief device designed to either Class 1 or Class 2, as classified by the Design Specification, may be used for Section III NE service.

(3) Pressure relief valves certified for a steam-discharging capacity under the provisions of Part 9 and bearing the Certification Mark and V Designator may be used on Section VIII, Division 1 or Division 2, and Section X pressure vessels.

(4) Pressure relief valves meeting the requirements of Section VIII, Division 1 or Division 2 may be used on pressure vessels constructed to Section VIII, Division 3, provided they also meet specific requirements for Section VIII, Division 3.

(5) Pressure relief devices certified for service in unfired pressure vessels per Section VIII, Division 1 may be used for Section XII applications if they meet the additional requirements of Section XII, particularly the Modal Appendices.

(6) Pressure relief devices, rupture disk devices, or pin devices certified for service in unfired pressure vessels per Section VIII, Division 1 may be used in transport tank service, provided the tank Manufacturer or user of the tank has determined that the devices are suitable for the intended service application. Suitability shall be determined based on the temperatures, pressures, and compatibility with the goods transported in the specific application.

(7) Section VIII, Division 3 power-actuated pressure relief valves are not within the scope of Section XIII. See Section VIII, Division 3 for requirements.

(8) Non-reclosing pressure relief devices are unacceptable. See Section III, Division 1, Subsection NE, NE-7161.

(9) Rupture disk devices bearing the Certification Mark and UD Designator in accordance with Section XIII may be used [see Section VIII, Division 3, KOP-152(c)].

(10) Each device of a combination shall be marked with the Certification Mark and appropriate Designator.

(11) Rupture disks are permitted on the inlet of pressure relief valves for organic vaporizers only. See Section I, PVG-12.3.

(12) Non-reclosing pressure relief devices for Section XII applications shall be used only as part of a combination relief device, except where their use as the sole overpressure protection device is specifically authorized by the competent authorities with jurisdiction over the tank's operation.

(13) The Certification Mark and Designator are not required. See Section XII for requirements.

PART 3
REQUIREMENTS FOR PRESSURE RELIEF VALVES

3.1 GENERAL

3.1.1 Applicability of Part 3 Requirements

This Part contains requirements applicable to all pressure relief valves that are to be marked with the Certification Mark and any Designator. Requirements unique to a specific Designator are identified.

3.1.2 Valve Characteristics

(a) All pressure relief valves shall be of the direct spring-loaded, pilot-operated, or power-actuated type.

(b) Pilot-operated pressure relief valves shall be designed such that

(1) the pilot is self-actuated

(2) the main valve will open automatically at a pressure not exceeding the set pressure

(3) if some essential part of the pilot fails, the main valve will discharge its full rated capacity at or below the relieving pressure used to determine its rated capacity

(c) Section VIII, Division 1 and Division 2 (UV Designator) pressure relief valves shall be designed and constructed such that when installed per Section VIII, Division 1, UG-156, they comply with the following:

(1) They shall operate without chattering.

(2) When operating at the flow-rated pressure, they shall not flutter in a way that would either interfere with the measurement of capacity or result in damage.

3.2 DESIGN AND MECHANICAL REQUIREMENTS

3.2.1 Body

In the design of the body of the pressure relief valve, consideration shall be given to minimizing the effects of deposits.

3.2.2 Drains

(a) If the design of a pressure relief valve is such that liquid can collect on the discharge side of the disk, then, except as permitted in (b), the valve shall be equipped with a drain at the lowest point at which liquid can collect.

(b) Pressure relief valves that cannot be equipped with a drain as required in (a) because of design or application may be used, provided all the following conditions are met:

(1) The pressure relief valves are used only on gas service where there is neither liquid discharged from the valve nor liquid formed by condensation on the discharge side of the valve.

(2) The pressure relief valves are provided with a cover or discharge piping per 12.8(c) to prevent liquid or other contaminant from entering the discharge side of the valve.

(3) The pressure relief valve is marked FOR GAS SERVICE ONLY in addition to being marked as required by 3.9.

(c) For Section IV (HV Designator) pressure relief valves exceeding DN 65 (NPS $2^1/_2$), the drain hole or holes shall be tapped not less than DN 10 (NPS $^3/_8$). For valves of DN 65 (NPS $2^1/_2$) or smaller, the drain hole shall not be less than 6 mm ($^1/_4$ in.) in diameter.

3.2.3 Bonnet (25)

(a) The bonnet of balanced direct spring-loaded pressure relief valves shall be vented to prevent accumulation of pressure in the bonnet.

(b) The bonnet of Section VIII, Division 3 (UV3 Designator) pressure relief valves shall be vented to prevent accumulation of pressure. Sealing or isolation of the bonnet area from the relieving fluid may be required for protection of the spring assembly from corrosion or solids accumulation.

3.2.4 Seat

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

3.2.5 Springs for Direct Spring-Loaded Valves

(a) The spring of a direct spring-loaded valve 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. Alternatively, for Section XII (TV Designator) valves only, a design in which the spring compression at full lift equals or exceeds 80% is permitted, provided the valve has been tested and meets the acceptance criteria of Part 9.

(b) The permanent set of the spring shall not exceed 0.5% of the original free length. Permanent set is defined as the difference between the original free length and the free length after the spring has been preset at room temperature by compressing it to its solid height three times. Measurement shall be taken at least 10 min following the preset.

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

$$R_{sf} = F_{so}/F_{sc}$$

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

3.2.6 Guiding Arrangements

(a) The design of the pressure relief valve shall incorporate guiding arrangements necessary to ensure consistent operation and seat tightness.

(b) Bottom-guided designs are not permitted on Section IV (HV Designator) pressure relief valves.

3.2.7 Lifting Device

(a) Section VIII (UV Designator) pressure relief valves intended for use on air or steam service, or on water service where the valve inlet temperature exceeds 60°C (140°F) excluding overpressure or relief events, shall have a substantial lifting device that, when activated, will release the seating force on the disk when the pressure relief valve is subjected to a pressure of at least 75% of the set pressure of the valve.

(b) Section VIII (UV Designator) pilot-operated pressure relief valves used on the services described in (a) shall be provided with either a lifting device as described in (a) or a means for connecting and applying pressure to the pilot adequate to verify that the moving parts critical to proper operation are free to move.

(c) Section IV (HV Designator) pressure relief valves shall have a lifting device and a mechanical connection between the lifting device and the disk capable of lifting the disk from the seat a distance of at least 1.5 mm ($^1/_{16}$ in.) with no pressure on the boiler.

3.2.8 Wrenching Surfaces

Pressure relief valves having threaded inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damage to operating parts.

3.2.9 Sealing of Adjustments

(a) Means shall be provided in the design of all pressure relief valves for sealing all external adjustments that can be made without disassembly of the valve.

(b) Seals shall be installed by the Manufacturer or Assembler after all adjustments required for production testing.

(c) Seals shall be installed in a manner to prevent changing the adjustment without breaking the seal.

(d) For pressure relief valves larger than DN 15 (NPS $^1/_2$), the seal shall serve as a means of identifying the Manufacturer or Assembler making the adjustment.

3.2.10 Diaphragm-Type Direct Spring-Loaded Pressure Relief Valves (25)

Diaphragm-type direct spring-loaded pressure relief valves shall meet the following requirements:

(a) The space above the diaphragm shall be vented to prevent accumulation of pressure above the diaphragm.

(b) The valve shall be designed so that failure or deterioration of the diaphragm material will not impair the valve's ability to relieve at the rated capacity.

3.2.11 Restricted-Lift Designs

Valve capacity may be limited by restricting the lift of a valve, provided the following requirements are met:

(a) The valve size shall be DN 20 (NPS $^3/_4$) or larger.

(b) No changes shall be made in the design of the valve, except to change the valve lift by use of a lift-restraining device described in (c).

(c) The restriction of valve capacity shall be permitted only by the use of a lift-restraining device that shall limit valve lift and shall not otherwise interfere with flow through the valve.

(1) The design of the lift-restraining device shall be subject to review by an ASME Designated Organization.

(2) The lift-restraining device shall be designed so that, if the device is adjustable, the adjustable feature can be sealed. Seals shall be installed by the valve Manufacturer or Assembler at the time of initial adjustment.

(d) The valve lift shall be no less than 30% of full rated lift, or 2 mm (0.080 in.), whichever is greater.

(e) The restricted-lift nameplate capacity shall be determined by multiplying the capacity at full rated lift by the ratio of the restricted lift to the full rated lift.

3.2.12 O-Rings and Packing

O-rings or other packing devices used on the stems of pressure relief valves shall be arranged so that valve performance meets the requirements of this Section.

3.2.13 Inlet/Outlet Connections

(a) The inlet opening of a Section IV (HV Designator) pressure relief valve shall have an inside diameter approximately equal to, or greater than, the seat diameter. In no case shall the maximum opening through any part of the valve be less than 6 mm ($^1\!/_4$ in.) in diameter or its equivalent area.

(b) Pressure relief valves for Section IV, Part HLW (HV Designator) potable water heaters shall be at least DN 20 (NPS $^3\!/_4$).

(c) Any Section VIII (UV Designator) pressure relief valve in liquid service shall be at least DN 15 (NPS $^1\!/_2$).

(d) Threaded inlet or outlet connections for Section VIII, Division 3 (UV3 Designator) valves shall be in accordance with Section VIII, Division 3, KD-6.

3.2.14 Pop Action

Section IV (HV Designator) pressure relief valves shall have pop action (rapid opening) when tested using steam.

3.3 MATERIAL REQUIREMENTS

3.3.1 General

(a) Materials used in bodies, bonnets, yokes, and body-to-bonnet or body-to-yoke bolting shall be as permitted in Section II, Part D by the referencing Code, except for Section IV (HV Designator) pressure relief valves, for which the Manufacturer may use materials other than those listed in Section II. In those cases, the Manufacturer shall establish and maintain specifications requiring equivalent control of chemical and physical properties and quality.

In addition, the following requirements apply:

(1) For Section VIII, Division 1 (UV Designator) pressure relief valves, the bodies, bonnets, yokes, and body-to-bonnet or body-to-yoke bolting shall meet all applicable requirements of Section VIII, Division 1, Subsection C.

(2) For Section VIII, Division 3 (UV3 Designator) pressure relief valves, the bodies, bonnets, yokes, and body-to-bonnet or body-to-yoke bolting shall meet all applicable requirements of Section VIII, Division 3, Article KM.

(3) For Section XII (TV Designator) pressure relief valves, the bodies, bonnets, yokes, and body-to-bonnet or body-to-yoke bolting shall meet all applicable requirements of Section XII, Part TM.

(b) Other than as specified in (a), all parts required for the pressure-relieving or pressure-retaining function shall be of materials that are

(1) listed in Section II, or

(2) listed in ASTM specifications, or

(3) controlled by the Manufacturer of the pressure relief valve by a specification ensuring control of chemical and physical properties and quality at least equivalent to that of ASTM standards

(c) No materials liable to fail due to deterioration or vulcanization when subjected to saturated steam temperature corresponding to capacity test pressure shall be used for Section IV (HV Designator) pressure relief valves.

3.3.2 Seats and Disks

(a) Cast iron seats and disks are not permitted.

(b) The seats and disks of pressure relief valves shall be of suitable material to resist corrosion by the fluid to be contained. The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the Manufacturer and the purchaser.

(c) When selecting materials for seating surfaces, the Manufacturer shall consider the potential for brinelling and its effects on the performance of the pressure relief valve.

(d) Material for seats and disks should be such as to provide a reasonable degree of resistance to erosion caused by high-velocity steam (i.e., steam cutting) when the pressure relief valve is used in steam or hot water applications.

(e) Nonmetallic disk inserts and seals shall be compatible with the maximum design temperature established for the pressure relief valve.

3.3.3 Guiding/Sliding Surfaces (25)

(a) When selecting materials for sliding surfaces, the Manufacturer shall consider the potential for galling and its effects on the performance of the pressure relief valve.

(b) Adjacent sliding surfaces, such as guides and disks or disk holders, shall both be of corrosion-resistant material. The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the Manufacturer and the purchaser.

(c) For Section VIII, Division 3 (UV3 Designator) pressure relief valves, galling resistance shall be demonstrated on a prototype valve by popping a valve to full lift ten times, with subsequent disassembly and inspection showing no indication of galling.

3.3.4 Springs

Springs shall be made of corrosion-resistant material or shall have a corrosion-resistant coating.

3.4 INSPECTION OF MANUFACTURING AND/OR ASSEMBLY

3.4.1 General

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

(b) At the time of the submission of pressure relief valves for capacity certification or testing in accordance with 3.4.2, the representative of the ASME Designated Organization has the authority to review the device design for conformity with the requirements of 3.2 and 3.3, and to reject or require modification of designs that do not conform.

(c) Manufacturing, assembly, inspection, and test operations, including capacity testing, are subject to inspections at any time by a representative of the ASME Designated Organization.

3.4.2 Production Certification

A Manufacturer or Assembler may be granted permission to apply the Certification Mark and appropriate Designator to production pressure relief valves whose capacity has been certified in accordance with Part 9, provided the testing described in this paragraph is 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 testing described in this paragraph is successfully repeated within the 6-month period before expiration.

3.4.2.1 Sample Selection. Two sample production pressure relief valves of a size and capacity within the testing capability of an ASME-accepted laboratory shall be selected by a representative from an ASME Designated Organization. All sample pressure relief valves having adjustable blowdown construction shall have the control elements positioned by the Manufacturer or Assembler per the Manufacturer's specification.

3.4.2.2 Testing. Operational and capacity tests shall be conducted in the presence of a representative from an ASME Designated Organization at a testing facility meeting the requirements of ASME CA-1. The pressure relief valve Manufacturer or Assembler shall be notified of the time of the test and may have representatives present to witness the tests.

3.4.2.3 Test Results

(a) Should any pressure relief valve fail to relieve at or above its certified capacity, or should it fail to meet performance requirements of this Section, the test shall be repeated at the rate of two replacement pressure relief valves, selected in accordance with 3.4.2.1, for each pressure relief valve that failed.

(b) If a sample pressure relief valve with adjustable blowdown construction selected from a Manufacturer exhibits a blowdown that exceeds the value in Table 3.4.2.3-1, then an adjustment shall be made to meet this performance condition, and the operational and capacity tests shall be repeated. This adjustment may be made at the flow test facility. For each valve whose blowdown requirement cannot be met through adjustment, the test shall be repeated with one replacement pressure relief valve, selected in accordance with 3.4.2.1.

(c) Should any of the replacement pressure relief valves described in (a) fail to meet the capacity or performance requirements of this Section, the Manufacturer or Assembler shall determine the cause of failure and take corrective action to guard against future occurrence. This cause of failure and corrective action shall be documented and submitted to the ASME Designated Organization within 60 days of the failure or be cause for revocation of the authorization to use the Certification Mark on that particular type of valve. Upon the ASME Designated Organization's acceptance of the submitted corrective action, the requirements of 3.4.2 shall apply.

3.4.3 Alternative Tests for Valves That Exceed the Laboratory Capabilities (25)

(a) For valves that exceed the laboratory testing capabilities and for which lift at rated overpressure can be measured, the alternative method described below shall be used in lieu of the test requirements of 3.4.2.1, 3.4.2.2, and 3.4.2.3(a).

(1) Two production valves that are representative of the design shall be tested per Mandatory Appendix V, Article V-3. The tests shall demonstrate to the satisfaction

Table 3.4.2.3-1
Maximum Blowdown for Sample Valves During Testing

Certification Mark Designator [Note (1)]	Maximum Blowdown for Sample Valves During Testing
HV	15 kPa to 30 kPa (2 psi to 4 psi) [Note (2)]
UV or UV3	7% of the set pressure or 20 kPa (3 psi), whichever is greater
TV	7% of the set pressure or 20 kPa (3 psi), whichever is greater

NOTES:
(1) See the General Note of Table 2.1-1 for the valve types to which the Certification Mark Designators apply.
(2) This maximum applies to low-pressure steam heating boiler pressure relief valves with set pressure equal to or less than 100 kPa (15 psi) only. This blowdown need not be adjustable.

of the representative of the ASME Designated Organization that the valves satisfy the following conditions:

(-a) The measured set pressure is consistent with the stamped set pressure within the tolerances required by Table 3.6.3.1-2.

(-b) The valve will achieve the minimum lift for its certified capacity.

(-c) The valve will operate without chatter or flutter.

If only one valve of the design will be produced within the 6-yr period for which the permission is granted, only that valve need be tested as stated above.

(2) The testing shall be performed at a facility that is mutually agreeable to the Manufacturer, the representative of an ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating the characteristics stated in (1)(-a) through (1)(-c).

(3) In the event of failure of the tests, 3.4.2.3(c) shall apply.

(b) For valves that exceed the laboratory testing capabilities and for which lift at rated overpressure cannot be measured, the alternative method described below shall be used.

(1) For initial certification, two functional models that are representative of the design shall be used, provided the test requirements of 3.4.2.1, 3.4.2.2, 3.4.2.3(a), and 3.4.2.3(c) are followed and the following additional test requirements are met:

(-a) Two production valves that are representative of the design shall be tested per Mandatory Appendix V, Article V-3. The testing shall demonstrate to the satisfaction of the representative of the ASME Designated Organization that

(-1) the measured set pressure is consistent with the stamped set pressure within the tolerances required by Table 3.6.3.1-2

(-2) a secondary pressure zone leakage test and a seat tightness test are demonstrated in accordance with 3.6.2 and 3.6.4

If only one valve of the design will be produced within the 6-yr period for which the permission is granted, only that valve need be tested as stated above.

(-b) The testing shall be performed at a facility that is mutually agreeable to the Manufacturer, the representative of an ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating the characteristics stated in (-a)(-1) and (-a)(-2).

(-c) In the event of failure of the tests, 3.4.2.3(c) shall apply.

(2) For 6-yr renewal of capacity certification, (1)(-a) through (1)(-c) shall apply.

(25) 3.5 ASSEMBLER REQUIREMENTS

The following requirements apply only to valves to be marked with the Certification Mark and UV, UV3, or TV Designator:

(a) Use of the Certification Mark and appropriate Designator by an Assembler indicates the use of original, unmodified parts in strict accordance with the instructions of the Manufacturer of the pressure relief valve.

(b) The Assembler shall be located in and work from facilities separate from the Manufacturer's facilities.

(c) An Assembler may be organizationally independent of the Manufacturer or may be wholly or partly owned by the Manufacturer.

(d) An Assembler may transfer original and unmodified pressure relief parts produced by the Manufacturer to another Assembler, provided all of the following conditions are met:

(1) Both Assemblers have been granted permission to apply the Certification Mark and appropriate Designator to the specific valve type in which the parts are to be used.

(2) The quality control system of the Assembler receiving the pressure relief valve parts defines the controls for the procurement and acceptance of those parts.

(3) The pressure relief valve parts are appropriately packaged, marked, or sealed by the Manufacturer to ensure that the parts are produced by the Manufacturer and are original and unmodified.

(e) An Assembler may convert original finished parts by either machining to another finished part or applying a corrosion-resistant coating to valve springs for a specific application under the following conditions:

(1) Conversions shall be specified by the Manufacturer. Drawings and/or written instructions used for part conversion shall be obtained from the Manufacturer and shall include a drawing or description of the converted part before and after the conversion.

(2) The Assembler's quality control system, as accepted by an ASME Designee, shall describe in detail the conversion of original parts, provisions for inspection and acceptance, personnel training, and control of current Manufacturer's drawings and/or written instructions.

(3) The Assembler shall document each use of a converted part and that the part was used in strict accordance with the instructions of the Manufacturer.

(4) The Assembler shall demonstrate to the Manufacturer the ability to perform each type of conversion. The Manufacturer shall document all authorizations granted to perform part conversions. The Manufacturer and Assembler shall maintain a file of such authorizations.

(5) For an Assembler to offer restricted lift valves, the Assembler shall demonstrate to the satisfaction of the Manufacturer the ability to perform valve lift restrictions. The Manufacturer shall document all authorizations granted to restrict the lift of the valves. The Assembler shall maintain a file of such authorizations and the records of each lift restriction made.

(6) At least annually the Manufacturer shall review each Assembler's system and conversion capabilities. The Manufacturer shall document the results of these reviews. The Assembler shall keep a copy of this documentation on file. The review results shall be made available to a representative from an ASME Designated Organization.

(f) In addition to the data required by 3.9, the marking shall include the name of the Manufacturer and the final Assembler. The Certification Mark shall be that of the final Assembler.

3.6 PRODUCTION TESTING

All pressure relief valves to which the Certification Mark is to be applied shall be subjected to the tests of this paragraph by the Manufacturer or Assembler. A Manufacturer or Assembler shall have a documented system for the application, calibration, and maintenance of gages and instruments used during these tests. Testing time on steam pressure relief valves shall be sufficient, depending on size and design, to ensure that test results are repeatable and representative of field performance.

(25) 3.6.1 Pressure Testing

The requirements of 3.6.1 shall not apply to Section IV (HV Designator) pressure relief valves.

(a) The pressure-containing parts of the shell of each valve are subject to pressure testing.

(b) A valve shell part is exempt from pressure testing if both of the following conditions apply:

(1) The stress that would be applied under hydrostatic test conditions does not exceed 50% of the allowable stress.

(2) The part is not cast or welded.

(c) When the valve is designed for discharging directly to atmosphere, the valve components downstream of the valve disk are exempt from pressure testing.

(d) Valve components are exempt from pressure testing if they are fully contained within pressure-containing parts that have been either pressure tested or exempted from pressure testing by (b).

(e) A valve shell part requiring pressure testing shall be tested either

(1) hydrostatically at a minimum 1.5 times the design pressure of the part, or

(2) pneumatically at a minimum 1.25 times the design pressure of the part

CAUTION: Pneumatic testing can be hazardous; it is therefore recommended that special precautions be taken when conducting a pneumatic test.

(f) Pressure testing may be done in the part or assembled condition.

(g) Pressure testing shall be conducted after all machining and welding operations have been completed.

(h) Parts subjected to pressure testing shall not exhibit a sign of leakage.

3.6.2 Secondary Pressure Zone Test

(a) Except for the valves described in (b), all closed-bonnet pressure relief valves that have an inlet size exceeding DN 25 (NPS 1) and that are designed for discharge to a closed system shall have their secondary pressure zones tested with air or other gas at a pressure of at least 200 kPa (30 psi). The user may specify a higher test pressure commensurate with the back pressure anticipated in service.

(b) The secondary pressure zone of each Section VIII, Division 3 (UV3 Designator) closed-bonnet pressure relief valve shall be tested at 1.25 times the stated design pressure of the secondary pressure zone but not at less than 0.125 times the design pressure of the primary parts.

(c) Parts subjected to secondary pressure zone testing shall not exhibit a sign of leakage.

3.6.3 Set Pressure Tests (25)

3.6.3.1 General

(a) Each pressure relief valve to which the Certification Mark and appropriate Designator is to be applied shall be tested by the Manufacturer or Assembler to demonstrate the valve's set pressure.

(b) Set pressure tests for pressure relief devices shall be conducted using the test fluid specified in Table 3.6.3.1-1.

(c) Test fixtures and test drums, where applicable, shall be of adequate size and capacity to ensure that pressure relief valve action is consistent with the marked set pressure within the applicable tolerances shown in Table 3.6.3.1-2.

(d) When pressure relief valve service conditions differ from test stand conditions due to superimposed back pressure or temperature, or both, the actual test pressure (cold differential test pressure) shall be adjusted and marked on the valve per 3.9(e)(4)(-a). When superimposed back pressure contributes to the cold differential test pressure, it shall also be marked on the valve per 3.9(e)(4)(-b).

(e) For Section IV (HV Designator) pressure relief valves for steam service (i.e., steam boiler), the applicable operating characteristic shall be popping pressure.

(f) For Section IV (HV Designator) pressure relief valves for other than steam service (i.e., steam boiler) and all other valve types (UV, UV3, and TV Designators), the applicable operating characteristic to be displayed for a specific valve design shall be specified by the device Manufacturer. See the definition of "set pressure" in Mandatory Appendix I for allowable operational characteristics.

3.6.3.2 Alternative Test Methods

(a) The following alternative method may be used in lieu of 3.6.3.1(a) to test pilot operated pressure relief valves:

Table 3.6.3.1-1
Test Fluid for Set Pressure Tests

Pressure Relief Device		
Certification Mark Designator [Note (1)]	**Service**	**Test Fluid**
HV	Steam	Steam or air
	Saturated water	Water, steam, or air
UV	Steam [Note (2)]	Steam [Note (3)]
	Gas or vapor	Air or other suitable gas
	Incompressible fluids (liquids)	Water or other suitable liquid
UV3	Compressible fluids	Air or other suitable gas
	Incompressible fluids (liquids)	Water or other suitable incompressible fluid
TV	Compressible fluids	Air or other suitable gas
	Incompressible fluids (liquids)	Water or other suitable liquid

NOTES:
(1) See the General Note of Table 2.1-1 for the valve types to which the Certification Mark Designators apply.
(2) Also applicable for valves having special internal parts for steam service.
(3) If the size or set pressure of the pressure relief valve to be tested is beyond the capability of the production steam test facility, the valve may be tested on air. Necessary corrections for differentials in set pressure between steam and air shall be established by the Manufacturer and applied to the set pressure on air.

Table 3.6.3.1-2
Set Pressure Tolerances for Pressure Relief Valves

Certification Mark Designator [Note (1)]	Set Pressure, kPa (psi)	Tolerance
HV	≤100 (≤15)	±15 kPa (±2 psi) [Note (2)]
	≤400 (≤60)	±20 kPa (±3 psi)
	>400 (>60)	±5% of set pressure
UV	≤500 (≤70)	±15 kPa (±2 psi)
	>500 (>70)	±3% of set pressure
	All pressures	−0%, +10% of set pressure [Note (3)]
UV3	All pressures	±3% of set pressure
TV	≤500 (≤70)	±15 kPa (±2 psi)
	>500 (>70)	±3% of set pressure

NOTES:
(1) See the General Note of Table 2.1-1 for the valve types to which the Certification Mark Designators apply.
(2) This set pressure tolerance applies to low-pressure steam heating boilers only.
(3) This set pressure tolerance applies to valves that are capacity certified for application in accordance with Section VIII, Division 1, UG-153(a)(3).

(1) The pilot of a pilot-operated pressure relief valve shall be tested separately to establish the pressure at which the pilot will actuate the main valve. The test fluid shall be that specified in Table 3.6.3.1-1.

(2) The fully assembled valve shall then be tested to verify that all components are properly connected and leak tight and that the pilot actuates the main valve. For liquid or steam service, this test may be conducted on air or other suitable gas.

(b) When the requirements of 3.6.3.1(c) cannot be met, one of the following alternative methods may be used:

(1) Direct Spring-Loaded Pressure Relief Valves

(-a) If testing of a direct spring-loaded pressure relief valve is beyond the capabilities of the production test equipment, an alternative test method [see (-b)] may be used, provided all the following conditions are met:

(-1) Testing the valve at full pressure could cause damage to the valve, or testing of the valve is impractical due to safety considerations related to operating the boiler system.

(-2) The valve lift has been mechanically verified as meeting or exceeding the required lift.

(-3) For valves with adjustable blowdown, the blowdown control elements are set to the valve manufacturer's specification.

(-4) The valve design is compatible with the alternative test method selected.

(-b) One of the following alternative test methods may be used:

(-1) The valve lift may be temporarily restricted to avoid damage and tested on the appropriate test fluid to demonstrate set pressure.

(-2) The valve may be fitted with an auxiliary lift-assist device and tested on the appropriate test fluid 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 shown in Table 3.6.3.1-2.

(2) All Pressure Relief Valves. When pressure relief valves to be tested with steam, air, or other suitable gas are beyond the capability of the production test facility, either because of size or set pressure, the valves may be tested using an alternate test fluid. Steam service valves may be tested on air or other gas. Gas or vapor service valves may be tested on steam.

When valves are tested with an alternate fluid, the test pressure shall be the product of the Manufacturer's correction factor for the differential between steam and air or gas multiplied by the set pressure. If a cold differential test pressure is applicable due to superimposed back pressure or service temperature, or both, then the Manufacturer's correction factor shall be applied to the cold differential test pressure. The correction factor between steam and air or gas shall not be included in the cold differential test pressure marked on the valve per 3.9(e)(4)(-a).

3.6.4 Seat Tightness Test

After completion of the tests required by 3.6.3, a seat tightness test shall be conducted in accordance with the following:

(a) For Valves to Be Marked With the Certification Mark and UV Designator. Unless otherwise designated by a Manufacturer's published pressure relief valve specification or another specification agreed to by the user, the seat tightness test and acceptance criteria shall be in accordance with API 527.

(b) For Valves to Be Marked With the Certification Mark and UV3 Designator. The seat tightness test shall be conducted at a maximum expected operating pressure but at a pressure not exceeding the reseating pressure of the valve. When the test is conducted with an incompressible fluid, the valve shall exhibit no visible signs of leakage. The leak rate of a valve tested with a compressible fluid shall meet the criteria specified in the User's Design Specification (see Section VIII, Division 3).

(c) For Valves to Be Marked With the Certification Mark and HV Designator. A tightness test shall be conducted at maximum expected operating pressure but at a pressure not exceeding the reseating pressure of the valve.

(d) For Valves to Be Marked With the Certification Mark and TV Designator. Unless otherwise designated by a Manufacturer's published pressure relief valve specification or another specification agreed to by the user, the seat tightness test and acceptance criteria shall be in accordance with API 527.

3.6.5 Blowdown Testing

Each Section IV (HV Designator) pressure relief valve with adjustable blowdown shall be tested to demonstrate blowdown in accordance with Table 3.4.2.3-1. When the blowdown is nonadjustable, the blowdown test may be performed on a sampling basis.

3.7 WELDING, BRAZING, HEAT TREATMENT, AND NONDESTRUCTIVE EXAMINATION

All welding, brazing, heat treatment, and nondestructive examination used in the construction of bodies, bonnets, and yokes shall be performed in accordance with the applicable requirements of the Section of the Certification Mark Designator applied to the pressure relief valve.

3.8 SET PRESSURE CHANGE

The set pressure of a valve may be changed after completion of the appropriate Certificate of Conformance (see Nonmandatory Appendix C) but before the valve is put into service for overpressure protection, provided all of the following requirements are met:

(a) All parts conversions, valve adjustments, and testing shall be performed by the Manufacturer or an Assembler that has been granted permission to apply the Certification Mark and appropriate Designator to the specific valve type.

(b) The valve Manufacturer or Assembler that performs the set pressure change shall update the Certificate of Conformance or create a new Certificate of Conformance (see Nonmandatory Appendix C).

(c) The change to the set pressure shall be validated per 3.6.3.

(d) The set pressure and capacity marked on the valve shall be obliterated. The new set pressure and capacity shall be marked in accordance with 3.9. When marking is accomplished by metal nameplate, the original nameplate shall be removed and destroyed, and a new nameplate affixed to the valve.

(e) All other requirements of this Section for the use of the Certification Mark and appropriate Designator shall apply, in particular leak testing per 3.6.1 and 3.6.4, and resealing adjustments per 3.2.9.

3.9 MARKING (25)

(a) The Manufacturer or Assembler shall plainly mark each pressure relief valve with the required data in such a way that the marking will not be obliterated in service.

(b) The markings shall be located on the valve or a corrosion-resistant metal plate or plates securely fastened to the valve.

(c) Small valves [less than DN 15 (NPS $^1\!/_2$) inlet] may have the nameplate attached with a chain or wire or adhesive meeting the requirements of Mandatory Appendix II or other means suitable for the service conditions.

(d) For units of measure other than those included in (e), see 1.5.

(e) The marking shall include the following:

(1) name, or an acceptable abbreviation, of the Manufacturer and the Assembler, as applicable.

(2) Manufacturer's design or type number.

(3) DN (NPS) size _____ (the nominal pipe size of the valve inlet).

(4) set pressure _____ kPa (psi) and, if applicable per 3.6.3.1(d)

(-a) cold differential test pressure _____ kPa (psi)

(-b) superimposed back pressure _____ kPa (psi)

(5) certified capacity as follows:

(-a) For Valves to Be Marked With the Certification Mark and UV Designator. The valve shall be marked with one of the following, as applicable:

(-1) _______ kg/h (lbm/hr) of saturated steam at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for valves certified on steam.

(-2) ________ L/min (gpm) of water at 20°C (70°F) at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for valves certified on water.

(-3) _______ m^3/min of air at 20°C and 101 kPa [standard cubic feet per minute (SCFM) of air at 60°F and 14.7 psia] or ________ kg/min (lbm/min) of air at an overpressure of 10% or 20 kPa (3 psi), whichever is greater for valves certified on air. Valves that are capacity certified for application in accordance with Section VIII, Division 1, UG-153(a)(3) shall be marked "at 20% overpressure."

In addition to one of the fluids specified in (-1) through (-3), the Manufacturer may indicate the capacity in other fluids (see Mandatory Appendix IV).

(-b) For Valves to Be Marked With the Certification Mark and UV3 Designator

_______ m^3/h of air at 20°C and 101 kPa (SCFM of air at 60°F and 14.7 psia), or _______ L/min (gpm) of water at 20°C (70°F) if the pressure relief valve is to be tested to have a certified flow capacity; see Section VIII, Division 3, KOP-153(b) and KOP-154(b). If the pressure relief valve is not flow capacity tested and certified, the flow capacity shall be marked "NONE" [see Section VIII, Division 3, KOP-154(c)]. In addition, the Manufacturer/Assembler may indicate the flow capacity in other fluids (see Mandatory Appendix IV).

(-c) For Valves to Be Marked With the Certification Mark and HV Designator

_______ kg/h (lbm/hr), or ____ kW (Btu/hr) in accordance with 9.7.1(d)

(-d) For Valves to Be Marked With the Certification Mark and TV Designator. The valve shall be marked with one of the following, as applicable:

(-1) ______ L/min (gpm) of water at 20°C (70°F) at the flow rating pressure [typically an overpressure of 10% or 20 kPa (3 psi), whichever is greater] for valves certified on water

(-2) ______ m^3/min of air at 20°C and 101 kPa (SCFM of air at 60°F and 14.7 psia) or ______ kg/min (lbm/min) of air at the flow rating pressure [typically an overpressure of 10% or 20 kPa (3 psi), whichever is greater] for valves certified on air. Valves that are capacity certified at 120% of marked set pressure as permitted by the appropriate Section XII Modal Appendix shall be marked "at 20% overpressure."

In addition to one of the fluids specified in (-1) and (-2), the Manufacturer may indicate the capacity in other fluids (see Mandatory Appendix IV).

(6) year built, or alternatively, a coding may be marked on the valve such that the valve Manufacturer or Assembler can identify the year the valve was assembled and tested.

(7) Certification Mark and the appropriate Designator placed under the Certification Mark (see Figure 10.1-1). A marking method other than the stamp issued by the Society may be used, provided it is acceptable to the ASME Designated Organization.

(f) Specific valve types require additional markings, as follows:

(1) The pilot of a pilot-operated pressure relief valve shall be plainly marked by the Manufacturer or Assembler with the name of the Manufacturer, the Manufacturer's design or type number, the set pressure in kilopascals (pounds per square inch), and the year built or, alternatively, a coding that the Manufacturer can use to identify the year built. The pilot and main valve of a pilot-operated pressure relief valve shall each be marked with the same unique identifier to establish association of both components.

(2) Restricted lift valves shall be marked with their restricted lift in millimeters (inches).

(3) Section XII (TV Designator) pressure relief valves shall be marked with the vessel class, based on the applicable Modal Appendix used to establish the certified flowing capacity.

PART 4
REQUIREMENTS FOR RUPTURE DISK DEVICES

4.1 GENERAL

4.1.1 Applicability of Part 4 Requirements

This Part contains requirements applicable to all rupture disk devices that are to be marked with the Certification Mark and any Designator. Requirements unique to a specific Designator are identified.

4.1.2 Burst Pressure

(a) Every rupture disk shall have a marked burst pressure established by the requirements of 4.5.2 within a manufacturing design range at a specified disk temperature and shall be traceable by lot number. The manufacturing design range shall 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 particular agreed-upon requirement. 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) For rupture disk devices with marked burst pressures up to and including 300 kPa (40 psi), the burst pressure tolerance at the specified disk temperature shall not exceed ±15 kPa (±2 psi); for devices with marked burst pressures above 300 kPa (40 psi), the burst pressure tolerance at specified disk temperature shall not exceed ±5%. For Section XII (TD Designator) devices, these tolerances apply unless other requirements are identified by the competent authority or by the Section XII Modal Appendices.

4.1.3 Relieving Capacity

4.1.3.1 The relieving capacity of rupture disk devices shall be certified based on the simple system or flow resistance methods described in 4.1.3.2 or the coefficient of discharge method described in 4.1.3.3.

(25) **4.1.3.2** The relieving capacity of a pressure relief system that uses a flow-resistance-certified rupture disk device as the sole relieving device shall be determined by the user based on a value calculated in accordance with one of the following methods:

(a) Simple System Method. The simple system method may be used to determine the relieving capacity of a pressure relief system that includes a rupture disk device, provided the following conditions are met:

(1) The pressure relief system that includes the rupture disk device discharges directly to the atmosphere.

(2) The rupture disk device is installed within eight pipe diameters of the vessel nozzle entry.

(3) The discharge piping downstream of the rupture disk device is not greater than five pipe diameters in length.

(4) The nominal diameters of the inlet and discharge piping are equal to or greater than the marked DN (NPS) designator of the device.

The calculated relieving capacity of the simple pressure relief system shall not exceed a value based on the applicable theoretical flow equation [see 9.7.6.4 and Mandatory Appendix IV] for the various fluids multiplied by a coefficient of discharge, K, equal to 0.62. The area, A, in the theoretical flow equation shall be the minimum net flow area as specified by the rupture disk device Manufacturer.

(b) Flow Resistance Method. The calculated capacity of any pressure relief system may be determined by analyzing the total system resistance to flow. This analysis shall take into consideration the flow resistance of the rupture disk device; piping; and piping components, including the exit nozzle on the vessels, and elbows, tees, reducers, and valves. The calculation shall be made using accepted engineering practices for determining fluid flow through piping systems. This calculated relieving capacity shall be multiplied by a factor of 0.90 or less to allow for uncertainties inherent to this method. The certified flow resistance, K_R, for the rupture disk device, expressed as the velocity head loss, shall be determined in accordance with Part 9.

4.1.3.3 The relieving capacity of a pressure relief system that uses a capacity-certified rupture disk device as the sole relieving device shall be determined based on the certified capacity marked on the device and the characteristics of the system fluid and system components upstream and downstream of the rupture disk device. The certified coefficient of discharge, K_D, for the rupture disk device shall be determined in accordance with Part 9.

4.2 DESIGN AND MECHANICAL REQUIREMENTS

(a) The design of the rupture disk device shall incorporate features 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 damage to the rupture disk.

(c) Section VIII, Division 3 (UD3 Designator) rupture disk holders shall comply with the applicable requirements of Section VIII, Division 3, Part KD. Alternatively, it is permissible to design rupture disk holders in accordance with the rules in ASME B31.3, Chapter IX, provided that

(1) the materials for the holder meet the requirements of 4.3.2

(2) all components of the rupture disk device are outside of the geometric scope of Section VIII, Division 3 and are part of the external piping as defined in Section VIII, Division 3, KG-110

(d) For Section VIII, Division 3 (UD3 Designator) rupture disk devices, the Manufacturer of the rupture disk holder may be different from the Manufacturer of the rupture disk.

4.3 MATERIAL REQUIREMENTS

4.3.1 Disk Material

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

(b) The rupture disk material shall be controlled by the Manufacturer of the rupture disk device by a specification ensuring the control of material properties.

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

4.3.2 Pressure-Retaining Parts

4.3.2.1 Materials used in pressure-containing or pressure-retaining holder components and pressure-retaining bolting shall be as permitted in Section II, Part D by the referencing Code. In addition, the following requirements apply:

(a) Section VIII, Division 1 (UD Designator) pressure-containing or pressure-retaining holder components and pressure-retaining rupture disk holders and bolting shall meet all applicable requirements of Section VIII, Division 1, Subsection C.

(b) Section VIII, Division 3 (UD3 Designator) pressure-containing or pressure-retaining holder components and pressure-retaining rupture disk holders and bolting shall meet all applicable requirements of Section VIII, Division 3, Article KM.

(c) Section XII (TD Designator) pressure-containing or pressure-retaining holder components and pressure-retaining rupture disk holders and bolting shall meet all applicable requirements of Section XII, Part TM.

4.3.2.2 Other than as specified in 4.3.2.1, all parts required for the pressure-relieving or pressure-retaining function shall be of materials that are

(a) listed in Section II, or

(b) listed in ASTM specifications, or

(c) controlled by the Manufacturer of the pressure relief device by a specification ensuring control of chemical and physical properties and quality at least equivalent to that of ASTM standards

4.4 INSPECTION OF MANUFACTURING

4.4.1 General

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

(b) At the time of the submission of rupture disk devices for capacity certification or testing in accordance with 4.4.3, the representative of the ASME Designated Organization has the authority to review the device design for conformity with the requirements of 4.2 and 4.3, and to reject or require modification of designs that do not conform.

4.4.2 Verification

Manufacturing, assembly, inspection, and test operations are subject to inspections at any time by an ASME Designee.

4.4.3 Production Certification (25)

A Manufacturer may be granted permission to apply the Certification Mark and appropriate Designator to production rupture disk devices capacity or flow resistance certified in accordance with Part 9, provided the testing described in this paragraph is 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 testing described in this paragraph are successfully repeated within the 6-month period before expiration.

4.4.3.1 Sample Selection

(a) Two production sample rupture disk devices of a size and capacity within the capability of an ASME accepted laboratory shall be selected by a representative of an ASME Designated Organization.

(b) If a Section VIII, Division 3 (UD3 Designator) 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.

(25) **4.4.3.2 Testing.** Burst and flow testing shall be conducted in the presence of a representative from an ASME Designated Organization at a testing facility meeting the requirements of ASME CA-1. The device Manufacturer shall be notified of the time of the test and may have representatives present to witness the test. Capacity or flow resistance flow testing shall be performed in accordance with the original certification method. For devices certified for flow resistance, a minimum net flow area evaluation shall also be performed.

4.4.3.3 Test Results

(a) Should any device fail to meet or exceed the applicable performance requirements of this Section, the test(s) shall be repeated at the rate of two replacement devices, selected and tested in accordance with 4.4.3.1 and 4.4.3.2, for each device that failed.

(b) Should any of the replacement devices fail to meet the capacity or performance requirements of this Section, the Manufacturer shall determine the cause of failure and take corrective action to guard against future occurrence. This cause of failure and corrective action shall be documented and submitted to the ASME Designated Organization within 60 days of the failure or be cause for revocation of the authorization to use the Certification Mark on that particular type of device. Upon acceptance of the submitted corrective action by the ASME Designated Organization, the requirements of 4.4.3 shall apply.

4.5 PRODUCTION TESTING

Each rupture disk device to which the Certification Mark is to be applied shall be tested by the Manufacturer in accordance with 4.5.1 and 4.5.2. The Manufacturer shall have a documented system for the application, calibration, and maintenance of gages and instruments used during these tests.

4.5.1 Pressure Testing

(a) The pressure-containing parts of each rupture disk holder are subject to pressure testing.

(b) Except as specified in (c), a rupture disk holder part requiring pressure testing shall be tested either

(1) hydrostatically at a pressure no less than 1.5 times the design pressure of the part, or

(2) pneumatically at a pressure no less than 1.25 times the design pressure of the part

CAUTION: Pneumatic testing can be hazardous; it is therefore recommended that special precautions be taken when conducting a pneumatic test.

(c) Devices to be marked with the Certification Mark and UD3 Designator shall be tested hydrostatically only, at a pressure no less than 1.25 times the design pressure and no greater than the pressure determined in accordance with Section VIII, Division 3, KT-312.

(d) Pressure testing may be done in the part or assembled condition.

(e) Pressure testing shall be conducted after all machining and welding operations have been completed.

(f) Parts subjected to pressure testing shall not exhibit a sign of leakage.

(g) Parts fully contained within the holder or vessel, or parts downstream of the rupture disk and not designed to contain pressure, are exempt from pressure testing.

(h) A rupture disk holder part to be marked with the Certification Mark and UD or TD Designator is exempt from pressure testing if both of the following conditions apply:

(1) The stress that would be applied under hydrostatic test conditions does not exceed 50% of the allowable stress.

(2) The holder is not cast or welded.

4.5.2 Burst Tests

(a) General. Each lot of rupture disks shall be tested in accordance with one of the methods described in (b). All tests of disks for a given lot shall be performed with 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 shall be of the same size as those to be used in service. Test results shall be applicable only to rupture disks used in disk holders supplied by the rupture disk Manufacturer or, for Section VIII, Division 3 (UD3 Designator) devices, installed in the Manufacturer's standard rupture disk holders as specified in the required rupture disk marking.

(b) Test Methods

(1) 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 4.1.2(b).

(2) 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 by more than the burst pressure tolerance specified in 4.1.2(b). The value for the marked burst pressure shall be derived from the curve for a specified temperature. 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.

(3) For prebulged solid metal disks or graphite disks only, at least four sample rupture disks using one size of disk from each lot of material shall be burst at four

different temperatures distributed over the applicable temperature range for which this 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 smooth curve shall be as in (2). 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.

4.6 WELDING, BRAZING, HEAT TREATMENT, AND NONDESTRUCTIVE EXAMINATION

All welding, brazing, heat treatment, and nondestructive examination used in the construction of rupture disk holders and pressure parts shall be performed in accordance with the applicable requirements of the Section of the Certification Mark Designator applied to the rupture disk device.

4.7 MARKING

4.7.1 General

(a) The Manufacturer shall plainly mark each rupture disk and holder with the required data in such a way that the marking will not be obliterated in service and will not interfere with the function of the disk (see 12.3).

(b) The markings may be placed on the flange of the disk or a metal tag. The metal tag shall be securely fastened to the disk or, when attaching the tag is impracticable, shall accompany the disk, provided the lot number is also marked on the disk.

(c) For units other than those included in 4.7.2 and 4.7.3, see 1.5.

4.7.2 Rupture Disks

Each rupture disk shall be marked with the following information:

(a) name of the Manufacturer, or an acceptable abbreviation thereof.

(b) Manufacturer's design or type number.

(c) lot number.

(d) disk material.

(e) DN (NPS) size ________ of rupture disk holder, or nominal diameter, mm (in.), as applicable.

(f) marked burst pressure ________ kPa (psi).

(g) specified disk temperature ________ °C (°F).

(h) for capacity-certified devices, one of the following:

(1) ________ kg/h (lbm/hr) of saturated steam at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for devices certified on steam.

(2) ________ L/min (gpm) of water at 20°C (70°F) at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for devices certified on water.

(3) ________ m^3/min of air at 20°C and 101 kPa [standard cubic feet per minute (SCFM) of air at 60°F and 14.7 psia] or ________ kg/min (lbm/min) of air, at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for devices certified on air or gas. Devices that are capacity certified in accordance with the Section VIII, Division 1, UG-153(a)(3) shall be marked "at 20% overpressure."

In addition to one of the fluids specified in (1) through (3), the Manufacturer may indicate the capacity in other fluids (see Mandatory Appendix IV).

(i) for flow-resistance-certified devices

(1) minimum net flow area ____ mm^2 ($in.^2$)

(2) certified flow resistance (one or more as applicable)

(-a) K_{RG} ________ for rupture disks certified on air or gases

(-b) K_{RL} ________ for rupture disks certified on liquid

(-c) K_{RGL} ________ for rupture disks certified on air or gases, and liquid

(j) Certification Mark and the appropriate Designator placed under the Certification Mark (see Figure 10.1-1). A marking method other than the stamp issued by the Society may be used, provided it is acceptable to the ASME Designated Organization.

(k) 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 manufactured and tested.

(l) design, type number, or drawing number of the intended Manufacturer's standard rupture disk holder [for Section VIII, Division 3 (UD3 Designator) devices only]

4.7.3 Rupture Disk Holders

Each rupture disk holder shall be marked with the following information:

(a) name of the Manufacturer, or an acceptable abbreviation thereof.

(b) Manufacturer's design or type number.

(c) DN (NPS) size ________ of rupture disk holder, or nominal diameter, mm (in.), as applicable.

(d) Certification Mark and the appropriate Designator placed under the Certification Mark (see Figure 10.1-1). A marking method other than the stamp issued by the Society may be used provided it is acceptable to the ASME Designated Organization.

(e) 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 manufactured and tested.

(f) flow direction.

(g) "DIV3" for UD rupture disk devices manufactured per Section VIII, Division 3, KOP-152(c).

PART 5
REQUIREMENTS FOR PIN DEVICES

5.1 GENERAL

5.1.1 Applicability of Part 5 Requirements

This Part contains requirements applicable to all pin devices that are to be marked with the Certification Mark and any Designator. Requirements unique to a specific Designator are identified.

(25) 5.1.2 Set Pressure

(a) Every pin device shall have a marked set pressure at the specified pin temperature established by the rules of 5.5.2.

(b) The pin temperature may be different from the process temperature for pin devices in which the pin is isolated from operating conditions.

(c) For pin devices with marked set pressures up to and including 300 kPa (40 psi), the set pressure tolerance at the pin temperature shall not exceed ±15 kPa (±2 psi). For pin devices with marked set pressures above 300 kPa (40 psi), the set pressure tolerance at pin temperature shall not exceed ±5%. For Section XII (TD Designator) pin devices, these tolerances apply unless other requirements are identified by the competent authority or by the Section XII Modal Appendices.

5.1.3 Relieving Capacity

5.1.3.1 The relieving capacity of pin devices shall be certified based on the simple system or flow resistance methods described in 5.1.3.2, or the coefficient of discharge method described in 5.1.3.3.

(25) **5.1.3.2** The relieving capacity of a pressure relief system that uses a flow-resistance-certified pin device as the sole relieving pin device shall be determined by the user based on a value calculated in accordance with one of the following methods:

(a) *Simple System Method.* The simple system method may be used to determine the relieving capacity of a pressure relief system that includes a pin device, provided the following conditions are met:

(1) The pressure relief system that includes the pin device discharges directly to the atmosphere.

(2) The pin device is installed within eight pipe diameters of the vessel nozzle entry.

(3) The discharge piping downstream of the pin device is not greater than five pipe diameters in length.

(4) The nominal diameters of the inlet and discharge piping are equal to or greater than the marked DN (NPS) designator of the pin device.

The calculated relieving capacity of the simple pressure relief system shall not exceed a value based on the applicable theoretical flow equation [see 9.7.6.4 and Mandatory Appendix IV] for the various fluids multiplied by a coefficient of discharge, K, equal to 0.62. The area, A, in the theoretical flow equation shall be the minimum net flow area as specified by the pin device Manufacturer.

(b) *Flow Resistance Method.* The calculated capacity of any pressure relief system may be determined by analyzing the total system resistance to flow. This analysis shall take into consideration the flow resistance of the pin device; piping; and piping components, including the exit nozzle on the vessels, and elbows, tees, reducers, and valves. The calculation shall be made using accepted engineering practices for determining fluid flow through piping systems. This calculated relieving capacity shall be multiplied by a factor of 0.90 or less to allow for uncertainties inherent with this method. The certified flow resistance, K_R, for the pin device, expressed as the velocity head loss, shall be determined in accordance with Part 9.

5.1.3.3 The relieving capacity of the pressure relief system that uses a capacity-certified pin device as the sole relieving pin device shall be determined based on the certified capacity marked on the pin device and the characteristics of the system fluid and system components upstream and downstream of the pin device. The certified coefficient of discharge, K_D, for the pin device shall be determined in accordance with Part 9.

5.2 DESIGN AND MECHANICAL REQUIREMENTS (25)

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

(b) The seat of a pin device shall be fastened to the body of the pin device in such a way that there is no possibility of the seat moving from its required position.

(c) In the design of the pin device, consideration shall be given to minimizing the effects of deposits.

(d) Pin devices having threaded inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damage to operating parts.

(e) Means shall be provided in the design for sealing all critical parts to ensure that these parts are original and unmodified. Seals shall be installed in a manner to prevent changing or modifying parts without breaking the seal. If the pin is replaceable, this component is not required to be sealed if it is marked in accordance with 5.7.3(a). Seals shall be installed by the Manufacturer. For pin devices larger than DN 15 (NPS $^1/_2$), the seal shall serve as a means of identifying the pin device Manufacturer.

(f) If the design of the pin device is such that liquid can collect on the discharge side, then, except as permitted in (g), the pin device shall be equipped with a drain at the lowest point at which liquid can collect.

(g) A pin device that cannot be equipped with a drain as required in (f) because of design or application may be used, provided all of the following conditions are met:

(1) The pin device is used only on gas service where there is neither liquid discharged from the pin device nor liquid formed by condensation on the discharge side of the pin device.

(2) The pin device is provided with a cover or discharge piping per 12.8 to prevent liquid or other contaminant from entering the discharge side of the pin device.

(3) The pin device is marked FOR GAS SERVICE ONLY in addition to being marked as required by 5.7.

(h) All pin devices shall be constructed so that the failure of any part cannot obstruct the free and full discharge of fluid from the pin device.

(i) O-rings or other packing devices, when used on the stems of pin devices, shall be arranged so that the pin device performance meets the requirements of this Section.

(j) Pilot-operated pin devices shall be designed such that

(1) the pilot is self-actuated

(2) the main valve will open automatically at a pressure not exceeding the set pressure

(3) if some essential part of the pilot fails, the main valve will discharge its full rated capacity at or below the relieving pressure used to determine its rated capacity

(k) Spring-actuated pin devices shall meet the requirements of Parts 5 and 6.

(l) Pins shall be manufactured by the pin device Manufacturer.

5.3 MATERIAL REQUIREMENTS

(a) Cast iron seats and disks are not permitted.

(b) Adjacent sliding and sealing surfaces shall both be of a corrosion-resistant material suitable for use with the fluid to be contained.

(c) Materials used in pressure-containing or pressure-retaining components and pressure-retaining bolting, excluding proprietary pin material, shall be as permitted in Section II, Part D by the referencing Code. In addition, the following requirements apply:

(1) For Section VIII, Division 1 (UD Designator) pin devices, the pressure-containing or pressure-retaining components and pressure-retaining bolting shall meet all applicable requirements of Section VIII, Division 1, Subsection C.

(2) For Section VIII, Division 3 (UD3 Designator) pin devices, the pressure-containing or pressure-retaining components and pressure-retaining bolting shall meet all applicable requirements of Section VIII, Division 3, Article KM.

(3) For Section XII (TD Designator) pin devices, the pressure-containing or pressure-retaining components and pressure-retaining bolting shall meet all applicable requirements of Section XII, Part TM.

(d) Other than as specified in (c), all parts required for the pressure-relieving or pressure-retaining function shall be of materials that are

(1) listed in Section II, or

(2) listed in ASTM specifications, or

(3) controlled by the Manufacturer of the pin device by a specification ensuring control of chemical and physical properties and quality at least equivalent to that of ASTM standards

(e) Materials used for pins shall be controlled by the Manufacturer of the pin device by a specification ensuring the control of material properties.

(f) The seats and disks of pin devices shall be of suitable material to resist corrosion by the fluid to be contained. The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the Manufacturer and the purchaser.

(g) Nonmetallic disk inserts and seals shall be compatible with the maximum design temperature established for the pin device.

(h) Adjacent sliding surfaces shall both be of corrosion-resistant material. The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the Manufacturer and purchaser.

5.4 INSPECTION OF MANUFACTURING

5.4.1 General

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

(b) At the time of the submission of pin devices for capacity certification or testing in accordance with 5.4.2, the representative of the ASME Designated Organization has the authority to review the pin device design for conformity with the requirements of 5.2, 5.3, and 5.5.3, and to reject or require modification of designs that do not conform.

(c) Manufacturing, assembly, inspection, and test operations, including capacity, are subject to inspections at any time by a representative from an ASME Designated Organization.

(25) **5.4.2 Production Certification**

A Manufacturer or Assembler may be granted permission to apply the Certification Mark and appropriate Designator to production pin devices whose capacity or flow resistance has been certified in accordance with Part 9, provided the testing described in this paragraph is 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 testing described in this paragraph is successfully repeated within the 6-month period before expiration.

5.4.2.1 Sample Selection. Two production sample pin devices of a size and capacity within the capability of an ASME-accepted laboratory shall be selected by a representative of an ASME Designated Organization.

(25) **5.4.2.2 Testing.** Operational and capacity or flow resistance testing shall be conducted in the presence of a representative from an ASME Designated Organization at a testing facility meeting the requirements of ASME CA-1. The pin device Manufacturer shall be notified of the time of the test and may have representatives present to witness the test.

5.4.2.3 Test Results

(a) Should any pin device fail to meet or exceed the applicable performance requirements of this Section, the test(s) may be repeated at the rate of two replacement pin devices, selected and tested in accordance with 5.4.2.1 and 5.4.2.2, for each pin device that failed.

(b) Should any of the replacement pin devices described in (a) fail to meet the capacity or performance requirements of this Section, the Manufacturer shall determine the cause of failure and take corrective action to guard against future occurrence. This cause of failure and corrective action shall be documented and submitted to the ASME Designated Organization within 60 days of the failure or be cause for revocation of the authorization to use the Certification Mark on that particular type of pin device. Upon acceptance of the submitted corrective action by the ASME Designated Organization, the requirements of 5.4.2 shall apply.

(25) **5.4.2.4 Alternative Tests for Pin Devices That Exceed the Laboratory Capabilities**

(a) For pin devices that exceed the laboratory testing capabilities and for which lift at rated overpressure can be measured or complete opening can be verified, the alternative method described below shall be used in lieu of the test requirements of 5.4.2, 5.4.2.1, and 5.4.2.3(a).

(1) Two production pin devices that are representative of the design shall be tested per Mandatory Appendix V, Article V-3. The tests shall demonstrate to the satisfaction of the representative of the ASME Designated Organization that the pin devices satisfy the following conditions:

(-a) The measured set pressure is consistent with the stamped set pressure within the tolerances required by 5.1.2(c).

(-b) The pin device will achieve complete opening or the minimum lift required to meet its certified capacity.

(-c) The pin device will operate in a stable manner.

If only one pin device of the design will be produced within the 6-yr period for which the permission is granted, only that pin device need be tested as stated above.

(2) The testing shall be performed at a facility that is mutually agreeable to the Manufacturer, the representative of an ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating the characteristics stated in (1)(-a) through (1)(-c).

(3) In the event of failure of the tests, 5.4.2.3(b) shall apply.

(b) For pin devices that exceed the laboratory testing capabilities and for which lift at rated overpressure cannot be measured or complete opening cannot be verified, the alternative method described below shall be used.

(1) For initial certification, two functional models that are representative of the design shall be used, provided the test requirements of 5.4.2 are followed and the following additional test requirements are met:

(-a) Two production pin devices that are representative of the design shall be tested per Mandatory Appendix V, Article V-3. The tests shall demonstrate to the satisfaction of the representative of the ASME Designated Organization that

(-1) the measured set pressure is consistent with the stamped set pressure within the tolerances required by 5.1.2(c)

(-2) a secondary pressure zone leakage test and a seat tightness test are demonstrated in accordance with 5.5.1(g) and 5.5.3

If only one pin device of the design will be produced within the 6-yr period for which the permission is granted, only that pin device need be tested as stated above.

(-b) The testing shall be performed at a facility that is mutually agreeable to the Manufacturer, the representative of an ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating the characteristics stated in (-a)(-1) and (-a)(-2).

(-c)) In the event of failure of the tests, 5.4.2.3(b) shall apply.

(2) For 6-yr renewal of capacity or flow resistance certification, (1)(-a) through (1)(-c) shall apply.

5.5 PRODUCTION TESTING

Each pin device to which the Certification Mark is to be applied shall be tested by the Manufacturer in accordance with 5.5.1 and 5.5.2. The Manufacturer shall have a documented system for the application, calibration, and maintenance of gages and instruments used during these tests.

5.5.1 Pressure Testing

(a) The pressure-containing parts of each pin device are subject to pressure testing.

(b) A pin device part is exempt from pressure testing if any of the following conditions exist:

(1) The stress that would be applied under hydrostatic test conditions does not exceed 50% of the allowable stress, and the part is not cast or welded.

(2) The part is downstream of the pressure-containing element and fully within pressure-containing parts that have been either pressure tested or exempted from pressure testing by (1).

(c) A pin device part requiring pressure testing shall be tested either

(1) hydrostatically at a pressure no less than 1.5 times the design pressure of the part, or

(2) pneumatically at a pressure no less than 1.25 times the design pressure of the part

CAUTION: Pneumatic testing can be hazardous; it is therefore recommended that special precautions be taken when conducting a pneumatic test.

(d) Pressure testing may be done in the part or assembled condition.

(e) Pressure testing shall be conducted after all machining and welding operations have been completed.

(f) Parts subjected to pressure testing shall not exhibit a sign of leakage.

(g) If a pin device designed for discharge to a closed system has a secondary pressure zone with an inlet size exceeding DN 25 (NPS 1), the secondary pressure zone shall be tested with air or other gas at a pressure of at least 200 kPa (30 psi). There shall be no visible signs of leakage. The user may specify a higher test pressure commensurate with the back pressure anticipated in service.

5.5.2 Set Pressure Qualification Testing

5.5.2.1 Set pressure qualification of a pin device shall be accomplished by completing set pressure testing in the pin device. At least two pins from the same lot shall be tested in the pin device. For single-use, permanently assembled pin devices that have the same specification and configuration and that will be supplied as a single lot, at least two completed pin devices shall be tested. The tests shall be conducted at the pin temperature or according to 5.5.2.2(d). The test pressure shall be within the tolerance specified in 5.1.2(c).

5.5.2.2 For all pin lot qualification testing, the following requirements apply:

(a) Sample pins selected from each lot shall be made from the same material and heat and shall be of the same critical dimension as those to be used in service.

(b) Test results shall be applicable only to pins used in pin devices supplied by the pin device Manufacturer.

(c) At least two pins or two single-use, permanently assembled pin devices from the same lot shall be tested.

(d) Tests shall be conducted at ambient temperature or the pin temperature (as agreed to between the pin device Manufacturer and the user). The Manufacturer shall establish a temperature range for which testing at ambient temperature is applicable. For qualification of a pin lot at a single pin temperature, at least two pin tests shall be conducted at the specified pin temperature.

(e) Pin testing shall be completed in the actual pin device(s) or in accordance with one or both of the following methods:

(1) Lot qualification testing shall be done in a test pin device of the same form and pressure area dimensions as that in which the pins will be used. At least two set pressure tests shall be completed at the pin temperature in accordance with (d). The tests shall be within the tolerance specified.

(2) The set pressure of a lot of pins for a pin device may be verified by a characterization test that determines the activation loading (force) under pin device–opening conditions. The following characterization test conditions shall apply:

(-a) The pin-retaining arrangement shall be the same for all characterization tests applied to a pin device.

(-b) At least two pins from the same lot as tested under 5.5.2.1 or (1) shall be tested to determine the activation force that correlates to the tested set pressure of the pin device. The average of these test results defines the base force that shall be used to permit further pin qualification by characterization rather than by set pressure testing of the pin device. The following equation shall be used to define a corrected base force that corresponds to the nominal set pressure of the pin device:

$$\text{corrected base force, N (lbf)} = \frac{\text{nominal set pressure, kPa (psi)} \times \text{average base force, N (lbf)}}{\text{average tested set pressure, kPa (psi) per 5.5.2.1 or (e)(1)}}$$

(-c) This corrected base force, rather than set pressure testing of the pin device, may be used to qualify additional pin quantities and lots, provided the pins function at activation forces that are within ±3% of the corrected base force for set pressures above 300 kPa (40 psi). For set pressures below 300 kPa (40 psi), the tested components shall function at activation forces within a plus–minus tolerance of the corrected base force determined as follows:

(SI Units)

$$\pm\%\ \text{tolerance for actual test forces} = \frac{300\ \text{kPa}}{\text{corresponding nominal set pressure, kPa}} \times 3\%$$

(U.S. Customary Units)

$$\pm\%\ \text{tolerance for actual test forces} = \frac{40\ \text{psi}}{\text{corresponding nominal set pressure, psi}} \times 3\%$$

5.5.3 Seat Tightness Test

A seat tightness test shall be conducted on each pin device. The test conditions and acceptance criteria shall be in accordance with the Manufacturer's published pin device specification or another specification agreed to by the user and the Manufacturer.

5.6 WELDING, BRAZING, HEAT TREATMENT, AND NONDESTRUCTIVE EXAMINATION

All welding, brazing, heat treatment, and nondestructive examination used in the construction of bodies, bonnets, and yokes shall be performed in accordance with the applicable requirements of the Section of the Certification Mark Designator applied to the pin device.

5.7 MARKING

(25) 5.7.1 General

The Manufacturer shall plainly mark each pin device with the required data in such a way that the marking will not be obliterated in service. The marking shall be placed on the pin device housing or on a metal plate or plates securely fastened to the pin device. If such markings will not be visible when the pin device is in service, the marking shall be placed on a tab attached as close as possible to the discharge side of the pin device. The tab shall remain visible when installed.

5.7.2 Pin Devices

Each pin device shall be marked with the following information. For units of measure other than those included below, see 1.5.

(a) name of the Manufacturer, or an acceptable abbreviation thereof.

(b) Manufacturer's design or type number.

(c) DN (NPS) size ________ (the nominal pipe size of the pin device inlet).

(d) set pressure ________ kPa (psi).

(e) flow direction.

(f) pin-to-pin device identifier.

(g) for capacity-certified pin devices, one of the following, as applicable:

(1) _____ kg/h (lbm/hr) of saturated steam at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for pin devices certified on steam.

(2) ______L/min (gpm) of water at 20°C (70°F) at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for pin devices certified on water.

(3) ______ m^3/min of air at 20°C and 101 kPa [standard cubic feet per minute (SCFM) of air at 60°F and 14.7 psia)] or _______ kg/min (lbm/min) of air at an overpressure of 10% or 20 kPa (3 psi), whichever is greater. Pin devices for use in accordance with Section VIII, Division 1, UG-153(a)(3) or at 120% of marked set pressure as permitted by the appropriate Section XII Modal Appendix shall be marked "at 20% overpressure."

In addition to one of the fluids specified in (1) through (3), the Manufacturer may indicate the capacity in other fluids (see Mandatory Appendix IV).

(h) for flow-resistance-certified pin devices

(1) minimum net flow area ________ mm^2 (in.^{2})

(2) certified flow resistance (one or more as applicable)

(-a) K_{RG} ________ for pin devices certified on air or gases

(-b) K_{RL} ________ for pin devices certified on liquid

(-c) K_{RGL} ________ for pin devices certified on air or gases, and liquid

(i) Certification Mark and the appropriate Designator placed under the Certification Mark (see Figure 10.1-1). A marking method other than the stamp issued by the Society may be used provided it is acceptable to the ASME Designated Organization.

(j) year built, or alternatively, a coding may be marked on the pin device such that the pin device Manufacturer can identify the year the pin device was tested.

5.7.3 Pin (25)

The pin shall be marked according to one of the following methods:

(a) For pin devices using replaceable pins, the pin shall be marked with its lot number; pin temperature, °C (°F); and the information required by 5.7.2(a), 5.7.2(d), 5.7.2(f), and 5.7.2(j).

(b) For pin devices that are single use and permanently assembled, the pin shall be marked with its lot number.

When the pin size or configuration does not permit the use of an attached metal tag, a metal tag may be attached using a nonmetallic connector with an adhesive that complies with Mandatory Appendix II.

PART 6 REQUIREMENTS FOR SPRING-ACTUATED NON-RECLOSING DEVICES

(25)

6.1 GENERAL

6.1.1 Applicability of Part 6 Requirements

This Part contains requirements that are applicable to all spring-actuated non-reclosing devices that are to be marked with the Certification Mark and UD Designator.

6.1.2 Set Pressure

For spring-actuated non-reclosing devices with marked set pressures up to and including 300 kPa (40 psi), the set pressure tolerance shall not exceed ±15 kPa (±2 psi). For spring-actuated non-reclosing devices with marked set pressures above 300 kPa (40 psi), the set pressure tolerance shall not exceed ±5%.

6.1.3 Relieving Capacity

The relieving capacity of spring-actuated non-reclosing devices shall be certified based on the simple system or flow resistance method described in 6.1.3.1 or the coefficient of discharge method described in 6.1.3.2.

6.1.3.1 The rated flow capacity of a pressure relief system that uses a spring-actuated non-reclosing device as the sole relieving device shall be determined by the user based on a value calculated in accordance with one of the following methods:

(a) Simple System Method. The simple system method may be used to determine the relieving capacity of a pressure relief system that includes a spring-actuated non-reclosing device, provided the following conditions are met:

(1) The pressure relief system that includes the spring-actuated non-reclosing device discharges directly to the atmosphere.

(2) The spring-actuated non-reclosing device is installed within 8 pipe diameters of the vessel nozzle entry.

(3) The discharge piping downstream of the spring-actuated non-reclosing device is not greater than 5 pipe diameters in length.

(4) The nominal diameters of the inlet and discharge piping are equal to or greater than the marked DN (NPS) designator of the spring-actuated non-reclosing device.

The calculated relieving capacity of the simple pressure relief system shall not exceed a value based on the applicable theoretical flow equation (see 9.7.6.4 and Mandatory Appendix IV) for the various fluids multiplied by a coefficient of discharge, K, equal to 0.62. The area, A, in the theoretical flow equation shall be the minimum net flow area as specified by the spring-actuated non-reclosing device Manufacturer.

(b) Flow Resistance Method. The calculated capacity of any pressure relief system may be determined by analyzing the total system resistance to flow. This analysis shall take into consideration the flow resistance of the spring-actuated non-reclosing device; piping; and piping components, including the exit nozzle on the vessels, and elbows, tees, reducers, and valves. The calculation shall be made using accepted engineering practices for determining fluid flow through piping systems. This calculated relieving capacity shall be multiplied by a factor of 0.90 or less to allow for uncertainties inherent with this method. The certified flow resistance, K_r, for the spring-actuated non-reclosing device, expressed as the velocity head loss, shall be determined in accordance with Part 9.

6.1.3.2 The relieving capacity of the pressure relief system that uses a capacity-certified spring-actuated non-reclosing device as the sole relieving device shall be determined based on the certified capacity marked on the spring-actuated non-reclosing device and the characteristics of the system fluid and system components upstream and downstream of the spring-actuated non-reclosing device. The certified coefficient of discharge, K_D, for the spring-actuated non-reclosing device shall be determined in accordance with Part 9.

6.2 DESIGN AND MECHANICAL REQUIREMENTS

(a) The design of spring-actuated non-reclosing devices shall incorporate guiding arrangements necessary to ensure consistent operation and seat tightness.

(b) The seat of a spring-actuated non-reclosing device shall be fastened to the body of the spring-actuated non-reclosing device in such a way that there is no possibility of the seat moving from its required position.

(c) In the design of the spring-actuated non-reclosing device, consideration shall be given to minimizing the effects of deposits.

(d) Spring-actuated non-reclosing devices with threaded inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damage to operating parts.

(e) Means shall be provided in the design for sealing all critical parts and external adjustments to ensure that these parts are original and unmodified. Seals shall be installed in a manner to prevent changing or modifying parts without breaking the seal. Seals shall be installed by the Manufacturer. For spring-actuated non-reclosing devices larger than DN 15 (NPS $^1/_2$), the seal shall serve as a means of identifying the device Manufacturer.

(f) If the design of the spring-actuated non-reclosing device is such that liquid can collect on the discharge side, then, except as permitted in (g), the spring-actuated non-reclosing device shall be equipped with a drain at the lowest point at which liquid can collect.

(g) A spring-actuated non-reclosing device that cannot be equipped with a drain as required in (f) because of design or application may be used, provided all the following conditions are met:

(1) The spring-actuated non-reclosing device is used only on gas service where there is neither liquid discharged from the spring-actuated non-reclosing device nor liquid formed by condensation on the discharge side of the spring-actuated non-reclosing device.

(2) The spring-actuated non-reclosing device is provided with a cover or discharge piping per 12.8 to prevent liquid or other contaminant from entering the discharge side of the spring-actuated non-reclosing device.

(3) The spring-actuated non-reclosing device is marked FOR GAS SERVICE ONLY in addition to being marked as required by 6.7.

(h) All spring-actuated non-reclosing devices shall be constructed so that the failure of any part cannot obstruct the free and full discharge of fluid from the device.

(i) O-rings or other packing devices, when used on the stems of spring-actuated non-reclosing devices, shall be arranged so that the spring-actuated non-reclosing device performance meets the requirements of this Section.

(j) Pilot-operated spring-actuated non-reclosing devices shall be designed such that

(1) the pilot is self-actuated

(2) the spring-actuated non-reclosing device will open automatically at a pressure not exceeding the set pressure

(3) if some essential part of the pilot fails, the spring-actuated non-reclosing device will achieve full opening at or below its rated overpressure

(k) If the pilot of a pilot-operated spring-actuated device contains a diaphragm, the space above the diaphragm shall be vented to prevent pressure buildup.

(l) Springs for direct spring-loaded devices shall meet the following requirements:

(1) The spring shall be designed so that the spring compression at full lift of the device shall not be greater than 80% of the nominal solid deflection.

(2) The permanent set of the spring shall not exceed 0.5% of the original free length. Permanent set is defined as the difference between the original free length and the free length after the spring has been preset at room temperature by compressing it to its solid height three times. Measurement shall be taken at least 10 min following the preset.

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

$$R_{sf} = F_{so}/F_{sc}$$

where

F_{sc} = force exerted by the spring when the device is closed or seated

F_{so} = force exerted by the spring when the device is at rated lift

6.3 MATERIAL REQUIREMENTS

(a) Cast iron seats and disks are not permitted.

(b) Adjacent sliding and sealing surfaces shall both be of a corrosion-resistant material suitable for use with the fluid to be contained.

(c) Materials used in pressure-containing or pressure-retaining components and pressure-retaining bolting shall be as permitted in Section II, Part D and Section VIII, Division 1, Subsection C.

(d) Other than as specified in (c), all parts required for the pressure-relieving or pressure-retaining function shall be of materials that are

(1) listed in Section II, or

(2) listed in ASTM specifications, or

(3) controlled by the Manufacturer of the spring-actuated non-reclosing device by a specification ensuring control of chemical and physical properties and quality at least equivalent to that of ASTM standards

(e) Springs shall be made of corrosion-resistant material or shall have a corrosion-resistant coating.

(f) The seats and disks of spring-actuated non-reclosing devices shall be of suitable material to resist corrosion by the fluid to be contained. The degree of

corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the Manufacturer and the purchaser.

(g) Nonmetallic disk inserts and seals shall be compatible with the maximum design temperature established for the spring-actuated non-reclosing device.

(h) Adjacent sliding surfaces shall both be of corrosion resistant material. The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the Manufacturer and purchaser.

6.4 INSPECTION OF MANUFACTURING

6.4.1 General

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

(b) At the time of the submission of spring-actuated non-reclosing devices for capacity certification or testing in accordance with 6.4.2, the representative of the ASME Designated Organization has the authority to review the spring-actuated non-reclosing device design for conformity with the requirements of 6.2, 6.3, and 6.5.3, and to reject or require modification of designs that do not conform.

(c) Manufacturing, assembly, inspection, and test operations, including capacity, are subject to inspections at any time by a representative from an ASME Designated Organization.

6.4.2 Production Certification

A Manufacturer may be granted permission to apply the Certification Mark and appropriate Designator to production spring-actuated non-reclosing devices whose capacity or flow resistance has been certified in accordance with Part 9, provided the testing described in this paragraph is 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 testing described in this paragraph is successfully repeated within the 6-month period before expiration.

6.4.2.1 Sample Selection. Two production sample spring-actuated non-reclosing devices of a size and capacity within the capability of an ASME-accepted laboratory shall be selected by a representative of an ASME Designated Organization.

6.4.2.2 Testing. Operational and capacity testing shall be conducted in the presence of a representative from an ASME Designated Organization at a testing facility meeting the requirements of ASME CA-1. The spring-actuated non-reclosing device Manufacturer shall be notified of the time of the test and may have representatives present to witness the test.

6.4.2.3 Test Results

(a) Should any spring-actuated non-reclosing device fail to meet or exceed the applicable performance requirements of this Section, the test or tests may be repeated at the rate of two replacement spring-actuated non-reclosing devices, selected and tested in accordance with 6.4.2.1 and 6.4.2.2, for each device that failed.

(b) Should any of the replacement spring-actuated non-reclosing devices described in (a) fail to meet the capacity or performance requirements of this Section, the Manufacturer shall determine the cause of failure and take corrective action to guard against future occurrence. This cause of failure and corrective action shall be documented and submitted to the ASME Designated Organization within 60 days of the failure or be cause for revocation of the authorization to use the Certification Mark on that particular type of spring-actuated non-reclosing device. Upon acceptance of the submitted corrective action by the ASME Designated Organization, the requirements of 6.4.2 shall apply.

6.4.2.4 Alternative Tests for Spring-Actuated Non-reclosing Devices That Exceed the Laboratory Capabilities

(a) For spring-actuated non-reclosing devices that exceed the laboratory testing capabilities and for which lift at rated overpressure can be measured or complete opening can be verified, the alternative method described in (1) through (3) shall be used in lieu of the test requirements of 6.4.2, 6.4.2.1, and 6.4.2.3(a).

(1) Two production spring-actuated non-reclosing devices that are representative of the design shall be tested per Mandatory Appendix V, Article V-3. The tests shall demonstrate to the satisfaction of the representative of the ASME Designated Organization that the spring-actuated non-reclosing devices satisfy the following conditions:

(-a) The measured set pressure is consistent with the stamped set pressure within the tolerances required by 6.1.2.

(-b) The spring-actuated non-reclosing device will achieve complete opening or the minimum lift required to meet its certified capacity.

(-c) The spring-actuated non-reclosing device will operate in a stable manner. If only one spring-actuated non-reclosing device of the design will be produced within the 6-yr period for which the permission is granted, only that spring-actuated non-reclosing device need be tested as stated here.

(2) The testing shall be performed at a facility that is mutually agreeable to the Manufacturer, the representative of an ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating the characteristics stated in (1)(-a) through (1)(-c).

(3) In the event of failure of the tests, 6.4.2.3(b) shall apply.

(b) For spring-actuated non-reclosing devices that exceed the laboratory testing capabilities and for which lift at rated overpressure cannot be measured or complete opening cannot be verified, the alternative method described in (1) and (2) shall be used.

(1) For initial certification, two functional models that are representative of the design shall be used, provided the test requirements of 6.4.2 are followed and the following additional test requirements are met:

(-a) Two production spring-actuated non-reclosing devices that are representative of the design shall be tested per Mandatory Appendix V, Article V-3. The tests shall demonstrate to the satisfaction of the representative of the ASME Designated Organization that

(-1) the measured set pressure is consistent with the stamped set pressure within the tolerances required by 6.1.2.

(-2) a secondary pressure zone leakage test and a seat tightness test are demonstrated in accordance with 6.5.1(g) and 6.5.3 If only one spring-actuated non-reclosing device of the design will be produced within the 6-yr period for which the permission is granted, only that spring-actuated non-reclosing device need be tested as stated here.

(-b) The testing shall be performed at a facility that is mutually agreeable to the Manufacturer, the representative of an ASME Designated Organization, and the facility owner. The facility shall be capable of demonstrating the characteristics stated in (-a)(-1) and (-a)(-2).

(-c) In the event of failure of the tests, 6.4.2.3(b) shall apply.

(2) For 6-yr renewal of capacity or flow resistance certification, (1)(-a) through shall apply.

6.5 PRODUCTION TESTING

Each spring-actuated non-reclosing device to which the Certification Mark is to be applied shall be tested by the Manufacturer in accordance with 6.5.1 through 6.5.3. The Manufacturer shall have a documented system for the application, calibration, and maintenance of gages and instruments used during these tests.

6.5.1 Pressure Testing

(a) The pressure-containing parts of each spring-actuated non-reclosing device are subject to pressure testing.

(b) A spring-actuated non-reclosing device part is exempt from pressure testing if any of the following conditions exist:

(1) The stress that would be applied under hydrostatic test conditions does not exceed 50% of the allowable stress, and the part is not cast or welded.

(2) The part is downstream of the pressure containing element and fully within pressure-containing parts that have been either pressure tested or exempted from pressure testing by (1).

(c) A spring-actuated non-reclosing device part requiring pressure testing shall be tested either

(1) hydrostatically at a pressure no less than 1.5 times the design pressure of the part, or

(2) pneumatically at a pressure no less than 1.25 times the design pressure of the part

CAUTION: Pneumatic testing can be hazardous; it is therefore recommended that special precautions be taken when conducting a pneumatic test.

(d) Pressure testing may be done in the part or assembled condition.

(e) Pressure testing shall be conducted after all machining and welding operations have been completed.

(f) Parts subjected to pressure testing shall not exhibit a sign of leakage.

(g) If a spring-actuated non-reclosing device with an inlet size exceeding DN 25 (NPS 1) designed for discharge to a closed system has a secondary pressure zone, the secondary pressure zone shall be tested with air or other gas at a pressure of at least 200 kPa (30 psi). There shall be no visible signs of leakage. The user may specify a higher test pressure commensurate with the back pressure anticipated in service.

6.5.2 Set Pressure Tests

(a) Each spring-actuated non-reclosing device to which the Certification Mark and UD Designator is to be applied shall be tested by the Manufacturer to demonstrate the device's set pressure.

(b) Set pressure tests for spring-actuated non-reclosing devices used for compressible fluid service shall be conducted using air or other suitable gas.

(c) Set pressure tests for spring-actuated non-reclosing devices used for incompressible fluid service shall be conducted using water or other suitable liquid.

(d) Test fixtures and test drums, where applicable, shall be of adequate size and capacity to ensure that the spring-actuated non-reclosing device opening is consistent with the marked set pressure within the applicable tolerances shown in 6.1.2.

6.5.3 Seat Tightness Tests

A seat tightness test shall be conducted on each spring-actuated non-reclosing device. The test conditions and acceptance criteria shall be in accordance with the Manufacturer's published spring-actuated non-reclosing device specification, or another specification agreed to by the user and the Manufacturer.

6.6 WELDING, BRAZING, HEAT TREATMENT, AND NONDESTRUCTIVE EXAMINATION

All welding, brazing, heat treatment, and nondestructive examination used in the construction of bodies, bonnets, and yokes shall be performed in accordance with the applicable requirements of the Section of the Certification Mark Designator applied to the spring-actuated non-reclosing relief device.

6.7 MARKING

6.7.1 General

The Manufacturer shall plainly mark each spring-actuated non-reclosing device with the required data in such a way that the marking will not be obliterated in service. The marking may be placed on the spring-actuated non-reclosing device housing or on one or more metal plates securely fastened to the spring-actuated non-reclosing device. If such markings will not be visible when the device is in service, the marking may be placed on a tab attached as close as possible to the discharge side of the spring-actuated non-reclosing device. The tab shall remain visible when installed.

6.7.2 Spring-Actuated Non-reclosing Devices

(a) Each spring-actuated non-reclosing device shall be marked with the following information. For units of measure other than those included here, see 1.5.

(1) name of the Manufacturer or an acceptable abbreviation thereof.

(2) Manufacturer's design or type number.

(3) DN (NPS) size _______ (the nominal pipe size of the spring-actuated non-reclosing device inlet).

(4) set pressure _______ kPa (psi).

(5) flow direction.

(6) Certification Mark and the appropriate Designator placed under the Certification Mark (see Figure 10.1-1). A marking method other than the stamp issued by the Society may be used provided it is acceptable to the ASME Designated Organization.

(7) year built or, alternatively, a coding such that the Manufacturer of the spring-actuated non-reclosing device can identify the year the device was tested.

(b) Capacity-certified spring-actuated non-reclosing devices shall be marked with the information described in (a)(1) through (a)(7) and one of the following, as applicable:

(1) _______ kg/h (lbm/hr) of saturated steam at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for spring-actuated non-reclosing devices certified on steam

(2) _______ L/min (gpm) of water at 20°C (70°F) at an overpressure of 10% or 20 kPa (3 psi), whichever is greater, for spring-actuated non-reclosing devices certified on water

(3) _______ m^3/min of air at 20°C and 101 kPa [standard cubic feet per minute (SCFM) of air at 60°F and 14.7 psia)] or _______ kg/min (lbm/min) of air at an overpressure of 10% or 20 kPa (3 psi), whichever is greater.

In addition to one of the fluids specified in (1) through (3), the Manufacturer may indicate the capacity in other fluids (see Mandatory Appendix IV).

(c) Flow-resistance-certified spring-actuated non-reclosing devices shall be marked with the information described in (a)(1) through (a)(7) and the following:

(1) minimum net flow area _______ mm^2 ($in.^2$)

(2) one or more of the following, as applicable:

(-a) K_{RG} _______ for spring-actuated non-reclosing devices certified on air or gases.

(-b) K_{RL} _______ for spring-actuated non-reclosing devices certified on liquid.

(-c) K_{RGL} _______ for spring-actuated non-reclosing devices certified on air or gases, and liquid

(d) The pilot of a pilot-operated spring-actuated non-reclosing device shall be plainly marked by the Manufacturer with the name of the Manufacturer, the Manufacturer's design or type number, the set pressure in kilopascals (pounds per square inch), and the year built or, alternatively, a coding that the Manufacturer can use to identify the year built. The pilot and main valve of a pilot-operated spring-actuated non-reclosing device shall each be marked with the same unique identifier to establish association of both components.

PART 7
REQUIREMENTS FOR TEMPERATURE AND PRESSURE RELIEF VALVES

7.1 GENERAL

(a) This Part contains requirements that are applicable to temperature and pressure relief valves that are to be marked with the Certification Mark and HV Designator.

(b) A temperature and pressure relief valve is a pressure relief valve that may be actuated by pressure at the valve inlet or by temperature at the valve inlet. The pressure-relieving feature is normally achieved by a conventional direct spring-loaded type of relief valve design. The temperature-relieving feature is achieved by a separate thermal-sensing element. The pressure- and temperature-relieving features are independent of one another.

7.2 DESIGN AND MECHANICAL REQUIREMENTS

Temperature and pressure relief valves shall meet the design and mechanical requirements in 3.2. Additionally, the thermal-sensing elements for temperature and pressure relief valves shall be so designed and constructed that they will not fail in any manner that could obstruct flow passages or reduce capacities of the valves when the elements are subjected to saturated steam temperature corresponding to capacity test pressure. Temperature and pressure relief valves incorporating these elements shall comply with a nationally recognized standard (e.g., ANSI Z21.22/CSA 4.4).

7.3 MATERIAL REQUIREMENTS

Temperature and pressure relief valves shall meet the material requirements in 3.3.

7.4 INSPECTION OF MANUFACTURING AND/OR ASSEMBLY

Temperature and pressure relief valves shall meet the inspection of manufacturing and/or assembly requirements in 3.4.

7.5 PRODUCTION TESTING

Production testing of temperature and pressure relief valves shall be in accordance with 3.6.

7.6 WELDING

Welding is not allowed on temperature and pressure relief valves.

7.7 MARKING

Temperature and pressure relief valves shall be marked in accordance with 3.9.

7.8 CERTIFICATION OF CAPACITY

The capacity of temperature and pressure relief valves shall be certified in accordance with Part 9 and the following additional requirements:

(a) Set Pressure Tests of Temperature and Pressure Relief Valves. For the purpose of determining the set pressure of temperature and pressure relief valves, the test fluid shall be room temperature water. The actual set pressure is defined as the pressure at the valve inlet when the flow rate through the valve is 40 cc/min (2.4 $in.^3$/min).

(b) Capacity Tests of Temperature and Pressure Relief Valves. For the purpose of determining the capacity of temperature and pressure relief valves, dummy elements of the same size and shape as the regularly applied thermal element shall be substituted and the relieving capacity shall be based on the pressure element only. Valves selected to meet the requirements of production testing shall have their temperature elements deactivated by the Manufacturer prior to or at the time of capacity testing.

PART 8
REQUIREMENTS FOR DEVICES IN COMBINATION

8.1 GENERAL

(a) The rules of this Part are applicable only when specified by the referencing Code or Standard.

(b) A non-reclosing pressure relief device that meets the requirements of Part 4 or Part 5 may be used in combination with a pressure relief valve that meets the requirements of Part 3. This combination of devices may be advisable on pressurized equipment subject to one or more of the following conditions:

(1) The vessel contains substances that may render a pressure relief valve inoperative by fouling.

(2) A loss of valuable material by leakage should be avoided.

(3) Contamination of the atmosphere by leakage of noxious, flammable, or hazardous fluids must be avoided.

8.2 RUPTURE DISK DEVICE INSTALLED BETWEEN A PRESSURE RELIEF VALVE AND THE PRESSURIZED EQUIPMENT

A rupture disk device may be installed between a pressure relief valve and the pressurized equipment, provided the following conditions are met:

(a) The flow capacity of the combined pressure relief valve and the rupture disk device shall meet the maximum permissible overpressure requirements of the referencing Code or Standard.

(b) The combined capacity of the pressure relief valve (nozzle type) and rupture disk device shall be the rated capacity of the valve multiplied by a factor of 0.90. Alternatively, the capacity of such a combination shall be established in accordance with (c).

(c) The capacity of the combination of the rupture disk device and the pressure relief valve may be established in accordance with the appropriate paragraphs of 9.5.

(d) The space between the rupture disk device and the pressure relief valve shall be provided with a pressure gage, try cock, free vent, or other suitable telltale indicator. This arrangement permits detection of disk rupture or leakage. For Section VIII, Division 3 (UD3 Designator) devices, in lieu of one of the previously mentioned indicators, the series combination can be provided with a second rupture disk device in parallel whose burst pressure is 116% of vessel design pressure. Users are warned that a rupture disk will not burst at its marked bursting pressure if back pressure builds up in the space between the disk and the pressure relief valve, which will occur should leakage develop in the rupture disk due to corrosion or other cause.

(e) The opening provided through the rupture disk after the disk bursts shall be sufficient to permit a flow equal to the capacity of the pressure relief valve [see (b) and (c)], and there shall be no chance of interference with proper functioning of the pressure relief valve. However, in no case shall this area be less than the inlet area of the pressure relief valve unless the capacity and functioning of the specific combination of rupture disk device and pressure relief valve have been established by test according to 9.5.

(f) The use of a rupture disk device in combination with a pressure relief valve should be carefully evaluated to ensure that the fluid being handled and the valve operational characteristics will result in opening action of the valve coincident with the bursting of the rupture disk.

(g) The installation shall ensure that solid material will not collect in the inlet or outlet of the rupture disk; accumulation of such material could impair the relieving capacity of the relief system.

(h) Fragmenting-type rupture disks shall not be used upstream of a pressure relief valve.

8.3 RUPTURE DISK DEVICE INSTALLED ON THE OUTLET SIDE OF A PRESSURE RELIEF VALVE (25)

A rupture disk device may be installed on the outlet side of a pressure relief valve, provided (a) through (i) are met. This use of a rupture disk device in series with the pressure relief valve is permitted to minimize leakage through the valve of valuable material or of noxious or otherwise hazardous materials, to accommodate the use of rupture disks on pressurized equipment for which a rupture disk alone or disk located on the inlet side of the valve is impracticable, or to prevent corrosive gases from a common discharge line from reaching the valve internals.

(a) The pressure relief valve shall not fail to open at its proper pressure setting regardless of any back pressure that can accumulate between the pressure relief valve disk and the rupture disk. The space between the pressure relief valve disk and the rupture disk shall be vented or drained to prevent accumulation of pressure, or suitable means shall be provided to ensure that an accumulation of pressure does not affect the proper operation of the pressure relief valve. Users are warned that many

types of pressure relief valves will not open at the set pressure if pressure builds up in the space between the pressure relief valve disk and the rupture disk device. A pressure relief valve that is balanced against back pressure may be required.

(b) The valve and disk combination shall meet the maximum permissible overpressure requirements of the referencing Code or Standard.

(c) The marked 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 components on the discharge side of the pressure relief valve and any pipe or fitting between the pressure relief valve and the rupture disk device. In addition, the marked 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 device after the disk bursts shall be sufficient to permit a flow equal to the rated capacity of the attached pressure relief valve without exceeding the allowable overpressure.

(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 pressurized equipment shall be clean fluids, free from gumming or clogging matter, so accumulation in the relief system will not interfere with pressure relief valve function.

(g) The system shall be designed to consider the adverse effects of any leakage through the pressure relief valve or outlet-side rupture disk device, to ensure system performance and reliability. Some adverse effects resulting from leakage may include obstruction of the flow path, corrosion of pressure relief valve components, and undesirable bursts of the outlet-side rupture disk.

8.4 PIN DEVICE INSTALLED BETWEEN A PRESSURE RELIEF VALVE AND THE PRESSURIZED EQUIPMENT

(a) A pin device may be installed between a pressure relief valve and the pressurized equipment, provided the following conditions are met:

(1) The capacity of the combination of the pressure relief valve and the pin device shall meet the maximum permissible overpressure requirements of the referencing Code or Standard.

(2) The combined capacity of a Section XII (TV Designator) nozzle-type pressure relief valve and pin device (TD Designator) shall be the rated capacity of the valve multiplied by a factor of 0.90. Alternatively, the capacity of such a combination shall be established in accordance with (4).

(3) For Section VIII, Division 1 (UV Designator) valves, the combined capacity of the pressure relief valve and pin device shall be the rated capacity of the valve multiplied by a factor of 0.90, provided the appropriate resistance factor, K_{RG}, K_{RGL}, or K_{RL}, of the device is less than 6.0, or by a combination capacity factor established in accordance with (4).

(4) The capacity of the combination of the pin device and the spring-loaded pressure relief valve may be established in accordance with 9.5.

(5) The space between the pin device and the pressure relief valve shall be provided with a pressure gage, try cock, free vent, or suitable telltale indicator. Users are warned that a pin will not activate at its marked set pressure if back pressure builds up in the space between the pin device and the pressure relief valve because of leakage through the pin due to corrosion or other forms of deterioration.

(6) The opening provided through the pin device after activation shall be sufficient to permit flow equal to the capacity of the valve, and there shall be no chance of interference with proper functioning of the valve. However, in no case shall this area be less than the area of the inlet of the valve unless the capacity and functioning of the specific combination of pin device and pressure relief valve have been established by test in accordance with Part 9.

(7) The set pressure of the pin device shall be equal to or greater than 90% of the set pressure of the pressure relief valve.

(b) A pin device shall not be installed on the discharge side of a pressure relief valve.

8.5 MARKING (25)

DELETED

PART 9
CAPACITY AND FLOW RESISTANCE CERTIFICATION

(25) ## 9.1 GENERAL

9.1.1 General Certification Requirements

(a) Before the Certification Mark is applied to any pressure relief device, the Manufacturer shall have the capacity or flow resistance of their devices certified in accordance with the provisions of this Part.

(b) At the time of the submission of pressure relief devices for capacity or flow resistance certification or testing in accordance with this Part, an ASME Designated Organization has the authority to review the design for conformity with the requirements of this Section and to reject or require modification of designs that do not conform.

(c) Certified values for pressure relief devices are published in NBBI NB-18.

9.1.2 Test Facility and Supervision

(a) Capacity and flow resistance certification shall be conducted in accordance with Mandatory Appendix V.

(b) Testing shall be conducted by an accredited testing laboratory, in the presence of an Authorized Observer.

(c) Testing laboratories shall be accredited, and test supervisors shall have been accepted as Authorized Observers, in accordance with the requirements of ASME CA-1.

9.1.3 Test Data Report

Certification test data report for each pressure relief device model, type, and size, signed by the Manufacturer and the Authorized Observer witnessing the tests, together with drawings showing the device construction shall be submitted to the ASME Designated Organization for review and acceptance.

9.1.4 Design Changes

(a) When changes are made in the design of a pressure relief device or power-actuated pressure relief valve in such a manner as to affect the flow path, lift, or performance characteristics of the device, new tests in accordance with this Part shall be performed.

(b) When changes are made in the design of a nonreclosing pressure relief device that affect the flow path or activation performance characteristics of the device, new tests in accordance with this Part shall be performed.

9.2 REQUIREMENTS FOR PRESSURE RELIEF VALVES

Pressure relief valves shall be capacity certified in accordance with 9.7.3, 9.7.4, 9.7.5, or 9.7.6, and 9.9, if applicable.

9.2.1 Blowdown

(a) Pressure relief valves for compressible fluids having an adjustable blowdown construction shall be adjusted prior to testing so that the blowdown does not exceed 5% of the set pressure or 20 kPa (3 psi), whichever is greater.

(b) Pressure relief valves for incompressible fluids and pressure relief valves for compressible fluids having nonadjustable blowdown shall have the blowdown noted and recorded.

(c) Pressure relief valves for Section I power boilers for steam service to be marked with the Certification Mark and V Designator shall be adjusted so that the blowdown does not exceed 4% of the set pressure. For pressure relief valves set at or below 700 kPa (100 psi), the blowdown shall be adjusted so as not to exceed 30 kPa (4 psi). Pressure relief valves used on forced-flow steam generators with no fixed steam and waterline, and pressure relief valves used on high-temperature water boilers shall be adjusted so that the blowdown does not exceed 10% of the set pressure. The reseating pressure shall be noted and recorded.

(d) Blowdown adjustment is not a requirement for Section IV (HV Designator) pressure relief valves.

9.2.2 Pilot-Operated Pressure Relief Valves

Capacity certification of pilot-operated pressure relief valves may be based on tests without the pilot devices installed, provided that, prior to capacity tests, it has been demonstrated by test to the satisfaction of the Authorized Observer that the following conditions have been met:

(a) The pilot device will cause the main device to open fully at a pressure that does not exceed the set pressure by more than specified below.

(1) 10% or 20 kPa (3 psi), whichever is greater, for all pilot-operated pressure relief valves except as specified in (2)

(2) 3% or 15 kPa (2 psi), whichever is greater, for steam pilot-operated pressure relief valves for Section I boilers marked with Certification Mark and V Designator

(b) The pilot device in combination with the main device will meet all the requirements of this Section.

9.2.3 Use of V-Designated Valves for UV-Designated Applications

(a) It is permissible to rate Section I pressure relief valves marked with the Certification Mark and V Designator and having capacity ratings at a flow pressure of 103% of the set pressure for use on pressure vessels in Section VIII, Division 1 compressible fluid service with absolute pressures up to 10.9 MPa (1,580 psia) without further test. In such instances, the capacity rating of the pressure relief valve may be increased by the following multiplier to allow for the Section VIII, Division 1 flow pressure of 110% of the set pressure:

(SI Units)

$$\frac{1.10p + 0.101}{1.03p + 0.101}$$

(U.S. Customary Units)

$$\frac{1.10p + 14.7}{1.03p + 14.7}$$

where

p = set pressure, MPa gage (psig)

Such valve capacity shall be marked in accordance with the requirements of 3.9 for for Section VIII (UV Designator) pressure relief valves. This multiplier shall not be used as a divisor to transform test ratings from a higher to a lower flow.

(b) For absolute steam pressures above 10.9 MPa (1,580 psia), the multiplier in (a) is not applicable. For pressure relief valves with absolute relieving pressures between 10.9 MPa (1,580 psia) and 22.1 MPa (3,200 psia), the capacity shall be determined by the equation for steam and the correction factor for high-pressure steam in 9.7.6.4(a), with the permitted absolute relieving pressure (for SI units, $1.10p + 0.101$; for U.S. Customary units, $1.10p + 14.7$) and the coefficient K for that valve design.

9.2.4 Nozzle-Type Pressure Relief Valves for Saturated Water

Rating of nozzle-type pressure relief valves, i.e., valves having a coefficient of discharge, K_D, greater than 0.90 and nozzle construction, for saturated water shall be in accordance with Mandatory Appendix IV, IV-2(f).

9.3 REQUIREMENTS FOR NON-RECLOSING PRESSURE RELIEF DEVICES (25)

(a) Non-reclosing pressure relief devices shall be certified for either capacity or flow resistance. This requirement does not apply to Section VIII, Division 3 (UD3 Designator) devices.

(b) For devices to be certified for capacity, the requirements of 9.7.3, 9.7.4, 9.7.5, or 9.7.6 shall apply except where noted.

(c) For devices to be certified for flow resistance, 9.7.7 shall apply except where noted.

9.4 REQUIREMENTS FOR SPRING-ACTUATED NON-RECLOSING PRESSURE RELIEF DEVICES (25)

DELETED

9.5 REQUIREMENTS FOR PRESSURE RELIEF VALVES IN COMBINATION WITH NON-RECLOSING PRESSURE RELIEF DEVICES

(a) For each combination of pressure relief valve design and non-reclosing pressure relief device design, the pressure relief valve Manufacturer or the non-reclosing pressure relief device Manufacturer may have the capacity of the combination certified as prescribed in (c) and (d).

(b) Capacity certification tests shall be conducted using the test fluids specified in 9.7.1.

(c) The pressure relief valve Manufacturer or the non-reclosing pressure relief device Manufacturer may submit for tests a non-reclosing pressure relief device of the smallest size intended to be used in a combination device, along with the equivalent-size pressure relief valve. The pressure relief valve to be tested shall have the largest orifice used in the particular inlet size.

(d) Tests may be performed in accordance with (1) through (6). The non-reclosing pressure relief device and pressure relief valve combination to be tested shall be arranged to duplicate the combination assembly design.

(1) The test shall embody the minimum set pressure of the non-reclosing pressure relief device design to be used in combination with the pressure relief valve design. The marked set pressure of the non-reclosing pressure relief device shall be between 90% and 100% of the marked set pressure of the valve.

(2) The test procedure to be used shall be as follows:

(-a) The pressure relief valve (one valve) shall be tested for capacity as an individual valve, without the non-reclosing pressure relief device, at a pressure 10% or 20 kPa (3 psi), whichever is greater, above the valve set pressure.

(-b) The non-reclosing pressure relief device shall then be installed at the inlet of the pressure relief valve and activated to operate the valve. The capacity test shall be performed on the combination at 10% or 20 kPa (3 psi), whichever is greater, above the valve set pressure, duplicating the individual pressure relief valve capacity test.

(3) Tests shall be repeated with two additional activation components of the same nominal rating for a total of three activation components to be tested with the single pressure relief valve. The results of the capacity test shall fall within a range of 10% of the average capacity of the three tests. Failure to meet this requirement shall be cause to require retest for determination of the cause of the discrepancies.

(4) From the results of the tests, a combination capacity factor shall be determined. The combination capacity factor is the ratio of the average capacity determined by the combination tests to the capacity determined on the individual valve. The maximum value for the combination capacity factor shall not be greater than 1.0.

(5) The combination capacity factor shall be used as a multiplier to make appropriate changes in the ASME-rated relieving capacity of the pressure relief valve in all sizes of the design. The combination capacity factor shall apply only to combinations of the same design of pressure relief valve and same design of non-reclosing pressure relief device as those tested.

(6) The test laboratory shall submit the test results to the ASME Designated Organization for acceptance of the combination capacity factor.

9.6 OPTIONAL TESTING OF NON-RECLOSING PRESSURE RELIEF DEVICES AND PRESSURE RELIEF VALVES

(a) If desired, a valve Manufacturer or a non-reclosing pressure relief device Manufacturer may conduct tests in the same manner as outlined in 9.5(d)(3) and 9.5(d)(4) using the next two larger sizes of the design of non-reclosing pressure relief device and pressure relief valve to determine a combination capacity factor applicable to larger sizes. If a greater combination capacity factor is established and can be certified, it may be used for all larger sizes of the combination, but it shall not be greater than 1.0.

(b) If desired, additional tests may be conducted at higher pressures, in accordance with 9.5(d)(3) and 9.5(d)(4), to establish a maximum combination capacity factor to be used at all pressures higher than the highest pressure previously tested, but it shall not be greater than 1.0.

9.7 CERTIFICATION METHODS

9.7.1 Test Fluid (25)

Certification tests for pressure relief devices shall be conducted using test fluids in accordance with the following:

(a) For Devices to Be Marked With the Certification Mark and V or NV (for Main Steam) Designator

(1) For steam service, capacity certification tests shall be conducted using dry saturated steam. The limits for test purposes shall be 98% minimum quality and 10°C (20°F) maximum superheat. Correction from within these limits may be made to the dry saturated condition.

(2) For liquid service, capacity certification tests shall be conducted using water at a temperature between 5°C (40°F) to 50°C (125°F).

(b) For Devices to Be Marked With the Certification Mark and NV, UV, or UD Designator

(1) Compressible fluid devices shall be flow tested using dry saturated steam, or air or other gas. For test purposes, the temperature limit of air or other gases at the device inlet shall be between −20°C (0°F) and 90°C (200°F), and the limits of 98% minimum quality and 10°C (20°F) maximum superheat shall apply for steam. Correction from within these limits may be made to the dry saturated condition. Steam service valves flow tested with air or other gases shall have at least one valve of each series flow tested using steam to demonstrate the steam capacity and performance.

(2) Incompressible fluid devices certified for capacity shall be flow tested using water. For test purposes, the water temperature shall be between 5°C (40°F) and 50°C (125°F).

(c) For Devices to Be Marked With the Certification Mark and UV3 Designator. Flow capacity certification tests shall be conducted with liquids or vapors, as appropriate. For fluids that are 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 device (flashing), the flow capacity shall be determined using appropriate correlations and procedures from the vapor and liquid capacity data obtained in accordance with 9.7. Alternatively, the flow capacity and design of the pressure relief system may be specified by the user or the user's designated 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.

(d) For Devices to Be Marked With the Certification Mark and HV Designator. Flow capacity certification tests shall be made with dry saturated steam. For test purposes, the limits of 98% minimum quality and 10°C (20°F) maximum

(25)

Table 9.7.2-1
Test Pressure for Certification Tests

Pressure Relief Device		
Certification Mark Designator [Note (1)]	**Service**	**Maximum Pressure for Capacity or Flow Resistance Certification Test**
V NV for main steam valves	Steam	103% of set pressure, or set pressure + 15 kPa (2 psi), whichever is greater
	Liquids	110% of set pressure, or set pressure + 20 kPa (3 psi), whichever is greater
HV	Steam boilers	Set pressure + 35 kPa (5 psi)
	Hot water heating and water supply boilers	110% set pressure
UV or UD NV for pressure relief valves	All except those indicated below	110% of set pressure, or set pressure + 20 kPa (3 psi), whichever is greater [Note (2)]
	Fire or unexpected external heating for vessels with no permanent supply connection [Note (3)]	120% of marked set pressure
UV3	All	110% of set pressure
TV or TD	All except those indicated below	110% of set pressure, or set pressure + 20 kPa (3 psi), whichever is greater [Note (2)]
	As permitted by the appropriate Section XII Modal Appendix [Note (4)]	120% of marked set pressure

NOTES:
(1) See the General Note of Table 2.1-1 for a listing of the devices to which the Certification Mark Designators apply.
(2) For pressure relief valves, minimum pressure for capacity certification tests shall be at least 20 kPa (3 psi) above the set pressure.
(3) See Section VIII, Division 1, UG-153(a)(3).
(4) See Section XII, Article TR-1.

superheat shall apply. Correction from within these limits may be made to the dry saturated condition. The relieving capacity shall be measured by condensing the steam or by using a calibrated steam flowmeter. To determine the discharge capacity of pressure relief valves in terms of other units permitted in 3.9(e)(5)(-c), use the applicable formula below:

(SI Units)

$$\text{capacity, kW} = \text{capacity, kg/h} \times 0.646\ \text{kW}\cdot\text{h/kg}$$

(U.S. Customary Units)

$$\text{capacity, Btu/hr} = \text{capacity, lbm/hr} \times 1{,}000\ \text{Btu/lbm}$$

(e) For Devices to Be Marked With the Certification Mark and TV or TD Designator

(1) Compressible fluid devices shall be tested using air or gas. For test purposes, the temperature limit of air or other gases at the device inlet shall be between −20°C (0°F) and 90°C (200°F).

(2) Incompressible fluid devices certified for capacity shall be flow tested using water. For test purposes, the water temperature shall be between 5°C (40°F) and 50°C (125°F).

9.7.2 Test Pressure

Certification tests shall be conducted at an absolute flow rating pressure as indicated in Table 9.7.2-1.

9.7.3 Design Certification by the Single-Device Method (25)

A Manufacturer may obtain permission to apply the Certification Mark to a single device and pressure setting. For certification of multiple devices with the same pressure setting, see 9.7.4.

(a) When a single device is to be capacity tested, the certified capacity may be based on three separate tests at the set pressure for which capacity certification is required.

(b) The certified capacity associated with each set pressure shall not exceed 90% of the average capacity established by the tests. Failure of the individual test capacities to fall within ±5% of the average capacity associated with each set pressure shall be cause for rejection of the test. The reason for the failure shall be determined and the test repeated.

(c) Should additional devices of the same design be constructed at a later date, the results of the tests on the original device may be included as applicable to the particular test method selected.

(25) 9.7.4 Design Certification by the Three-Device Method

A Manufacturer may obtain permission to apply the Certification Mark to a single device size, design, and pressure setting. For certification of a device design with a range of pressure settings, see 9.7.5.

(a) A capacity certification test is required on a set of three pressure relief devices for each combination of size, design, and pressure setting.

(b) The rated capacity for each combination of design, size, and test pressure shall be 90% of the average capacity of the three devices tested.

(c) The capacity of each device of the set shall fall within a range of ±5% of the average capacity.

(d) If the capacity of one of the three pressure relief devices tested falls outside the range specified in (c), the device shall be replaced by two devices, and a new average shall be calculated based on all four devices, excluding the replaced device. Failure of any of the four capacities to fall within a range of ±5% of the new average shall be cause to refuse certification of that particular device design.

(25) 9.7.5 Design Certification by the Four-Device Method

A Manufacturer may obtain permission to apply the Certification Mark to a pressure relief device design by certifying an individual orifice size over a range of set pressures. Capacity testing of four devices shall be conducted on the orifice size to be certified. These four devices shall cover the range of pipe sizes to be certified and be set at pressures that cover the approximate range of pressures for which the device will be used or the range of pressures available at the certified test facility that shall conduct the tests. The capacities based on these four tests shall be as follows:

(a) For compressible fluids, the slope, S_m, of the measured capacity versus the absolute flow-rating pressure shall be determined for each test point as follows:

$$S_m = W/P_f$$

where

P_f = absolute flow-rating pressure, MPa (psia) (see Table 9.7.2-1)

S_m = slope, kg/h/MPa (lbm/hr/psia) or m^3/min/MPa (SCFM/psia)

W = measured capacity, kg/h (lbm/hr) of saturated steam, or m^3/min of air at 20°C and 101 kPa (SCFM of air at 60°F and 14.7 psia)

The average slope, S_{avg}, shall be the arithmetic mean of all calculated slope values, S_m. All experimentally determined slope values, S_m, shall fall within a range of ±5% of the average slope, S_{avg}. If all slope values, S_m, are not within ±5% of the average slope, S_{avg}, two additional devices shall be tested for each device beyond the ±5% range, up to a limit of four additional devices.

The average slope, S_{avg}, shall be multiplied by 0.90, and this product shall be taken as the rated slope, S, for that design and orifice size combination. The relieving capacity to be marked on the device shall not exceed the rated slope, S, multiplied by the absolute relieving pressure.

For direct spring-loaded valves, the results may be extrapolated to valves with set pressures higher than the highest set pressure used in the capacity certification tests if the spring in the valve with the higher set pressure meets the requirements of 3.2.5.

(b) For incompressible fluids, the flow factor, F_m, shall be determined from the ratio of the measured volumetric capacity versus the square root of the differential flow-rating pressure for each test point as follows:

$$F_m = \frac{Q}{\sqrt{P_f - P_d}}$$

where

P_d = absolute discharge pressure, MPa (psia)

P_f = absolute flow-rating pressure, MPa (psia) (see Table 9.7.2-1)

Q = measured volumetric capacity, L/min (gpm), corrected to 20°C (70°F)

The average flow factor, F_{avg}, shall be the arithmetic mean of all calculated flow factors, F_m. All experimentally determined flow factors, F_m, shall fall within a range of ±5% of the average flow factor, F_{avg}. If all the flow factors, F_m, are not within ±5% of F_{avg}, two additional devices shall be tested for each device beyond the ±5% range, up to a limit of four additional devices.

The average flow factor, F_{avg}, shall be multiplied by 0.90, and this product shall be taken as the flow factor, F, for that design and orifice size combination. The relieving capacity to be marked on the device shall not exceed the flow factor, F, multiplied by the square root of the differential relieving pressure.

For direct spring-loaded valves, the results may be extrapolated to valves with set pressures higher than the highest set pressure used in the capacity certification tests if the spring in the valve with the higher set pressure meets the requirements of 3.2.5.

9.7.6 Design Certification by the Coefficient of Discharge Method (25)

A Manufacturer may obtain permission to apply the Certification Mark to a pressure relief device design by certifying multiple orifice sizes over a range of set pressures. A coefficient of discharge for the design, K, may be established for a specific pressure relief device design according to the procedures described in 9.7.6.1 through 9.7.6.5.

9.7.6.1 For each design, the pressure relief device Manufacturer shall submit for test at least three devices for each of three different sizes (a total of nine devices), together with detailed drawings showing the device construction. Each device of a given size shall be set at a different pressure so that the tests cover the range of pressures for which the device will be used or the range available at the facility where the tests are conducted. However, pressure relief valves for steam boilers marked with the Certification Mark and HV Designator shall have all nine valves set at 100 kPa (15 psig).

9.7.6.2 For each valve design intended to be restricted in lift, the Manufacturer shall have capacity tests conducted on three valves of different sizes. Each size valve shall be tested for capacity at the minimum lift for which certification is required, and at two intermediate lift points between the full-rated lift and minimum lift certification points. Each of the three test valves shall be set at a different pressure.

9.7.6.3 For each restricted-lift valve tested, it shall be verified that actual measured capacity at restricted lift will equal or exceed the ASME-rated capacity at full-rated lift multiplied by the ratio of measured restricted lift to full-rated lift.

9.7.6.4 Tests shall be made on each pressure relief device to determine its lift (if applicable) at capacity, set pressure and blowdown (for pressure relief valves), and measured relieving 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:

$$K_D = \frac{W}{W_T}$$

where
W = measured relieving capacity determined quantitatively by test, kg/h (lbm/hr)
W_T = theoretical relieving capacity calculated by the appropriate equation as given in (a) through (d), kg/h (lbm/hr)

(a) For Tests With Dry Saturated Steam

(1) For 45-deg seat

(SI Units)

$$W_T = 5.25 \times \pi DLP \times 0.707$$

(U.S. Customary Units)

$$W_T = 51.5 \times \pi DLP \times 0.707$$

where
D = seat diameter, mm (in.)
L = lift at pressure, P, mm (in.)
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
W_T = theoretical relieving capacity, kg/h (lbm/hr)

(2) For flat seat

(SI Units)

$$W_T = 5.25 \times \pi DLP$$

(U.S. Customary Units)

$$W_T = 51.5 \times \pi DLP$$

where
D = seat diameter, mm, (in.)
L = lift at pressure, P, mm (in.)
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
W_T = theoretical relieving capacity, kg/h (lbm/hr)

(3) For nozzle

(SI Units)

$$W_T = 5.25AP$$

(U.S. Customary Units)

$$W_T = 51.5AP$$

where
A = actual discharge area through the device at developed lift, mm^2 (in.^{2})
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
W_T = theoretical relieving capacity, kg/h (lbm/hr)

For dry saturated steam pressures over 10.9 MPa (1,580 psia) and up to 22.1 MPa (3,200 psia), W_T calculated from the equations in (1) through (3) shall be multiplied by one of the following correction factors only if the calculated correction factor is greater than 1.0:

(SI Units)

$$\frac{27.6P - 1\,000}{33.2P - 1\,061}$$

(U.S. Customary Units)

$$\frac{0.1906P - 1{,}000}{0.2292P - 1{,}061}$$

where
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)

(b) For Tests With Air

For nozzle

(SI Units)

$$W_T = 27.03AP\sqrt{\frac{M}{T}}$$

(U.S. Customary Units)

$$W_T = 356AP\sqrt{\frac{M}{T}}$$

where

A = actual discharge area through the device at developed lift, mm^2 (in.^{2})
M = molecular weight of air
= 28.97 kg/kg-mol (28.97 lbm/lb-mole)
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
T = absolute temperature at inlet, K (°R)
K = °C + 273
°R = °F + 460
W_T = theoretical relieving capacity, kg/h (lbm/hr)

(c) For Tests With Other Gases

For nozzle

$$W_T = CAP\sqrt{\frac{M}{ZT}}$$

where

A = actual discharge area through the device at developed lift, mm^2 (in.^{2})
C = constant for gas or vapor based on ideal ratio, k, of the specific heat in constant pressure, c_p, to the specific heat in constant volume, c_v: $k = c_p/c_v$ [see Mandatory Appendix IV, Figure IV-1-1M (Figure IV-1-1)]. C is determined from one of the following equations:

(SI Units)

$$C = 39.48\frac{\sqrt{\text{kg} \times \text{kg-mol} \times \text{K}}}{\text{mm}^2 \times \text{h} \times \text{MPa}}\sqrt{k\left(\frac{2}{k+1}\right)^{\left(\frac{k+1}{k-1}\right)}}$$

(U.S. Customary Units)

$$C = 520\frac{\sqrt{\text{lbm} \times \text{lb-mole} \times {}^\circ\text{R}}}{\text{in.}^2 \times \text{hr} \times \text{psia}}\sqrt{k\left(\frac{2}{k+1}\right)^{\left(\frac{k+1}{k-1}\right)}}$$

M = molecular weight for specific fluid or mixture, kg/kg-mol (lbm/lb-mole)
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
T = absolute temperature at inlet, K (°R)
K = °C + 273
°R = °F + 460
W_T = theoretical relieving capacity, kg/h (lbm/hr)
Z = compressibility factor for the specific fluid at the specified conditions of P and T, unitless

(d) For Tests With Water or Other Incompressible Fluids

(1) For 45-deg seat

(SI Units)

$$W_T = 5.092\pi DL(0.707)\sqrt{(P - P_d)\rho}$$

(U.S. Customary Units)

$$W_T = 2{,}407\pi DL(0.707)\sqrt{(P - P_d)\rho}$$

where

D = seat diameter, mm (in.)
L = lift at pressure, P, mm (in.)
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
P_d = absolute discharge pressure, MPa (psia)
W_T = theoretical relieving capacity, kg/h (lbm/hr)
ρ = density of fluid at device inlet conditions, kg/m^3 (lbm/ft^3)

(2) For flat seat

(SI Units)

$$W_T = 5.092\pi DL\sqrt{(P - P_d)\rho}$$

(U.S. Customary Units)

$$W_T = 2{,}407\pi DL\sqrt{(P - P_d)\rho}$$

where

D = seat diameter, mm (in.)
L = lift at pressure, P, mm (in.)
P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)
P_d = absolute discharge pressure, MPa (psia)
W_T = theoretical relieving capacity, kg/h (lbm/hr)
ρ = density of fluid at device inlet conditions, kg/m^3 (lbm/ft^3)

(3) For nozzle

(SI Units)

$$W_T = 5.092A\sqrt{(P - P_d)\rho}$$

(U.S. Customary Units)

$$W_T = 2{,}407A\sqrt{(P - P_d)\rho}$$

where

A = actual discharge area through the device at developed lift, mm^2 (in.^{2})

P = absolute relieving pressure, MPa (psia) (see Table 9.7.2-1)

P_d = absolute discharge pressure, MPa (psia)

W_T = theoretical relieving capacity, kg/h (lbm/hr).

ρ = density of fluid at device inlet conditions, kg/m^3 (lbm/ft^3)

To convert kilograms of water per hour to liters of water per minute, multiply the capacity, W_T, in kilograms per hour by $^1/_{60}$. To convert pounds mass of water per hour to gallons of water per minute, multiply the capacity, W_T, in pounds mass per hour by $^1/_{500}$.

9.7.6.5 All experimentally determined coefficients, K_D, shall fall within a range of ±5% of the average K_D found. If a device fails to meet this requirement, two additional devices shall be tested as replacements for each device having an individual coefficient, K_D, outside the ±5% range, with a limit of four additional devices. Failure to meet this requirement shall be cause to refuse certification of that particular device design. The average of the coefficients, K_D, of the nine tests required shall be multiplied by 0.90, and this product shall be taken as the coefficient, K, of that design. The coefficient of the design shall not be greater than 0.878 (the product of 0.9 × 0.975).

9.7.6.6 The coefficient shall not be applied to devices whose beta ratio (ratio of device bore to inlet diameter) lies outside the range of 0.15 to 0.75, unless tests have demonstrated that the individual coefficient of discharge, K_D, for devices at the extreme ends of a larger range is within ±5% of the average coefficient, K_D.

9.7.6.7 For designs where the lift is used to determine the flow area, all valves shall have the same nominal lift to seat diameter ratio, L/D.

9.7.6.8 For direct spring-loaded valves, the results may be extrapolated to valves with set pressures higher than the highest set pressure used in the capacity certification tests, provided the spring in the valve with the higher set pressure meets the requirements of 3.2.5.

9.7.6.9 For pressure relief valves, the results may be extrapolated to valves larger or smaller than the valves used in the capacity certification tests, provided all dimensions of the flow path and all dimensions of the parts that can affect the overall thrust exercised by the fluid on the moving parts are scaled with the corresponding dimensions of the valves used in the capacity certification testing.

9.7.6.10 The coefficient shall not be applied to direct spring-loaded valves with springs that do not meet the requirements of 3.2.5.

9.7.6.11 The rated relieving capacity of all sizes and set pressures of a given design for which K has been established under the provision of 9.7.6 shall be determined by the following equation:

$$W_R \leq W_T \times K$$

where

K = coefficient of discharge for the design

W_R = rated relieving capacity, kg/h (lbm/hr)

W_T = theoretical relieving capacity, defined by the same equation as used to determine K_D, kg/h (lbm/hr)

9.7.7 Flow Resistance Method (25)

The certified flow resistance, K_R, of the non-reclosing pressure relief device (Parts 4 and 5) shall be either 2.4 or as determined in accordance with 9.7.7.1 through 9.7.7.9.

9.7.7.1 Test fluids for flow resistance certification tests shall be as follows:

(a) Non-reclosing pressure relief devices for air or gas service shall be activated and flow tested with air or gas to determine flow resistance, K_{RG}.

(b) Non-reclosing pressure relief devices for liquid service shall be activated with water and flow tested with air or gas to determine flow resistance, K_{RL}.

(c) The flow resistance of non-reclosing pressure relief devices for air or gas and liquid service, K_{RGL}, may be certified with air or gas as in (a) and (b), but at least one device of the number required under 9.7.7.6 for each size of each series shall be activated with water and flow tested with air or gas to demonstrate the liquid service flow resistance.

9.7.7.2 Flow resistance certification tests shall be conducted at an inlet pressure that does not exceed 110% of the device set pressure.

9.7.7.3 The flow resistance for devices tested with non-pressure-containing items, such as seals, support rings, and vacuum supports, is applicable to the same device design without seals, support rings, or vacuum supports.

9.7.7.4 A change in material for rupture disks and their non-pressure-containing disk items, such as seals, support rings, and vacuum supports, is not considered a design change and does not require retesting.

9.7.7.5 Additional linings, coatings, or platings may be used for the same design of devices, provided the following conditions are met:

(a) The Certificate Holder has performed a verification test with the additional linings, coatings, or platings and has documented that the addition of these materials does not affect the device opening configuration.

(b) The verification test described in (a) shall be conducted with devices of the smallest size and minimum set pressure for which the certified flow resistance with additional materials is to be used.

9.7.7.6 Flow resistance certification shall be determined by one of the following methods:

(a) *One-Size Method*

(1) For each non-reclosing pressure relief device design, three activation components from the same lot shall be individually activated and the device tested in accordance with 9.7.7.7. The set pressure shall be the minimum for the pressure to be certified.

(2) The certified flow resistance, K_R, determined in 9.7.7.7 shall apply only to the non-reclosing pressure relief device design of the size tested.

(3) If additional activation components of the same design are constructed at a later date, the test results on the original components may be included, as applicable, in the three-size method described in (b).

(b) *Three-Size Method*

(1) The three-size method of flow resistance certification may be used for a non-reclosing pressure relief device design of three or more sizes.

(2) For each of the three sizes of the non-reclosing pressure relief device design being tested, three activation components from the same lot shall be activated and the device flow tested in accordance with 9.7.7.7. For each size tested, the set pressure shall be the minimum pressure to be certified.

(3) The certified flow resistance, K_R, shall apply to all sizes and pressures of the non-reclosing pressure relief device design tested.

9.7.7.7 A certified flow resistance, K_R, may be established for a specific non-reclosing pressure relief device design according to the following procedure:

(a) For each design, the non-reclosing pressure relief device Manufacturer shall submit for test the required devices in accordance with 9.7.7.6, together with the cross section drawings showing the device design.

(b) Tests shall be made on each device to determine its set pressure and flow resistance at a facility that meets the requirements of 9.1.2.

(c) An average flow resistance shall be calculated from the individual flow resistances determined in (b). All individual flow resistances shall fall within the average flow resistance by an acceptance band of ±3 times the average of the absolute values of the deviations of the individual flow resistances from the average flow resistance. Any device for which the individual flow resistance falls outside of this band shall be replaced on a two-for-one basis. A new average flow resistance shall be computed and the individual flow resistances evaluated as stated above.

(d) The certified flow resistance, K_R, for a non-reclosing pressure relief device design shall be not less than zero and shall be not less than the sum of the average flow resistance plus 3 times the average of the absolute values of the deviations of individual flow resistances from the average flow resistance. The certified flow resistance, K_R, for a non-reclosing pressure relief device design

(1) shall not be less than zero

(2) shall not be less than the sum of the average flow resistance plus 3 times the average of the absolute values of the deviations of individual flow resistances from the average flow resistance

(3) shall not be less than 110% of the highest measured individual flow resistance

9.7.7.8 After completion of the flow resistance testing in 9.7.7.7, a minimum net flow area evaluation shall be conducted to verify the measured flow capacity meets or exceeds the rated flow capacity calculated for the simple system method in 4.1.3.2(a). Devices shall be activated using the appropriate media per 9.7.7.1 based on their flow resistance certification, K_{RG}, K_{RL}, or K_{RGL}.

(a) The test arrangement shall meet the following requirements:

(1) The nominal diameters of the inlet and discharge piping is equal to or greater than the marked DN (NPS) designator of the device.

(2) The rupture disk device is installed eight pipe diameters from the vessel nozzle entry.

(3) The discharge piping downstream of the rupture disk device is five pipe diameters in length.

(4) The discharge piping vents directly to the atmosphere.

(b) The test fluid for flow capacity test shall be air or gas.

(c) The flow capacity shall be measured at a flow rating pressure that does not exceed the maximum pressure for capacity certification test from Table 9.7.2-1 based on the measured burst pressure established during activation testing in 9.7.7.1.

(d) The rated flow capacity of the simple system shall be determined in accordance with 4.1.3.2(a) using the specified minimum net flow area and relieving pressure equal to the actual flow rating pressure corresponding to the measured flow capacity established in (c).

(e) The specified minimum net flow area shall be acceptable if the measured flow meets or exceeds the rated flow capacity calculated for the simple system. If the measured flow capacity is less than the rated flow capacity calculated for the simple system, the measured flow capacity shall be used with the applicable theoretical flow equation from 9.7.6.4 multiplied by 0.62 coefficient of

discharge and the actual flow rating pressure corresponding to the measured flow capacity established in (c) to establish the minimum net flow area for the rupture disk device.

(f) For air or gas and liquid service devices, K_{RGL}, the requirements of (e) shall be met for the device activated using air or gas and the device activated using liquid. If calculation of the minimum net flow area based on measured flow capacity is performed, the minimum net flow area shall be the lesser of the values determined for the air- or gas-activated and liquid-activated devices.

9.7.7.9 Flow resistance and minimum net flow area capacity test data reports for each non-reclosing pressure relief device design, signed by the Manufacturer and the Authorized Observer witnessing the tests, shall be submitted to the ASME Designated Organization for review and acceptance.

(25) 9.8 ALTERNATIVE METHODS FOR VALVES, PIN DEVICES, AND SPRING-ACTUATED NON-RECLOSING PRESSURE RELIEF DEVICES EXCEEDING THE LABORATORY CAPABILITIES

(a) If the design of the valve, pin device, or spring-actuated non-reclosing pressure relief device exceeds the laboratory pressure capability, the method in 9.7.5, 9.7.6, or 9.7.7 shall be followed with the following exceptions:

(1) Valves shall be tested with their disks fixed at the minimum design lift to establish the rated capacity.

(2) Pin devices or spring-actuated non-reclosing pressure relief devices shall be tested with their disks fixed at the minimum design lift or in the fully open position to establish rated capacity.

(b) If the design of the valve, pin device, or spring-actuated non-reclosing pressure relief device exceeds the laboratory size or capacity capability, 9.7.5, 9.7.6, or 9.7.7 shall be followed except that flow models of three different sizes, each tested at three different pressures, shall be used in place of the valves, pin devices, or spring-actuated non-reclosing pressure relief devices required in 9.7.5, 9.7.6.1, 9.7.6.2, 9.7.6.3, or 9.7.7.6. Such flow models shall be sized consistent with the capabilities of the accepted test laboratory where the test will be conducted, and shall accurately model those features that affect flow capacity, such as orifice size, valve lift, and internal flow configuration. The test models need not be functional but shall be geometrically similar to the final product.

(c) In the case of either (a) or (b), the valve, pin device, or spring-actuated non-reclosing pressure relief device design (i.e., parameters such as spring properties, seat geometry, internal flow configuration in the fully open position, and mechanical valve lift) shall be evaluated to ensure that production valves, pin devices, or spring-actuated non-reclosing pressure relief devices will achieve design lift or complete opening as modeled above.

9.9 CAPACITY CERTIFICATION OF SECTION III (NV-DESIGNATED) PRESSURE RELIEF VALVES

The following paragraphs are revisions or additions to the requirements in 9.1 through 9.8 that apply only for Section III (NV Designator) pressure relief valves:

(a) Capacity Certification. Capacity certification obtained in compliance with other Designators which comply with all requirements of the NV Designator are qualified for capacity certification under the NV Designator. Capacity certification obtained under these requirements for one specific Class under the NV Designator which comply with all requirements of other classes under the NV Designator are qualified for capacity certification under these rules for those other Classes.

(b) Demonstration-of-Function Test. For each design, a demonstration-of-function test program as required by 9.9.4 shall be performed.

(c) Proration of Capacity

(1) The capacity of a pressure relief valve applied to a system may be prorated to an overpressure greater than the overpressure for which the valve design is certified. This overpressure shall be within the allowable limits of the system.

(2) Prorated capacity shall be determined by one of the following, depending on the method used for the initial capacity certification:

(-a) The prorated capacity shall be 90% of the average slope determined in 9.7.5 multiplied by the prorated relieving pressure, kPa abs (psia).

(-b) The prorated capacity shall be calculated using the appropriate equation from 9.7.6, where P is the prorated relieving pressure, kPa abs (psia), multiplied by the coefficient K.

9.9.1 Certification Set Pressures of 20 kPa (3 psig) Up to but Not Including 100 kPa (15 psig)

Capacity certification tests for air or gas service with set pressures of 20 kPa gage (3 psig) up to but not including 100 kPa gage (15 psig) shall be conducted in accordance with the requirements of 9.7.3, 9.7.5, 9.7.6, or 9.9.3 modified as follows:

(a) The capacity shall be determined at no more than 13.8 kPa (2 psi) above the actual set pressure.

(b) Valves set below 100 kPa gage (15 psig) and having adjustable blowdown construction shall be adjusted prior to capacity certification testing so that the blowdown shall not be greater than 20 kPa (3 psi) nor less than 4 kPa (0.5 psi).

9.9.1.1 Design Certification by the Four-Device Method

(a) For air and gas service valves with set pressures of 20 kPa gage (3 psig) up to but not including 100 kPa gage (15 psig) that are being certified by the four-device

method (see 9.7.5), slope is defined as the measured capacity divided by the following quantity:

$$F\left[P(P-P_o)\right]^{1/2}$$

where

$$F = \sqrt{\left(\frac{k}{k-1}\right)\left(r^{2/k}\right)\left[\frac{1-(r)^{\frac{k-1}{k}}}{1-r}\right]}$$

k = ratio of specific heats, c_p/c_v
P = inlet pressure, kPa (psi)
P_o = discharge pressure, kPa (psi)
r = pressure ratio, P_o/P

(b) If any of the experimentally determined slopes fall outside of a range of ±5% of the average slope, the unacceptable valves shall be replaced by two valves of the same size and set pressure. Following the test of these valves, a new average slope shall be determined, excluding the replaced valve test results. If any individual slope is now outside of the ±5% range, then the tests shall be considered unsatisfactory and shall be cause for the ASME Designated Organization to refuse certification of the particular valve design.

(c) The certified slope shall be 90% of the average slope.

(d) The certified capacity shall be the certified slope multiplied by the quantity $F\left[P(P-P_o)\right]^{1/2}$.

(25) **9.9.1.2 Design Certification by the Coefficient of Discharge Method**

(a) For air and gas service valves with set pressures of 20 kPa gage (3 psig) up to but not including 100 kPa gage (15 psig) that are being certified by the coefficient of discharge method as required by 9.7.6, one of the following equations shall be used for other than saturated steam flow:

(SI Units)

$$W = 55.8\,FA\left[\frac{MP(P-P_o)}{T}\right]^{1/2}$$

$$Q = 1\,320\,FA\left[\frac{MP(P-P_o)}{MT}\right]^{1/2}$$

(U.S. Customary Units)

$$W = 735\,FA\left[\frac{MP(P-P_o)}{T}\right]^{1/2}$$

$$Q = 279{,}000\,FA\left[\frac{P(P-P_o)}{MT}\right]^{1/2}$$

where

A = flow area, mm^2 (in.^{2})
F = $\sqrt{\left(\frac{k}{k-1}\right)\left(r^{2/k}\right)\left[\frac{1-(r)^{\frac{k-1}{k}}}{1-r}\right]}$ or is obtained from Figure 9.9.1.2-1
k = ratio of specific heats, c_p/c_v
M = molecular weight
P = inlet pressure, MPa (psi)
P_o = discharge pressure, MPa (psi)
Q = m^3/hr at 101 kPa and 20°C (ft^3/hr at 14.7 psi and 60°F)
r = pressure ratio, P_o/P
T = temperature, K (°R)
W = kg/hr (lb/hr)

(b) The average of the coefficients of discharge, K_D, of the tests required shall be multiplied by 0.90 and their product shall be the coefficient K of that design. The coefficient of the design shall not be greater than 0.878 (the product of 0.90 × 0.975).

9.9.2 Vacuum Pressure Relief Valves

(a) Capacity tests may be conducted by pressurizing the valve instead of using a vacuum, provided the following conditions are met:

(1) Inlet conditions of the valve (not the vessel) are known.

(2) The inlet pressure is not greater than 35 kPa (5 psi).

(3) The direction of flow through the valve is the same on pressure as is experienced on vacuum.

(b) Tests shall be conducted at twice the set pressure or 7 kPa (1 psi), whichever is greater.

9.9.2.1 Vacuum Valve Design Certification by the Four-Device Method. 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 appropriate range of pressures for which the valves are to be used or set within the range of the test facility. The slope of each test shall be calculated and averaged, where slope is defined as the measured capacity divided by the quantity

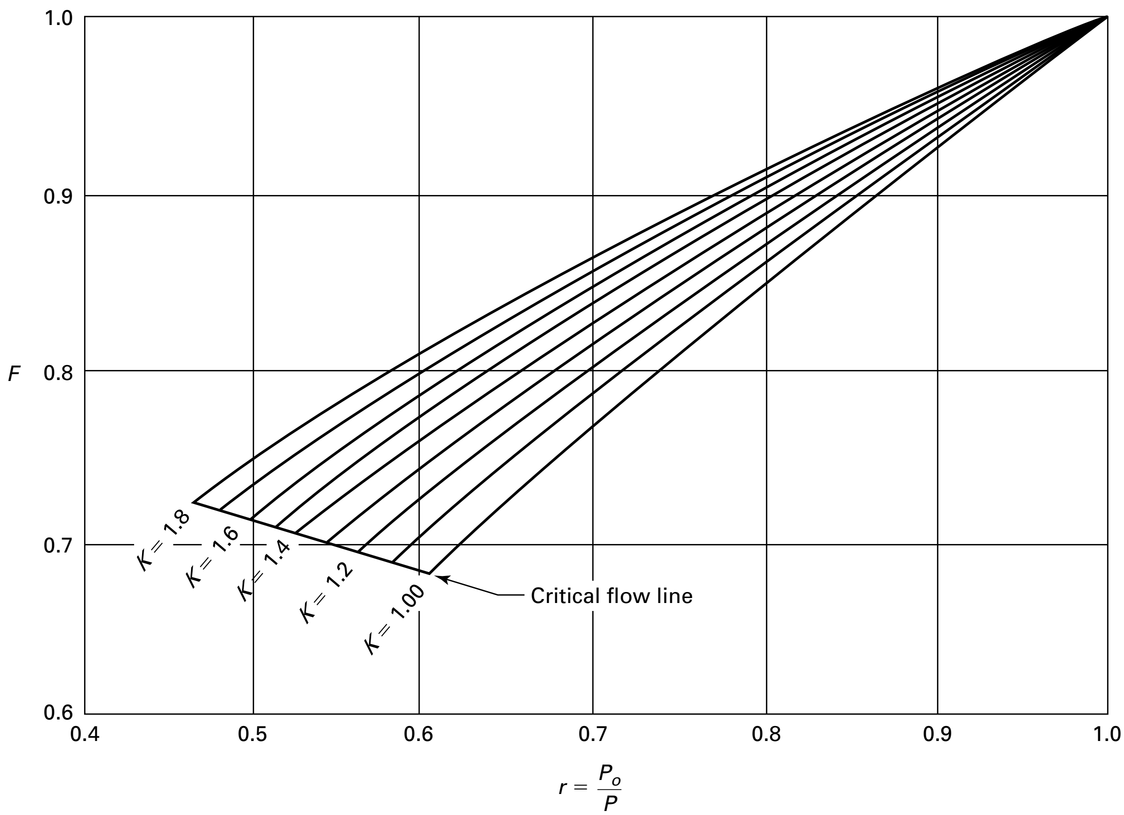
$$F\left[P(P-P_o)\right]^{1/2}$$

where

$$F = \sqrt{\left(\frac{k}{k-1}\right)\left(r^{2/k}\right)\left[\frac{1-(r)^{\frac{k-1}{k}}}{1-r}\right]}$$

k = ratio of specific heats, c_p/c_v

Figure 9.9.1.2-1
Values of *F* for Nonchoking Flow



P = inlet pressure
P_o = discharge pressure
r = pressure ratio, P_o/P

If any of the experimentally determined slopes fall outside of a range of ±5% of the average slope, the unacceptable valves shall be replaced by two valves of the same size and set pressure. Following the test of these valves, a new average slope shall be determined, excluding the replaced valve test results. If any individual slope is now outside of the ±5% range, then the tests shall be considered unsatisfactory and shall be cause for the ASME Designated Organization to refuse certification of the particular valve design.

The certified capacity shall be 90% of the average slope multiplied by the quantity $F[P(P - P_o)]^{1/2}$.

(25) **9.9.2.2 Vacuum Valve Design Certification by the Coefficient of Discharge Method.** A coefficient, K, may be established for a specific vacuum relief valve design in accordance with 9.7.6, except the equations in this paragraph shall be used.

For each design, three valves of three different sizes, a total of nine valves, shall be tested. Each valve of a given size shall be set at a different pressure. Tests shall be made on each relief valve to determine its lift, opening and closing pressures, and actual capacity. A coefficient of discharge, K_D, shall be established for each run, as follows:

$$K_D = \frac{\text{actual flow}}{\text{theoretical flow}} = \text{coefficient of discharge}$$

where actual flow is determined quantitatively by test, and theoretical flow is calculated from the appropriate equation for the test fluid. The following equation may be used for other than saturated steam flow:

(SI Units)

$$W = 55.8\,FA\left[\frac{MP(P - P_o)}{T}\right]^{1/2}$$

$$Q = 1\,320\,FA\left[\frac{P(P - P_o)}{MT}\right]^{1/2}$$

(U.S. Customary Units)

$$W = 735\,FA\left[\frac{MP(P - P_o)}{T}\right]^{1/2}$$

$$Q = 279{,}000\,FA\left[\frac{P(P - P_o)}{MT}\right]^{1/2}$$

where

A = flow area, mm^2 (in.^{2})

$F = \sqrt{\left(\frac{k}{k-1}\right)\left(r^{2/k}\right)\left[\frac{1-(r)^{\frac{k-1}{k}}}{1-r}\right]}$ or is obtained from 9.9.1

k = ratio of specific heats, c_p/c_v

M = molecular weight

P = inlet pressure, MPa (psi)

P_o = discharge pressure, MPa (psi)

Q = m^3/hr at 0.101 MPa and 15°C (ft^3/hr at 14.7 psi and 60°F)

r = pressure ratio, P_o/P

T = temperature, K (°R)

W = kg/hr (lb/hr)

The average of the coefficients of discharge, K_D, of the tests required shall be multiplied by 0.90, and their product shall be the coefficient K of that design. The coefficient of the design shall not be greater than 0.878 (the product of 0.9 × 0.975).

9.9.3 Flow Model Testing of Valve Capacity in Excess of Test Facility Limits

(a) For valve designs with a single orifice size whose capacity exceeds the capacity limits of the test facility, the certified capacity may be based on a flow coefficient, *K*, determined from blocked open flow tests with the valve disk fixed at the minimum design value. Four tests shall be performed at four different pressures as outlined in 9.7.5 or 9.9.1.1.

(b) When test facility limitations make it impossible to perform capacity tests of the full-scale pressure relief valves, alternative methods in 9.8(b) and 9.8(c) may be used.

The relieving capacity of valve designs certified by use of flow models shall be established by the coefficient of discharge method similar to that outlined in 9.7.6 or 9.9.1.2, with each flow model being flow tested at three different pressures.

The orifice area for flow models shall be such that for designs where choked-flow conditions are expected, the model flow area shall ensure that choked flow in the model is attained.

(c) The function of each design to be certified by flow model testing shall be demonstrated by test.

9.9.4 Demonstration of Function

(a) General. For Section III (NV Designator) pressure relief valves, demonstration-of-function tests shall be conducted. Such tests may be performed in conjunction with the capacity certification tests outlined in 9.9 or as separate tests using production valves.

(b) Number of Valves to Be Tested

(1) For a design being certified including one single valve (see 9.7.3), that valve shall be tested. If two valves are being constructed, two valves of the specific inlet size, orifice size, and design shall be tested. Should additional valves of the same design be constructed at a later date, the results of the tests on the original valve or valves may be included, as applicable.

(2) For a design being certified by the three-device method (see 9.7.4), three sample valves shall be tested.

(3) For a design being certified by the four-valve method (see 9.7.5), three sample valves, each set at a different set pressure, shall be tested.

(4) For a design being certified by the coefficient of discharge method (see 9.7.6), the function of three valves in three different sizes shall be demonstrated by test.

(c) Test Location and Class-Specific Methods. These tests shall be conducted at a place where the testing facilities, methods, and procedures provide for sufficient testing capacity and range of fluid properties so that the testing requirements of this paragraph are met. The tests shall be performed to the satisfaction of a representative from an ASME Designated Organization and shall show that the valves will open at set pressure within the required opening-pressure tolerance, will achieve full lift, and will reclose within required blowdown specification.

(1) Class 1 Construction. For Class 1 construction, the following additional requirements apply:

(-a) The three valves selected shall envelop the largest and smallest combination of inlet size and orifice size of the specific design.

(-b) The NV Certificate Holder shall specify the range of pressures, temperatures, and other fluid conditions for which the valves are to be tested. The range shall be sufficient to cover all expected operating fluid conditions. Additionally, tests shall include the range of inlet pressure losses and discharge back pressure conditions for which the valves are expected to be used.

(2) Class 2 and Class 3 Construction. If required due to test facility limitations, these tests may be conducted at reduced-flow capabilities. Measurement of valve blowdown may not be possible.

(d) Data Report Form. The NV Certificate Holder shall document in the "Remarks" section of the Data Report Form NV-1 (see Section III Appendices, Mandatory Appendix V) that the requirements of 9.9.4 have been met.

PART 10
AUTHORIZATION TO USE THE ASME CERTIFICATION MARK

(25) 10.1 CERTIFICATION MARK

Each pressure relief device to which the Certification Mark and appropriate Designator (see Figure 10.1-1) will be applied shall be fabricated or assembled by a Manufacturer or Assembler, as applicable, holding a valid Certificate of Authorization, and capacity or flow resistance certified in accordance with the requirements of ASME CA-1 and this Section.

10.2 CERTIFICATES OF AUTHORIZATION

(a) A Certificate of Authorization to use the Certification Mark and HV, UV, UD, UV3, UD3, TV, or TD Designator will be granted by the Society in accordance with the provisions of ASME CA-1. Stamps for applying the Certification Mark shall be obtained from the Society.

(b) 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.

10.3 DESIGNATED OVERSIGHT

The Manufacturer or Assembler shall comply with the requirements of ASME CA-1 for Designated Oversight by use of a Certified Individual (CI).

10.4 QUALITY MANAGEMENT SYSTEM

Any Manufacturer or Assembler holding or applying for a Certificate of Authorization shall demonstrate a quality management system that meets the requirements of ASME CA-1 and establishes that all ASME BPVC requirements, including material, design, manufacture, and examination, will be met. The quality management system shall be in accordance with the requirements of Mandatory Appendix III. Certificates of Authorization shall be endorsed to indicate the scope of activity authorized.

10.5 EVALUATION OF THE QUALITY MANAGEMENT SYSTEM

(a) The issuance or renewal of a Certificate of Authorization is based on ASME's evaluation and approval of the quality management system and shall be in accordance with ASME CA-1.

(b) Before issuance or renewal of a Certificate of Authorization for use of the Designator, the pressure relief device Manufacturer's or Assembler's facilities and organization are subject to a review by a representative from an ASME Designated Organization.

(c) Certificates of Authorization are valid for the period given in ASME CA-1.

(d) Any changes made to the quality management system shall be made and accepted in accordance with the requirements specified in ASME CA-1.

10.6 CERTIFIED INDIVIDUAL (CI) (25)

(a) General. A CI meeting the requirements of ASME QAI-1 shall provide oversight to ensure that each use of the Certification Mark and appropriate Designator on a pressure relief device is in accordance with the requirements of this Section, and that each use of the Certification Mark and appropriate Designator is documented on the appropriate Certificate of Conformance, as indicated in the table below. (See Nonmandatory Appendix C for Forms.)

Certification Mark Designator	Certificate of Conformance Form
HV	HV-1
UV	UV-1
UD	UD-1
UV3	K-4
UD3	K-5
TV	TV-1
TD	TD-1

(b) Requirements for the CI. The CI shall

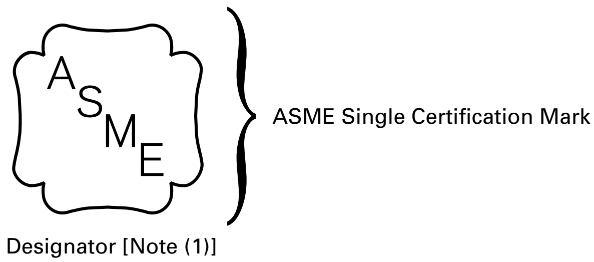
(1) be qualified and certified by the Certificate Holder. Qualifications shall include the following as a minimum:

(-a) knowledge of the requirements of this Section for the application of the Certification Mark with applicable Designator

(-b) knowledge of the Certificate Holder's Quality Management System

(-c) training commensurate with the scope, complexity, or special nature of the activities for which the CI will provide oversight

Figure 10.1-1
ASME Certification Mark With Designator



NOTE: (1) The appropriate Certification Mark Designator shall be placed beneath the Certification Mark.

(2) comply with the National Board "Rules for Certified Individuals" and hold a valid National Board Certification for the specific ASME BPVC Section activities the CI undertakes

(3) have a record maintained by the Certificate Holder containing objective evidence of the qualifications of the CI and the training provided

(4) have sufficient and well-defined responsibility, authority, and organizational freedom to perform the duties in (c)

(c) *Duties of the Certified Individual.* The CI shall

(1) verify that each item to which the Certification Mark is applied meets all the applicable requirements of this Section and has a current capacity or flow resistance certification for the applicable Designator

(2) review the documentation to verify that requirements of this Section have been completed for each item to which the Certification Mark is applied

(3) sign the appropriate Certificate of Conformance form prior to release of control of the item or items

10.7 CERTIFICATE OF CONFORMANCE (25)

(a) The appropriate Certificate of Conformance [see 10.6(a)] shall be filled out by the Manufacturer or Assembler and signed by the CI. Multiple pressure relief devices may be recorded as a single entry, provided the devices are identical and are released from the CI's control at the same time.

(b) The Manufacturer's or Assembler's written quality management system shall include requirements for completion and retention of the appropriate Certificate of Conformance form.

PART 11
REQUIREMENTS FOR OPEN FLOW PATHS OR VENTS

11.1 APPLICABILITY

Flow paths or vents that open directly or indirectly to the atmosphere may be used as the sole pressure-relieving device as permitted by the referencing Code or Standard.

PART 12 INSTALLATION

12.1 APPLICABILITY

Pressure relief devices shall be installed in accordance with the equipment's code or standard unless the code or standard has also adopted by reference specific requirements of Part 12. For installation requirements not addressed by the code or standard, the guidance in this Part may be used.

12.2 GENERAL

(a) Pressure relief devices shall be installed to minimize the possibility that they will be damaged or otherwise rendered inoperable during expected operating and relieving conditions.

(b) The pressure relief devices on all pressurized equipment shall be so installed that their proper functioning will not be hindered by the nature of the pressurized equipment's contents.

(c) The selection of the pressure relief device or the installation design shall not allow accumulation of rainwater, snow, ice, or debris in the discharge system.

(d) Materials of construction for the relief system shall be selected to minimize deterioration from exposure to the ambient atmosphere and system contents.

12.3 LOCATION

(a) Pressure relief devices shall be selected and located based on normal operation and potential overpressure scenarios. Each installation shall meet the overpressure limits of the referencing Code or Standard.

(1) Normally, pressure relief devices for relief of compressible fluids should be connected to the vapor space above any contained liquid or to piping connected to the vapor space, and pressure relief devices for liquid should be connected below the liquid level.

(2) Alternate connections may be used depending on the selected device and the overpressure scenarios.

(b) Consideration should be given to pressure relief device proximity to the protected equipment or system to ensure pressure during a relief event remains below the maximum allowed relief pressure.

(c) The relief device should be installed in the cleanest portion of the process to avoid plugging, fouling, or other conditions that would adversely affect the operability of the relief device.

(d) Consideration should be given to the pressurized equipment internals and possible obstructions to the relief path.

(e) Pressure relief device testing, inspection, replacement, and repair should be a design consideration for the pressure relief system, including the location of components such as the pressure relief devices, stop valves, telltales and pressure gages.

12.4 RUPTURE DISK INSTALLATION

For rupture disks that are marked with only a lot number in accordance with 4.7.1: Following the installation of the disk, the metal tag shall be sealed to the installation in a manner that will prevent removal of the disk without breaking the seal. The seal shall identify the organization responsible for performing the installation.

12.5 INLET PIPING SYSTEM (25)

(a) The Designer shall consider the effects of the pressure drop during venting in the pressure relief system piping when specifying the set pressures and flow capacities of pressure relief valves and non-reclosing devices.

(b) The pressure drop through the upstream system to the pressure relief valve shall not reduce the relieving capacity below that required to prevent the pressure from exceeding its maximum allowed relief pressure or adversely affect the proper operation, including stability, of the pressure relief valve.

(c) The opening through all equipment nozzles, pipe, fittings, and non-reclosing pressure relief devices (if installed) between the pressurized equipment and its pressure relief valve shall have an area at least equal to the pressure relief valve inlet area.

(d) The design of the inlet line and connection to the pressurized equipment should consider stresses caused by discharge reactive forces and static loads from the relief device.

12.6 MOUNTING OF TWO OR MORE REQUIRED DEVICES

(a) When two or more relief devices are installed on the same line to the equipment being protected, the pressure drop through the upstream system while all devices are relieving shall not reduce the relieving capacity below that

required to prevent the pressure from exceeding its maximum allowed relief pressure.

(b) If one or more pressure relief valves are used, the upstream system shall not adversely affect the proper operation, including stability.

(c) For pressure relief valves, consideration should be given to staggering the set pressures to improve valve stability during operation.

12.7 ORIENTATION OF PRESSURE RELIEF VALVES

Spring-loaded pressure relief valves should be installed in the upright position with the spindle vertical.

(25) 12.8 DISCHARGE PIPING SYSTEM

(a) The size of the discharge lines shall be such that any pressure that may exist or develop will not reduce the relieving capacity of the pressure relief devices below that required to properly protect the pressurized equipment, or adversely affect the proper operation of the pressure relief devices.

(b) The design of the discharge system and associated supports should consider stresses caused by discharge reactive forces and static loads on the relief device.

(c) Discharge lines from pressure relief devices shall be designed to facilitate drainage or fitted with drains to prevent liquid from lodging in the discharge side of the pressure relief device, and such lines shall lead to a safe place of discharge.

(d) When multiple pressure relief devices can discharge through a common stack or vent path, the maximum back pressure that can exist at the exit of each pressure relief device during simultaneous releases shall not impair its operation or limit its capacity below that required to simultaneously protect each pressurized equipment.

12.9 STOP VALVES

See Nonmandatory Appendix B for guidance on the use of stop valves in pressure-relieving systems.

12.10 BONNET VENTING (25)

The bonnet of the pressure relief valves in 3.2.3 and 3.2.10 shall be configured in one of the following ways:

(a) vented to atmosphere

(b) piped to a location that maintains atmospheric pressure

(c) piped to a location that is not at atmospheric pressure provided the user has consulted the device Manufacturer to ensure that the pressure in the bonnet does not interfere with the proper operation of the valve

PART 13
RULES FOR OVERPRESSURE PROTECTION BY SYSTEM DESIGN

(25) ## 13.1 GENERAL

(a) The rules of this Part are applicable only when specified by the referencing Code or Standard.

(b) Pressurized equipment may be provided with overpressure protection by system design in lieu of a pressure relief device or pressure relief devices if all provisions of this Part and the referencing Code or Standard are satisfied.

(25) ## 13.2 PRESSURIZED EQUIPMENT FOR WHICH THE PRESSURE IS SELF-LIMITING

The decision to limit the pressure by system design is the responsibility of the user. Pressurized equipment does not require a pressure relief device if the pressure is self-limiting (e.g., the maximum discharge pressure of a pump or compressor), this pressure is less than or equal to the maximum allowable working pressure (MAWP) of the pressurized equipment at the coincident temperature, and the following conditions are met:

(a) The user shall conduct a detailed analysis to identify and examine all potential overpressure scenarios. The "Causes of Overpressure" described in API Standard 521 [see Table 1.4-1, Note (1)] shall be considered. Other standards or recommended practices that are more appropriate to the specific application may also be considered. A multidisciplinary team experienced in methods such as hazards and operability analysis (HazOp); failure modes, effects, and criticality analysis (FMECA); "what-if" analysis; or other equivalent methodology shall establish that there are no sources of pressure that can exceed the MAWP at the coincident temperature.

(b) The results of the analysis shall be documented and signed by the individual in responsible charge of the management of the operation of the pressurized equipment. This documentation shall include the following, as a minimum:

(1) detailed process flow diagrams (PFDs) and piping and instrument flow diagrams (P&IDs) showing all pertinent elements of the system associated with the pressurized equipment

(2) a description of all operating and upset scenarios, including scenarios involving fire and those that result from operator error, equipment malfunctions, and instrumentation malfunctions

(3) an analysis showing the maximum coincident pressure and temperature that can result from each of the scenarios listed in (2) do not exceed the MAWP at that temperature

13.3 PRESSURIZED EQUIPMENT FOR WHICH THE PRESSURE IS NOT SELF-LIMITING (25)

If the pressure is not self-limiting, pressurized equipment may be protected from overpressure by system design or by a combination of overpressure by system design and pressure relief devices, if the following conditions are met. The rules below are not intended to allow for normal operation above the MAWP at the coincident temperature.

(a) The pressurized equipment is not exclusively in air, water, or steam service except where any of the following apply:

(1) These services are critical to preventing the release of fluids that may result in safety or environmental concerns.

(2) Failure or premature opening of the pressure relief device would result in an unacceptably high probability of failure or damage to the pressurized equipment or other equipment in the system.

(3) Failure or premature opening of the pressure relief device would result in significant operational upset(s).

(b) The decision to limit the overpressure by system design is the responsibility of the user. If no pressure relief device is to be installed, acceptance of the jurisdiction may be required.

(c) The user shall conduct a detailed analysis to identify and examine all scenarios that could result in an overpressure condition and magnitude of the overpressure. The "Causes of Overpressure" as described in API Standard 521 [see Table 1.4-1, Note (1)] shall be considered. Other standards or recommended practices that are more appropriate to the specific application may also be considered. A multidisciplinary team experienced in methods such as hazards and operability analysis (HazOp); failure modes, effects, and criticality analysis (FMECA); "what-if" analysis; or other equivalent methodology shall conduct the analysis.

(d) The overpressure scenario shall be readily apparent so that operators or protective instrumentation will take corrective action to prevent operation above the MAWP at the coincident temperature.

(e) There shall be no credible overpressure scenario in which the pressure exceeds that specified by the referencing Standard for vessels with overpressure protection by system design where the pressure is not self-limiting at or below the vessel MAWP. For example, Section VIII, Division 1 specifies 116% of the MAWP times the ratio of the allowable stress value at the temperature of the overpressure scenario to the allowable stress value at the design temperature. The overpressure limit shall not exceed the vessel test pressure. Credible events or scenario analysis as described in WRC Bulletin 498 shall be considered.

(f) The results of the analysis shall be documented and signed by the individual in responsible charge of the management of the operation of the pressurized equipment. This documentation shall include the following, as a minimum:

(1) detailed process flow diagrams (PFDs) and piping and instrument flow diagrams (P&IDs) showing all pertinent elements of the system associated with the pressurized equipment

(2) a description of all operating and upset scenarios, including those involving fire and those that result from operator error, and equipment and/or instrumentation malfunctions

(3) a detailed description of any safety-critical instrumentation used to limit the system pressure, including the identification of all truly independent redundancies and a reliability evaluation (qualitative or quantitative) of the overall safety system

(4) an analysis showing the maximum pressure that can result from each of the scenarios described in (2)

MANDATORY APPENDIX I
DEFINITIONS

I-1 INTRODUCTION

This Appendix contains definitions of terms generally used in this Section. These terms define pressure relief devices and their functional and operational characteristics and standardize the terminology covering such devices, their characteristics, and testing methods. These definitions and terms shall take precedence should there be any discrepancy with the referenced material for the construction of pressure relief devices.

(23) I-2 DEFINITIONS OF TERMS

40-cc pressure: the value of increasing inlet static pressure of a pressure relief valve at which the discharge of water is measured at 40 cm^3/min.

adjusting ring: a ring used to control the opening characteristics or the reseat pressure, or both, of a direct spring-loaded valve.

adjustment screw: a screw used to adjust the set pressure or the reseat pressure of a reclosing pressure relief device.

Assembler: an organization that holds an ASME Certificate of Authorization to apply the Certification Mark and is responsible for assembly, adjustment, testing, sealing, and shipping of pressure relief devices certified under this Section.

ASME Designated Organization: an entity appointed by ASME to perform an administrative activity in accordance with an applicable code or standard. (ASME CA-1)

ASME Designee: an individual authorized by ASME to perform administrative functions on its behalf. (ASME CA-1)

back pressure: the pressure existing at the outlet of a pressure relief device due to pressure in the discharge system. Back pressure includes built-up back pressure and superimposed back pressure.

built-up back pressure: pressure existing at the outlet of a pressure relief device caused by the flow through that device into a discharge system.

superimposed back pressure: the static pressure existing at the outlet of a pressure relief device at the time the device is required to operate. It is the result of pressure in the discharge system from other sources.

variable back pressure: a superimposed back pressure that will vary with time.

backflow preventer: a part or feature of a pilot-operated pressure relief valve used to prevent the valve from opening and flowing backward when the pressure at the valve outlet is greater than the pressure at the valve inlet.

bellows: a flexible pressure-containing component of a valve used to isolate the valve's bonnet from the valve's discharge or to prevent changes in set pressure when the valve is subjected to a superimposed back pressure or to prevent corrosion between the disk holder and guide.

bench testing: testing of a pressure relief device on a test stand using an external pressure source with or without an auxiliary lift device to determine some or all its operating characteristics.

blowdown: the difference between measured set pressure of a pressure relief valve and measured reseating pressure after having been subjected to a pressure equal to or greater than the set pressure. Blowdown is usually expressed as a percentage of set pressure or in pressure units.

dynamic blowdown: the difference between the set pressure and reseating pressure of a pressure relief valve when the valve is overpressured to the flow-rating pressure.

static blowdown: the difference between the set pressure and the reseating pressure of a pressure relief valve when the valve is not overpressured to the flow-rating pressure.

blowdown ring: see *adjusting ring*.

body: a pressure-retaining or pressure-containing member of a pressure relief device that supports the parts of the valve assembly and has provisions for connecting to the primary and secondary pressure sources, as applicable. Also called valve body.

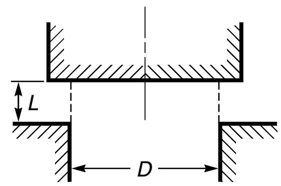
bonnet: a component of a direct spring-loaded valve or of a pilot in a pilot-operated valve that supports the spring. It may or may not be pressure containing.

bore area: the minimum cross-sectional flow area of a nozzle (see Figure I-2-1).

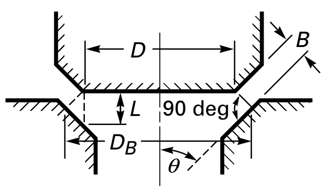
bore diameter: the minimum diameter of a nozzle.

breaking pin: the load-carrying element of a breaking pin non-reclosing pressure relief device.

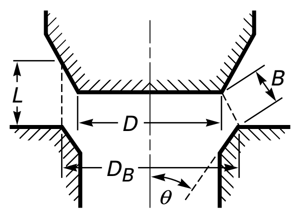
Figure I-2-1
Typical Curtain Areas of Pressure Relief Devices



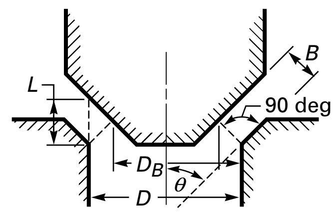
(a) Flat-Seated Valve [Note (1)]



(b-1)

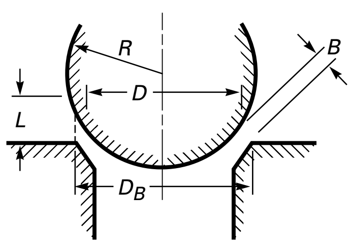


(b-2)

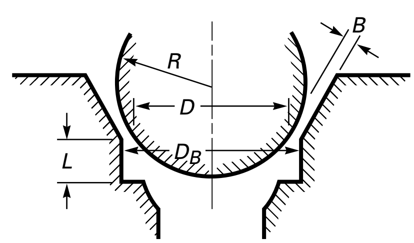


(b-3)

(b) Bevel-Seated Valves [Note (2)]



(c-1)



(c-2)

(c) Radial-Seated Valves [Note (2)]

Legend:
- B = slant height of frustum of cone
- D = seat diameter = smallest diameter at which seat touches disk
- D_B = other diameter of frustum of cone
- L = lift
- R = radius
- Θ = seat angle = angle of seating surface with axis of valve

GENERAL NOTE: Curtain area is the discharge area unless the disk attains sufficient lift for the valve bore to become the controlling area. See I-2, definitions of *actual discharge area*, *bore area*, and *curtain area*.

NOTES:
(1) Curtain area = surface of cylinder = πDL.
(2) Curtain area = surface of frustum of cone = $\pi B \frac{D + D_B}{2}$.

breaking pressure: the value of inlet static pressure at which a breaking pin or shear pin device functions.

bubble pressure: the value of increasing inlet static pressure of a pressure relief valve at which the onset of a continuous stream of bubbles occurs when the valve is tested by means of air or other suitable gas under a specified water seal on the outlet.

buckling pin: the load-carrying element of a buckling pin device.

buckling pressure: the value of inlet static pressure at which a buckling pin device functions.

burst pressure: the value of inlet static pressure at which a rupture disk device functions.

cap: a component used to restrict access and protect the adjustment screw in a reclosing pressure relief device. The cap may or may not be a pressure-containing part.

capacity test pressure: see *flow-rating pressure*

Certificate of Authorization: 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.

Certificate of Compliance: a document that states that the material represented has been manufactured, sampled, tested, and inspected in accordance with the requirements of the material specification (including year of issue) and any other requirements specified in the purchase order or contract shown on the certificate, and has been found to meet such requirements. This document may be combined with a Material Test Report as a single document.

Certification Designator (Designator): the symbol used in conjunction with the Certification Mark for the scope of activity described in a Manufacturer's Certificate of Authorization.

Certification Mark: an ASME symbol identifying a product as meeting ASME BPVC requirements.

Certification Mark stamp: a metallic stamp issued by the Society for use in impressing the Certification Mark.

certified flow resistance, K_R: a dimensionless term that expresses the number of velocity head lost due to flow through a non-reclosing pressure relief device.

chatter: abnormal rapid reciprocating motion of the movable parts of a pressure relief valve in which the disk contacts the seat.

coefficient of discharge: the ratio of the measured relieving capacity to the theoretical relieving capacity.

coincident pressure and temperature: combination of concurrent pressure and temperature that is coincident with a specific operating, design, or relieving condition

cold differential test pressure: the inlet static pressure at which a pressure relief valve is adjusted to open on the test stand. This test pressure includes corrections for service conditions of superimposed back pressure or temperature, or both.

combination device: one non-reclosing pressure relief device 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.

constant backpressure: a superimposed backpressure that is constant with time.

cracking pressure: see *opening pressure*.

curtain area: the area of the cylindrical or conical discharge opening between the seating surfaces created by the lift of the disk above the seat (see Figure I-2-1).

design pressure: the pressure used in the design of a pressure relief device or component together with the coincident design metal temperature, for determining the minimum permissible thickness or physical characteristics of the device, different zones of the device, or device components.

developed lift: the actual travel of the disk from closed position to the position reached when the valve is at flow-rating pressure.

diaphragm: a flexible metallic, plastic, or elastomer pressure-containing member of a reclosing pressure relief device used to sense pressure or provide opening or closing force.

discharge area: see below.

actual discharge area: the measured minimum cross-sectional area that determines the flow through a pressure relief device.

effective discharge area: a nominal or computed area of flow through a pressure relief device, differing from the actual discharge area, for use in recognized flow formulas to determine the capacity of a pressure relief device.

disk: a movable component of a pressure relief device that contains the primary pressure when it rests against the nozzle.

disk holder: a movable component of a pressure relief device that contains the disk (definition does not apply to rupture disks).

dome: the volume on the side of the unbalanced moving member opposite the nozzle in the main relieving valve of a pilot-operated pressure relief device.

effective seat area: a computed area for use in calculating the set pressure of a given pressure relief valve when the valve is tested using an auxiliary lift-assist device.

field test connection: a device for in-service or bench testing of a pilot-operated pressure relief device to measure the set pressure.

field testing: testing of a pressure relief device installed on a system to determine some or all of its operating characteristics. Field testing may be accomplished by either of the following methods:

in-place testing: testing of a pressure relief device installed on but not protecting a system, using an external pressure source, with or without an auxiliary lift device to determine some or all of its operating characteristics.

in-service testing: testing of a pressure relief device installed on and protecting a system, using system pressure or an external pressure source, with or without an auxiliary lift device to determine some or all of its operating characteristics.

first steady stream: the value of increasing static inlet pressure of a pressure relief valve at which liquid discharge flow is continuous and separates from the valve outlet flange or pipe nipple at approximately a 90-deg angle to the outlet centerline.

flow resistance: see *certified flow resistance*.

flow capacity: the relieving capacity of a pressure relief device measured at the flow-rating pressure, expressed in gravimetric or volumetric units.

flow capacity testing: testing of a pressure relief device to determine its operating characteristics, including measured relieving capacity.

flow path: the three-dimensional and geometric characteristics of a device that affects the measured relieving capacity. The flow path is defined from the cross section of the inlet to the cross section of the outlet, including all streamlines in the flow.

flow-rating pressure: the inlet stagnation pressure at which the relieving capacity of a pressure relief device is measured.

flutter: abnormal, rapid reciprocating motion of the movable parts of a pressure relief valve in which the disk does not contact the seat.

full-area stop valve: a valve in which the flow area of the valve is equal to or greater than the inlet flow area of the pressure relief device

fusible plug device: a device designed to function by the yielding or melting of a plug, at a predetermined temperature, that supports a pressure-containing member or contains pressure by itself.

gag: a device used on reclosing pressure relief devices to prevent the device from opening.

gas: a fluid that undergoes a significant change in density as it flows through the pressure relief device.

guide: a component in a direct spring- or pilot-operated pressure relief device used to control the lateral movement of the disk or disk holder.

huddling chamber: the annular pressure chamber between the nozzle exit and the disk or disk holder that produces the lifting force to obtain a pop action.

initial audible discharge pressure: the value of increasing static inlet pressure of a pressure relief valve at which the discharge becomes continuous by hearing with the naked ear as specified by the Manufacturer.

inlet area: the cross-sectional flow area at the inlet opening of a pressure relief device.

inlet size: the nominal pipe size of the inlet of a pressure relief device, unless otherwise designated.

knife blade: a component with multiple blades used with reverse-acting rupture disks to cut the disk when it reverses.

leak test pressure: the specified inlet static pressure at which a quantitative seat leakage test is performed in accordance with a standard procedure.

lift: the actual travel of the disk from closed position to the position reached when the valve is relieving.

lifting device: a device to apply an external force to the stem spindle of a pressure relief valve to manually operate the valve at some pressure below the set pressure. Also called *lifting lever*.

liquid: 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, and of the same size, thickness, type, heat, and manufacturing process, including heat treatment.

main valve: that part of a pilot-operated pressure relief device through which the rated flow occurs during relief.

Manufacturer: an organization that holds an ASME Certificate of Authorization to apply the Certification Mark and is responsible for design, material selection, capacity or flow resistance certification, manufacture of component parts, assembly, adjustment, testing, sealing, and shipping of pressure relief devices certified under this Section.

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 the user's designated agent.

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.

marked breaking pressure: the value of pressure marked on a breaking pin or shear pin device or its nameplate.

marked burst pressure: the value of pressure marked on the rupture disk device or its nameplate or on the tag of the rupture disk, indicating the burst pressure at the coincident disk temperature.

marked relieving capacity: see *rated relieving capacity*.

marked set pressure: the value of pressure marked on the pressure relief device or its nameplate, indicating the nominal pressure at which the device opens.

material: any substance or product form covered by a specification in Section II, Part A, B, or C. Also, any other substance or product form permitted for use in pressure relief device construction by this Section.

material manufacturer: the organization that is responsible for the production of products meeting the requirements of the material specification, and that accepts the responsibility for any statements or data in any required Certificate of Compliance or Material Test Report representing the material.

Material Test Report: a document in which the results of tests, examinations, repairs, or treatments required by the material specification to be reported are recorded, including those of any supplementary requirements or other requirements stated in the order for the material. This document may be combined with a Certificate of Compliance as a single document. When preparing a Material Test Report, a material manufacturer may transcribe data produced by other organizations, provided the material manufacturer accepts responsibility for the accuracy and authenticity of the data.

measured relieving capacity: see *flow capacity*.

minimum net flow area: the calculated net area after a complete activation of the rupture disk or pin device with appropriate allowance for any structural members that may reduce the net flow area through the device.

normal operating condition: a sustained or expected condition that is a stable mode of operation of the equipment or system being protected.

nozzle: a primary pressure-containing component in a pressure relief valve that forms a part or all of the inlet flow passage.

opening pressure: the value of increasing inlet static pressure of a pressure relief valve at which there is a measurable lift or at which the discharge becomes continuous as determined by seeing, feeling, or hearing.

operating pressure: the normal or expected pressure of the fluid in the system or vessel during operation.

operating temperature: the normal or expected temperature of the fluid in the system or vessel during operation. Also called working temperature.

orifice area: see *effective discharge area*.

outlet size: the nominal pipe size of the outlet of a pressure relief device, unless otherwise designated.

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

pilot: the pressure- or vacuum-sensing component of a pilot-operated pressure relief valve that controls the opening and closing of the main valve.

pin temperature: the specified temperature of the pin when an emergency condition exists and the pin is expected to actuate.

piston: the moving element in the main valve of a pilot-operated, piston-type pressure relief valve that contains the seat that forms the primary pressure containment zone when the piston is in contact with the nozzle.

popping pressure: the value of increasing inlet static pressure at which the disk moves in the opening direction at a faster rate as compared with corresponding movement at higher or lower pressures.

pressure-containing member: a component that is exposed to and contains pressure.

pressure relief device: a general term for a device designed to prevent pressure or vacuum from exceeding a predetermined value by the transfer of fluid during emergency or abnormal conditions.

reclosing pressure relief device: a pressure relief device designed to actuate and reclose after operating.

pressure relief valve: a pressure relief device designed to actuate on inlet static pressure and reclose after normal conditions have been restored. It may be one of the following types and have one or more of the following design features:

balanced direct spring-loaded pressure relief valve: a direct spring-loaded pressure relief valve that incorporates means (e.g., balancing bellows, piston, diaphragm) of minimizing the effect of back pressure on the operational characteristics (opening pressure, reseating pressure, and relieving capacity).

conventional direct spring-loaded pressure relief valve: a direct spring-loaded pressure relief valve whose operational characteristics are directly affected by changes in the back pressure.

diaphragm-type direct spring-loaded pressure relief valve: a direct spring-loaded pressure relief valve that uses a diaphragm to boost the lifting forces on the disk and/or isolate the bonnet area from service fluids.

direct spring-loaded pressure relief valve: a pressure relief valve in which the disk is held closed by a spring.

full-bore pressure relief valve: a pressure relief valve in which the bore area is equal to the flow area at the inlet to the valve, and there are no protrusions in the bore.

full-lift pressure relief valve: a pressure relief valve in which the actual discharge area is the bore area.

internal spring pressure relief valve: a direct spring-loaded pressure relief valve whose spring and all or part of the operating mechanism is exposed to the system pressure when the valve is in the closed position.

low-lift pressure relief valve: a pressure relief valve in which the actual discharge area is the curtain area.

pilot-operated pressure relief valve: a pressure relief valve in which the disk is held closed by system pressure, and the holding pressure is controlled by a pilot valve actuated by system pressure.

power-actuated pressure relief valve: a pressure relief valve actuated by an externally powered control device.

reduced-bore pressure relief valve: a pressure relief valve in which the flow path area below the seat is less than the flow area at the inlet to the valve.

relief valve: a spring-loaded pressure relief valve actuated by the static pressure upstream of the valve. The valve opens normally in proportion to the pressure increase over the opening pressure. A relief valve is used primarily with incompressible fluids.

restricted-lift pressure relief valve: a full-lift pressure relief valve whose lift is restricted such that the capacity is reduced proportionally to the ratio of restricted lift to full lift.

safety relief valve: a pressure relief valve characterized by rapid opening (popping) or by gradual opening that is generally proportional to the increase in pressure. It can be used for compressible or incompressible fluids.

safety valve: a pressure relief valve characterized by rapid opening (popping) and normally used to relieve compressible fluids

temperature and pressure relief valve: a pressure relief valve that may be actuated by pressure at the valve inlet or by temperature at the valve inlet.

non-reclosing pressure relief device: a pressure relief device designed to actuate and remain open after operation. A manual resetting means may be provided. A non-reclosing device may be one of the following types and have one or more of the following design features:

breaking pin device: a device designed to function by the breakage of a load-carrying section of a pin that supports a pressure-containing member.

buckling pin device: a device designed to function by the buckling of an axially loaded compressive pin that supports a pressure-containing member.

bursting disk device: see *rupture disk device*.

direct spring-loaded device: a device actuated by static differential pressure or static inlet pressure in which the disk is held closed by a spring. Upon actuation, the disk is held open by a latching mechanism.

frangible disk device: see *rupture disk device*.

full-bore device: a device in which the flow path area below the seat is equal to the flow path area of the inlet to the device.

full-lift device: a device in which the actual discharge area is independent of the lift of the disk.

low-lift device: a device in which the actual discharge area is dependent on the lift of the disk.

pin device: a device actuated by static differential pressure or static inlet pressure and designed to function by the activation of a load-bearing section of a pin that supports a pressure-containing member. A pin is the load-bearing element of a pin device. A pin device housing is the structure that encloses the pressure-containing members.

pilot-operated device: a device in which the disk is held closed by system pressure and the holding pressure is controlled by a pilot actuated by system pressure. The pilot may consist of one of the non-reclosing relief devices listed in this section.

reduced-bore device: a device in which the flow path area below the seat is less than the flow path area of the inlet to the device.

rupture disk device: a device containing a disk that ruptures when the static differential pressure between the upstream and downstream side of the disk reaches a predetermined value. A rupture disk device includes a rupture disk, a rupture disk holder (as applicable), and all other components that are required for the device to function in the prescribed manner.

shear pin device: a device designed to function by the shearing of a load-carrying member that supports a pressure-containing member.

spring-actuated device: a device that is opened or assisted in opening by a spring.

pressure relief system: the fluid flow path and its associated equipment for relieving excessive pressure from the pressurized equipment to final point of discharge. The associated equipment typically includes one or more pressure relief devices, piping, and piping components, and may include a muffler, liquid separator, scrubber, thermal oxidizer, flare, and/or other equipment necessary to safely discharge the effluent.

pressure-retaining member: a component that holds pressure-containing members together but is not exposed to the pressure.

pressurized equipment: equipment designed to operate with internal pressure that is above and/or below atmospheric pressure, such as, but not limited to, vessels, boilers, tanks, and piping.

primary pressure: the pressure at the inlet in a pressure relief device.

rated lift: the design lift at which a valve attains its rated relieving capacity.

rated pressure: the pressure at which a non-reclosing pressure relief device operates to allow relief of pressure at the specified temperature.

rated relieving capacity: that portion of the measured relieving capacity permitted by the applicable code or regulation to be used as a basis for the application of a pressure relief device.

reference conditions: those conditions of a test medium that are specified by either an applicable standard or an agreement between the parties to the test, which may be used for uniform reporting of measured flow test results.

referencing Code or Standard: the code or standard that adopts requirements of Section XIII by reference.

relieving conditions: the inlet pressure and temperature on a pressure relief device during an overpressure condition. The relieving pressure is equal to the valve set pressure or burst (or the rupture disk burst pressure) plus the overpressure. (The temperature of the flowing fluid at relieving conditions may be higher or lower than the operating temperature.)

relieving pressure: set pressure plus overpressure.

resealing pressure: the value of decreasing inlet static pressure at which no further leakage is detected after closing of the pressure relief valve.

reseating pressure: the value of decreasing inlet static pressure at which the valve disk reestablishes contact with the seat or at which lift becomes zero.

rupture disk: the pressure-containing element in a rupture disk device that is designed to burst at its rated pressure at a specified temperature.

rupture disk holder: the structure that clamps a rupture disk in position.

seat: the pressure-sealing surfaces of the fixed and moving pressure-containing components.

seat angle: the angle between the axis of a valve and the seating surface. A flat-seated valve has a seat angle of 90 deg (see Figure I-2-1).

seat diameter: the smallest diameter of contact between the fixed and moving portions of the pressure-containing elements of a valve.

secondary pressure: the pressure existing in the passage between the actual discharge area and the device outlet in a pressure relief device.

set pressure: the value of increasing (or decreasing) inlet static pressure at which a pressure relief device displays one of the operational characteristics as defined by *40-cc pressure*, *breaking pressure*, *bubble pressure*, *buckling pressure*, *burst pressure*, *first-steady stream*, *initial audible discharge pressure*, *opening pressure*, *popping pressure*, or *start-to-leak pressure*.

shear pin: the load-carrying element of a shear pin device.

shell: an assembly of pressure-containing members that isolate primary or secondary pressure from atmosphere. Examples of these members include, but are not limited to, the body, nozzle, bonnet, and cap for a direct spring-loaded pressure relief valve using a pressurized bonnet; the nozzle and disk for a direct spring-loaded pressure relief valve using a yoke or open bonnet; and the body and cap of the main valve and the body of the pilot for a pilot-operated pressure relief valve.

simmer: the audible or visible escape of fluid between the seat and disk at an inlet static pressure below the popping pressure and at no measurable capacity. Can also be a warning that the pressure relief device is about to relieve. Simmer applies to safety or safety relief valves on compressible fluid service.

specified burst pressure: the value of increasing inlet static pressure, at a specified temperature, at which a rupture disk is designed to function.

specified disk temperature: the specified temperature of the disk at which the disk is expected to burst.

spindle: a part whose axial orientation is parallel to the travel of the disk. A spindle may be used in one or more of the following functions: assist in alignment, guide disk travel, or transfer internal or external forces.

spring: the element in a pressure relief valve that provides the force to keep the disk on the nozzle.

spring button: see *spring step.*

spring step: a load-transferring component in a pressure relief valve that supports the spring.

spring washer: see *spring step.*

start-to-discharge pressure: see *opening pressure.*

start-to-leak pressure: the value of increasing inlet static pressure at which the first bubble occurs when a pressure relief valve is tested by means of air under a specified water seal on the outlet.

theoretical relieving capacity: the computed capacity expressed in gravimetric or volumetric units of a theoretically perfect nozzle having a minimum cross-sectional flow area equal to the actual discharge area of a pressure relief valve or net flow area of a non-reclosing pressure relief device.

two-phase: term used to describe a fluid that contains a combination of both liquid and gas phases in a single flow stream.

user: the organization that purchases the finished equipment for its own use or as an agent for the owner. The user's designated agent may be either a design agency specifically engaged by the user, the Manufacturer of a system for a specific service that includes a pressure relief device as a part and that is purchased by the user, or an organization that offers the equipment for sale or lease for specific services.

vacuum support: a component of a rupture disk to prevent flexing due to upstream vacuum or downstream back pressure.

warn: see *simmer*.

yield temperature: the temperature at which the fusible material of a fusible plug device becomes sufficiently soft to extrude from its holder and relieve pressure. Also called *melt temperature.*

yoke: a pressure-retaining component in a pressure relief device that supports the spring in a pressure relief valve or pin in a non-reclosing device but does not enclose them from the surrounding ambient environment.

MANDATORY APPENDIX II ADHESIVE ATTACHMENT OF NAMEPLATES

(25)

II-1 SCOPE

This Appendix covers minimum requirements for the use of adhesive systems for the attachment of nameplates. The use of adhesive-backed nameplates shall

(a) be limited to pressure-sensitive acrylic adhesives that have been preapplied by the nameplate manufacturer to a nominal thickness of at least 0.13 mm (0.005 in.) and that are protected with a moisture-stable liner

(b) be used on pressure relief devices with design temperatures within the range of −40°C to 150°C (−40°F to 300°F)

(c) be applied to clean, bare metal surfaces, with attention being given to removal of antiweld spatter compound that may contain silicone

(d) have been prequalified as outlined in II-2

(e) be used within 2 yr of its initial application on the nameplate

II-2 NAMEPLATE APPLICATION PROCEDURE QUALIFICATION

(a) The Manufacturer's quality control system (see Mandatory Appendix III) shall define that written procedures, acceptable to the ASME Designated Organization, for the application of adhesive-backed nameplates shall be prepared and qualified.

(b) Each procedure for the attachment of nameplates by use of pressure-sensitive acrylic adhesive systems shall be qualified for outdoor exposure in accordance with UL 969, and the following additional requirements:

(1) Width of nameplate test strip shall not be less than 25 mm (1 in.).

(2) Nameplates shall have an average adhesion of not less than 1.4 N·mm (8 lbf-in.) of width after all exposure conditions, including low temperature.

(c) The application procedure qualification shall include the following essential variables, based on the adhesive and nameplate manufacturer's recommendations, where applicable:

(1) description of the pressure-sensitive acrylic adhesive system used, including generic composition.

(2) the qualified temperature range [the cold-box test temperature shall be −40°C (−40°F) for all applications].

(3) materials of the nameplate and substrate when the mean coefficient of expansion at the design temperature of one material is less than 85% of that for the other material.

(4) finish of the nameplate and substrate surfaces.

(5) the nominal thickness and modulus of elasticity at application temperature of the nameplate when nameplate preforming is used. A change of more than 25% in the value of N will require requalification:

$$N = t^2 \times M$$

where

M = nameplate modulus of elasticity at application temperature, N·m^2 (psi)

N = force, N (lbf)

t = nameplate nominal thickness, mm (in.)

(6) the qualified range of preformed nameplate and companion substrate contour combinations when preforming is used.

(7) cleaning requirements for the substrate.

(8) application temperature range and application pressure technique.

(9) application steps and safeguards.

(d) Any change to the variables in (c) shall require requalification.

(e) Each lot or package of nameplates shall be identified with the adhesive application date.

MANDATORY APPENDIX III QUALITY CONTROL SYSTEM

III-1 GENERAL

(a) The Manufacturer or Assembler shall have and maintain a quality control system that will establish that all ASME BPVC requirements, including those for material, design, manufacture, and examination (by the Manufacturer or Assembler), and inspection (by the ASME Designee) of relief devices, will be met. The quality control system shall include duties of a Certified Individual (CI), as required by this Section. The CI authorized to provide oversight may also serve as the Certificate Holder's authorized representative responsible for signing Certificates of Conformance. Provided that ASME BPVC requirements are suitably identified, the system may include provisions for satisfying any requirements of the Manufacturer, Assembler, or user that exceed minimum ASME BPVC requirements, and may include provisions for quality control of non-Code work. In such systems, the Manufacturer or Assembler may make changes in parts of the system that do not affect the ASME BPVC requirements without securing acceptance by the ASME Designee. Before implementation, revisions to quality control systems of Manufacturers and Assemblers of pressure relief devices shall have been found acceptable by an ASME Designee if such revisions affect ASME BPVC requirements.

(b) The system that the Manufacturer or Assembler uses to meet the requirements of this Section must be one suitable for their 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 or Assembler's organization.

(c) A written description of the system the Manufacturer or Assembler will use to produce an ASME BPVC item shall be available for review. Depending upon the circumstances, the description may be brief or voluminous.

(d) The written description may contain information of proprietary nature relating to the Manufacturer's or Assembler's processes. Therefore, the ASME BPVC does not require any distribution of this information except to the ASME Designee. It is intended that information learned about the system in connection with evaluation will be treated as confidential and that all loaned descriptions will be returned to the Manufacturer or Assembler upon completion of the evaluation.

III-2 OUTLINE OF FEATURES INCLUDED IN THE QUALITY CONTROL SYSTEM

Paragraphs III-2.1 through III-2.14 provide guidance on some of the features that should be covered in the written description of the quality control system; the information is equally applicable to both shop and field work.

III-2.1 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, and the authority and organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

III-2.2 Organization

An organization chart showing the relationship between management and engineering, purchasing, manufacturing, 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 ASME BPVC 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 ASME BPVC work.

III-2.3 Drawings, Design Calculations, and Specifications Control

The Manufacturer's or Assembler's quality control system shall provide procedures that will ensure that the latest applicable drawings, design calculations, specifications, and instructions required by the ASME BPVC, as well as authorized changes, are used for manufacture, assembly, examination, inspection, and testing.

III-2.4 Material Control

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

III-2.5 Examination and Inspection Program

The Manufacturer's or Assembler's quality control system shall describe the manufacture, assembly, and inspection operations, including examinations and the stages at which specific inspections are to be performed.

III-2.6 Correction of Nonconformities

There shall be a system for correction of nonconformities. A nonconformity is any condition that does not comply with the applicable rules of this Section. Nonconformities must be corrected or eliminated in some way before the completed pressure relief device can be considered to comply with this Section.

III-2.7 Welding

The quality control system shall include provisions for indicating that welding conforms to requirements of Section IX as supplemented by this Section.

III-2.8 Nondestructive Examination

The quality control system shall include provisions for identifying nondestructive examination (NDE) procedures the Manufacturer will apply to conform with requirements of this Section. Section V, Article 1 shall be applied for the qualification of NDE procedures and for the certification of NDE personnel unless otherwise specified in this Section.

III-2.9 Heat Treatment

The quality control system shall provide controls to ensure that heat treatments as required by the rules of this Section are applied. It shall indicate the means by which the Inspector for the ASME Designated Organization may verify that these requirements have been met. This may be by review of heat treatment time–temperature records or by other methods, as appropriate.

III-2.10 Calibration of Measurement and Test Equipment

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

III-2.11 Records Retention

The Manufacturer or Assembler shall have a system for the maintenance of Certificates of Conformance and records as required by this Section.

(a) The Manufacturer or Assembler shall maintain the following documents for a period of at least 3 yr:

(1) manufacturing drawings

(2) design calculations including any applicable Proof Test Reports

(3) Material Test Reports and/or Material Certifications

(4) Welding Procedure Specifications and Procedure Qualification Records

(5) Welding or Welding Operator Performance Qualification Records

(6) nondestructive examination reports

(7) heat treatment records and test results

(8) postweld heat treatment records

(9) nonconformance and disposition records

(10) transfer form, if applicable

(b) The Manufacturer or Assembler shall maintain the Manufacturer's Certificate of Conformance for a period of at least 5 yr.

III-2.12 Sample Forms

The forms used in the 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.

III-2.13 Inspection of Pressure Relief Devices

(a) Inspection of manufacturing or assembly of pressure relief devices shall be by a representative of an ASME Designated Organization, as described in this Section.

(b) The written description of the quality control system shall include reference to the CI and 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 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 the Designee's duties in accordance with this Section. The Manufacturer or Assembler may provide such access either by making their own files of such documents available to the ASME Designee or by providing copies.

III-2.14 Certifications

(a) The Certificate of Compliance and the Material Test Report may be combined as a single document. The preparing organization accepts responsibility for the accuracy and authenticity of the data.

(b) Methods other than written signature may be used for indicating certifications, authorizations, and approval where allowed and as described elsewhere in this Section. If such alternative methods are used, controls and safeguards shall be provided and described to ensure the integrity of the certification, authorization, and approval.

MANDATORY APPENDIX IV
CAPACITY CONVERSION

(25) IV-1 INTRODUCTION

(a) The capacity of a pressure relief device in terms of a gas or vapor other than the medium for which the device was officially rated shall be determined by application of the equations given in IV-2(a) and IV-2(b).

(b) If the actual discharge area of the pressure relief device, A, and the coefficient of discharge, K, are not known, the official rated capacity of the pressure relief device, which is marked on the device, can be used to determine the overall value of KA, as follows:

Official Rating in Steam

$$KA = \frac{W_s}{C_N P}$$

Official Rating in Air

$$KA = \frac{W_a}{CP}\sqrt{\frac{T}{M}}$$

where

A = actual discharge area through the device at developed lift, mm^2 (in.^{2})

C = constant for gas or vapor, which is function of the ratio of specific heats, $k = c_p/c_v$ [see Figure IV-1-1M (Figure IV-1-1)]

C_N = Napier constant
= 5.25 for SI calculations
= 51.5 for U.S. Customary calculations

K = coefficient of discharge (see 9.7.6)

M = molecular weight (see Table IV-3-1)

P = (set pressure × 1.10) + atmospheric pressure, MPa_{abs} (psia)

T = absolute gas temperature at the inlet, K (°R)
K = °C + 273
°R = °F + 460

W_a = rated capacity at inlet temperature, converted to kg/h of air at 20°C (lbm/hr of air at 60°F)

W_s = rated capacity, kg/h (lbm/hr) of steam

This value for KA is then substituted into the equations given in IV-2(a) and IV-2(b) to determine the capacity of the pressure relief device in terms of the new gas or vapor.

IV-2 EQUATIONS FOR DETERMINING CAPACITY (25)

For all equations, nomenclature is as defined in IV-1(b) and as noted below.

(a) For steam

$$W_s = C_N KAP$$

where

C_N = 5.25 for SI calculations
= 51.5 for U.S. Customary calculations

(b) The following equations are for low-pressure gases and vapors (gases or vapors at pressures less than two-thirds of their critical pressure):

(1) For air

$$W_a = CKAP\sqrt{\frac{M}{T}}$$

where

C = 27.03 for SI calculations
= 356 for U.S. Customary calculations

M = 28.97 (see Table IV-3-1)

T = 293K for SI calculations when W_a is the rated capacity
= 520°R for U.S. Customary calculations when W_a is the rated capacity

(2) For any gas or vapor with linear thermodynamic properties through the device

$$W = CKAP\sqrt{\frac{M}{TZ}}$$

where

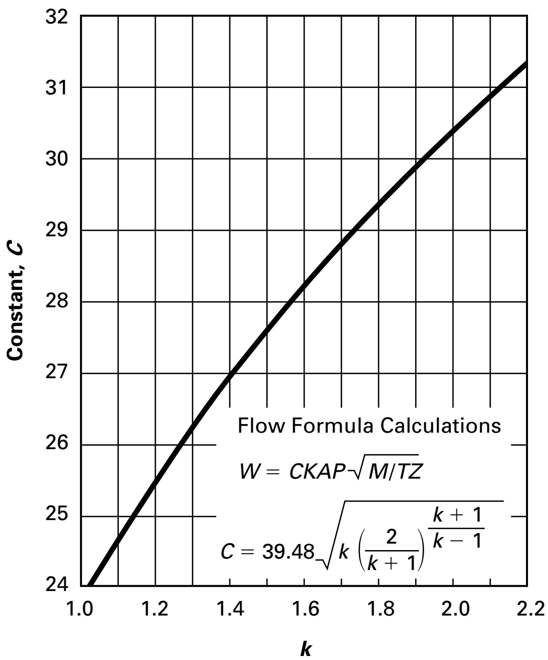
W = flow of any gas or vapor, kg/h (lbm/hr)

Z = compressibility factor

(c) The equation in (b)(2) may also be used when the required flow of any gas or vapor is known and it is necessary to compute the rated capacity of steam or air.

Figure IV-1-1M
Constant, *C*, for Gas or Vapor Related to Ratio of Specific Heats ($k = c_p/c_v$)

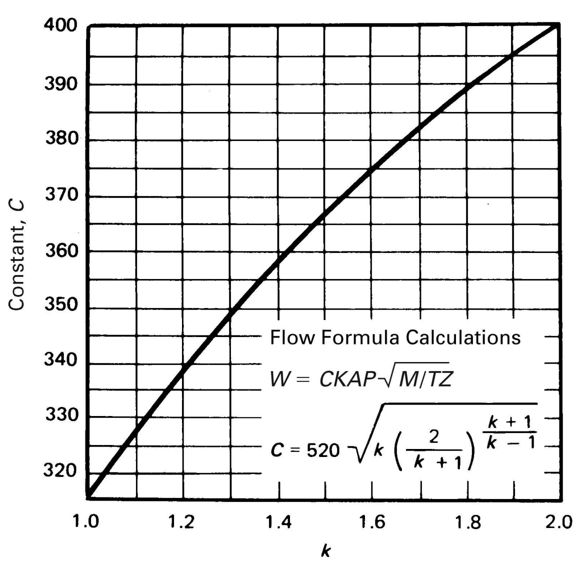
(25)



k	Constant, *C*	*k*	Constant, *C*	*k*	Constant, *C*
1.001	23.95	1.26	26.05	1.52	27.80
1.02	24.12	1.28	26.20	1.54	27.93
1.04	24.30	1.30	26.34	1.56	28.05
1.06	24.47	1.32	26.49	1.58	28.17
1.08	24.64	1.34	26.63	1.60	28.29
1.10	24.81	1.36	26.76	1.62	28.40
1.12	24.97	1.38	26.90	1.64	28.52
1.14	25.13	1.40	27.03	1.66	28.63
1.16	25.29	1.42	27.17	1.68	28.74
1.18	25.45	1.44	27.30	1.70	28.86
1.20	25.60	1.46	27.43	2.00	30.39
1.22	25.76	1.48	27.55	2.20	31.29
1.24	25.91	1.50	27.68	. . .	. . .

Figure IV-1-1
Constant, *C*, for Gas or Vapor Related to Ratio of Specific Heats ($k = c_p/c_v$)

(25)



k	Constant, *C*	*k*	Constant, *C*	*k*	Constant, *C*
1.001	315	1.26	343	1.52	366
1.02	318	1.28	345	1.54	368
1.04	320	1.30	347	1.56	369
1.06	322	1.32	349	1.58	371
1.08	324	1.34	351	1.60	372
1.10	327	1.36	352	1.62	374
1.12	329	1.38	354	1.64	376
1.14	331	1.40	356	1.66	377
1.16	333	1.42	358	1.68	379
1.18	335	1.44	359	1.70	380
1.20	337	1.46	361	2.00	400
1.22	339	1.48	363	2.20	412
1.24	341	1.50	364	. . .	. . .

(d) For hydrocarbon vapors, where the actual value of k is not known, the conservative value k = 1.00 has been commonly used and the equation becomes

$$W = CKAP\sqrt{\frac{M}{T}}$$

where

C = 24 for SI calculations
= 315 for U.S. Customary calculations

(e) For gas pressure service above the pressure limits given in IV-1, and for liquid service, additional consideration shall be given to the fact that the actual flow capacity of a given pressure relief device may be influenced by any of the following:

(1) fluid conditions close to or above the critical point

(2) liquid flashing to vapor and other phase changes that may occur and cause a two-phase or multiphase flow regime in the device

(3) conditions in which decomposition reactions occur and the chemical composition of the resulting fluid cannot be definitively established

The user or the user's designated agent shall be responsible for establishing a procedure for sizing and/or flow capacity conversion based on the pressure relief device geometry, as well as the change in fluid conditions and fluid properties during flow through the device 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.

(f) The saturated water capacity of a pressure relief device currently rated under Part 9 can be determined from Figure IV-2-1M (Figure IV-2-1), as described in (1) and (2) below. However, since the saturated water capacity is configuration sensitive, the following method applies only to those pressure relief devices that have a nozzle-type construction (bore-to-inlet-diameter ratio of 0.25 to 0.80 with a continuously contoured change) and that have exhibited a coefficient K_D in excess of 0.90. No saturated water rating shall apply to other types of construction. The method is as follows:

(1) Enter the graph in Figure IV-2-1M (Figure IV-2-1) at the set pressure of the device.

(2) Move vertically upward to the saturated water line, and read horizontally to determine the relieving capacity. This capacity is the theoretical, isentropic value arrived at by assuming equilibrium flow and calculated values for the critical pressure ratio.

NOTE: The Manufacturer, user, and Inspector are all cautioned that for the rating determined as described in (1) and (2) to apply, the device shall be continuously subjected to saturated water. If after initial relief the flow fluid changes to quality steam, the device shall be rated as per dry saturated steam. Devices installed on vessels or lines containing steam–water mixture shall be rated on dry saturated steam.

IV-3 CAPACITY CONVERSION EXAMPLES

Table IV-3-1 lists the molecular weights for common gases and vapors, which are used in the examples.

IV-3.1 EXAMPLE 1

GIVEN: A pressure relief device bears a certified capacity rating of 1 370 kg/h (3,020 lbm/hr) of steam for a pressure setting of 1.40 MPa (200 psi).

PROBLEM: What is the relieving capacity of that device in terms of air at 40°C (100°F) for the same pressure setting?

SOLUTION:

(a) For steam

$$W_s = C_N KAP$$

(SI Units)

$$W_s = 5.25KAP$$

$$1\,370 = 5.25KAP$$

$$KAP = \frac{1\,370}{5.25} = 261$$

(U.S. Customary Units)

$$W_s = 51.5KAP$$

$$3{,}020 = 51.5KAP$$

$$KAP = \frac{3{,}020}{51.5} = 58.5$$

(b) For air

$$W_a = CKAP\sqrt{\frac{M}{T}}$$

(SI Units)

$$\begin{aligned} W_a &= 27.03KAP\sqrt{\frac{28.97}{40+273}} \\ &= (27.03)(261)\sqrt{\frac{28.97}{313}} \\ &= 2\,146\ \text{kg/h} \end{aligned}$$

Figure IV-2-1M
Flow Capacity Curve for Rating Nozzle-Type Pressure Relief Devices on Saturated Water (Based on 10% Overpressure)

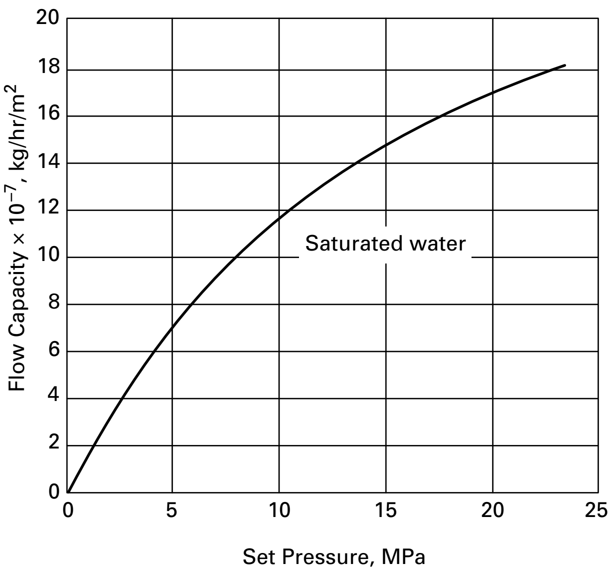
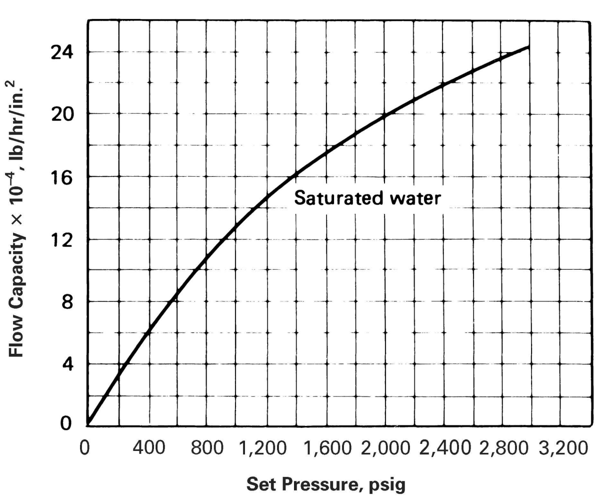


Figure IV-2-1
Flow Capacity Curve for Rating Nozzle-Type Pressure Relief Devices on Saturated Water (Based on 10% Overpressure)



(U.S. Customary Units)

$$\begin{aligned} W_a &= 356KAP\sqrt{\frac{28.97}{100 + 460}} \\ &= (356)(58.5)\sqrt{\frac{28.97}{560}} \\ &= 4{,}750 \text{ lbm/hr} \end{aligned}$$

IV-3.2 EXAMPLE 2

GIVEN: It is required to relieve 2,270 kg/h (5,000 lbm/hr) of propane from a pressure vessel through a pressure relief device set to relieve at a pressure of P_s [in megapascals (pounds force per square inch)] and with an inlet temperature at 50°C (125°F).

PROBLEM: What total capacity in kilograms (pounds mass) of steam per hour must the pressure relief device be capable of providing?

SOLUTION:

(a) For propane

$$W = CKAP\sqrt{\frac{M}{T}}$$

The value of C is not definitely known. Use the conservative value: C = 24 for SI units (315 for U.S. Customary units).

(SI Units)

$$2\,270 = 24KAP\sqrt{\frac{44.09}{50 + 273}}$$

$$KAP = 256.0$$

Table IV-3-1
Molecular Weights of Gases and Vapors

Gas or Vapor	Molecular Weight	Gas or Vapor	Molecular Weight
Air	28.97	Freon 114	170.90
Acetylene	26.04	Hydrogen	2.02
Ammonia	17.03	Hydrogen sulfide	34.08
Butane	58.12	Methane	16.04
Carbon dioxide	44.01	Methyl chloride	50.48
Chlorine	70.91	Nitrogen	28.02
Ethane	30.07	Oxygen	32.00
Ethylene	28.05	Propane	44.09
Freon 11	137.371	Sulfur dioxide	64.06
Freon 12	120.9		
Freon 22	86.48		

(U.S. Customary Units)

$$5{,}000 = 315KAP\sqrt{\frac{44.09}{125 + 460}}$$

$$KAP = 57.7$$

(b) For steam

(SI Units)

$$\begin{aligned} W_s &= 5.25KAP = 5.25 \times 256.0 \\ &= 1\,344 \text{ kg/h set to relieve at } P_s\text{, MPa} \end{aligned}$$

(U.S. Customary Units)

$$\begin{aligned} W_s &= 51.5\,KAP = 51.5 \times 57.7 \\ &= 2{,}970 \text{ lbm/hr set to relieve at } P_s\text{, psi} \end{aligned}$$

IV-3.3 EXAMPLE 3

GIVEN: It is required to relieve 450 kg/h (1,000 lbm/hr) of ammonia from a pressure vessel at 65°C (150°F).

PROBLEM: What is the required total capacity in kilograms (pounds mass) of steam per hour at the same pressure setting?

SOLUTION:

(a) For ammonia

$$W = CKAP\sqrt{\frac{M}{T}}$$

The Manufacturer and the user agree to use k = 1.33; interpolated from Figure IV-1-1M (Figure IV-1-1), C = 26.56 for SI units (350 for U.S. Customary units).

(SI Units)

$$450 = 26.56KAP\sqrt{\frac{17.03}{65 + 273}}$$

$$KAP = 75.48$$

(U.S. Customary Units)

$$1{,}000 = 350KAP\sqrt{\frac{17.03}{150 + 460}}$$

$$KAP = 17.10$$

(b) For steam

(SI Units)

$$\begin{aligned} W_s &= 5.25KAP = 5.25 \times 75.48 \\ &= 396 \text{ kg/h} \end{aligned}$$

(U.S. Customary Units)

$$\begin{aligned} W_s &= 51.5KAP = 51.5 \times 17.10 \\ &= 880 \text{ lbm/hr} \end{aligned}$$

IV-3.4 EXAMPLE 4

GIVEN: A pressure relief device bearing a certified rating of 285 m^3/min (10,000 ft^3/min) of air at 20°C (60°F) and 101.3 kPa_{abs} (14.7 psia) (atmospheric pressure). The weight of dry air at atmospheric pressure is 1.225 kg/m^3 (0.0766 lbm/ft^3).

PROBLEM: What is the flow capacity of this device in kilograms (pounds mass) of saturated steam per hour for the same pressure setting?

SOLUTION:

(a) For air

(1) Convert the certified rated capacity to kilograms per hour (pounds mass per hour).

$$\begin{aligned} W_a = {} & \text{rated capacity in m}^3\text{/min}\left(\text{ft}^3\text{/min}\right) \\ & \times \text{weight of dry air at atmospheric pressure} \times \text{min/hr} \end{aligned}$$

(SI Units)

$$W_a = 285 \times 1.225 \times 60 = 20\,947 \text{ kg/h}$$

(U.S. Customary Units)

$$W_a = 10{,}000 \times 0.0766 \times 60 = 45{,}960 \text{ lbm/hr}$$

(2) Determine *KAP.*

(SI Units)

$$20\,947 = 27.03KAP\sqrt{\frac{28.97}{20 + 273}}$$

$$KAP = 2\,464$$

(U.S. Customary Units)

$$45{,}960 = 356KAP\sqrt{\frac{28.97}{60 + 460}}$$

$$KAP = 546$$

(b) For steam

(SI Units)

$$\begin{aligned} W_s &= 5.25KAP = 5.25 \times 2\,464 \\ &= 12\,939 \text{ kg/h} \end{aligned}$$

(U.S. Customary Units)

$$W_s = 51.5KAP = 51.5 \times 546 = 28{,}119\ \text{lbm/hr}$$

NOTE: Before the capacity of a pressure relief device is converted from any gas to steam, the requirements of 9.7.1 must be met.

(25) IV-4 EQUATIONS FOR CONVERSION (INCOMPRESSIBLE FLUIDS)

(a) General. The capacity of a pressure relief valve in terms of a nonflashing liquid other than the fluid for which the valve was officially rated shall be determined by the following equation:

$$W_t = CKA\sqrt{(P - P_d)\rho}$$

where

- A = actual discharge area of valve, mm^2 (in.^{2})
- C = 5.092 for SI units
  = 2,407 for U.S. Customary units
- K = coefficient of discharge
- P = (set pressure × 1.10) + atmospheric pressure, MPa_{abs} (psia)
- P_d = pressure at discharge from valve, MPa_{abs} (psia)
- W_t = rated capacity, kg/h (lb/hr) of any liquid
- ρ = density of liquid at value inlet conditions, kg/m^3 (lb/ft^3)

The volumetric capacity of a pressure relief valve in terms of a nonflashing liquid other than the fluid for which the valve was officially rated may be determined by the following equation:

$$Q_l = C_l KA\sqrt{\frac{(P - P_d)}{G}}$$

where

- A = actual discharge area through the device at developed lift, mm^2 (in.^{2})
- C_l = 2.685 for SI units
  38 for U.S. Customary units
- G = specific gravity of the fluid at device inlet conditions relative to water at 20°C (70°F)
- K = coefficient of discharge
- P = absolute relieving pressure, MPa (psia)
- P_d = absolute discharge pressure, MPa (psia)
- Q_l = liquid volumetric capacity, L/min (gpm)

Using the liquid rated capacity marked on the pressure relief valve, it is possible to determine the overall value of *KA* by rearranging the preceding equation when the value of the individual terms is not known:

$$KA = \frac{Q_w}{C_l}\sqrt{\frac{G_w}{(P - P_d)}}$$

where

- G_w = specific gravity of water at 20°C (70°F) relative to water at 20°C (70°F)
  = 1
- Q_w = liquid volumetric rated capacity, L/min (gpm), of water at 20°C (70°F)

(b) Example

GIVEN: A pressure relief valve bears a certified rating of 5 678 L/min (1,500 gpm) water at 20°C (70°F) with a set pressure of 0.827 MPag (120 psig).

PROBLEM: What is the the flow capacity of this pressure relief valve in liters (gallons) of kerosene (specific gravity = 0.82) per minute at the same pressure rating?

SOLUTION:

(1) For water at 20°C (70°F)

(SI Units)

$$KA = \frac{5\,678}{2.685}\sqrt{\frac{1}{(1.0111 - 0.1013)}} = 2\,217.2\ \text{mm}^2$$

(U.S. Customary Units)

$$KA = \frac{1{,}500}{38}\sqrt{\frac{1}{(146.7 - 14.7)}} = 3.436\ \text{in.}^2$$

(2) For kerosene

(SI Units)

$$Q_l = 2.685(2\,217.2)\sqrt{\frac{(1.0111 - 0.1013)}{0.82}}$$

$$Q_l = 6\,270.3\text{L/min}$$

(U.S. Customary Units)

$$Q_l = 38(3.436)\sqrt{\frac{(146.7 - 14.7)}{0.82}}$$

$$Q_l = 1{,}656.4\ \text{gpm}$$

MANDATORY APPENDIX V PERFORMANCE TESTING OF PRESSURE RELIEF DEVICES

(25)

ARTICLE V-I GENERAL

V-1.1 OBJECT

The object of the test is to determine the performance of pressure relief devices. These tests determine one or more of the following:

(a) dimensional, operational, and mechanical characteristics

(b) relieving pressure

(c) relieving flow capacity at test pressure

(d) individual flow resistance

Procedures for conducting the tests, calculating the results, and making corrections are defined.

V-1.2 SCOPE

(a) This Appendix provides instructions in Article V-2 for flow capacity testing and in Article V-3 for in-service and bench testing. Testing of reclosing and non-reclosing pressure relief devices is conducted under various inlet and outlet conditions using steam, gases, and liquids for which valid physical properties are known.

(b) The validity of tests shall be determined in accordance with the requirements of V-1.3.

V-1.3 MEASUREMENT UNCERTAINTY

In order to qualify as a valid test in accordance with this Appendix, the total uncertainties of the test, as calculated by the procedures of ASME PTC 19.1, shall be equal to or less than the values of maximum acceptable uncertainty. The maximum acceptable uncertainty of the final flow measurement shall not exceed ±2.0% of the measured value. For results other than flow measurements, the maximum acceptable uncertainty shall not exceed ±0.5% of the measured value as determined in accordance with Article V-2 or ±1.0% of the measured value as determined in accordance with Article V-3.

An example calculation showing the various methods used to establish meaningful estimates for the limits of uncertainty of a final flow measurement is provided in Nonmandatory Appendix D.

V-1.4 GENERAL

(a) It is assumed that the testing facility has adequate capacity and sufficient pressure to conduct the tests. However, the users of this Appendix are cautioned that the capacity and pressure limitations of the testing facility may restrict the determination of satisfactory operating conditions and other operational features of the pressure relief device.

(b) In addition, field installation or abnormal operating conditions, or both, may adversely affect the function of the pressure relief device. It is not the intent of this Appendix to attempt to assess the suitability or reliability of the pressure relief device under such conditions. It should also be noted that if the temperature of the medium used to test the pressure relief device differs substantially from the temperature to which the pressure relief device is subjected while in service, the functional characteristics will be different from the test pressures, i.e., opening, closing, blowdown, and bursting pressure. In this case, it is necessary to develop appropriate corrections for the pressure relief device under test to account for these differences, which is outside the scope of this Appendix.

(c) This Appendix provides recommended test procedures and instrumentation for testing devices. Other test procedures or instrumentation may be used provided they can be demonstrated as having accuracy and reliability at least equal to the requirements of this Appendix. If another procedure or instrumentation will be used, it is subject to written agreement by the parties to the test prior to the test.

(d) The test results shall be reported as measured and calculated. Only tests that comply fully with the mandatory requirements of this Appendix may be designated as tests conducted in accordance with this Appendix. Should any specific direction in this Appendix, or any particular measurement, differ from those given in other ASME Performance Test Codes for similar measurements, the instructions of this Appendix shall prevail.

(e) In some cases, the testing of pressure relief devices may involve the use of high-pressure and high-temperature fluid. Hazards to personnel will exist unless adequate precautionary measures are taken. Special consideration should be given to adequate design and overpressure

protection to the piping system and components, safe discharge from the pressure relief devices undergoing testing, and the high noise level usually associated with the discharge of pressure relief devices. The users of this Appendix should consult the authority having jurisdiction over these safety matters to ensure the testing facility meets the mandatory requirements.

V-1.5 NOMENCLATURE

The following nomenclature is used in this Appendix. The terms defined below shall take precedence should there be any discrepancy with the referenced material.

a = minimum net flow area, in.^{2} (mm^2)
a_d = actual discharge area, in.^{2} (mm^2)
a_m = meter-bore area, in.^{2} (m^2)
C = valve-inlet temperature correction
= discharge coefficient, dimensionless
C_{tap} = sonic velocity at pressure tap, ft/sec (m/s)
C^* = critical flow function
D = test rig inside diameter, ft (m)
= internal diameter of meter run pipe, in. (m)
d = meter-bore diameter, in. (m)
d_b = minimum holder bore diameter, in. (mm)
= bore diameter, in. (mm)
d_o = diameter of orifice plate, in. (mm)
d_s = seat diameter, in. (mm)
E = pipe roughness, in. (mm)
f = fanning friction factor, dimensionless
F_a = area factor for thermal expansion, dimensionless
G = mass velocity, lbm/ft^2-sec (kg/m^2-s)
= specific gravity with respect to dry air, M/M_a
h_w = differential pressure at the meter, in. water (mm water)
K = flow coefficient
= $\dfrac{c}{\sqrt{1-\beta^4}}$
k = ratio of specific heats
$K_{A\text{-}B}$ = resistance factor between pressure taps A and B
$K_{B\text{-}C}$ = resistance factor between pressure taps B and C
$K_{B\text{-}D}$ = resistance factor between pressure taps B and D
$K_{C\text{-}D}$ = resistance factor between pressure taps C and D
K_o = trial flow coefficient
$K_{pipe\ B\text{-}C}$ = pipe resistance factor between pressure taps B and C without the rupture disk device
$K_{pipe\ B\text{-}D}$ = pipe resistance factor between pressure taps B and D without the rupture disk device
K_{Ri} = individual flow resistance
K_{tap} = total resistance factor to pressure tap
L = ratio of location of pressure taps to D
l = valve-disk lift, in. (mm)
$L_{A\text{-}B}$ = length between taps A and B, ft (m)
$L_{B\text{-}C}$ = length between taps B and C, ft (m)
$L_{B\text{-}D}$ = length between taps B and D, ft (m)
$L_{C\text{-}D}$ = length between taps C and D, ft (m)
M = molecular weight of gas
m = mass flow rate, lbm/hr (kg/h)
M_a = molecular weight of air
M_{tap} = Mach number at pressure tap
M_w = molecular weight
M_1 = Mach number at pipe entrance
N_{Re} = Reynolds number
P = static pressure, psia (kPa)
P_B = base pressure, psia (kPa)
P_b = barometric pressure, psia (kPa)
P_f = flow-rating pressure, psia (kPa)
P_m = static pressure at the meter calorimeter, psia (kPa)
P_o = back pressure, psig (kPag)
P_s = meter inlet stagnation pressure, psia (kPa)
P_{set} = set pressure, psig (kPag)
P_{tapA} = pressure at tap A, psia (kPa)
P_{tapB} = pressure at tap B, psia (kPa)
P_{tapC} = pressure at tap C, psia (kPa)
P_{tapD} = pressure at tap D, psia (kPa)
P_1 = pressure at pipe entrance, psia (kPa)
Q = relieving capacity of water at reference condition, U.S. gallons per minute (gpm) (L/min)
q_b = volumetric rate at base condition at the meter, cfm (m^3/min)
q_r = valve capacity at reference inlet temperature, cfm (m^3/min)
R = gas constant, ft-lbf/lbm-°R (kPa/kgK)
= 1,545.4/M (8.3143/M)
R_D = Reynolds number referred to internal diameter of meter run pipe, D
R_d = throat Reynolds number
S_g = specific gravity (ideal)
T = temperature, °R (K)
= fluid temperature, °F (°C)
t = length of test, min
T_B = base temperature, °F (°C)
T_b = base temperature, absolute, °R (K)
T_{cal} = fluid temperature at the calorimeter, °F (°C)
$T_{cal,\ drum}$ = fluid temperature at the test drum calorimeter, °F (°C)

$T_{cal, meter}$ = fluid temperature at the meter calorimeter, °F (°C)
T_m = fluid temperature at the meter, °F (°C)
= temperature upstream of the meter, °F (°C)
T_o = base temperature, °R (K)
T_r = reference temperature at the valve inlet, absolute, °R (K)
T_s = meter inlet stagnation temperature, absolute, °R (K)
T_{tap} = temperature at pressure tap, °R (K)
T_v = fluid temperature, °F (°C)
= temperature at the valve inlet, absolute, °R (K)
T_1 = temperature at pipe entrance, °R (K)
v = specific volume, ft^3/lbm (m^3/kg)
V_{act} = specific volume at inlet conditions, ft^3/lbm (m^3/kg)
$V_{act, drum}$ = specific volume at inlet conditions, ft^3/lbm (m^3/kg)
$V_{act, meter}$ = specific volume at flowing conditions at the meter, ft^3/lbm (m^3/kg)
V_{ref} = specific volume at reference condition, ft^3/lbm (m^3/kg)
$V_{ref, drum}$ = specific volume at reference condition, ft^3/lbm (m^3/kg)
$V_{ref, meter}$ = specific volume at reference conditions at the meter, ft^3/lbm (m^3/kg)
V_{tap} = specific volume at pressure tap, ft^3/lbm (m^3/kg)
W = measured relieving capacity, lbm/sec (kg/s)
w = mass of water or condensate, lbm (kg)
W_c = measured relieving capacity adjusted to the reference condition, lbm/hr (kg/h)
$W_{cal, drum}$ = test-drum calorimeter flow adjusted to the reference condition, lbm/hr (kg/h)
$W_{cal, meter}$ = meter calorimeter flow adjusted to the reference condition, lbm/hr (kg/h)
w_{cl} = condenser leakage, lbm/hr (kg/h)
W_{dc} = test-drum calorimeter flow, lbm/hr (kg/h)
W_{dr} = test-drum drainage, lbm/hr (kg/h)
W_h = flow rate, lbm/hr (kg/h)
= measured relieving capacity adjusted to the reference condition, lbm/hr (kg/h)
W_{mc} = meter calorimeter flow, lbm/hr (kg/h)
W_r = relieving capacity adjusted to water at reference condition, lbm/hr (kg/h)
W_t = trial flow rate, lbm/hr (kg/h)
w_{vl} = valve-steam leakage, lbm/hr (kg/h)
Y = expansion factor
Y_{tap} = expansion factor at pressure tap
Z = compressibility factor as defined in the equation of state, $Pv = ZRT$
Z_b = base compressibility factor
β = beta ratio
= d/D
ρ = fluid density, lbm/ft^3 (kg/m^3)
ρ_{act} = density of water at inlet conditions, lbm/ft^3 (kg/m^3)
ρ_B = density at base temperature and pressure, lbm/ft^3 (kg/m^3)
ρ_m = fluid density at meter inlet, lbm/ft^3 (kg/m^3)
ρ_{ref} = density of water at reference condition, lbm/ft^3 (kg/m^3)
ρ_s = density of dry air at 14.696 psia (101.33 kPa) and at the base temperature, lbm/ft^3 (kg/m^3)
ρ_{std} = density of dry air at 14.696 psia (101.33 kPa) and reference temperature, lbm/ft^3 (kg/m^3)
μ = viscosity, lbm/ft-sec (kg/m-s)
= viscosity of air at T_B and P_B, centipoise
ΔP = differential pressure head across meter, in. water (mm water)
$\Delta P_{A\text{-}B}$ = differential pressure between taps A and B, psia (kPa)
$\Delta P_{B\text{-}C}$ = differential pressure between taps B and C, psia (kPa)
$\Delta P_{C\text{-}D}$ = differential pressure between taps C and D, psia (kPa)

V-1.6 SI (METRIC) UNITS AND CONVERSION FACTORS

See Tables V-1.6-1 and V-1.6-2.

ARTICLE V-2
CAPACITY AND FLOW RESISTANCE TESTING

V-2.1 GUIDING PRINCIPLES

V-2.1.1 Items on Which Agreement Shall Be Reached

The parties to the test shall reach agreement on the following items prior to conducting the test:

(a) object of the test
(b) parties to the test
(c) test site
(d) testing fluid reference condition at flow-rating pressure
(e) methods of measurement, instrumentation, and equipment to be used (calibration of instruments shall be in accordance with V-2.1.7)
(f) number, size, type, condition, source, set pressure, and expected relieving capacity of the devices to be tested
(g) person who shall supervise the test

Table V-1.6-1
SI (Metric) Units

Quantity	Unit	Symbol	Other Units or Limitations
Space and Time			
Plane angle	radian	rad	degree (decimalized)
Length	meter	m	...
Area	square meter	m^2	...
Volume	cubic meter	m^3	liter (L) for fluids only (use without prefix)
Time	second	s	minute (min), hour (h), day, week, and year (y)
Periodic and Related Phenomena			
Frequency	hertz	Hz	hertz = cycle per second
Rotational speed	radian per second	rad/s	revolutions per minute (rpm)
Fluence	nvt	...	...
Neutron energy	MeV	E_n	...
Sound (pressure level)	decibel	db	...
Mechanics			
Mass	kilogram	kg	...
Density	...	kg/m^3	...
Moment of inertia	...	$kg{\cdot}m^2$	...
Force	newton	N	...
Moment or force (torque)	newton-meter	N·m	...
Pressure and stress	pascal	Pa	pascal = newton per square meter
Energy, work	joule	J	kilowatt-hour (kW·h)
Power	watt	W	...
Impact strength	joule	J	...
Section modulus	cubic meter	m^3	...
Moment of section (second moment of area)	...	m^4	...
Fracture tougheners	$Pa{\cdot}\sqrt{m}$	K_{1C}	...
Heat			
Temperature (thermodynamic) [Note (1)]	kelvin	K	degree Celsius (°C)
Temperature (other than thermodynamic)	degree Celsius	°C	kelvin (K)
Linear expansion coefficient	...	K^{-1}	$°C^{-1}$
Quantity of heat	joule	J	...
Heat flow rate	watt	W	...
Thermal conductivity	...	W/(m·K)	W/(m·°C)
Thermal diffusivity	...	m^2/s	...
Specific heat capacity	...	J/(kg·K)	J/(kg·°C)
Electricity and Magnetism			
Electric current	ampere	A	...
Electric potential	volt	V	...
Current density	...	A/m^2	...
Electrical energy	watt	W	...
Magnetization current	ampere/meter	A/m	...
Light			
Illumination	lux	lx	...
Wavelength	angstrom	Å	...

NOTE: (1) Preferred use for temperature and temperature interval is degree Celsius (°C), except for thermodynamic and cryogenic work where kelvins may be more suitable. For temperature interval, 1K = 1°C exactly.

Table V-1.6-2
Commonly Used Conversion Factors

Quantity	Conversion From	Conversion To	Multiplication Factor [Notes (1), (2)]
Plane angle	degree	rad	1.745 329 E−02
Length	in.	m	2.54 E−02*
	ft	m	3.048 E−01*
	yd	m	9.144 E−01*
Area	in.^{2}	m^2	6.451 6 E−04*
	ft^2	m^2	9.290 34 E−02*
	yd^2	m^2	8.361 274 E−01
Volume	in.^{3}	m^3	1.638 706 E−05
	ft^3	m^3	2.831 685 E−02
	U.S. gallon	m^3	3.785 412 E−05
	Imperial gallon	m^3	4.546 090 E−03
	liter	m^3	1.0 E−03*
Mass	lb (avoir.)	kg	4.535 924 E−01
	ton (metric)	kg	1.000 00 E+03*
	ton (short 2,000 lbm)	kg	9.071 847 E+02
Force	kgf	N	9.806 65 E+00*
	lbf	N	4.448 222 E+00
Bending, torque	kgf-m	N·m	9.806 65 E+00*
	lbf-in.	N·m	1.129 848 E−01
	lbf-ft	N·m	1.355 818 E+00
Pressure, stress	kgf/m^2	Pa	9.806 65 E+00*
	lbf/ft^2	Pa	4.788 026 E−01
	lbf/in.^{2} (psi)	Pa	6.894 757 E+03
	kips/in.^{2}	Pa	6.894 757 E+06
	bar	Pa	1.0 E−05*
	in. water (60°F)	Pa	2.4884 E+02
Energy, work	Btu	J	1.055 056 E+03
	ft-lbf	J	1.355 818 E+00
Power	hp (550 ft-lbf/sec)	W	7.456 999 E+02
Temperature	°C	K	$t_K = t_C + 273.15$
	°F	K	$t_K = (t_F + 459.67)/1.8$
	°F	°C	$t_C = (t_F - 32)/1.8$
Temperature interval	°C	K	1.0 E+00*
	°F	K or °C	5.555 556 E−01
Viscosity, dynamic	lbf-sec/ft^2	Pa·s	4.788 026 E+01
	lbm/ft-sec	Pa·s	1.488 164 E+00

GENERAL NOTE: A more extensive list of conversion factors between SI (metric) units and U.S. Customary units is given in ASME SI-1 and ASTM E380.

NOTES:
(1) The factors are written as a number greater than 1 and less than 10 with six decimal places. The number is followed by the letter "E" (for exponent), a plus or minus symbol, and two digits that indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example, 3.523 907 E−02 is $3.523\,907 \times 10^{-2}$ or 0.035 239 07.
(2) Factors followed by an asterisk are exact.

(h) the written test procedure, which shall include the observations and readings to be taken and recorded to comply with the object or objectives of the test

V-2.1.2 Qualification of Person Supervising the Test

The person who supervises the test shall have a formal education in thermodynamics and fluid mechanics. In addition, the person shall have practical experience in fluid flow measurement and have had experience in test supervision.

V-2.1.3 Responsibility of Person Supervising the Test

The person supervising the test shall be present at all times during the test and shall be solely responsible for ensuring that all persons who are involved in taking readings, making pressure and temperature adjustments, or any other function that will affect the test results are fully informed as to the correct method of performing such functions. The person supervising the test shall also be responsible for ensuring that the written test procedures are followed. The person supervising the test shall sign and date the test report, thereby verifying to the best of the person's knowledge that the report is correct and that the test was conducted in accordance with the written test procedures. The person supervising the test shall verify that the instruments have been calibrated as required by V-2.1.7.

V-2.1.4 Test Apparatus

Procedures and arrangement of the test apparatus shall be in accordance with V-2.2.

V-2.1.5 Preliminary Tests

Sufficient preliminary tests shall be conducted to ensure that test conditions can be attained and that operating personnel are completely familiar with the test equipment and their respective assignments. Preliminary tests shall include the recording of all data necessary to the completeness of an actual test.

V-2.1.6 Spare Instruments

If intended for use as replacements during the test, spare instruments shall be calibrated in accordance with V-2.1.7.

V-2.1.7 Calibration of Instruments

Each instrument used during the test shall be serialized or otherwise positively identified. Each instrument, depending on the type, shall be calibrated in accordance with V-2.1.7.1 through V-2.1.7.5. Records of pertinent instrument calibrations shall be available for review by the interested parties.

V-2.1.7.1 Pressure. Pressure-measuring instruments shall be calibrated in accordance with ASME PTC 19.2, before and after any test or series of tests, but in no case shall a period of greater than 10 days elapse between pretest calibration and post-test calibration check. Calibration of other means of indicating or recording pressure shall be agreed upon by the interested parties.

V-2.1.7.2 Temperature. Temperature-measuring instruments shall be calibrated in accordance with ASME PTC 19.3. Instruments of the types listed in V-2.2.2.2(a), except bimetallic thermometers, shall be calibrated against at least two temperatures within a 90-day period preceding the test or series of tests. Bimetallic thermometers shall be calibrated before and after each test or series of tests. Calibration of other means of indicating or recording temperature shall be agreed upon by the interested parties.

V-2.1.7.3 Lift Indicators and Recorders. Since these instruments are usually subjected to some shock in the course of tests under this Appendix, their accuracy shall be checked before and after each test or series of tests.

V-2.1.7.4 Weighing Scales. Scales used in test procedures for weighted condensate or gravimetric methods shall have a minimum value of the indicating element equal to or less than 0.25% of the expected load. Weighing scales used in tests conducted under this Appendix shall be calibrated at sufficient points to ensure their accuracy within their range of intended usage at least once within a 90-day period preceding a test or series of tests.

V-2.1.7.5 Steam Calorimeters. Methods of calibrating steam calorimeters are given in ASME PTC 19.11. The calorimeters shall be calibrated separately with steam at the time of their installation and at regular intervals not exceeding 1 yr. Further calibrations shall be carried out if results indicate an obvious error in their readings or if their installation is altered.

V-2.1.8 Metering Sections

The calibration of any type of flow meter (see V-2.2.2) shall include the actual piping and all fittings both upstream and downstream of the meter (see ASME PTC 19.5), including control valves, test vessels, and vessel-to-test device adapters. Such calibration shall be by means of measuring the flow rate through a test device with a known coefficient of discharge upon completion of the initial installation or construction and prior to the performance of any formal test. Agreement with the coefficient of the test object shall be within ±2%.

The initial calibration shall include runs at the smallest, intermediate, and highest flow rates compatible with the comparison installation. Adapter fittings for test devices having different types of inlet connections shall be calibrated by laboratory personnel at the time of their manufacture or purchase. In addition, the meter installation shall undergo a calibration check as described above at least once within each 1-yr period. These calibration checks shall include runs with at least two sizes of adapters. Records of calibrations shall be maintained and available for review by the interested parties. Modifications to the equipment shall be evaluated for the effect they may have on the system calibration, and new calibrations shall be performed if deemed necessary.

V-2.1.9 Flow Resistance Test Rigs

The calibration of any type of test rig (see V-2.2.9.1) shall include the actual piping and all fittings downstream of the test vessel (see Figure V-2.1.9-1). Calibration shall be conducted upon completion of the initial installation or construction and prior to the performance of any formal test and repeated at least once every 5 yr. Records of calibration shall be maintained and available for review by the interested parties. Modifications to the equipment shall be evaluated for the effect they have on the test rig, and new calibrations shall be performed if deemed necessary. The calibration shall be conducted per V-2.1.9.1 and V-2.1.9.2.

V-2.1.9.1 Measured Flow Resistance

With no test device installed, conduct three flow resistance tests at the smallest, intermediate, and highest test pressures compatible with the test rig. The measured flow resistance, K_{Ri}, for each test shall be 0 ± 0.075.

V-2.1.9.2 Pressure Tap Profile Comparison

With no test device installed, conduct a flow test at an intermediate test pressure; see the following steps:

Step 1. With the data from the flow test, calculate the average friction factor for the length of pipe between taps A-B and C-D.

Step 2. Using the Lapple (1943) and Levenspiel (1977) model of the adiabatic ideal-gas integration of the mechanical energy (or momentum) balance for adiabatic flow from an ideal nozzle on a large reservoir, through an equivalent length of pipe, to a second large reservoir (or to the atmosphere), calculate the equivalent pipe length to tap A using the measured flow rate, the average friction factor from Step 1, and the measured pressure at tap A.

Step 3. Subtract the actual pipe length from the test rig entrance to tap A from the equivalent pipe length from Step 2 to determine a nozzle equivalent length.

Step 4. Repeat Steps 2 and 3 for taps B through D.

Step 5. Calculate the average nozzle equivalent length using the values determined in Steps 1 through 4. This average nozzle equivalent length is used to compensate for the actual pressure loss up to the test rig entrance.

Step 6. Using again the adiabatic ideal-gas integration model of Step 2, calculate the pressure at tap A using the measured flow rate, average friction factor, and average nozzle equivalent length from Step 5 and actual pipe length for tap A.

Step 7. Repeat Step 6 for taps B through D.

Step 8. Calculate the difference between the measured pressure and the calculated pressure from Step 7 at each of the four pressure taps. The difference at each tap shall be within ±6.0% of the calculated pressure.

Nonmandatory Appendix E presents an example using the pressure tap profile comparison procedure to calibrate a flow resistance test rig.

V-2.1.10 Adjustments During Tests

No adjustment to the pressure relief device shall be made while readings are being taken. Following any change or deviation of the test conditions, a sufficient period of time shall be allowed to permit the rate of flow, temperature, and pressure to reach stable conditions before readings are taken.

V-2.1.11 Records and Test Results

The test records shall include all observations, measurements, instrument readings, and instrument calibration records (if required) used in the test. Original test records shall remain in the custody of the facility that conducted the test for a period not fewer than 5 yr. Copies of all test records shall be furnished to each of the parties to the test. Corrections and corrected values shall be entered separately in the test record. The test shall be reported in accordance with V-2.4.

V-2.1.12 Measurement Uncertainty

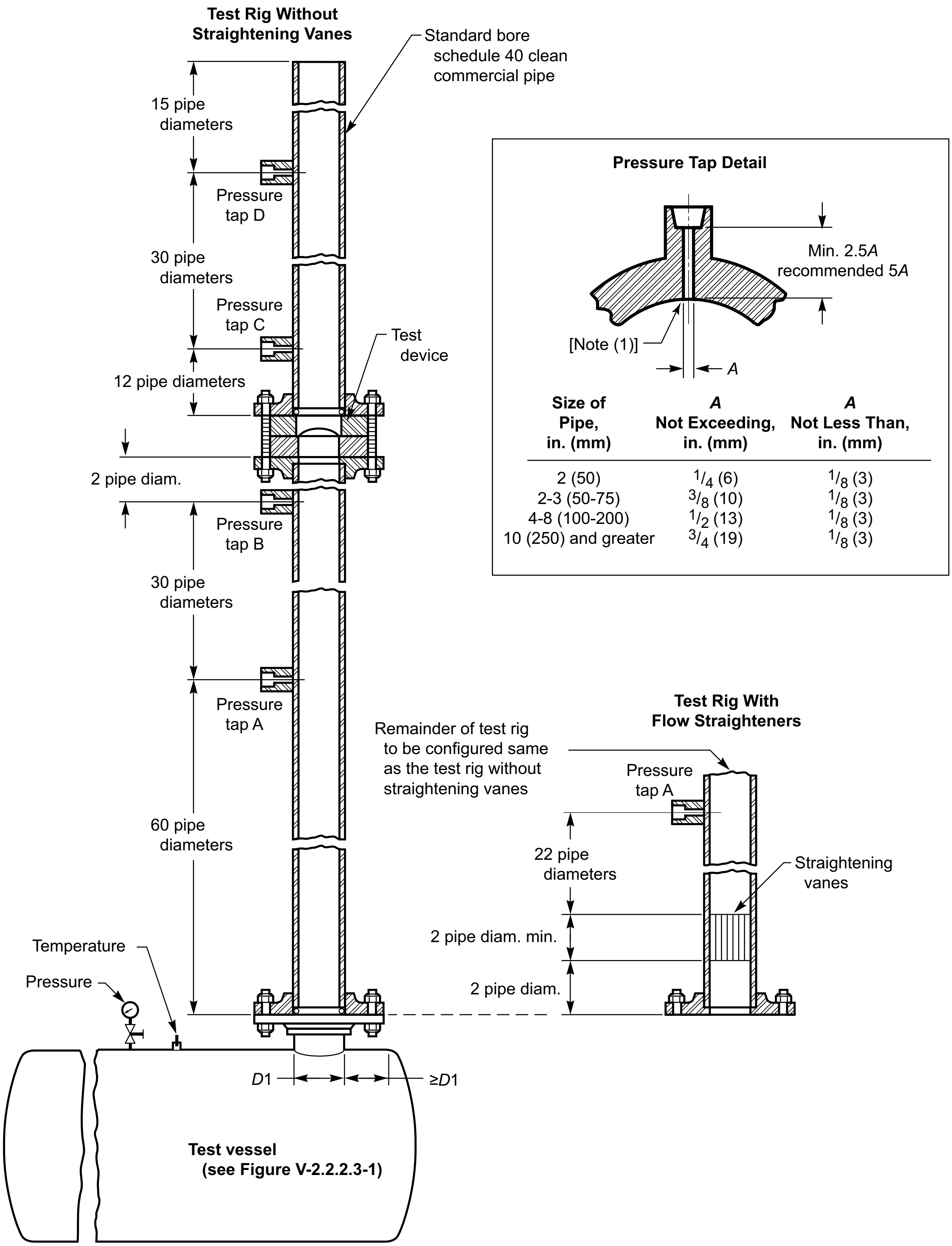
A post-test uncertainty analysis shall be performed to determine that the limits of uncertainty of the final flow measurement specified in V-1.1 were met. A pretest determination may be performed to determine that the limits of uncertainty of the final flow measurement specified in V-1.1 can be met by the specified instrument and procedures. A guide for such determination is given in ASME PTC 19.1. These determinations shall be documented by the laboratory and available for review.

V-2.2 INSTRUMENTS AND METHODS OF MEASUREMENTS

V-2.2.1 General

Subarticle V-2.2 describes the instruments, methods, procedures, and precautions that shall be used in testing pressure relief devices under this Appendix. The Performance Test Code Supplements on Instruments and Apparatus provide authoritative general information

Figure V-2.1.9-1
Recommended Arrangements for Testing Flow Resistance of Non-reclosing Pressure Relief Devices



Size of Pipe, in. (mm)	A Not Exceeding, in. (mm)	A Not Less Than, in. (mm)
2 (50)	1/4 (6)	1/8 (3)
2-3 (50-75)	3/8 (10)	1/8 (3)
4-8 (100-200)	1/2 (13)	1/8 (3)
10 (250) and greater	3/4 (19)	1/8 (3)

Figure V-2.1.9-1
Recommended Arrangements for Testing Flow Resistance of Non-reclosing Pressure Relief Devices (Cont'd)

NOTE: (1) The edge of hole shall be clean and sharp or slightly rounded and free from burrs, wire edges, or other irregularities. In no case shall any fitting protrude inside the pipe.

concerning instruments and their use and may be consulted for such information.

V-2.2.2 Fluid Conditions, Test Conditions, and Instrumentation

V-2.2.2.1 Atmospheric Pressure. Barometric pressure shall be measured with a barometer (see ASME PTC 19.2). In calculations involving the capacity of pressure relief devices having a flow-rating pressure of 20 psig (150 kPa) or higher, the use of the mean barometric pressure at the test site satisfies the accuracy requirements of this Appendix. In such cases, the recorded pressure may be the mean barometric pressure.

V-2.2.2.2 Temperature. Instructions on thermometers or thermocouples and associated instruments are given in ASME PTC 19.3, except that commercial, metal-encased thermometers shall not be used in tests conducted under this Appendix. Other means of temperature measurement and indication may be used, provided they are of the same or greater degree of accuracy as those described therein.

(a) Depending on operating conditions, or convenience, the temperature may be measured with certified or calibrated liquid-in-glass thermometers, bimetallic thermometers, resistance-type thermometers, or thermocouples. All of the above may be inserted directly into the pipe or wells except for liquid-in-glass thermometers, which shall be inserted into wells. The installation of the temperature-measuring device directly into the pipe, without the addition of a well, is desirable for temperatures below 300°F (150°C).

(b) The following precautions shall be taken when making any temperature measurements:

(1) No significant quantity of heat shall be transferred by radiation or conduction to or from the temperature-measuring device other than by the temperature of the medium being observed (see ASME PTC 19.3).

(2) The immediate vicinity of the point of insertion and the external projecting parts shall be insulated.

(3) The temperature-measuring device shall extend across the centerline in pipes of small diameter or shall be inserted at least 6 in. (150 mm) into the fluid stream in pipes over 12 in. (300 mm) in diameter.

(4) Temperature-measuring devices installed in pipes carrying compressible fluids shall, wherever possible, be installed at locations where the maximum fluid velocity during any flow measurement does not exceed 100 ft/sec (30 m/s). Where such an installation is not possible, it may be necessary to correct the temperature readings to the appropriate static or total temperature (see ASME PTC 19.5).

(5) The temperature-measuring devices shall be inserted in locations so as to measure temperatures that are representative of the flowing medium as described under test arrangements.

(c) When measuring temperatures with a mercury-in-glass thermometer, the instrument shall have an etched stem. When the measured temperature differs from the ambient by more than 10°F (5°C), and the mercury is exposed, an emergent stem correction shall be made (see ASME PTC 19.3) or an appropriate emergent-stem thermometer used.

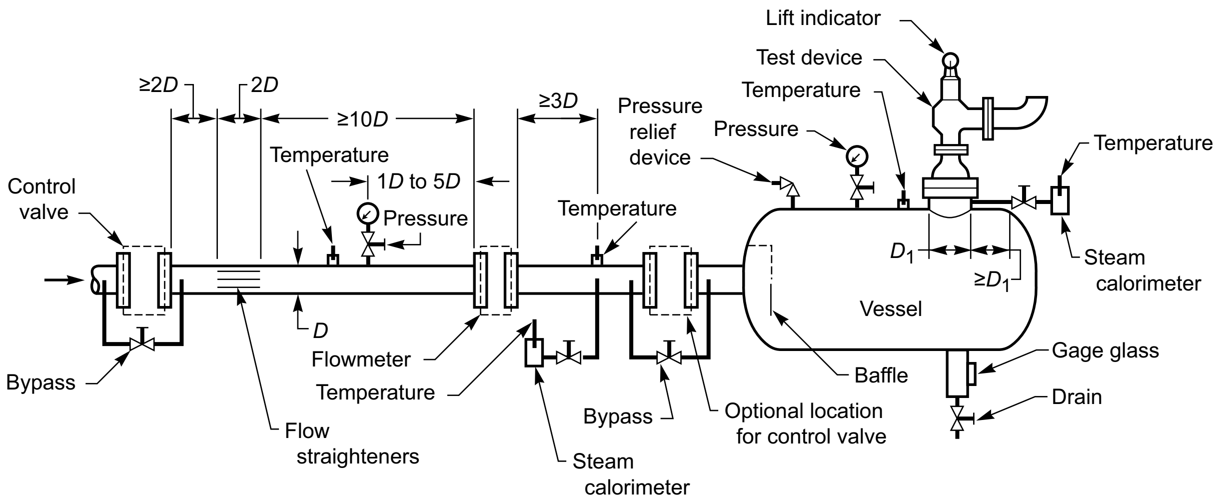
(d) Thermometer wells, when used, shall be of the type shown in ASME PTC 19.3. They shall be as thin-walled and of as small a diameter as practicable; their outer surfaces shall be substantially free from corrosion or foreign matter. The well shall be filled with a suitable fluid. Mercury should not be used for this fluid since its very low vapor pressure presents a serious health hazard to personnel. However, if mercury is used for this purpose, suitable precautions shall be taken.

(e) Thermocouples, if used, shall have a welded hot junction and shall be calibrated together with their extension wires over the anticipated operating range. They shall be constructed of materials suitable for the temperature and fluid being measured. The electromotive force of a thermocouple shall be measured by a potentiometer instrument or millivoltmeter of such precision that the accuracy of the overall system is within the limit specified in V-1.3. The cold junction shall be established by an ice bath, reference standard, or by a compensating circuit built into the potentiometer.

V-2.2.2.3 Pressure Measurements. Instructions on pressure gages, differential gages, and manometers are given in ASME PTC 19.2. Other means of pressure measurements and indication may be used provided they are of the same or lesser degree of uncertainty as those described therein.

(a) Pressure-measuring stations shall be located in the region where the flow is essentially parallel to the pipe or vessel wall. For the measurement of static gage-pressure differentials below 15 psi (100 kPa), liquid manometers may be used.

Figure V-2.2.2.3-1
Recommended Arrangements for Testing Devices With Atmospheric Back Pressure — Flowmeter Test Arrangement



(b) The test vessel pressure shall be the static pressure as measured with a pressure tap positioned, as shown in Figure V-2.2.2.3-1.

(c) Back pressure shall be the static pressure measured with a pressure tap positioned, five pipe diameters from the valve outlet.

(d) Proper corrections to the pressure readings shall be made if there is a height of water or other liquid between the point at which the pressure is to be measured and the pressure instrument.

V-2.2.2.4 Flow Measurement

(a) This paragraph provides for the measurement of pressure relief device capacity by use of the following methods:

(1) subsonic-inferential meters, including orifice plate, flow nozzle, and venturi

(2) sonic-inferential meters, including choked nozzles

(3) direct volumetric or gravimetric measurement of collected condensate or discharge

(b) To measure pressure relief device capacity, the following methods shall be used:

(1) steam flow, with atmospheric back pressure method (a)(1) or (3) herein

(2) steam flow, with back pressure above atmospheric method (a)(1) herein

(3) gas or air flow, with atmospheric back pressure method (a)(1) or (2) herein

(4) gas or air flow, with back pressure above atmospheric method (a)(1) herein

(5) liquid flow, with atmospheric back pressure method (a)(1) or (3) herein

(6) liquid flow, with back pressure above atmospheric method (a)(1) herein

NOTE: It is not the intent of this Appendix to exclude pressure-relief-device testing at back pressures above atmospheric wherein capacity is measured by means of a sonic-inferential meter. However, due to the high degree of pressure drop through this type of meter, such testing would probably be impractical.

(c) Instruction on Primary Elements. Instructions on primary elements are given in ASME PTC 19.5. Other means of capacity determinations may be used [see V-2.2.3.1(c)], provided they are of the same or greater degree of accuracy as those outlined therein.

(1) The primary element shall be located upstream of the test pressure relief device inlet. A recommended installation arrangement is shown in Figure V-2.2.2.3-1. The ratio of orifice plates to internal pipe diameter shall be between 0.2 and 0.7. The primary element shall be inspected and known to be clean and free of damage prior to the test period.

(2) The differential pressure across the primary element and temperature of the fluid shall be measured. The precautions of V-2.2.2.2 shall apply to the measurement of temperature and those of V-2.2.2.3 to the measurement of pressure.

(3) There shall be sufficient length of straight pipe ahead of the primary element to secure a fairly uniform velocity profile in the approaching stream (see ASME PTC 19.5). To ensure reliable pressure measurement, there shall also be a sufficient length of straight pipe of the same nominal size as the inlet on the outlet side of the primary element.

(4) The flow during capacity measurements shall be steady state, and differential pressure devices shall not show total pulsations (double amplitude) greater than 2% of the differential pressure being measured. Any greater pulsation in the flow shall be corrected at its source; attempts to reduce pulsations at the instrument are not permissible.

(5) Precautions shall be taken to avoid the use of excessively wet steam, which usually results in unstable conditions. When testing with steam, throttling calorimeters shall be used (see V-2.2.2.6).

(6) ASME PTC 19.5 provides detailed information relative to most of the flow techniques and flow elements recommended for this Appendix. The equations for the calculation of discharge coefficients for orifices, flow nozzles, and venturi meters contained in that document shall be used.

These equations are valid for uncalibrated nozzles constructed in strict accordance with ASME PTC 19.5. Calibrated nozzles may be used to give additional accuracy.

V-2.2.2.5 Valve-Lift Measurements

(a) The lift of the valve disk, under flowing conditions, shall be determined by suitable means to whatever degree of accuracy is imposed by the procedure under which the valve is being tested.

(b) In open- or vented-bonnet designs, when the top of the spindle may be exposed during the tests, a dial indicator of appropriate range may be attached to the top of the valve to indicate the movement of the spindle. In closed-bonnet valves where the top of the spindle cannot be exposed, arrangements shall be made to permit indicating, reading, or recording spindle movement outside the valve bonnet or cap. In either case, care shall be exercised that the arrangement does not impose an additional load on the valve spindle or interfere with the operation of the valve.

Possible misreading of lift indicators may occur under conditions of testing valves with steam with superimposed back pressure (see V-2.2.6). When introducing steam into the back-pressure portion of the valve, the temperature of the steam may cause thermal expansion of the valve parts, producing an erroneous initial reading on the lift indicator. When extreme accuracy in results is desired, measures shall be taken to distinguish between this thermal expansion and actual valve lift.

V-2.2.2.6 Steam Quality. Quality of steam flowing shall be measured by means of throttling calorimeters, installed in the test vessel nozzle, with the tube extending to the test device centerline. Alternatively, the steam-sampling tube may be installed directly on the vessel, provided that the tube extends into the flow path directly below the centerline of the device inlet nozzle and not lower than the horizontal centerline of the test vessel. Instructions for their use are given in ASME PTC 19.11.

V-2.2.2.7 Reference Conditions. Reference conditions shall be within the stated limits in (a) through (c). If reference conditions are not within these limits, then no corrections from actual test conditions may be applied and no corrections shall be made from actual test pressure.

(a) Steam. The reference condition shall be dry saturated steam, and the condition of the steam during test at the device inlet shall be within limits of 98% minimum quality and 20°F (10°C) maximum superheat.

(b) Water. The reference condition of water shall be between 65°F (20°C) and 75°F (25°C), and the temperature limit of water during test at the device inlet shall be between 40°F (5°C) and 125°F (50°C).

(c) Air and Other Gases. The reference condition of air or other gases shall be between 55°F (10°C) and 75°F (25°C), and the temperature limit of air or other gases during test at the device inlet shall be between 0 °F (-20°C) and 200°F (90°C).

V-2.2.2.8 Specific Gravity. The specific gravity of the fluid, other than air or water, used for the test shall be determined in accordance with ASTM D1070 or ASTM D1298.

NOTE: In some special cases, it may be a requirement that tests be conducted on liquids outside the range of these specifications. In these cases, agreement shall be reached on the method of specific gravity (density–specific volume) determination.

V-2.2.2.9 Chemical Composition. If the physical properties of the fluid are in doubt [see V-1.2(a)], they shall be determined by physical tests or from chemical analysis.

V-2.2.2.10 General Features of Tests. The proper number and size of pressure relief devices to be tested shall be provided at the test site. There shall be assurance that the pressure relief devices are properly assembled with components that meet the design specification requirements. The pressure relief device shall be clean and ready for test.

The pressure relief device to be tested shall be installed with adapter fittings (flanged, screwed, welded, etc.) directly on a test vessel (see Figure V-2.2.2.10-1 for acceptable contours). Other adapter fittings may be used provided the accuracy of the test is not affected. The diameter and volume of the test vessel should be large enough to obtain an accurate static pressure measurement and an accurate determination of the operational characteristics of the pressure relief device to be tested. Operating conditions shall be maintained in accordance with the requirements of the procedure used (see V-2.2.3 through V-2.2.9). The duration of the test shall be that required to obtain the necessary performance and capacity data under stable conditions.

(a) For testing with atmospheric back pressure before discharging, the test arrangement shall provide discharge from the pressure relief device directly to the atmosphere or condenser (see Figures V-2.2.2.10-1 through

V-2.2.2.10-3). If discharge piping is used, it shall be at least the same size as the pressure relief device outlet. This pipe shall be supported independently of the pressure relief device and in such a way as to not affect the operation of the pressure relief device. Precautions shall be taken to ensure that the pressure relief device and discharge piping are adequately secured to resist the resultant forces generated by the discharge.

(b) For testing with superimposed back pressure before discharging, the test arrangement shall provide a means for introducing and maintaining back pressure on the test pressure relief device outlet (see Figure V-2.2.2.10-4). The discharge pipe shall have at least the same nominal size as the pressure relief device outlet and shall discharge into a system of sufficient size to allow satisfactory back-pressure control. A control pressure relief device shall be provided to regulate the building up and maintaining of any desired back pressure while the pressure relief device is discharging.

The remainder of V-2.2 is divided into seven parts according to the back pressure, fluid used, and type of device tested. The first three parts for tests with atmospheric back pressure before discharging are: steam (see V-2.2.3); gases, including air (see V-2.2.4); and liquids (see V-2.2.5). The second three parts for test with superimposed back pressure before discharging are: steam (see V-2.2.6); gases, including air (see V-2.2.7); and liquids (see V-2.2.8). The last part (see V-2.2.9) concerns testing rupture disks to determine resistance factors.

(c) Tests of non-reclosing pressure relief devices in combination with pressure relief valves shall be conducted in accordance with V-2.2.3 through V-2.2.8 (see Figure V-2.2.2.10-5).

V-2.2.2.11 Establishing Set Pressure and Blowdown

(a) Increase the pressure at the device inlet. During the pressure interval starting at 90% of the expected set pressure, the rate of pressure increase shall not exceed 2.0 psi/sec (15 kPa/s) or whatever lesser rate of increase is necessary for the accurate reading of the pressure. Observe and record the set pressure of the device and any other desired or pertinent characteristics.

(b) For reclosing pressure relief devices, continue increasing the pressure at the device inlet until the device remains open. Observe the action of the device. Gradually decrease the inlet pressure until the device closes. Record the reseating pressure of the device. Observe the action of the device.

(c) For reclosing pressure relief devices, repeat (a) and (b) herein until the set pressure is established and stabilized.

(d) Set pressure is established by computing the average of at least the last three measured values. Set pressure is considered stable when the measured values show no significant upward or downward trend whereby all are within ±1% or ±0.5 psi (4 kPa), whichever is greater, of the average value. If the parties to the test agree, an alternative criteria of stability may be used.

(e) Blowdown is established by computing the average of the individual blowdowns of those tests used to determine set pressure in (d) herein.

V-2.2.3 Testing With Steam, Pressure Relief Device Discharging to Atmospheric Pressure

V-2.2.3.1 Test Arrangements

(a) Flowmeter Method. Figure V-2.2.2.3-1 illustrates the use of a flowmeter together with its associated instrumentation. The use of calorimeters at the pressure relief devices inlet and primary element is mandatory; however, the thermometers at the primary element and test vessel may be omitted. Provisions shall be made for collecting and measuring the condensate accumulating in the test vessel during a test run.

(b) Weighed Condensate. Figure V-2.2.2.10-2 illustrates the weighed-condensate method of test, including the condenser and associated instrumentation. The use of a calorimeter at the device inlet is mandatory.

NOTE: If the test pressure relief device is of the open- or vented-bonnet design, this test arrangement will not measure all the steam passing through the pressure relief device. A loss may occur due to steam leakage around the spindle and through drains. Therefore, the capacity results obtained by test will be less than the actual device capacity. When considered necessary by the interested parties, agreement shall be reached as to the method used for determining the rate of this steam leakage.

(c) Alternative Arrangements. Test arrangements other than those described in (a) and (b) may be used if agreed to by all interested parties, provided the uncertainty of the final results is within ±2.0% (see V-1.3).

V-2.2.3.2 Preliminary Tests. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and/or device being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus and that primary element reservoirs are filled, properly cooled, and initially vented.

V-2.2.3.3 Barometric Pressure. Record the barometric pressure (see V-2.2.2.1).

V-2.2.3.4 Details of Procedure for Flow Measurement of Devices Using the Flowmeter Method

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11.

(b) Establish and maintain the flow-rating pressure until flow instruments indicate stable condition.

(c) Close test-drum drain, and establish and record or mark starting condensate level in gage glass.

(d) Record the following:

(1) device-inlet pressure

(2) device-inlet calorimeter discharge temperature

(3) device-disk lift, as applicable
(4) flowmeter static pressure
(5) flowmeter differential pressure
(6) flowmeter calorimeter discharge temperature

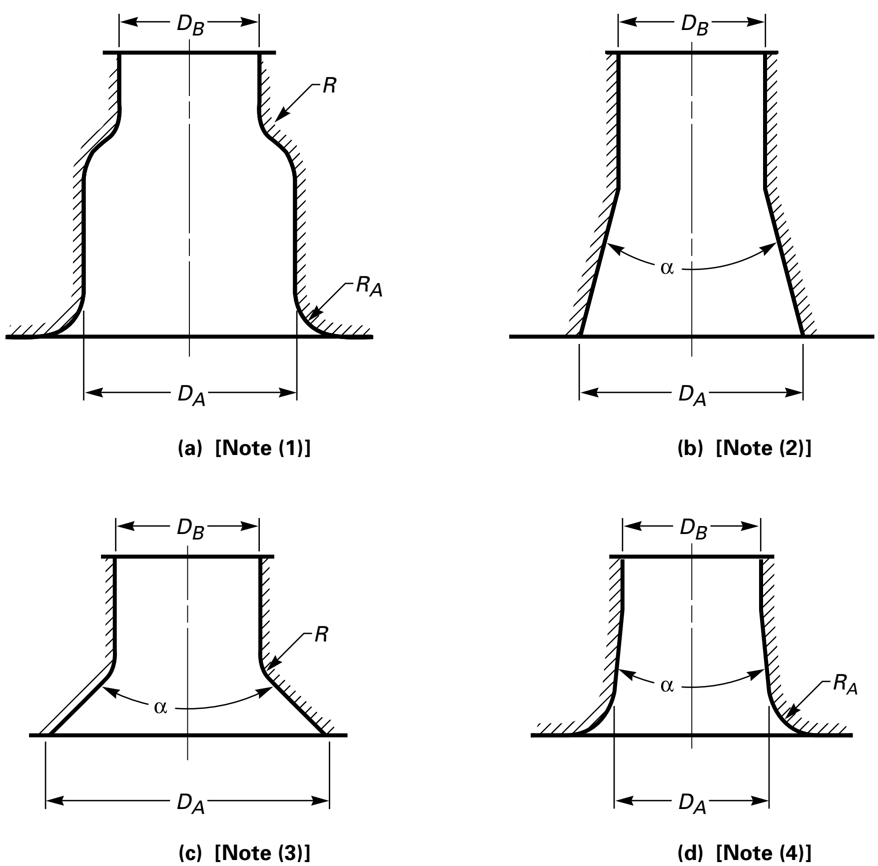
(e) Maintain stable conditions, and read and record data in same sequence for period of run as agreed upon.

(f) Record length of run and times of recording data as measured by stopwatch, electric synchronous clock with second hand, or other appropriate means.

(g) Determine test vessel condensate by weight or volume measure, and record.

(h) Decrease inlet pressure slowly, and again record reseating pressure of a reclosing pressure relief device.

Figure V-2.2.2.10-1
Recommended Internal Contours of Nozzles, Fittings, Adapters, and Reducers Between Test Vessel and Test Device



GENERAL NOTE: In no case shall the size of the fitting exceed the size of the connection on the test vessel.

NOTES:
(1) If $D_B \geq 0.75D_A$, then $R_A \geq 0.25D_A$.
If $D_B < 0.75D_A$, then $R \geq 0.25D_B$.
(2) If $\alpha \leq 30$ deg and $D_B < 0.75D_A$, break all edges.
(3) If $\alpha > 30$ deg and $D_B < 0.75D_A$, then $R \geq 0.25D_B$.
(4) If $\alpha \leq 30$ deg and $D_B \geq 0.75D_A$, then $R_A \geq 0.25D_A$.

Figure V-2.2.2.10-2
Recommended Arrangements for Testing Devices With Atmospheric Back Pressure — Weighed-Condensate Test Arrangement

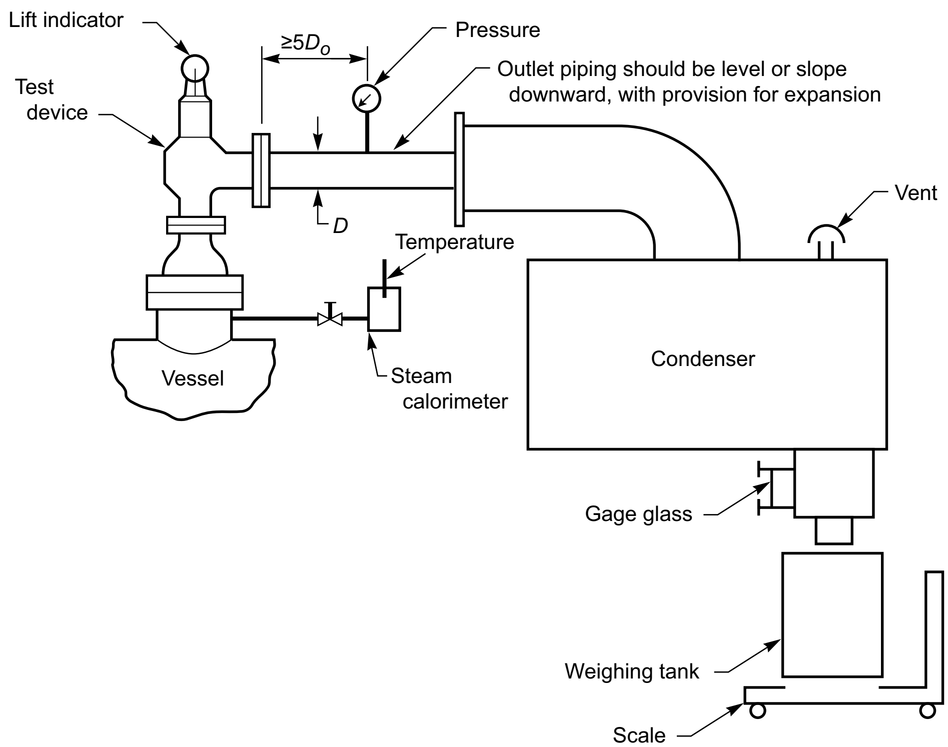


Figure V-2.2.2.10-3
Recommended Arrangements for Testing Devices With Atmospheric Back Pressure — Weighed-Water Test Arrangement

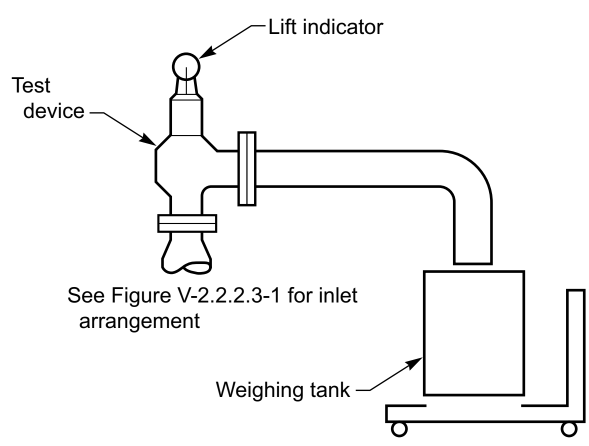


Figure V-2.2.2.10-4
Recommended Discharge Arrangement for Testing Devices With Superimposed Back Pressure

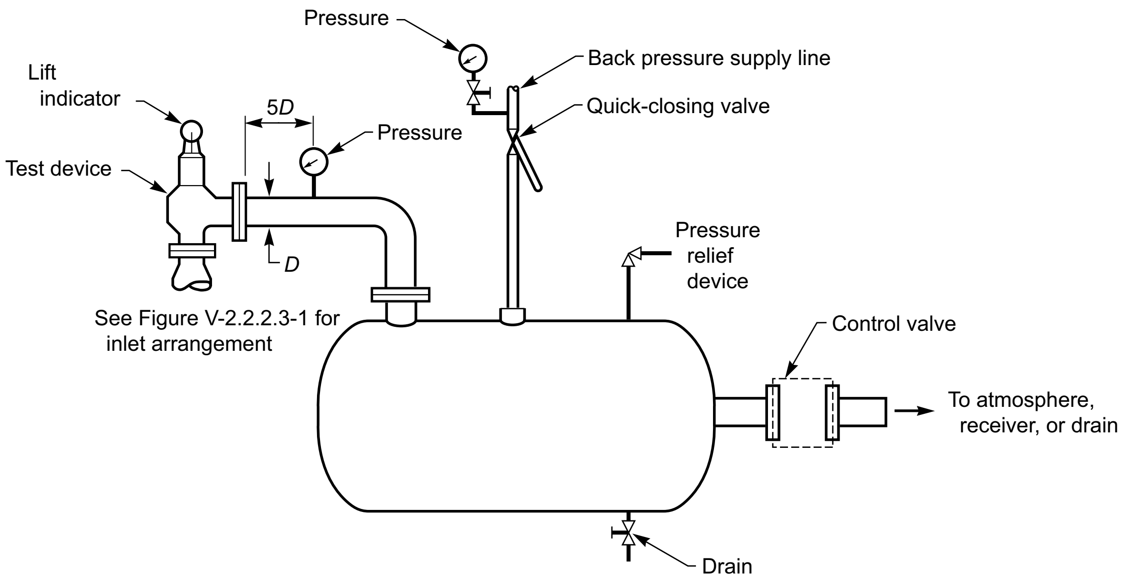
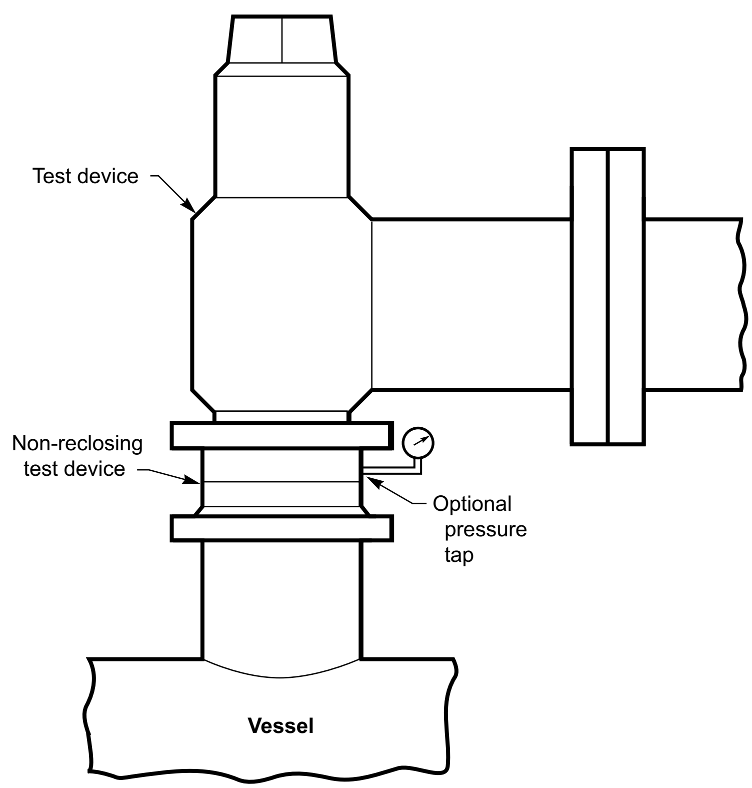


Figure V-2.2.2.10-5
Recommended Arrangement for Testing Non-reclosing Pressure Relief Devices in Combination With Pressure Relief Valves



V-2.2.3.5 Details of Procedure for Flow Measurement of Devices Using the Weighed-Condensate Method

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11.

(b) Establish and maintain flow-rating pressure until flow instruments indicate stable condition.

(c) Establish condenser hot-well level.

(d) Record the following:

(1) device-inlet pressure

(2) device-inlet calorimeter discharge temperature

(3) device-disk lift, as applicable

(e) Maintain stable conditions, and read and record data in same sequence for period of run as agreed upon.

(f) Record length of run and times of recording data as measured by stopwatch, electric synchronous clock with second hand, or other appropriate means.

(g) Reestablish condenser hot-well level, and accurately determine and record amount (volume or weight) of condensate formed in condensers during run.

(h) Decrease inlet pressure slowly, and again record reseating pressure of a reclosing pressure relief device.

V-2.2.3.6 Observation of the Device Mechanical Characteristics. During the flowmeter and weighed-condensate methods of test, the mechanical characteristics shall be observed by hearing, feeling, or seeing and recorded during the flow test. If the valve chatters, flutters, or does not reseat (as designed) satisfactorily, such action shall be recorded. Upon agreement of all interested parties, the device may be readjusted or repaired and retested.

V-2.2.3.7 Recording Additional Data. During the flowmeter or weighed-condensate methods of test, it may be desirable or a requirement to record pressure other than, or in addition to, those listed in V-2.2.3.4 or V-2.2.3.5. Where possible, such recorded pressures shall be identified in accordance with V-1.6. With closed discharge systems, such as V-2.2.3.1(b), it is not possible to observe or record some characteristic pressures.

V-2.2.4 Testing With Gas or Air, Pressure Relief Device Discharging to Atmospheric Pressure

V-2.2.4.1 Test Arrangement. A recommended test arrangement is shown in the flowmeter test arrangement, Figure V-2.2.2.3-1. The primary element shall be either a subsonic-inferential meter [see V-2.2.2.4(a)(1)] or a sonic-inferential meter [see V-2.2.2.4(a)(2)].

Instrumentation for each type of meter is listed in the following subparagraphs. The test pressure relief device discharge may be provided as shown in Figure V-2.2.2.3-1. See V-2.2.2.10(a) for long discharge connections.

(a) Subsonic-Inferential Meters. Measurements associated with subsonic-inferential meters are

(1) inlet static pressure

(2) inlet temperature

(3) differential pressure

(b) Sonic-Inferential Meters. Measurements associated with sonic-inferential meters are

(1) inlet total (stagnation) pressure

(2) inlet total (stagnation) temperature

V-2.2.4.2 Preliminary Device Tests. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and/or device being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus.

V-2.2.4.3 Barometric Pressure. Record the barometric pressure (see V-2.2.2.1).

V-2.2.4.4 Details of Procedure for Flow Measurement of Devices Using Subsonic-Inferential-Meter Method

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11.

(b) Establish and maintain flow-rating pressure until flow instruments indicate a steady-state condition.

(c) Record the following:

(1) device-inlet pressure

(2) device-inlet temperature

(3) device-disk lift, as applicable

(4) flowmeter-inlet static pressure

(5) flowmeter-inlet temperature

(6) flowmeter differential pressure

(d) Decrease inlet pressure slowly, and again record reseating pressure of the device.

V-2.2.4.5 Details of Procedure for Flow Measurement of Devices Using Sonic-Inferential-Meter Method

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11.

(b) Establish and maintain flow-rating pressure until flow instruments indicate a steady-state condition.

(c) Record the following:

(1) device-inlet pressure

(2) device-inlet temperature

(3) device-disk lift, as applicable

(4) flowmeter-inlet total pressure

(5) flowmeter-inlet total temperature

(d) Decrease inlet pressure slowly, and again record reseating pressure of a reclosing pressure relief device.

V-2.2.4.6 Observation of the Mechanical Characteristics. During the subsonic- or sonic-inferential-meter method of test, the mechanical characteristics shall be observed by hearing, feeling, or seeing and recorded during the flow test. If the valve chatters, flutters, or does not reseat satisfactorily, such action shall be recorded. Upon agreement of all interested parties, the valve may be readjusted or repaired and retested. Excessive and continual chatter could cause mechanical failure of the valve and thereby create a hazard to personnel in the test area.

V-2.2.4.7 Recording Additional Data. During the subsonic- or sonic-inferential-meter method of test, it may be desirable or a requirement to record pressures other than or in addition to those listed in V-2.2.4.4 or V-2.2.4.5. Where possible, such recorded pressures shall be identified in accordance with V-1.6.

V-2.2.5 Testing With Liquid, Pressure Relief Device Discharging to Atmospheric Pressure

V-2.2.5.1 Test Arrangements. The pressure source may be a pump or an accumulator of liquid in combination with high-pressure compressed gas. Measures shall be taken to ensure that pressure pulsations in the system are reduced to a minimum. The flowmeter test arrangement shown in Figure V-2.2.2.3-1 illustrates a recommended arrangement up to and including the test pressure relief device. Figure V-2.2.2.10-3 illustrates a recommended discharge arrangement.

(a) If a flowmeter [see V-2.2.2.4(a)(1)] is used, the associated measurements shall include, as a minimum, flowmeter differential pressure, device-inlet pressure, and liquid temperature. In this case, the use of a means of determining the volume or weight of the discharge is not a requirement.

NOTE: When conducting flowmeter tests involving a pressure relief device having high inlet pressure and low flow rates, it may be desirable to install the flowmeter downstream of the pressure relief device. Such installations are acceptable provided the installation has been calibrated in accordance with V-2.1.8.

(b) If a flowmeter is not used, volumetric or gravimetric determination of the pressure relief device discharge over a period of time shall be made. Readings of the device-inlet pressure and liquid temperature shall be made and recorded. Means shall be provided for directing the discharge into and diverting it from the tank used for measuring purposes.

V-2.2.5.2 Preliminary Tests. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and/or device being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus and ensure that all gas or air has been vented from the component parts of the system, except those referred to in V-2.2.5.1.

V-2.2.5.3 Details of Procedure for Flow Measurement of Devices Using the Flowmeter Method

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11.

(b) Establish and maintain flow-rating pressure until instruments indicate a steady-state condition.

(c) Record the following:

(1) device-inlet pressure

(2) device-disk lift, as applicable

(3) liquid temperature

(4) flowmeter differential pressure

(d) Decrease inlet pressure slowly, and again record reseating pressure of a reclosing pressure relief device.

V-2.2.5.4 Details of Procedure for Flow Measurement of Devices Using the Volumetric or Gravimetric Method

NOTE: The period of the test is determined by the measured time the discharge of the device is directed into the tank used for measuring purposes. Care shall be taken that the pressure at the device inlet remains stable during this period.

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11.

(b) Establish and maintain flow-rating pressure until instruments indicate a steady-state condition.

(c) Record the following:

(1) device-inlet pressure

(2) device-disk lift, as applicable

(3) liquid temperature

(d) Direct valve discharge into measuring tank.

(e) Repeat (c) herein at specified intervals.

(f) Divert device discharge from measuring tank.

(g) Record length of runs and times of recording data as measured by stopwatch, electric synchronous clock with second hand, or other appropriate means.

(h) Decrease inlet pressure slowly, and again record reseating pressure of a reclosing pressure relief device.

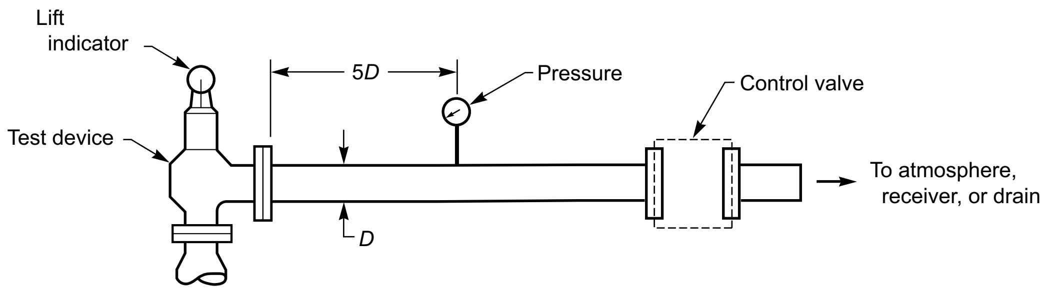
V-2.2.5.5 Observation of Mechanical Characteristics. During the flowmeter or volumetric method of test, the mechanical characteristics shall be observed by hearing, feeling, or seeing and recorded during the flow test. If the valve chatters, flutters, or does not reseat satisfactorily, such action shall be recorded. Upon agreement of all interested parties, the valve may be readjusted or repaired and retested.

V-2.2.5.6 Recording Additional Data. During the flowmeter or volumetric method test, it may be desirable or a requirement to record pressures other than or in addition to those listed in V-2.2.5.3 and V-2.2.5.4. Where possible, such recorded pressures shall be identified in accordance with V-1.6. With closed discharge systems, it is not possible to observe or record some characteristic pressures.

V-2.2.6 Testing With Steam, With Back Pressure Above Atmospheric

V-2.2.6.1 Test Arrangements. Recommended test arrangements are illustrated in Figures V-2.2.2.3-1, V-2.2.2.10-4, and V-2.2.6.1-1. Capacity determination shall be made by means of a flowmeter [see V-2.2.2.4(a)(1)] installed at the upstream side of the valve. Figure V-2.2.2.3-1 shows a recommended test arrangement, up to and including the test valve.

Figure V-2.2.6.1-1
Recommended Discharge Arrangement for Testing Devices With Built-Up Back Pressure



See Figure V-2.2.2.3-1 for inlet arrangement

Figures V-2.2.2.10-4 and V-2.2.6.1-1 show discharge arrangements.

(a) Figure V-2.2.2.10-4 illustrates a recommended test arrangement for testing with superimposed back pressure. Means are provided for applying back pressure to the valve prior to the valve reaching its set pressure [see V-2.2.5.5(b)]. A control valve shall be provided for controlling the back pressure prior to, during, and after the opening of the test valve. The piping shall be so arranged that condensate will not collect in the piping and a drain shall be provided on the back pressure vessel.

(b) Figure V-2.2.6.1-1 illustrates a recommended test arrangement for testing with built-up back pressure. Required equipment includes a means of controlling the degree of back pressure built up on the test valve after opening and for measuring the static pressure in the test-valve discharge.

V-2.2.6.2 Preliminary Tests. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and the valve being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus and that flowmeter reservoirs (meter-pots) are filled, properly cooled, and initially vented.

V-2.2.6.3 Barometric Pressure. Record the barometric pressure (see V-2.2.2.1).

V-2.2.6.4 Details of Procedure for Flow Measurement

(a) Atmospheric Back-Pressure Test. Tests may be conducted to determine the performance of the valve when discharging at atmospheric back pressure. The valve shall be equipped with an atmospheric discharge, as shown in Figure V-2.2.2.3-1 Test procedure shall be in accordance with V-2.2.3.4(a) through V-2.2.3.4(h), performing such portions of the procedure and recording such data as has been agreed upon.

NOTE: The objectives of this portion of the test may be only to determine and record the set pressure and closing pressure of the valve, and the lift of the valve at the flow-rating pressure, when the valve is discharging to atmosphere. In this case, the portions of V-2.2.3.4(a) through V-2.2.3.4(h) relating to capacity determination may be eliminated.

(b) Back-Pressure Test. Following the atmospheric back-pressure test, if performed, install the discharge arrangement required by Figure V-2.2.2.10-4 or Figure V-2.2.6.1-1 depending on the type of back pressure desired.

V-2.2.6.5 Testing With Superimposed Back Pressure [See V-2.2.6.1(a)]

(a) Adjust the back pressure on the valve and the discharge piping to the required value.

(b) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11. The back pressure shall be maintained as uniformly as possible and recorded during the tests in V-2.2.2.11(a) and V-2.2.2.11(b).

(c) Establish and maintain flow-rating pressure until flow instruments and back pressure gage indicate a steady-state condition.

(d) Close test-drum drain, and establish and record or mark starting condensate level in a gage glass.

(e) Record the following:

- *(1)* valve-inlet pressure
- *(2)* valve-inlet calorimeter discharge temperature
- *(3)* valve-disk lift
- *(4)* flowmeter static pressure
- *(5)* flowmeter differential pressure
- *(6)* flowmeter calorimeter discharge temperature
- *(7)* back pressure

(f) Reestablish original gage-glass level or new level at end of run, determine condensate by weight or volume measurement, and record.

(g) Decrease inlet pressure slowly, and again record reseating pressure of valve and back pressure.

(h) In most instances, it is desirable or a requirement that the valve be tested over a given range of back pressure. In such cases, it is convenient if the value of back pressure chosen in (c) herein be either the lowest or highest of this range. Back pressure may then be increased

or decreased in increments, repeating (c) through (g) herein at each incremental value.

V-2.2.6.6 Testing With Built-Up Back Pressure [See V-2.2.6.1(b)]

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11. During the V-2.2.2.11(b) test, back pressure shall be adjusted to the desired value and recorded. Prior to repeating tests in V-2.2.2.11(a) and V-2.2.2.11(b) as applicable in para. V-2.2.2.11(c), remove any flow restriction in the discharge test arrangement imposed during the previous test, as failure to do so may prevent the valve from achieving the same lift as the initial test.

(b) Establish and maintain flow-rating pressure until flow instruments and back pressure gage indicate a steady-state condition.

(c) Close test-drum drain, and establish and record or mark starting condensate level in a gage glass.

(d) Record the following:

(1) valve-inlet pressure
(2) valve-inlet calorimeter discharge temperature
(3) valve-disk lift
(4) flowmeter static pressure
(5) flowmeter differential pressure
(6) flowmeter calorimeter discharge temperature
(7) back pressure

(e) Reestablish original gage-glass level or new level at end of run, determine condensate by weight or volume measurement, and record.

(f) Decrease inlet pressure slowly, and again record reseating pressure of valve and back pressure.

(g) In most instances, it is desirable or a requirement that the valve be tested over a given range of back pressure. In such cases, it is convenient if the value of back pressure chosen in (a) herein be either the lowest or highest of this range. Back pressure may then be increased or decreased in increments, repeating (a) through (f) herein at each incremental value.

V-2.2.6.7 Observation of Mechanical Characteristics. During the tests with superimposed or built-up back pressure, mechanical characteristics shall be observed by hearing, feeling, or seeing and recorded during the flow test. If the valve chatters, flutters, or does not reseat satisfactorily, such action shall be recorded. Upon agreement of all interested parties, the valve may be readjusted or repaired and retested. When testing valves against back pressure, any range in which the valve does not reach rated lift at the flow-rating pressure shall be recorded.

V-2.2.6.8 Recording Additional Data. During tests with superimposed or built-up back pressure, it may be desirable or a requirement to record pressures other than or in addition to those listed in V-2.2.6.5 or V-2.2.6.6. Where possible, such recorded pressures shall be identified in accordance with V-1.6. With closed discharge systems, such as described in V-2.2.6.1(a), it is not possible to observe or record some characteristic pressures.

V-2.2.7 Testing With Gas or Air, With Back Pressure Above Atmospheric

V-2.2.7.1 Test Arrangements. Recommended test arrangements are illustrated in Figures V-2.2.2.3-1, V-2.2.2.10-4, and V-2.2.6.1-1. Capacity determination shall be made by means of a flowmeter [see V-2.2.2.4(a)(1)] installed at the upstream side of the valve. Figure V-2.2.2.3-1 shows a recommended test arrangement, up to and including the test valve. Figures V-2.2.2.10-4, and V-2.2.6.1-1 show discharge arrangements.

(a) Figure V-2.2.2.10-4 illustrates a recommended test arrangement for testing with superimposed back pressure to the valve prior to the valve reaching its set pressure [see V-2.2.2.5(b)]. A control valve shall be provided for controlling the back pressure prior to, during, and after the opening of the test valve. The piping shall be so arranged that condensate will not collect in the piping and a drain shall be provided on the back-pressure vessel.

(b) Figure V-2.2.6.1-1 illustrates a recommended test arrangement for testing with built-up back pressure. Required equipment includes a means of controlling the degree of back pressure built up on the test valve after opening and for measuring the static pressure in the test-valve discharge.

V-2.2.7.2 Preliminary Tests. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and/or valve being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus.

V-2.2.7.3 Barometric Pressure. Record the barometric pressure (see V-2.2.2.1).

V-2.2.7.4 Details of Procedure for Flow Measurement

(a) Atmospheric Back-Pressure Test. Tests may be conducted to determine the performance of the valve when discharging at atmospheric back pressure. The valve shall be equipped with an atmospheric discharge, as shown in Figure V-2.2.2.3-1. Test procedure shall be in accordance with V-2.2.4.4(a) through V-2.2.4.4(d), performing such portions of the procedure and recording such data as has been agreed upon.

NOTE: The objectives of this portion of the test may be only to determine and record the set pressure and closing pressure of the valve, and the lift of the valve at the flow-rating pressure, when the valve is discharging to atmosphere. In this case, the portions of V-2.2.4.4(a) through V-2.2.4.4(d) relating to capacity determination may be eliminated.

(b) Back-Pressure Test. Following the atmospheric back-pressure test, if performed, install the discharge arrangement required by Figure V-2.2.2.10-4 or Figure V-2.2.6.1-1, depending on the type of back pressure desired.

V-2.2.7.5 Testing With Superimposed Back Pressure [See V-2.2.7.1(a)]

(a) Adjust the back pressure on the valve and the discharge piping to the required value.

(b) Establish the set pressure, and blowdown if applicable, in accordance V-2.2.2.11. The back pressure shall be maintained as uniformly as possible and recorded during the tests in V-2.2.2.11(a) and V-2.2.2.11(b).

(c) Establish and maintain flow-rating pressure until flow instruments and back pressure gage indicate a steady-state condition.

(d) Record the following:

(1) valve-inlet pressure
(2) valve-inlet temperature
(3) valve-disk lift
(4) flowmeter-inlet static pressure
(5) flowmeter-inlet temperature
(6) flowmeter differential pressure
(7) back pressure

(e) Decrease inlet pressure slowly, and again record reseating pressure of valve and back pressure.

(f) In most instances, it is desirable or a requirement that the valve be tested over a given range of back pressure. In such cases, it is convenient if the value of back pressure chosen in (a) be either the lowest or highest of this range. Back pressure may then be increased or decreased in increments, repeating (b) through (e) herein at each incremental value.

V-2.2.7.6 Testing With Built-Up Back Pressure [See V-2.2.7.1(b)]

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11. During the V-2.2.2.11(b) test, back pressure shall be adjusted to the desired value and recorded. Prior to repeating tests in V-2.2.2.11(a) and V-2.2.2.11(b) as applicable in V-2.2.2.11(c), remove any flow restriction in the discharge test arrangement imposed during the previous test, as failure to do so may prevent the valve from achieving the same lift as the initial test.

(b) Establish and maintain flow-rating pressure and back pressure until flow instruments and back pressure gage indicate a steady-state condition.

(c) Record the following:

(1) valve-inlet pressure
(2) valve-inlet temperature
(3) valve-disk lift
(4) flowmeter-inlet static pressure
(5) flowmeter-inlet temperature
(6) flowmeter differential pressure
(7) back pressure

(d) Decrease inlet pressure slowly, and again record reseating pressure and back pressure.

(e) In most instances, it is desirable or a requirement that the valve be tested over a given range or back pressure. In such cases, it is convenient if the value of back pressure chosen in V-2.2.7.5(a) be either the lowest or highest of this range. Back pressure may then be increased or decreased in increments, repeating (a) through (d) herein at each incremental value.

V-2.2.7.7 Observation of Mechanical Characteristics. During the tests with superimposed or built-up back pressure, mechanical characteristics shall be observed by hearing, feeling, or seeing and recorded during the flow test. If the valve chatters, flutters, or does not reseat satisfactorily, such action shall be recorded. Upon agreement of all interested parties, the valve may be readjusted or repaired and retested. When testing valves against back pressure, any range in which the valve does not reach rated lift at the flow-rating pressure shall be recorded.

V-2.2.7.8 Recording Additional Data. It may be desirable or a requirement to record pressures other than or in addition to those listed in V-2.2.3.4. Where possible, such recorded pressures shall be identified in accordance with V-1.6. With closed discharge systems, it is not possible to observe or record some characteristic pressures.

V-2.2.8 Testing With Liquids, With Back Pressure Above Atmospheric

V-2.2.8.1 Test Arrangements. Pressure sources can be a pump or an accumulator of liquid, in combination with high-pressure compressed gas. Precautions shall be taken to ensure that pressure pulsations are reduced to a minimum. Figure V-2.2.2.3-1 shows a recommended test arrangement, up to and including the test valve. Figures V-2.2.2.10-4 and V-2.2.6.1-1 show discharge arrangements for testing with superimposed and built-up back pressure, respectively. A flowmeter [see V-2.2.2.4(b)(1)] shall be used in either case. Instrumentation shall be suitably installed to indicate or record the following:

(a) liquid temperature
(b) flowmeter differential pressure
(c) valve-inlet pressure
(d) back pressure

V-2.2.8.2 Preliminary Tests. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and/or valve being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus and that all gas or air has been vented from the component parts of the system.

V-2.2.8.3 Details of Procedure for Flow Measurement

(a) Atmospheric Back-Pressure Test. Tests may be conducted to determine the performance of the valve when discharging at atmospheric back pressure. The valve shall be equipped with an atmospheric discharge, as shown in Figure V-2.2.2.3-1. Test procedure shall be in accordance with V-2.2.5.3(a) through V-2.2.5.3(d) performing such portions of the procedure and recording such data as has been agreed upon.

NOTE: The objectives of this portion of the test may be only to determine and record the set pressure and closing pressure of the valve, and the lift of the valve at the flow-rating pressure, when the valve is discharging to atmosphere. In this case, the portions of V-2.2.5.3(a) through V-2.2.5.3(d) relating to capacity determination may be eliminated.

(b) Back-Pressure Test. Following the atmospheric back-pressure test, if performed, install the discharge arrangement required by Figure V-2.2.2.10-4 or Figure V-2.2.6.1-1, depending on the type of back pressure desired.

V-2.2.8.4 Testing With Superimposed Back Pressure (See Figure V-2.2.2.10-4)

(a) Adjust the back pressure on the valve and discharge piping to the required value.

(b) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11. The back pressure shall be maintained as uniformly as possible and recorded during the tests in V-2.2.2.11(a) and V-2.2.2.11(b).

(c) Establish and maintain flow-rating pressure until flow instruments and back pressure gage indicate a steady-state condition.

(d) Record the following:

(1) valve-inlet pressure

(2) valve-disk lift

(3) liquid-inlet temperature

(4) flowmeter differential pressure

(5) back pressure

(e) Decrease inlet pressure slowly, and again record reseating pressure of valve and back pressure.

(f) In most instances, it is desirable or a requirement that the valve be tested over a given range of back pressure. In such cases, it is convenient if the value of back pressure chosen in (a) be either the lowest or highest of this range. Back pressure may then be increased or decreased in increments, repeating (b) through (e) herein at each incremental value.

V-2.2.8.5 Testing With Built-Up Back Pressure (See Figure V-2.2.6.1-1)

(a) Establish the set pressure, and blowdown if applicable, in accordance with V-2.2.2.11. During the V-2.2.2.11(b) test, back pressure shall be adjusted to the desired value and recorded. Prior to repeating tests in V-2.2.2.11(a) and V-2.2.2.11(b) as applicable in V-2.2.2.11(c), remove any flow restriction in the discharge test arrangement imposed during the previous test, as failure to do so may prevent the valve from achieving the same lift as the initial test.

(b) Establish and maintain flow-rating pressure and back pressure until flow instruments and back-pressure gage indicate a steady-state condition.

(c) Record the following:

(1) valve-inlet pressure

(2) valve-disk lift

(3) liquid-inlet temperature

(4) flowmeter differential pressure

(5) back pressure

(d) Decrease inlet pressure slowly, and again record reseating pressure of valve and back pressure.

(e) In most instances, it is desirable or a requirement that the valve be tested over a given range of back pressure. In such cases, it is convenient if the value of back pressure chosen in V-2.2.8.4(a) be either the lowest or highest of this range. Back pressure may then be increased or decreased in increments, repeating (a) through (d) herein at each incremental value.

V-2.2.8.6 Tests With Built-Up Back Pressure With Measuring Tank. The use of volumetric or gravimetric determination of valve discharge when testing with built-up back pressure is permissible. In such cases, the interested parties shall agree on a test procedure prior to conducting the tests.

V-2.2.8.7 Observation of Mechanical Characteristics. During the tests with superimposed or built-up back pressure, mechanical characteristics shall be observed by hearing, feeling, or seeing and recorded during the flow test. If the valve chatters, flutters, or does not reseat satisfactorily, such action shall be recorded. Upon agreement of all interested parties, the valve may be readjusted, repaired, and retested. When testing valves against back pressure, any range in which the valve does not reach rated lift at the flow-rating pressure shall be recorded.

V-2.2.8.8 Recording Additional Data. During the tests with superimposed or built-up back pressure, it may be desirable or a requirement to record pressures other than or in addition to those listed in V-2.2.8.4 or V-2.2.8.5. Where possible, such recorded pressure shall be identified in accordance with V-1.6. With closed discharge systems, it is not possible to observe or record some characteristic pressures.

V-2.2.9 Testing With Gas or Air, Non-reclosing Pressure Relief Device Flow Resistance Method

V-2.2.9.1 Test Arrangement. A recommended flow resistance test rig arrangement is shown in Figure V-2.1.9-1, which represents the test vessel and test device of Figure V-2.2.2.3-1. The device shall have the same nominal pipe size dimension as the test rig. Differential pressure measurement instruments or transducers shall be used between pressure taps A-B, B-C, and C-D. The primary element shall be either a subsonic-inferential meter or a sonic-inferential meter as shown in Figure V-2.2.2.3-1 and described in para. V-2.2.2.4(a). Instrumentation for each type of meter is listed in the following:

(a) *Subsonic-Inferential Meters*. Measurements associated with subsonic-inferential meters are

(1) inlet static pressure
(2) inlet temperature
(3) differential pressure

(b) *Subsonic-Inferential Meters*. Measurements associated with sonic-inferential meters are

(1) inlet total (stagnation) pressure
(2) inlet total (stagnation) temperature

V-2.2.9.2 Preliminary Tests. Preliminary tests may be permitted for testing the test apparatus. Such tests may be necessary to ensure the absence of leaks in the test apparatus and that all differential pressure measurement devices are functioning properly and within their pressure measurement range.

V-2.2.9.3 Barometric Pressure. Record the barometric pressure (see para. V-2.2.2.1).

V-2.2.9.4 Details of Procedure for Flow Resistance Measurement Using Subsonic-Inferential-Meter Method

(a) Install the device into the flow resistance test rig.

(b) Increase the pressure at pressure tap B. During the interval starting at 90% of the expected set pressure, the rate of pressure increase shall not exceed 2.0 psi/sec (15 kPa/s) or whatever lesser rate of increase is necessary for the accurate reading of the pressure. Observe and record the set pressure of the device and any other desired or pertinent characteristics.

(c) Establish and maintain flow-rating pressure until flow instruments indicate a steady-state condition.

(d) Simultaneously record the following measurements (it is preferable to use a data acquisition system for these measurements):

(1) test rig inlet pressure
(2) test rig inlet temperature
(3) flowmeter-inlet static pressure
(4) flowmeter-inlet total temperature
(5) flowmeter differential pressure
(6) tap B pressure
(7) differential pressure tap A-B
(8) differential pressure tap B-C
(9) differential pressure tap C-D

V-2.2.9.5 Details of Procedure for Flow Resistance Measurement Using Sonic-Inferential-Meter Method

(a) Install the device into the flow resistance test rig.

(b) Increase the pressure at pressure tap B. During the interval starting at 90% of the expected set pressure, the rate of pressure increase shall not exceed 2.0 psi/sec (15 kPa/s) or whatever lesser rate of increase is necessary for the accurate reading of the pressure. Observe and record the set pressure of the device and any other desired or pertinent characteristics.

(c) Establish and maintain flow-rating pressure until flow instruments indicate a steady-state condition.

(d) Simultaneously record the following measurements (it is preferable to use a data acquisition system for these measurements):

(1) test rig inlet pressure
(2) test rig inlet temperature
(3) flowmeter-inlet static pressure
(4) flowmeter-inlet total temperature
(5) tap B pressure
(6) differential pressure tap A-B
(7) differential pressure tap B-C
(8) differential pressure tap C-D

V-2.2.9.6 Recording Additional Data. During the subsonic- or sonic-inferential-meter method of test, it may be desirable or a requirement to record pressures other than or in addition to those listed in para. V-2.2.9.4 or para. V-2.2.9.5. Where possible, such recorded pressures shall be identified in accordance with V-1.6.

V-2.2.9.7 Resistance Testing on Non-reclosing Pressure Relief Devices With Connections Not Compatible With Figure V-2.1.9-1. The use of an adapter for devices with inlet/outlet connections that are not compatible with the test rigs of Figure V-2.1.9-1 is allowed provided the devices are the same nominal size as the test rigs and the adapter's resistance to flow, if the adapter constitutes part of a flow path, is properly accounted for as follows:

(a) Install the adapter into the test rig of Figure V-2.1.9-1, and conduct three baseline flow tests to determine the average flow resistance of the adapter.

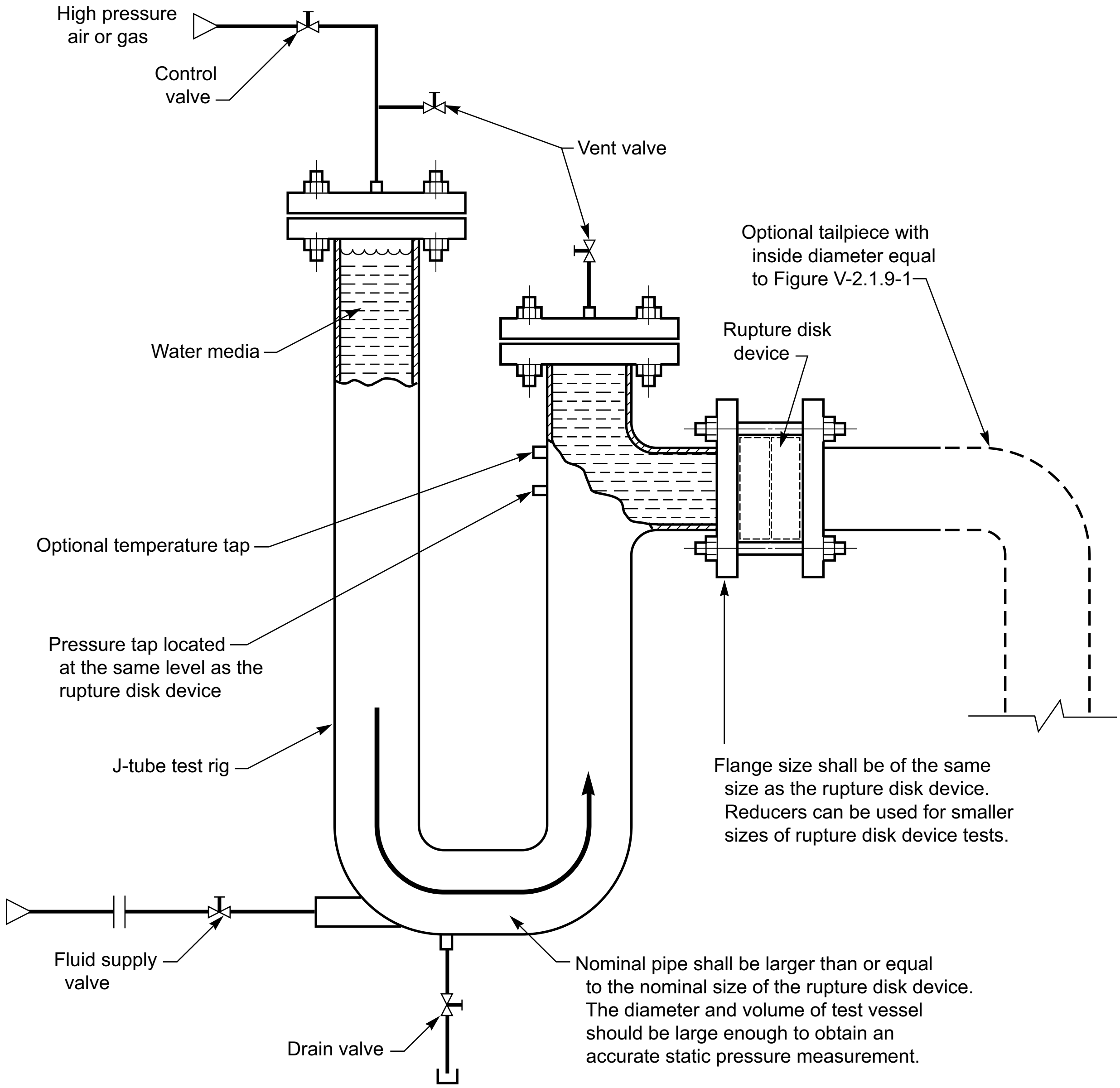
(b) Proceed with determining the flow resistance of the combined assembly, the test device, and adapter, per V-2.2.9.4 or V-2.2.9.5.

(c) Calculate the test device individual flow resistance, KRi, by subtracting the average flow resistance of the adapter. The use of, and specification of, the adapter shall be included in the test report.

V-2.2.10 Testing Non-reclosing Pressure Relief Devices to Determine a Set Pressure for Incompressible Fluids

V-2.2.10.1 Test Arrangement. A recommended test arrangement for conducting set pressure tests on incompressible fluids is shown in Figure V-2.2.10.1-1. The test arrangement shall have the same for larger nominal pipe size dimensions as the device. Unless no portion of the

Figure V-2.2.10.1-1
Recommended Arrangement for Conducting Opening Test on Non-reclosing Pressure Relief Devices With Incompressible Fluids



device extends into the outlet connection arrangement, the outlet connection shall match the internal bore of the flow resistance test arrangement of V-2.2.9. The test medium shall be water or other suitable incompressible fluid. The test shall be conducted in such a way as to prevent compressed gas from passing through the device at any time. After set pressure tests have been conducted, the device shall be removed from this test arrangement and installed within the resistance factor test arrangement shown in Figure V-2.1.9-1. The device flow resistance factor shall be tested per V-2.2.9 using gas or air as the fluid.

V-2.2.10.2 Preliminary Test. Preliminary tests may be permitted for testing and adjusting operation of the test apparatus and/or device being tested (see V-2.1.5). Such tests may be necessary to ensure the absence of leaks in the test apparatus.

V-2.2.10.3 Details of Procedure for Determining a Non-reclosing Pressure Relief Device Flow Resistance Factor Applicable for Incompressible Fluids

(a) Install the device between the flanges of the test apparatus.

(b) Position valves to fill the test apparatus with liquid, and vent any trapped gas immediately upstream to the device.

(c) Reposition valves to pressurize the system. Increase the pressure at the pressure tap. During the interval starting at 90% of the expected set pressure, the rate of pressure increase shall not exceed 2.0 psi/sec (15kPa/s) or whatever lesser rate of increase is necessary for the accurate reading of the pressure. Observe and record the set pressure of the device and any other desired or pertinent characteristics.

(d) Remove the device from the test apparatus. Care shall be taken not to disturb the opening pattern of the device.

(e) Complete the device flow resistance testing per V-2.2.9.4 using gas or air as the test medium.

V-2.3 COMPUTATION OF RESULTS

V-2.3.1 Correction of Measured Variables

The values of measured variables shall be corrected in accordance with instrument calibrations. No other corrections to the data are permitted.

V-2.3.2 Review of Instrument Readings

Before calculations are undertaken, the instrument readings, as recorded in the log, shall be reviewed for inconsistency and large fluctuation in accordance with ASME PTC 19.1.

V-2.3.3 Use of Equation Symbols

The symbols used in this Appendix are ones that are already in common use in the particular fields of engineering involved. In a few cases, the same letter has different meanings in different parts of the Code according to its application. In order to avoid confusion, each equation has been provided with its own list of definitions of symbols. Users are cautioned not to assume that a symbol has the same meaning in another equation.

V-2.3.4 Density

Computation of density shall be made from measured values of pressure, temperature, and specific gravity.

(a) For steam and other condensible fluids, the density ρ shall be taken as $1/v$ where v, the specific volume, in ft^3/lbm (m^3/kg), is obtained from the latest edition of ASME Steam Tables for steam or other established tables for other fluids at the measured pressure and temperature.

(b) The following relations shall be used for computing the density of gases where the physical properties are accurately known:

(1) For any dry gas

(U.S. Customary Units)

$$\rho = \frac{144P}{ZRT}$$

(SI Units)

$$\rho = \frac{P}{ZRT}$$

(2) For dry air, ρ reduces to

(U.S. Customary Units)

$$\rho = \frac{2.699P}{ZT}$$

(SI Units)

$$\rho = \frac{3.488P}{ZT}$$

(3) For air and other gases

(U.S. Customary Units)

$$\rho = \frac{2.699GP}{ZT}$$

(SI Units)

$$\rho = \frac{3.488GP}{ZT}$$

where

G = specific gravity with respect to dry air
= M/M_a
M = molecular weight of gas
M_a = molecular weight of air
P = static pressure, psia (kPa)
R = gas constant, ft-lbf/lbm-°R (kPa/kgK)
= $1{,}545.4/M(8.3143/M)$
T = temperature, °R (K)
Z = compressibility factor as defined in the equation of state, $Pv = ZRT$. If more details are desired, see ASME PTC 19.5.

V-2.3.5 Capacity Calculations

The information in V-2.3.5.1 through V-2.3.5.7 is provided to assist in the use of the calculation sheets and aid in carrying out the several methods of computing capacity. Flow equations, correction factors, and procedures for calculations are in accordance with ASME PTC 19.5.

V-2.3.5.1 Volumetric or Weighed-Water Method. This technique requires the collection of the discharge from the valve under test either as a mass or a volume over a known period of time. Care shall be taken to ensure that the valve-inlet conditions are maintained throughout the test and that neither extraneous water is measured nor any valve discharge is lost.

Form V-2.3.5.1-1 (Form V-2.3.5.1-1M) should be used for recording the data and computing the results. The first eight items on this form are primarily for identification purposes. Items 9 through 12 record the amount of water collected over the given time interval. Item 11 is any leakage after the valve throat that might be at the valve stem, drain hole in the valve, or in the discharge piping. The manner in which this leakage is to be evaluated shall be agreed upon by the parties to the test, and the amount shall be added to the total accumulated (see Item 20, Item 27, or both). Item 12 is to account for any leakage of the condenser circulating water into the condensate. This is determined by a condenser leakage test, and the amount is to be subtracted from the total accumulated (see Item 20).

Items 13 through 20 record more data and show the calculation of the steam flow through the valve per hour, corrected to dry and saturated conditions at the valve inlet. In the equation for Item 20, the weight of water accumulated is divided by the time interval and multiplied by 60 to obtain the accumulated flow rate in pounds-mass (kilograms) per hour. This is multiplied by the ratio of the square root of the specific volume of the flowing steam at the valve inlet to the specific volume of dry and saturated steam at the inlet pressure. To this quantity is added the valve-stem leakage. The condenser leakage is subtracted for the test using water.

Items 21 through 25 record additional data. Item 27 determines the measured relieving capacity for a water test with no correction being made for either specific volume or condenser leakage (it being assumed that a condenser was required). Item 28 provides a capacity correction to whatever reference condition has been specified for the test. Item 29 changes the unit to gallons (liters) per minute at the reference condition.

V-2.3.5.2 Steam — Flowmeter Method. This technique meters the steam flow upstream of the valve under test. Care shall be taken that all the metered steam passes through the valve or is accounted for in the calculations. In addition to leakage, metered steam that does not reach the valve can occur by condensation of the steam in connecting piping and particularly in the test vessel.

The flow equations, correction factors, and procedures for calculations incorporated in Form V-2.3.5.2-1 (Form V-2.3.5.2-1M) are in accordance with ASME PTC 19.5.

Form V-2.3.5.2-1 (Form V-2.3.5.2-1M) should be used for recording the data and computing the results. The first eight items on this form are primarily for identification purposes. Form V-2.3.5.2-1 (Form V-2.3.5.2-1M) proceeds through the trial flow calculation in order to evaluate the proper factors and goes on to Item 28, which provides the flow rate of steam at the reference condition in pounds-mass (kilograms) per hour.

Items 29 through 38 transfer and adjust the meter flow to the flow through the valve. Item 35 and its use in calculating the valve-relieving capacity assumes the meter calorimeter's sampling tube is downstream of the meter. If this is not the case, the subtraction should not be made, since the correction shown is to account for metered steam not reaching the valve. All values used are corrected to the reference condition.

V-2.3.5.3 Liquids — Flowmeter Method. This technique meters the liquid flow upstream of the valve under test. Care shall be taken that all the metered liquid passes through the valve or is accounted for in the calculations.

The flow equations, correction factors, and procedures for calculations incorporated in Form V-2.3.5.3-1 (Form V-2.3.5.3-1M) are in accordance with ASME PTC 19.5.

Form V-2.3.5.3-1 (Form V-2.3.5.3-1M) should be used for recording data and computing the results. The first eight items on this form are primarily for identification purposes. The form proceeds through the trial flow calculation in order to evaluate the proper factors and goes on to Item 26, the measured relieving capacity through the meter at the meter conditions.

Items 27 through 33 provide the data and equation to calculate the relieving capacity at a reference condition if it is specified by the test. The evaluation assumes no change in fluid temperature between the meter and valve inlet.

V-2.3.5.4 Air or Gas — Flowmeter Method. This technique meters the gas flow upstream of the valve under test. Care shall be taken that all the metered gas passes through the valve or is accounted for in the calculations.

The flow equations, correction factors, and procedures for calculations incorporated in Form V-2.3.5.4-1 (Form V-2.3.5.4-1M) are in accordance with ASME PTC 19.5.

Form V-2.3.5.4-1 (Form V-2.3.5.4-1M) should be used for recording the data and computing the results. The first 12 items on this form are primarily for identification purposes. Form V-2.3.5.4-1 (Form V-2.3.5.4-1M) proceeds through the trial flow calculation to be able to evaluate the proper factors for refinement, through the measured capacity in pounds-mass (kilograms) per hour (Item 25), and on to the flow rate through the meter in cubic feet (meters) per minute at some prespecified base condition.

Items 35 through 40 then provide for the calculation of the flow through the valve in cubic feet (meters) per minute at a reference inlet condition.

V-2.3.5.5 Air or Gas — Sonic-Flow Method. This technique meters the gas flow upstream of the valve under test. Care shall be taken that all the metered gas passes through the valve or is accounted for in the calculations.

The flow equations, flow functions, correction factors, and procedures for calculation incorporated in Form V-2.3.5.5-1 (Form V-2.3.5.5-1M) are in accordance with ASME PTC 19.5.

The use of Form V-2.3.5.5-1 (Form V-2.3.5.5-1M) is recommended for either air or gas, and with the addition of basic data and valve identification, the form follows the procedure of ASME PTC 19.5.

This calculation follows through to evaluate the flow through the meter (Item 23) in pounds-mass (kilograms) per hour.

Items 24 through 30 are then used to determine the flow through the valve in cubic feet (meters) per minute at a reference condition.

V-2.3.5.6 Fuel-Gas Flow — Flowmeter Method. This technique meters the gas flow upstream of the valve under test. Care shall be taken that all of the metered gas passes through the valve or is accounted for in the calculations.

The flow equations, correction factors, and procedures for calculation incorporated in Form V-2.2.5.6-1 (Form V-2.2.5.6-1M) are in accordance with ASME PTC 19.5.

Form V-2.2.5.6-1 (Form V-2.2.5.6-1M) should be used for recording the data and computing the results. The first 12 items on this form are primarily for identification purposes.

Form V-2.2.5.6-1 (Form V-2.2.5.6-1M) proceeds through the trial flow calculation to be able to evaluate the proper factors for refinement, through the measured capacity in cubic feet (meters) per hour at some prespecified base condition converted from the required pounds-mass (kilograms) per hour (Item 32).

Items 35 through 40 provide for the calculation of the flow through the valve in cubic feet (meters) per minute at a reference inlet condition.

V-2.2.5.7 Air or Gas — Non-reclosing Pressure Relief Device Flow Resistance Method. This technique measures the resistance due to the presence of a non-reclosing pressure relief device in a piping system. It is used in conjunction with either the flowmeter or sonic-flow methods described in V-2.3.5.4 or V-2.3.5.5, respectively.

Form V-2.2.5.7-1 (Form V-2.2.5.7-1M) should be used for recording the data and computing the results. The first 17 items on this form are for identification purposes and listing of the measured variables. Item 6 is obtained from either Form V-2.2.5.4-1 (Form V-2.2.5.4-1M) or Form V-2.2.5.5-1 (Form V-2.2.5.5-1M). Care shall be taken that all of the metered gas passes through the test arrangement (see Figure V-2.2.6.1-1) or is accounted for in the calculations.

The remaining items on Form V-2.2.5.7-1 (Form V-2.2.5.7-1M) are used to determine the resistance factor between each of the established pressure taps. An individual flow resistance associated with the non-reclosing pressure relief device is then calculated from these results.

Two test checks shall be done to verify the test results.

(a) First, verify that the value $K_{\text{C-D}}$ is within 3% of the value $K_{\text{A-B}}$. If not, verify that the test arrangement is properly set up. Next, run a calibration test with no non-reclosing pressure relief device installed to verify that the value $K_{\text{C-D}}$ is within 3% of the value $K_{\text{A-B}}$. If so, calculate the resistance factor $K_{\text{B-D}} = K_{\text{D}} - K_{\text{B}}$ and the pipe length $L_{\text{B-D}} = L_{\text{D}} - L_{\text{B}}$. Complete the non-reclosing pressure relief device individual flow resistance calculation, replacing $K_{\text{B-C}}$, $K_{\text{pipe B-C}}$, and $L_{\text{B-C}}$ with $K_{\text{B-D}}$, $K_{\text{pipe B-D}}$, and $L_{\text{B-D}}$, respectively, in Items 34 and 35. This is done since the air turbulence caused by the non-reclosing pressure relief device is affecting the true pressure reading of tap C.

(b) Second, verify that the calculated pipe roughness from Item 33 is within the range 0.0018 in. to 0.00006 in. (0.0460 mm to 0.00150 mm). This is the range for schedule 40 clean commercial pipe.

V-2.4 TEST SUMMARY REPORT FORM

V-2.4.1 General Instructions

(a) The Report of Test shall be prepared for the purpose of formally recording observed data and computed results. It shall contain sufficient supporting information to prove that all objectives of any tests conducted in accordance with this Appendix have been attained.

(b) The procedures described in V-2.3 are recommended for use in computing the test results.

(c) The Report of Test shall include Parts I to IV as listed in (1) through (4) herein. It may also be appropriate to include any of the remaining sections, depending on the circumstances or by agreement of multiple parties of the test.

(1) Part I: General Information

(2) Part II: Summary of Results

(3) Part III: Description of Device Under Test

(4) Part IV: Observed Data and Computed Results

(5) Part V: Test Conditions and Corrections Agreements

(6) Part VI: Test Methods and Procedures

(7) Part VII: Supporting Data

(8) Part VIII: Graphical Presentation of Back-Pressure Test Results

Paragraphs V-2.4.2 through V-2.4.9 give a discussion of each Part of the Test Report.

V-2.4.2 Part I: General Information

This Part shall include the following items:

(a) date of test

(b) location of test facilities

(c) device manufacturer's name

(d) manufacturer's serial number and complete identification of device

(e) inlet and outlet connections (stating size, pressure ratings, and type, such as screwed, flanged, etc.)

(f) test conducted by

(g) representatives of interested parties

(h) object of test

(i) fluid through device (wherever applicable, give name, molecular weight, specific gravity, and ratio of specific heats)

V-2.4.3 Part II: Summary of Results

This Part shall include those quantities and characteristics that describe the performance of the device at test conditions. The Test Summary Report Form for the particular test shall list the quantities, characteristics, and units of measurement required for the report.

V-2.4.4 Part III: Description of Device Under Test

This Part may include assembly drawings, manufacturing drawings, and measured dimensions. Manufacturing drawings for these parts may be submitted with the assembly drawing. The dimensions of these parts shall include the following, if applicable:

(a) bore diameter, in. (mm)

(b) seat diameter, in. (mm)

(c) seat angle, deg

(d) inlet opening diameter, in. (mm)

(e) ratio of throat diameter to the diameter of the inlet opening

(f) actual discharge area, in.^{2} (mm^2)

Forms V-2.4.5-1 through V-2.4.5-4 shall be used to record this information for steam; liquids and water; or air, gas, or fuel gas.

V-2.4.5 Part IV: Observed Data and Computed Results

This Part shall include a record of data and calculations required for the results of the tests. Computed results shall include final flow measurement uncertainty. The data shall be corrected for instrument calibrations and conditions prevailing for each test run.

The calculations for measured relieving capacity may be made in accordance with the procedures in V-2.3 and reported in the recommended Report of Test using Forms V-2.4.5-1 through V-2.4.5-4 as applicable. Calculation forms are provided in V-2.3 for the following listed fluids:

(a) steam

(b) air or gas

(c) fuel gas

(d) liquids

(e) water

V-2.4.6 Part V: Test Conditions and Corrections Agreements

Operating conditions, such as the following, that have been agreed upon prior to the test shall be reported for each test:

(a) device-inlet maximum

(b) device-inlet temperature

(c) setting of device

(d) back pressure (built-up, superimposed, or both)

V-2.4.7 Part VI: Test Methods and Procedures

This Part shall include a detailed description of the instruments and apparatus used to measure the various quantities and procedures for observing the mechanical characteristics of the device under test.

V-2.4.8 Part VII: Supporting Data

This Part shall include pertinent material supplementing data presented elsewhere in the test report, whereby an independent verification of the report results can be made. This material may include, but not necessarily be limited to, the following:

(a) instrument calibration records

(b) detailed log sheets

(c) sample calculations

TEST REPORT FORM V-2.3.5.1-1
PRESSURE RELIEF DEVICE TESTED WITH STEAM AND WATER — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Weighed-Water Method

(1) Test number
(2) Test date
(3) Manufacturer's name

Measured Device Dimensions

Valve

(4) Bore diameter, in. (d_b)
(5) Seat diameter, in. (d_s)
(6) Seat angle, deg
(7) Valve-disk lift, in. (l)
(8) Actual discharge area, in.^{2} (a_d)

Non-reclosing Devices

(4) Minimum holder-bore diameter, in. (d_b)
(5) Minimum net flow area, in.^{2} (a)

Observed Data

(9) Length of test, min (t)
(10) Mass of water or condensate, lbm (w)
(11) Valve-steam leakage, lbm/hr (w_{vl})
(12) Condenser leakage, lbm/hr (w_{cl})

STEAM
Observed Data and Computed Results at the Device Inlet

(13) Set pressure, psig (P_{set})
(14) Flow-rating pressure, psia (P_f)
(15) Back pressure, psig (P_o)
(16) Fluid temperature at the calorimeter, °F (T_{cal})
(17) Percent quality or deg superheat
(18) Specific volume at reference condition, ft^3/lbm (V_{ref})
(19) Specific volume at inlet conditions, ft^3/lbm (V_{act})
(20) Measured relieving capacity adjusted to the reference condition, lbm/hr

$$W_h = \frac{60 \times w}{t}\sqrt{\frac{V_{act}}{V_{ref}}} + w_{vl} - w_{cl}$$

WATER
Observed Data and Computed Results at the Device Inlet

(21) Set pressure, psig (P_{set})
(22) Flow-rating pressure, psia (P_f)
(23) Back pressure, psig (P_o)
(24) Fluid temperature, °F (T)
(25) Density of water at inlet conditions, lbm/ft^3 (ρ_{act})
(26) Density of water at reference condition, lbm/ft^3(ρ_{ref})
(27) Measured relieving capacity, lbm/hr

$$W_h = \frac{60 \times w}{t} + w_{vl}$$

(28) Relieving capacity adjusted to water at reference condition, lbm/hr

$$W_r = W_h \times \sqrt{\frac{\rho_{ref}}{\rho_{act}}}$$

(29) Relieving capacity in gpm of water at reference condition (U.S. gallons), Q (gpm)

$$Q = 0.1247\,\frac{W_r}{\rho_{ref}}$$

TEST REPORT FORM V-2.3.5.1-1M
PRESSURE RELIEF DEVICE TESTED WITH STEAM AND WATER — SI UNITS
Observed Data and Computed Results — Weighed-Water Method

(1) Test number
(2) Test date
(3) Manufacturer's name

Measured Device Dimensions

Valve

(4) Bore diameter, mm (d_b)
(5) Seat diameter, mm (d_s)
(6) Seat angle, deg
(7) Valve-disk lift, mm (l)
(8) Actual discharge area, mm^2 (a_d)

Non-reclosing Devices

(4) Minimum holder-bore diameter, mm (d_b)
(5) Minimum net flow area, mm^2 (a)

Observed Data

(9) Length of test, min (t)
(10) Mass of water or condensate, kg (w)
(11) Valve-steam leakage, kg/h (w_{vl})
(12) Condenser leakage, kg/h (w_{cl})

STEAM
Observed Data and Computed Results at the Device Inlet

(13) Set pressure, kPag (P_{set})
(14) Flow-rating pressure, kPa (P_f)
(15) Back pressure, kPag (P_o)
(16) Fluid temperature at the calorimeter, °C (T_{cal})
(17) Percent quality or deg superheat
(18) Specific volume at reference condition, m^3/kg (V_{ref})
(19) Specific volume at inlet conditions, m^3/kg (V_{act})
(20) Measured relieving capacity adjusted to the reference condition, kg/h

$$W_h = \frac{60 \times w}{t}\sqrt{\frac{V_{act}}{V_{ref}}} + w_{vl} - w_{cl}$$

WATER
Observed Data and Computed Results at the Device Inlet

(21) Set pressure, kPag (P_{set})
(22) Flow-rating pressure, kPa (P_f)
(23) Back pressure, kPag (P_o)
(24) Fluid temperature, °C (T)
(25) Density of water at inlet conditions, kg/m^3 (ρ_{act})
(26) Density of water at reference condition, kg/m^3 (ρ_{ref})
(27) Measured relieving capacity, kg/h

$$W_h = \frac{60 \times w}{t} + w_{vl}$$

(28) Relieving capacity adjusted to water at reference condition, kg/h

$$W_r = W_h \times \sqrt{\frac{\rho_{ref}}{\rho_{act}}}$$

(29) Relieving capacity in L/m of water at reference condition (liters), Q (L/m)

$$Q = 16.67\,\frac{W_r}{\rho_{ref}}$$

TEST REPORT FORM V-2.3.5.2-1
PRESSURE RELIEF DEVICE TESTED WITH STEAM — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name

Measured Device Dimensions

Valve

(4) Bore diameter, in. (d_b)
(5) Seat diameter, in. (d_s)
(6) Seat angle, deg
(7) Valve-disk lift, in. (l)
(8) Actual discharge area, in.^{2} (a_d)

Non-reclosing Devices

(4) Minimum holder-bore diameter, in. (d_b)
(5) Minimum net flow area, in.^{2} (a)

Flowmeter Calculations

(9) Internal diameter of meter run pipe, in. (D)
(10) Meter-bore diameter, in. (d)
(11) Meter-bore diameter squared, in.^{2} (d^2)
(12) Beta ratio ($\beta = d/D$)
(13) Trial flow coefficient (K_o)
(14) Differential pressure at the meter, inches of water (h_w)
(15) Barometric pressure, psia (P_b)
(16) Static pressure at the meter calorimeter, psia (P_m)
(17) Fluid temperature at the meter calorimeter, °F ($T_{\text{cal, meter}}$)
(18) Percent quality or deg superheat
(19) Area factor for thermal expansion (F_a)
(20) Expansion factor (Y)
(21) Specific volume at flowing conditions at the meter, ft^3/lbm ($V_{\text{act, meter}}$)
(22) Specific volume at reference conditions at the meter, ft^3/lbm ($V_{\text{ref, meter}}$)
(23) Trial flow rate, lbm/hr

$$W_t = 358.93 \times d^2 \times K_o \times F_a \times Y \times \sqrt{\frac{h_w}{V_{\text{act, meter}}}}$$

(24) Viscosity, lbm/ft-sec (μ)
(25) Reynolds number

$$R_D = \frac{0.00424 \times W_h}{(D)(\mu)}$$

(26) Orifice plate discharge coefficient (C)

(27) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(28) Flow rate (lbm/hr)

$$W_h = \frac{W_t \times K}{K_o}\sqrt{\frac{V_{\text{act, meter}}}{V_{\text{ref, meter}}}}$$

Observed Data and Computed Results at the Device Inlet

(29) Set pressure, psig (P_{set}) (burst pressure for non-reclosing device)
(30) Flow-rating pressure, psia (P_f)
(31) Fluid temperature at the test drum calorimeter, °F ($T_{\text{cal, drum}}$)
(32) Percent quality or deg superheat

TEST REPORT FORM V-2.3.5.2-1
PRESSURE RELIEF DEVICE TESTED WITH STEAM — U.S. CUSTOMARY UNITS (CONT'D)
Observed Data and Computed Results — Flowmeter Method

Observed Data and Computed Results at the Device Inlet (Cont'd)

(33) Specific volume at reference condition, ft^3/lbm ($V_{ref,\ drum}$)
(34) Specific volume at inlet conditions, ft^3/lbm ($V_{act,\ drum}$)
(35) Meter calorimeter flow, lbm/hr (W_{mc})
(36) Meter calorimeter flow adjusted to the reference condition, lbm/hr

$$W_{cal,\ meter} = W_{mc}\sqrt{\frac{V_{act,\ meter}}{V_{ref,\ meter}}}$$

(37) Test-drum calorimeter flow, lbm/hr (W_{dc})
(38) Test-drum calorimeter flow adjusted to the reference condition, lbm/hr

$$W_{cal,\ drum} = W_{dc}\sqrt{\frac{V_{act,\ drum}}{V_{ref,\ drum}}}$$

(39) Test-drum drainage, lbm/hr (W_{dr})
(40) Measured relieving capacity adjusted to the reference condition, lbm/hr

$$W_c = W_h\sqrt{\frac{V_{act,\ drum}}{V_{ref,\ drum}}} - W_{cal,\ meter} - W_{cal,\ drum} - W_{dr}$$

TEST REPORT FORM V-2.3.5.2-1M
PRESSURE RELIEF DEVICE TESTED WITH STEAM — SI UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name

Measured Device Dimensions

Valve	Non-reclosing Devices
(4) Bore diameter, mm (d_b)	(4) Minimum holder-bore diameter, mm (d_b)
(5) Seat diameter, mm (d_s)	(5) Minimum net flow area, mm^2 (a)
(6) Seat angle, deg	
(7) Valve-disk lift, mm (l)	
(8) Actual discharge area, mm^2 (a_d)	

Flowmeter Calculations

(9) Internal diameter of meter run pipe, m (D)
(10) Meter-bore diameter, m (d)
(11) Meter-bore diameter squared, m^2 (d^2)
(12) Beta ratio ($\beta = d/D$)
(13) Trial flow coefficient (K_o)
(14) Differential pressure at the meter, millimeters of water (ΔP)
(15) Barometric pressure, kPa (P_b)
(16) Static pressure at the meter calorimeter, kPa (P_m)
(17) Fluid temperature at the meter calorimeter, °C ($T_{\text{cal, meter}}$)
(18) Percent quality or deg superheat
(19) Area factor for thermal expansion (F_a)
(20) Expansion factor (Y)
(21) Specific volume at flowing conditions at the meter, m^3/kg ($V_{\text{act, meter}}$)
(22) Specific volume at reference conditions at the meter, m^3/kg ($V_{\text{ref, meter}}$)
(23) Trial flow rate, kg/h

$$W_t = 12\,510 \times d^2 \times K_o \times F_a \times Y \times \sqrt{\frac{\Delta P}{V_{\text{act, meter}}}}$$

(24) Viscosity, kg/m-s (μ)
(25) Reynolds number

$$R_D = \frac{0.35368 \times W_h}{(D)(\mu)}$$

(26) Orifice plate discharge coefficient (C)

(27) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(28) Flow rate (kg/h)

$$W_h = \frac{W_t \times K}{K_o}\sqrt{\frac{V_{\text{act, meter}}}{V_{\text{ref, meter}}}}$$

Observed Data and Computed Results at the Device Inlet

(29) Set pressure, kPag (P_{set}) (burst pressure for non-reclosing device)
(30) Flow-rating pressure, kPa (P_f)
(31) Fluid temperature at the test drum calorimeter, °C ($T_{\text{cal, drum}}$)
(32) Percent quality or deg superheat

TEST REPORT FORM V-2.3.5.2-1M
PRESSURE RELIEF DEVICE TESTED WITH STEAM — SI UNITS (CONT'D)
Observed Data and Computed Results — Flowmeter Method

Observed Data and Computed Results at the Device Inlet (Cont'd)

(33) Specific volume at reference condition, m^3/kg ($V_{ref,\ drum}$)
(34) Specific volume at inlet conditions, m^3/kg ($V_{act,\ drum}$)
(35) Meter calorimeter flow, kg/h (W_{mc})
(36) Meter calorimeter flow adjusted to the reference condition, kg/h

$$W_{cal,\ meter} = W_{mc}\sqrt{\frac{V_{act,\ meter}}{V_{ref,\ meter}}}$$

(37) Test-drum calorimeter flow, kg/h (W_{dc})
(38) Test-drum calorimeter flow adjusted to the reference condition, kg/h

$$W_{cal,\ drum} = W_{dc}\sqrt{\frac{V_{act,\ drum}}{V_{ref,\ drum}}}$$

(39) Test-drum drainage, kg/h (W_{dr})
(40) Measured relieving capacity adjusted to the reference condition, kg/h

$$W_c = W_h\sqrt{\frac{V_{act,\ drum}}{V_{ref,\ drum}}} - W_{cal,\ meter} - W_{cal,\ drum} - W_{dr}$$

TEST REPORT FORM V-2.3.5.3-1
PRESSURE RELIEF DEVICE TESTED WITH LIQUIDS — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name

Measured Device Dimensions

Valve	Non-reclosing Devices
(4) Bore diameter, in. (d_b)	(4) Minimum holder-bore diameter, in. (d_b)
(5) Seat diameter, in. (d_s)	(5) Minimum net flow area, in.^{2} (a)
(6) Seat angle, deg	
(7) Valve-disk lift, in. (l)	
(8) Actual discharge area, in.^{2} (a_d)	

Flowmeter Calculations

(9) Internal diameter of meter run pipe, in. (D)
(10) Meter-bore diameter, in. (d)
(11) Meter-bore diameter squared, in.^{2} (d^2)
(12) Beta ratio ($\beta = d/D$)
(13) Temperature upstream of the meter, °F (T_m)
(14) Differential pressure at the meter, inches of water (h_w)
(15) Barometric pressure, psia (P_b)
(16) Static pressure at the meter, psia (P_m)
(17) Fluid temperature at the meter, °F (T_m)
(18) Area factor for thermal expansion (F_a)
(19) Trial flow coefficient (K_o)
(20) Fluid density at meter inlet, lbm/ft^3 (ρ_m)
(21) Trial flow rate, lbm/hr (W_t)

$$W_t = 358.93 \times d^2 \times F_a \times K_o \sqrt{h_w \times \rho_m}$$

(22) Viscosity, lbm/ft-sec (μ)
(23) Reynolds number

$$R_D = \frac{0.00424 \times W_h}{(D)(\mu)}$$

(24) Orifice plate discharge coefficient (C)

(25) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(26) Measured relieving capacity, lbm/hr

$$W_h = W_t \times K/K_o$$

Observed Data and Computed Results at the Device Inlet

(27) Set pressure, psig (P_{set}) (burst pressure for non-reclosing device)
(28) Flow-rating pressure, psig (P_f)
(29) Back pressure, psig (P_o)
(30) Fluid temperature, °F (T_v)
(31) Density of liquid at inlet conditions, lbm/ft^3 (ρ_{act})
(32) Density of liquid at reference condition, lbm/ft^3 (ρ_{ref})
(33) Relieving capacity adjusted to liquid at reference condition, lbm/hr

$$W_r = W_h \sqrt{\rho_{ref}/\rho_{act}}$$

TEST REPORT FORM V-2.3.5.3-1M
PRESSURE RELIEF DEVICE TESTED WITH LIQUIDS — SI UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer’s name

Measured Device Dimensions

Valve

(4) Bore diameter, mm (d_b)
(5) Seat diameter, mm (d_s)
(6) Seat angle, deg
(7) Valve-disk lift, mm (l)
(8) Actual discharge area, mm^2 (a_d)

Non-reclosing Devices

(4) Minimum holder-bore diameter, mm (d_b)
(5) Minimum net flow area, mm^2 (a)

Flowmeter Calculations

(9) Internal diameter of meter run pipe, m (D)
(10) Meter-bore diameter, m (d)
(11) Meter-bore diameter squared, m^2 (d^2)
(12) Beta ratio ($\beta = d/D$)
(13) Temperature upstream of the meter, °C (T_m)
(14) Differential pressure at the meter, millimeters of water (ΔP)
(15) Barometric pressure, kPa (P_b)
(16) Static pressure at the meter, kPa (P_m)
(17) Fluid temperature at the meter, °C (T_m)
(18) Area factor for thermal expansion (F_a)
(19) Trial flow coefficient (K_o)
(20) Fluid density at meter inlet, kg/m^3 (ρ_m)
(21) Trial flow rate, kg/h (W_t)

$$W_t = 12\,510 \times d^2 \times F_a \times K_o \sqrt{\Delta P \times \rho_m}$$

(22) Viscosity, kg/m-s (μ)
(23) Reynolds number

$$R_D = \frac{0.35368 \times W_h}{(D)(\mu)}$$

(24) Orifice plate discharge coefficient (C)

(25) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(26) Measured relieving capacity, kg/h

$$W_h = W_t \times K/K_o$$

Observed Data and Computed Results at the Device Inlet

(27) Set pressure, kPag (P_{set}) (burst pressure for non-reclosing device)
(28) Flow-rating pressure, kPag (P_f)
(29) Back pressure, kPag (P_o)
(30) Fluid temperature, °C (T_v)
(31) Density of liquid at inlet conditions, kg/m^3 (ρ_{act})
(32) Density of liquid at reference condition, kg/m^3 (ρ_s)
(33) Relieving capacity adjusted to liquid at reference condition, kg/h

$$W_r = W_h \sqrt{\rho_{ref}/\rho_{act}}$$

TEST REPORT FORM V-2.3.5.4-1
PRESSURE RELIEF DEVICE TESTED WITH AIR OR GAS — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Test fluid
(5) Specific gravity (ideal) (S_g)
(6) Ratio of specific heats (k)
(7) Molecular weight (M_w)

Measured Device Dimensions

Valve

(8) Bore diameter, in.
(9) Seat diameter, in.
(10) Seat angle, deg
(11) Valve-disk lift, in. (l)
(12) Actual discharge area, in.^{2} (a_d)

Non-reclosing Devices

(8) Minimum holder-bore diameter, in. (d_b)
(9) Minimum net flow area, in.^{2} (a)

Flowmeter Calculations

(13) Internal diameter of meter run pipe, in. (D)
(14) Meter-bore diameter, in. (d)
(15) Meter-bore diameter squared, in.^{2} (d^2)
(16) Beta ratio ($\beta = d/D$)
(17) Trial flow coefficient (K_o)
(18) Differential pressure at the meter, inches of water (h_w)
(19) Barometric pressure, psia (P_b)
(20) Static pressure at the meter, psia (P_m)
(21) Fluid temperature at the meter, °F (T_m)
(22) Expansion factor (Y)
(23) Area factor for thermal expansion (F_a)
(24) Fluid density at meter inlet, lbm/ft^3 (ρ_m)
(25) Trial flow rate (W_t), lbm/hr

$$W_t = 358.93 \times d^2 \times K_o \times Y \times F_a \sqrt{h_w \times \rho_m}$$

(26) Viscosity, lbm/ft-sec (μ)
(27) Reynolds number

$$R_D = \frac{0.00424 \times W_t}{(D)(\mu)}$$

(28) Orifice plate discharge coefficient (C)

(29) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(30) Measured relieving capacity, lbm/hr

$$W_h = \frac{(W_t)(K)}{K_o}$$

(31) Base pressure, psia (P_B)
(32) Base temperature, °F (T_B)
(33) Density of dry air at 14.696 psia and at the base temperature, lbm/ft^3 (ρ_s)
(34) Density at base condition, lbm/ft^3

$$\rho_b = S_g \times P_B \rho_s / 14.696$$

TEST REPORT FORM V-2.3.5.4-1
PRESSURE RELIEF DEVICE TESTED WITH AIR OR GAS — U.S. CUSTOMARY UNITS (CONT'D)
Observed Data and Computed Results — Flowmeter Method

Observed Data and Computed Results at the Device Inlet

(35) Volumetric rate at base condition at the meter, cfm

$$q_b = \frac{W_h}{60\rho_B}$$

(36) Set pressure, psig (P_{set}) (burst pressure for non-reclosing device)
(37) Flow-rating pressure, psig (P_f)
(38) Temperature at the valve inlet, absolute °R (T_v)
(39) Reference temperature at the valve inlet, absolute °R (T_r)
(40) Valve-inlet temperature correction

$$C = \sqrt{T_v / T_R}$$

(41) Valve capacity at reference inlet temperature, cfm

$$q_r = q_b \times C$$

TEST REPORT FORM V-2.3.5.4-1M
PRESSURE RELIEF DEVICE TESTED WITH AIR OR GAS — SI UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Test fluid
(5) Specific gravity (ideal) (S_g)
(6) Ratio of specific heats (k)
(7) Molecular weight (M_w)

Measured Device Dimensions

Valve

(8) Bore diameter, mm
(9) Seat diameter, mm
(10) Seat angle, deg
(11) Valve-disk lift, mm (l)
(12) Actual discharge area, mm^2 (a_d)

Non-reclosing Devices

(8) Minimum holder-bore diameter, mm (d_b)
(9) Minimum net flow area, mm^2 (a)

Flowmeter Calculations

(13) Internal diameter of meter run pipe, m (D)
(14) Meter-bore diameter, m (d)
(15) Meter-bore diameter squared, m^2 (d^2)
(16) Beta ratio ($\beta = d/D$)
(17) Trial flow coefficient (K_o)
(18) Differential pressure at the meter, millimeters of water (ΔP)
(19) Barometric pressure, kPa (P_b)
(20) Static pressure at the meter, kPa (P_m)
(21) Fluid temperature at the meter, °C (T_m)
(22) Expansion factor (Y)
(23) Area factor for thermal expansion (F_a)
(24) Fluid density at meter inlet, kg/m^3 (ρ_m)
(25) Trial flow rate (W_t), kg/h

$$W_t = 12\,510 \times d^2 \times K_o \times Y \times F_a \sqrt{\Delta P \times \rho_m}$$

(26) Viscosity, kg/m-s (μ)
(27) Reynolds number

$$R_D = \frac{0.35368 \times W_t}{(D)(\mu)}$$

(28) Orifice plate discharge coefficient (C)

(29) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(30) Measured relieving capacity, kg/h

$$W_h = \frac{(W_t)(K)}{K_o}$$

(31) Base pressure, kPa (P_B)
(32) Base temperature, °C (T_B)
(33) Density of dry air at 101.33 kPa and at the base temperature, kg/m^3 (ρ_s)
(34) Density at base condition, kg/m^3

$$\rho_b = S_g \times P_B \rho_s / 101.33$$

TEST REPORT FORM V-2.3.5.4-1M
PRESSURE RELIEF DEVICE TESTED WITH AIR OR GAS — SI UNITS (CONT'D)
Observed Data and Computed Results — Flowmeter Method

Observed Data and Computed Results at the Device Inlet

(35) Volumetric rate at base condition at the meter, m^3/min

$$q_b = \frac{W_h}{60\rho_B}$$

(36) Set pressure, kPag (P_{set}) (burst pressure for non-reclosing device)
(37) Flow-rating pressure, kPag (P_f)
(38) Temperature at the valve inlet, absolute K (T_v)
(39) Reference temperature at the valve inlet, absolute K (T_r)
(40) Valve-inlet temperature correction

$$C = \sqrt{T_v / T_R}$$

(41) Valve capacity at reference inlet temperature, m^3/min

$$q_r = q_b \times C$$

TEST REPORT FORM V-2.3.5.5-1
PRESSURE RELIEF DEVICE TESTED WITH AIR OR GAS — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Sonic-Flow Method

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Test fluid
(5) Specific gravity (ideal) (S_g)
(6) Ratio of specific heats (k)
(7) Molecular weight (M_w)

Measured Device Dimensions

Valve	Non-reclosing Devices
(8) Bore diameter, in.	(8) Minimum holder-bore diameter, in. (d_b)
(9) Seat diameter, in.	(9) Minimum net flow area, in.^{2} (a)
(10) Seat angle, deg	
(11) Valve-disk lift, in. (l)	
(12) Actual discharge area, in.^{2} (a_d)	

Flowmeter Calculations

(13) Internal diameter of meter run pipe, in. (D)
(14) Meter-bore diameter, in. (d)
(15) Beta ratio ($\beta = d/D$)
(16) Meter discharge coefficient at sonic-flow conditions (C)
(17) Meter-bore area, in.^{2} (a_m)
(18) Critical flow function (C^*)
(19) Barometric pressure, psia (P_b)
(20) Meter inlet stagnation pressure, psia (P_s)
(21) Meter inlet stagnation temperature, absolute °R (T_s)
(22) Measured relieving capacity, lbm/hr

$$W_h = 3{,}600 \times C \times a_m \times C^* \times \frac{P_s}{\sqrt{1{,}545.4 \times T_s}} \times \sqrt{32.2}$$

Observed Data and Computed Results at the Device Inlet

(23) Set pressure, psig (P_{set}) (burst pressure for non-reclosing device)
(24) Flow-rating pressure, psig (P_f)
(25) Temperature at the valve inlet, absolute °R (T_v)
(26) Reference temperature at the valve inlet, absolute °R (T_r)
(27) Density of dry air at 14.696 psia and reference temperature, lbm/ft^3 (ρ_{std})
(28) Density of fluid at reference condition, lbm/ft^3

$$\rho_{ref} = S_g \times P_f \times \frac{\rho_{std}}{14.696}$$

(29) Valve capacity at reference condition, cfm

$$q_r = \frac{W_h}{60 \times \rho_{ref}} \sqrt{T_v / T_r}$$

TEST REPORT FORM V-2.3.5.5-1M
PRESSURE RELIEF DEVICE TESTED WITH AIR OR GAS — SI UNITS
Observed Data and Computed Results — Sonic-Flow Method

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Test fluid
(5) Specific gravity (ideal) (S_g)
(6) Ratio of specific heats (k)
(7) Molecular weight (M_w)

Measured Device Dimensions

Valve	Non-reclosing Devices
(8) Bore diameter, mm	(8) Minimum holder-bore diameter, mm (d_b)
(9) Seat diameter, mm	(9) Minimum net flow area, mm^2 (a)
(10) Seat angle, deg	
(11) Valve-disk lift, mm (l)	
(12) Actual discharge area, mm^2 (a_d)	

Flowmeter Calculations

(13) Internal diameter of meter run pipe, m (D)
(14) Meter-bore diameter, m (d)
(15) Beta ratio ($\beta = d/D$)
(16) Meter discharge coefficient at sonic-flow conditions (C)
(17) Meter-bore area, m^2 (a_m)
(18) Critical flow function (C^*)
(19) Barometric pressure, kPa (P_b)
(20) Meter inlet stagnation pressure, kPa (P_s)
(21) Meter inlet stagnation temperature, absolute K (T_s)
(22) Measured relieving capacity, kg/h

$$W_h = 3\,600 \times C \times a_m \times C^* \times \frac{P_s}{\sqrt{8\,314.3 \times T_s}}$$

Observed Data and Computed Results at the Device Inlet

(23) Set pressure, kPag (P_{set}) (burst pressure for non-reclosing device)
(24) Flow-rating pressure, kPag (P_f)
(25) Temperature at the valve inlet, absolute K (T_v)
(26) Reference temperature at the valve inlet, absolute K (T_r)
(27) Density of dry air at 101.33 kPa and reference temperature, kg/m^3 (ρ_{std})
(28) Density of fluid at reference condition, kg/m^3

$$\rho_{ref} = S_g \times P_f \times \frac{\rho_{std}}{101.33}$$

(29) Valve capacity at reference condition, m^3/min

$$q_r = \frac{W_h}{60 \times \rho_{ref}} \sqrt{T_v / T_r}$$

TEST REPORT FORM V-2.3.5.6-1
PRESSURE RELIEF DEVICE TESTED WITH FUEL GAS — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Test fluid
(5) Specific gravity (ideal) (S_g)
(6) Ratio of specific heats (k)
(7) Molecular weight (M_w)

Measured Device Dimensions

Valve	Non-reclosing Devices
(8) Bore diameter, in.	(8) Minimum holder-bore diameter, in. (d_b)
(9) Seat diameter, in.	(9) Minimum net flow area, in.^{2} (a)
(10) Seat angle, deg	
(11) Valve-disk lift, in. (l)	
(12) Actual discharge area, in.^{2} (a_d)	

Flowmeter Calculations

(13) Internal diameter of meter run pipe, in. (D)
(14) Meter-bore diameter, in. (d)
(15) Meter-bore diameter squared, in.^{2} (d^2)
(16) Beta ratio ($\beta = d/D$)
(17) Trial flow coefficient (K_o)
(18) Differential pressure at the meter, inches of water (h_w)
(19) Barometric pressure, psia (P_b)
(20) Static pressure at the meter, psia (P_m)
(21) Fluid temperature at the meter, absolute °R (T_m)
(22) Expansion factor (Y)
(23) Area factor for thermal expansion, absolute °R (F_a)
(24) Compressibility at meter (Z)
(25) Density, lbm/ft^3

$$\rho_m = \frac{(2.69991)(S_g)(P_m)}{(T_m)(Z)}$$

(26) Trial flow rate, lbm/hr

$$W_t = 358.93 \times d^2 \times K_o \times Y \times F_g \sqrt{h_w \times \rho_m}$$

(27) Viscosity, lbm/ft-sec (μ)
(28) Reynolds number

$$R_D = \frac{0.00424 \times W_t}{(D)(\mu)}$$

(29) Orifice plate discharge coefficient (C)

(30) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(31) Base pressure, psia (P_B)
(32) Base temperature, absolute °R (T_b)
(33) Base compressibility factor (Z_b)

TEST REPORT FORM V-2.3.5.6-1
PRESSURE RELIEF DEVICE TESTED WITH FUEL GAS — U.S. CUSTOMARY UNITS (CONT'D)
Observed Data and Computed Results — Flowmeter Method

Flowmeter Calculations (Cont'd)

(34) Density at base temperature and pressure

$$\rho_B = \frac{2.6991 \times S_g \times P_B}{T_b \times Z_b}$$

(35) Relieving capacity at base condition, cfh

$$q_b = \frac{(W_t)(K)}{(K_o)(\rho_B)}$$

Observed Data and Computed Results at the Device Inlet

(36) Set pressure, psig (P_{set}) (burst pressure for non-reclosing device)
(37) Flow-rating pressure, psig (P_f)
(38) Temperature at the valve inlet, absolute °R (T_v)
(39) Reference temperature at the valve inlet, absolute °R (T_r)
(40) Valve-inlet temperature correction

$$C = \sqrt{T_v / T_R}$$

(41) Valve capacity at reference inlet temperature, cfm

$$q_r = \frac{(q_b)(C)}{60}$$

TEST REPORT FORM V-2.3.5.6-1M
PRESSURE RELIEF DEVICE TESTED WITH FUEL GAS — SI UNITS
Observed Data and Computed Results — Flowmeter Method

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Test fluid
(5) Specific gravity (ideal) (S_g)
(6) Ratio of specific heats (k)
(7) Molecular weight (M_w)

Measured Device Dimensions

Valve	Non-reclosing Devices
(8) Bore diameter, mm	(8) Minimum holder-bore diameter, mm (d_b)
(9) Seat diameter, mm	(9) Minimum net flow area, mm^2 (a)
(10) Seat angle, deg	
(11) Valve-disk lift, mm (l)	
(12) Actual discharge area, mm^2 (a_d)	

Flowmeter Calculations

(13) Internal diameter of meter run pipe, m (D)
(14) Meter-bore diameter, m (d)
(15) Meter-bore diameter squared, m^2 (d^2)
(16) Beta ratio ($\beta = d/D$)
(17) Trial flow coefficient (K_o)
(18) Differential pressure at the meter, millimeters of water (ΔP)
(19) Barometric pressure, kPa (P_b)
(20) Static pressure at the meter, kPa (P_m)
(21) Fluid temperature at the meter, absolute K (T_m)
(22) Expansion factor (Y)
(23) Area factor for thermal expansion, absolute K (F_a)
(24) Compressibility at meter (Z)
(25) Density, kg/m^3

$$\rho_m = \frac{(0.003483)(S_g)(P_m)}{(T_m)(Z)}$$

(26) Trial flow rate, kg/h

$$W_t = 12\,510 \times d^2 \times K_o \times Y \times F_g \sqrt{\Delta P \times \rho_m}$$

(27) Viscosity, kg/m-s (μ)
(28) Reynolds number

$$R_D = \frac{0.35368 \times W_t}{(D)(\mu)}$$

(29) Orifice plate discharge coefficient (C)

(30) Flow coefficient

$$K = \frac{C}{\sqrt{1 - \beta^4}}$$

(31) Base pressure, kPa (P_B)
(32) Base temperature, absolute K (T_b)
(33) Base compressibility factor (Z_b)

TEST REPORT FORM V-2.3.5.6-1M
PRESSURE RELIEF DEVICE TESTED WITH FUEL GAS — SI UNITS (CONT'D)
Observed Data and Computed Results — Flowmeter Method

Flowmeter Calculations (Cont'd)

(34) Density at base temperature and pressure

$$\rho_B = \frac{0.003483 \times S_g \times P_B}{T_b \times Z_b}$$

(35) Relieving capacity at base condition, m^3/h

$$q_b = \frac{(W_t)(K)}{(K_o)(\rho_B)}$$

Observed Data and Computed Results at the Device Inlet

(36) Set pressure, kPag (P_{set}) (burst pressure for non-reclosing device)
(37) Flow-rating pressure, kPag (P_f)
(38) Temperature at the valve inlet, absolute K (T_v)
(39) Reference temperature at the valve inlet, absolute K (T_r)
(40) Valve-inlet temperature correction

$$C = \sqrt{T_v / T_R}$$

(41) Valve capacity at reference inlet temperature, m^3/min

$$q_r = \frac{(q_b)(C)}{60}$$

TEST REPORT FORM V-2.3.5.7-1
NON-RECLOSING PRESSURE RELIEF DEVICE TESTED WITH AIR — U.S. CUSTOMARY UNITS
Observed Data and Computed Results — Flow Resistance

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Ratio of specific heats (k)
(5) Molecular weight (M_w)
(6) Measured relieving capacity, lbm/hr (W_h) (from Form V-2.3.5.4-1 or Form V-2.3.5.5-1)
(7) Base pressure, psia (P_B)
(8) Base temperature, absolute °R (T_o)
(9) Test rig inside diameter, ft (D)
(10) Length between taps A and B, ft ($L_{A\text{-}B}$)
(11) Length between taps B and C, ft ($L_{B\text{-}C}$)
(12) Length between taps C and D, ft ($L_{C\text{-}D}$)
(13) Pressure at tap B, psia (P_{tapB})
(14) Differential pressure between taps A and B, psia ($\Delta P_{A\text{-}B}$)
(15) Differential pressure between taps B and C, psia ($\Delta P_{B\text{-}C}$)
(16) Differential pressure between taps C and D, psia ($\Delta P_{C\text{-}D}$)

Flow Resistance Factor Calculation

(17) Mass velocity, lb/ft^2-sec (G)

$$G = W_h/(3{,}600 \times \pi \times D^2/4)$$

(18) Mach number at pipe entrance

$$M_1 = G/144\ P_B \sqrt{\frac{Y_1^{[(k+1)/(k-1)]}}{32.2 \times M_w \times k/(1{,}544 \times T_o)}}$$

Solve by iteration

$$Y_1 = 1 + \frac{(k-1) \times M_1^2}{2}$$

(19) Pressure at pipe entrance

$$P_1 = P_B\left(\frac{2}{2 + (k-1) \times M_1^2}\right)^{\left(\frac{k}{k-1}\right)}$$

(20) Temperature at pipe entrance

$$T_1 = T_o \times (P_1/P_B)^{(k-1)/k}$$

Calculate total resistance factor at each pressure tap A, B, C, and D. Repeat steps (21) through (26) for each tap.

(21) Temperature at pressure tap, absolute °R

$$T_{tap} = T_1\left[\frac{-1 + \sqrt{1 + 2 \times (k-1) \times M_1^2 \times (P_1/P_{tap})^2 \times [1 + (k-1) \times M_1^2/2]}}{(k-1) \times M_1^2 \times (P_1/P_{tap})^2}\right]$$

(22) Sonic velocity at pressure tap, ft/sec

$$C_{tap} = \sqrt{32.2 \times k \times 1{,}544 \times T_{tap}/M_w}$$

(23) Specific volume at pressure tap, ft^3/lbm

$$V_{tap} = (1{,}544 \times T_{tap})/(M_w \times 144 P_{tap})$$

(24) Mach number at pressure tap

$$M_{tap} = G \times V_{tap}/C_{tap}$$

(25) Expansion factor at pressure tap

$$Y_{tap} = 1 + \frac{(k-1) \times (M_{tap})^2}{2}$$

TEST REPORT FORM V-2.3.5.7-1
NON-RECLOSING PRESSURE RELIEF DEVICE TESTED WITH AIR — U.S. CUSTOMARY UNITS (CONT'D)
Observed Data and Computed Results — Flow Resistance

Flow Resistance Factor Calculation (Cont'd)

(26) Total resistance factor to pressure tap

$$K_{tap} = \frac{1/M_1^2 - 1/(M_{tap})^2 - [(k+1)/2] \times \ln[(M_{tap}^2 \times Y_1)/(M_1^2 \times Y_{tap})]}{k}$$

(27) Resistance factor between pressure taps A and B

$$K_{A\text{-}B} = K_B - K_A$$

(28) Resistance factor between pressure taps B and C

$$K_{B\text{-}C} = K_C - K_B$$

(29) Resistance factor between pressure taps C and D

$$K_{C\text{-}D} = K_D - K_C$$

(30) Friction factor

$$f = K_{A\text{-}B} \times D/(4 \times L_{A\text{-}B})$$

(31) Obtain the viscosity of air at T_B and P_B, μ (centipoise)

(32) Reynolds number

$$N_{Re} = D \times G/(\mu/1{,}488)$$

(33) Pipe roughness, in.

$$E = 44.4 \times D \times [10^{[-1/(4 \times \sqrt{f})]} - 1.256/(N_{Re} \times \sqrt{f})]$$

(34) Pipe resistance factor between pressure taps B and C

$$K_{pipe\ B\text{-}C} = \frac{4fL_{B\text{-}C}}{D}$$

(35) Test object individual flow resistance

$$K_{Ri} = K_{B\text{-}C} - K_{pipe\ B\text{-}C}$$

GENERAL NOTE: Equations for calculations are in accordance with Lapple (1943), Levenspiel (1977), and the Colebrook equation cited in Perry and Green (1984).

TEST REPORT FORM V-2.3.5.7-1M
NON-RECLOSING PRESSURE RELIEF DEVICE TESTED WITH AIR — SI UNITS
Observed Data and Computed Results — Flow Resistance

(1) Test number
(2) Test date
(3) Manufacturer's name
(4) Ratio of specific heats (k)
(5) Molecular weight (M_w)
(6) Measured relieving capacity, kg/h (W_h) (from Form V-2.3.5.4-1M or Form V-2.3.5.5-1M)
(7) Base pressure, kPa (P_B)
(8) Base temperature, absolute K (T_o)
(9) Test rig inside diameter, m (D)
(10) Length between taps A and B, m ($L_{\text{A-B}}$)
(11) Length between taps B and C, m ($L_{\text{B-C}}$)
(12) Length between taps C and D, m ($L_{\text{C-D}}$)
(13) Pressure at tap B, kPa (P_{tapB})
(14) Differential pressure between taps A and B, kPa ($\Delta P_{\text{A-B}}$)
(15) Differential pressure between taps B and C, kPa ($\Delta P_{\text{B-C}}$)
(16) Differential pressure between taps C and D, kPa ($\Delta P_{\text{C-D}}$)

Flow Resistance Factor Calculation

(17) Mass velocity, kg/m^2-s (G)

$$G = W_h/(3\,600 \times \pi \times D^2/4)$$

(18) Mach number at pipe entrance

$$M_1 = G/1\,000 \times P_B \sqrt{\frac{Y_1^{[(k+1)/(k-1)]}}{M_w \times k/(8\,314.3 \times T_o)}}$$

Solve by iteration

$$Y_1 = 1 + \frac{(k-1) \times M_1^2}{2}$$

(19) Pressure at pipe entrance

$$P_1 = P_B\left(\frac{2}{2 + (k-1) \times M_1^2}\right)^{\left(\frac{k}{k-1}\right)}$$

(20) Temperature at pipe entrance

$$T_1 = T_o \times (P_1/P_B)^{(k-1)/k}$$

Calculate total resistance factor at each pressure tap A, B, C, and D. Repeat steps (21) through (26) for each tap.

(21) Temperature at pressure tap, absolute K

$$T_{\text{tap}} = T_1\left[\frac{-1 + \sqrt{1 + 2 \times (k-1) \times M_1^2 \times (P_1/P_{\text{tap}})^2 \times [1 + (k-1) \times M_1^2/2]}}{(k-1) \times M_1^2 \times (P_1/P_{\text{tap}})^2}\right]$$

(22) Sonic velocity at pressure tap, m/s

$$C_{\text{tap}} = \sqrt{k \times 8\,314.3 \times T_{\text{tap}}/M_w}$$

(23) Specific volume at pressure tap, m^3/kg

$$V_{\text{tap}} = (8.3143 \times T_{\text{tap}})/(M_w \times P_{\text{tap}})$$

(24) Mach number at pressure tap

$$M_{\text{tap}} = G \times V_{\text{tap}}/C_{\text{tap}}$$

(25) Expansion factor at pressure tap

$$Y_{\text{tap}} = 1 + \frac{(k-1) \times (M_{\text{tap}})^2}{2}$$

TEST REPORT FORM V-2.3.5.7-1M
NON-RECLOSING PRESSURE RELIEF DEVICE TESTED WITH AIR — SI UNITS (CONT'D)
Observed Data and Computed Results — Flow Resistance

Flow Resistance Factor Calculation (Cont'd)

(26) Total resistance factor to pressure tap

$$K_{tap} = \frac{1/M_1^2 - 1/(M_{tap})^2 - [(k+1)/2] \times \ln[(M_{tap}^2 \times Y_1)/(M_1^2 \times Y_{tap})]}{k}$$

(27) Resistance factor between pressure taps A and B

$$K_{A\text{-}B} = K_B - K_A$$

(28) Resistance factor between pressure taps B and C

$$K_{B\text{-}C} = K_C - K_B$$

(29) Resistance factor between pressure taps C and D

$$K_{C\text{-}D} = K_D - K_C$$

(30) Friction factor

$$f = K_{A\text{-}B} \times D/(4 \times L_{A\text{-}B})$$

(31) Obtain the viscosity of air at T_B and P_B, μ (centipoise)

(32) Reynolds number

$$N_{Re} = D \times G/(\mu/1\,000)$$

(33) Pipe roughness, mm

$$E = 3700 \times D \times \left[10^{[-1/(4 \times \sqrt{f})]} - 1.256/(N_{Re} \times \sqrt{f})\right]$$

(34) Pipe resistance factor between pressure taps B and C

$$K_{pipe\ B\text{-}C} = \frac{4fL_{B\text{-}C}}{D}$$

(35) Test object individual flow resistance

$$K_{Ri} = K_{B\text{-}C} - K_{pipe\ B\text{-}C}$$

GENERAL NOTE: Equations for calculations are in accordance with Lapple (1943), Levenspiel (1977), and the Colebrook equation cited in Perry and Green (1984).

TEST SUMMARY REPORT FORM V-2.4.5-1
Pressure and Relief Valve Performance Test Report
STEAM

General Information

(1) Test number
(2) Test date
(3) Location
(4) Manufacturer's name and address
(5a) Valve type or model number
(5b) Valve serial or identification number
(5c) Inlet connection (size, pressure rating, and type)
(5d) Outlet connection (size, pressure rating, and type)
(5e) Stamped pressure and tolerance, units
(6) Test objective

Summary of Test Results

(7) Simmer, units (factory setting)
(8) Simmer, units (reset)
(9) Set pressure, units (factory setting)
(10) Set pressure, units (reset)
(11) Reseating pressure, units (factory setting)
(12) Reseating pressure, units (reset)
(13) Blowdown, units (factory setting)
(14) Blowdown, units (reset)
(15) Back pressure, units (built-up, superimposed, or both)
(16) Flow-rating pressure (valve inlet), units
(17) Valve-disk lift, units
(18) Measured relieving capacity, units
(19) Final flow measurement uncertainty

Measured Valve Dimensions

(20) Bore diameter, units
(21) Seat diameter, units
(22) Seat angle, deg
(23) Valve-inlet-opening diameter, units
(24) Ratio of valve-disk lift to bore diameter
(25) Ratio of bore diameter to the diameter of the valve-inlet opening
(26) Actual discharge area, units
(27) Remarks and conclusions concerning the objective of the test and applicable items, such as chatter, flutter, and vibration.

Test Supervisor (Signed) ______________________________ Date ______________

TEST SUMMARY REPORT FORM V-2.4.5-2
Pressure and Relief Valve Performance Test Report
LIQUIDS AND WATER

General Information

(1) Test number
(2) Test date
(3) Location
(4) Manufacturer's name and address
(5a) Valve type or model number
(5b) Valve serial or identification number
(5c) Inlet connection (size, pressure rating, and type)
(5d) Outlet connection (size, pressure rating, and type)
(5e) Stamped pressure, units
(6) Test objective
(7) Test fluid
(8) Specific gravity (ideal)

Summary of Test Results

(9) Set pressure, units (factory setting)
(10) Set pressure, units (reset)
(11) Reseating pressure, units (factory setting)
(12) Reseating pressure, units (reset)
(13) Back pressure, units (built-up, superimposed, or both)
(14) Flow-rating pressure (valve inlet), units
(15) Valve-disk lift, units
(16) Measured relieving capacity, units
(17) Final flow measurement uncertainty

Measured Valve Dimensions

(18) Bore diameter, units
(19) Seat diameter, units
(20) Seat angle, deg
(21) Valve-inlet-opening diameter, units
(22) Ratio of valve-disk lift to bore diameter
(23) Ratio of bore diameter to the diameter of the valve-inlet opening
(24) Actual discharge area, units
(25) Remarks and conclusions concerning the objective of the test and applicable items, such as chatter, flutter, and vibration.

Test Supervisor (Signed) ______________________________ Date ______________

TEST SUMMARY REPORT FORM V-2.4.5-3
Pressure and Relief Valve Performance Test Report
AIR, GAS, OR FUEL GAS

General Information

(1) Test number
(2) Test date
(3) Location
(4) Manufacturer’s name and address
(5a) Valve type or model number
(5b) Valve serial or identification number
(5c) Inlet connection (size, pressure rating, and type)
(5d) Outlet connection (size, pressure rating, and type)
(5e) Stamped pressure and tolerance, units
(6) Test objective
(7) Test fluid
(8) Specific gravity (ideal)
(9) Ratio of specific heats
(10) Molecular weight

Summary of Test Results

(11) Start-to-discharge presssure, units (factory setting)
(12) Start-to-discharge pressure, units (reset)
(13) Simmer, units (factorysetting)
(14) Simmer, units (reset)
(15) Set pressure, units (factory setting)
(16) Set pressure, units (reset)
(17) Reseating pressure, units (factory setting)
(18) Reseating pressure, units (reset)
(19) Resealing pressure, units (factory setting)
(20) Resealing pressure, units (reset)
(21) Blowdown, units (factory setting)
(22) Blowdown, units (reset)
(23) Back pressure, units (built-up, superimposed, or both)
(24) Flow-rating pressure (valve inlet), units
(25) Valve-disk lift, units
(26) Measured relieving capacity, units
(27) Final flow measurement uncertainty

Measured Valve Dimensions

(28) Bore diameter, units
(29) Seat diameter, units
(30) Valve-inlet-opening diameter, units
(31) Ratio of valve-disk lift to bore diameter
(32) Ratio of bore diameter to the diameter of the valve-inlet opening
(33) Actual discharge area, units
(34) Remarks and conclusions concerning the objective of the test and applicable items, such as chatter, flutter, and vibration.

Test Supervisor (Signed) ______________________________ Date ______________

TEST SUMMARY REPORT FORM V-2.4.5-4
Non-reclosing Pressure Relief Device Performance Test Report
AIR, GAS, OR FUEL GAS

General Information

(1) Test number
(2) Test date
(3) Location
(4) Manufacturer's name and address
(5a) Device type or model number
(5b) Device lot or identification number
(5c) Connection (size, pressure rating, and type)
(5d) Marked set pressure and tolerance, units
(5e) Minimum net flow area, units (manufacturer specified)
(6) Test objective
(7a) Test fluid for set pressure
(7b) Test fluid for flow test
(8) Specific gravity (ideal)
(9) Ratio of specific heats
(10) Molecular weight

Summary of Test Results

(11) Set pressure, units
(12) Flow-rating pressure at device inlet, units
(13) Resistance factor (K_{Ri})

Measured Device Dimensions

(14) Minimum device bore diameter, units
(15) Remarks and conclusions concerning the objective of the test and applicable items, such as vibrations.

Test Supervisor (Signed) ______________________________ Date ____________

V-2.4.9 Part VIII: Graphical Presentation of Back-Pressure Test Results

Where a series of tests have been made with several back pressures for a given opening pressure, the test results can be presented by plotting curves, such as the following:

(a) *Abscissa:* back pressures in percent of the opening pressure at atmospheric back pressure

Ordinate: percent variation of opening pressures from the opening pressure at atmospheric back pressure

(b) *Abscissa:* back pressures in percent of the relieving pressure at atmospheric back pressure

Ordinate: relieving capacities in percent of relieving capacity at atmospheric back pressure

(c) *Abscissa:* back pressures in percent of the opening pressure at atmospheric back pressure

Ordinate: percent variation of closing pressures from the closing pressure at atmospheric back pressure

ARTICLE V-3
IN-SERVICE AND BENCH TESTING

V-3.1 GUIDING PRINCIPLES

V-3.1.1 Items on Which Agreement Shall Be Reached

The parties to the test shall reach agreement on the following items prior to conducting the test:

(a) object of the test

(b) parties to the test

(c) test site

(d) testing fluid

(e) methods of measurement, instrumentation, and equipment to be used (calibration of instruments shall be in accordance with V-2.1.7)

(f) number, size, type, condition, source, and set pressure of the devices to be tested

(g) method of determining seat tightness

(h) persons who shall conduct the test

(i) the written test procedure that shall include the observation and readings to be taken and recorded to comply with the object or objectives of the test

V-3.1.2 Qualification of Person Conducting the Test

A person who conducts the test shall have a working knowledge of pressure relief device operating characteristics. The person shall have practical experience in the safe and accurate operation of the testing equipment.

V-3.1.3 Responsibility of Person Conducting the Test

A person who meets the qualifications of V-3.1.2 shall be present at all times during the test and shall be solely responsible for ensuring that all persons who are involved in taking readings, making pressure and temperature adjustments, or any other function that will affect the test results are fully informed as to the correct method of performing such functions. This person conducting the test shall also be responsible for ensuring that the written test procedures are followed. This person shall sign and date the test report, thereby verifying to the best of the person's knowledge that the report is correct and that the test was conducted in accordance with the written test procedures. This person shall verify that the instruments have been calibrated as required by V-3.1.7.

V-3.1.4 Test Apparatus

Procedures and arrangement of the test apparatus shall be in accordance with V-3.2.

V-3.1.5 Preliminary Training

Sufficient training shall be conducted to ensure that operating personnel are completely familiar with the test equipment and their respective assignments.

V-3.1.6 Spare Instruments

If intended for use as replacements during the test, spare instruments shall be calibrated in accordance with V-3.1.7.

V-3.1.7 Calibration of Instruments

Each instrument used during the test shall be serialized or otherwise positively identified and shall be calibrated against certified equipment having known valid relationships to nationally recognized standards. Each instrument, depending on the type, shall be calibrated in accordance with V-3.1.7.1 through V-3.1.7.3. Records of instrument calibrations shall be available for review by the interested parties.

V-3.1.7.1 Pressure. Pressure-measuring instruments shall be calibrated in accordance with ASME PTC 19.2 within 30 days prior to the tests. Portable pressure-measuring instruments shall be calibrated at a frequency to ensure that measurements are within the uncertainty limits. Calibration of other means of indicating or recording pressure shall be agreed upon by the interested parties.

V-3.1.7.2 Temperature. Temperature-measuring instruments shall be calibrated in accordance with ASME PTC 19.3. Instruments of the types listed in V-2.2.2.2(a), except bimetallic thermometers, shall be calibrated to at least two temperatures within a 90-day period preceding the test or series of tests. Bimetallic thermometers shall be calibrated before and after each test or series of tests. Calibration of other means of indicating or recording temperature shall be agreed upon by the interested parties.

V-3.1.7.3 Force. Force-measuring instruments shall be calibrated at a time interval to ensure the desired accuracy using secondary force-measuring standards. Secondary force-measuring standards, such as higher accuracy force transducers or force proving rings, shall be calibrated at least once per year against a standard that is traceable to a nationally recognized standard.

V-3.1.8 Adjustments During Test

If adjustments are necessary during in-service or bench testing, a sufficient number of tests shall be performed to determine final operating characteristics.

V-3.1.9 Records and Test Results

The test records shall include all observations, measurements, instrument readings, and instrument identification (if required) for the objectives of the test. The parties of the test shall agree upon the responsibility of record retention and distribution. Corrections to data and corrected values shall be entered separately in the test record. The test shall be reported in accordance with V-3.4 of this Appendix.

V-3.1.10 Measurement Uncertainty

A pretest determination shall be performed to determine that the limits of uncertainty of the final measurement specified in V-1.3 can be met by the specified instrumentation and procedures. A post-test uncertainty analysis shall also be performed unless the parties to the test agree and verify that the specified instrumentation and procedures, including data scatter, were used and carried out in accordance with the test specification, thereby confirming the post-test validity of the pretest uncertainty determination. A guide for such determination is given in ASME PTC 19.1. These determinations shall be documented by the facility and available for review.

V-3.2 INSTRUMENTS AND METHODS OF MEASUREMENTS

V-3.2.1 General

Subarticle V-3.2 describes the instruments, methods, procedures, and precautions that shall be used in testing pressure relief devices under this Appendix. The Performance Test Code Supplements on Instruments and Apparatus provide authoritative general information concerning instruments and their use and may be consulted for such information.

V-3.2.2 Instrumentation

Where measurements of temperature, pressure, or lift are required in this Appendix, the instrumentation used shall comply with the specifications in V-3.2.2.1 through V-3.2.2.3.

V-3.2.2.1 Temperature. Instructions on thermometers or thermocouples and associated instruments are given in ASME PTC 19.3, except that commercial, metal-encased thermometers shall not be used in tests conducted under this Appendix. Other means of temperature measurement and indication may be used, provided they are of the same or greater degree of accuracy as for those described therein.

(a) Depending on operating conditions, or convenience, the temperature may be measured with certified or calibrated liquid-in-glass thermometers, bimetallic thermometers, resistance-type thermometers, or thermocouples. All of the above may be inserted directly into the pipe or wells except for liquid-in-glass thermometers, which shall be inserted into wells. The installation of the temperature-measuring device directly into the pipe, without the addition of a well, is desirable for temperatures below 300°F (150°C).

(b) The following precautions shall be taken when making any temperature measurements:

(1) No significant quantity of heat shall be transferred by radiation or conduction to or from the temperature-measuring device other than by the temperature of the medium being observed (see ASME PTC 19.3).

(2) The immediate vicinity of the point of insertion and external projecting parts shall be insulated.

(3) The temperature-measuring device shall extend across the centerline in pipes of small diameter or shall be inserted at least 6 in. (150 mm) into the fluid stream in pipes over 12 in. (300 mm) in diameter.

(4) Temperature-measuring devices installed in pipes carrying compressible fluids shall, wherever possible, be installed at locations where the maximum fluid velocity does not exceed 100 ft/sec (30 m/s). Where such an installation is not possible, it may be necessary to correct the temperature readings to the appropriate static or total temperature (see Bean, 1971, para. I-3-17).

(5) The temperature-measuring devices shall be inserted in locations so as to measure temperatures that are representative of the flowing medium as described under test arrangements.

(c) Thermometer wells, when used, shall be of the type shown in ASME PTC 19.3. They shall be as thin walled and of as small a diameter as practicable; their outer surfaces shall be substantially free from corrosion or foreign matter. The well shall be filled with a suitable fluid.

Mercury should not be used for this fluid since its very low-vapor pressure presents a serious health hazard to personnel.

(d) Thermocouples, if used, shall have a welded hot junction and shall be calibrated together with their extension wires over the anticipated operating range. They shall be constructed of materials suitable for the temperature and fluid being measured. The electromotive force of a thermocouple shall be measured by a potentiometric instrument or millivoltmeter of such precision that the accuracy of the overall system is within the limit specified in V-1.3. The cold junction shall be established by an ice bath, reference standard, or compensating circuit built into the potentiometer.

V-3.2.2.2 Pressure Measurements. Instructions on pressure gages, water U-tubes, differential gages, and manometers are given in ASME PTC 19.2. Other means of pressure measurements and indication may be used provided they are of the same or greater degree of accuracy as those described therein.

(a) Pressure-measuring stations shall be located in the region where the flow is essentially parallel to the pipe or vessel wall. For the measurement of static gage-pressure differentials below 15 psi (100 kPa), liquid manometers may be used.

(b) Pressure relief device-inlet pressure shall be the static pressure as measured with a pressure tap positioned as shown in Figures V-3.2.2.2-1 and V-3.2.2.2-2.

(c) Back pressure shall be the static pressure measured with a pressure tap positioned as shown in Figures V-2.2.2.10-2, V-2.2.2.10-4, and V-2.2.6.1-1.

(d) Proper corrections to the pressure readings shall be made if there is a height of water or other liquid between the point at which the pressure is to be measured and the pressure instrument.

V-3.2.2.3 Valve-Lift Measurements

(a) The lift of the valve disk, under testing conditions, shall be determined by suitable means to whatever degree of accuracy is imposed by the procedure under which the valve is being tested.

(b) In open- or vented-bonnet designs, when the top of the spindle may be exposed during the tests, an indicator of appropriate range may be attached to the top of the valve to indicate the movement of the spindle. In closed-bonnet valves where the top of the spindle cannot be exposed, arrangements shall be made to permit indicating, reading, or recording spindle movement outside the valve bonnet or cap. In either case, care shall be exercised that the arrangement does not impose an additional load on the valve spindle or interfere with the operation of the valve.

Erroneous lift indications are possible under conditions of testing valves with fluids at elevated temperatures. The temperature of the fluid may cause thermal expansion of the valve parts, producing an erroneous initial reading on the lift indicator. When extreme accuracy in results is desired, measures shall be taken to distinguish between this thermal expansion and actual valve lift.

V-3.2.3 In-Service Testing Procedures

V-3.2.3.1 General Features of Tests

(a) These valve tests are designed to ensure service readiness for valve set pressure and operation, not necessarily to demonstrate total valve conformance to this Appendix or its specifications. The test methods per V-3.2.3.2 or V-3.2.3.3 are acceptable to meet this requirement subject to agreement between the interested parties.

(b) As a safety precaution, all operating personnel shall be properly trained in the appropriate test equipment procedures, test preparations, and emergency plans. Care shall be taken to protect personnel from elevated temperature, noise levels, and escaping fluids during testing. Prior to testing, a visual inspection of the valve is recommended. Observations should include the following as a minimum:

(1) gagging of the valve
(2) valve leakage
(3) inspection of discharge piping
(4) corrosion or residue
(5) installation of appropriate cap and lever
(6) seal integrity (to ensure against unauthorized adjustment)
(7) proper valve installation

CAUTION: Valves should be gagged during inspection when personnel are within close proximity to the valve, provided adequate overpressure protection of the system is maintained. The gag should be removed from the valve following inspection and prior to the test. Gagging of valves should be performed in accordance with the instructions outlined by the valve manufacturer.

(c) A suitable pressure measurement instrument meeting the requirements of V-3.2.2.2 shall be installed at a location that allows accurate measurement of system pressure at the valve inlet. Other measurement instruments used with various test devices shall be in conformance with the requirements of the device manufacturer.

V-3.2.3.2 Test Methods

(a) Testing With System Pressure. The pressure to the valve inlet is increased until the set pressure is reached. Observe and record the set pressure of the pressure relief device and any other desired or pertinent valve characteristics. Gradually decrease the inlet pressure until the valve closes, and, if required, record the reseat pressure. This test shall be repeated such that the operational characteristics can be computed in accordance with the requirements of V-3.3.3.

Figure V-3.2.2.2-1
Recommended Arrangement for Testing Valves With Compressible Fluids

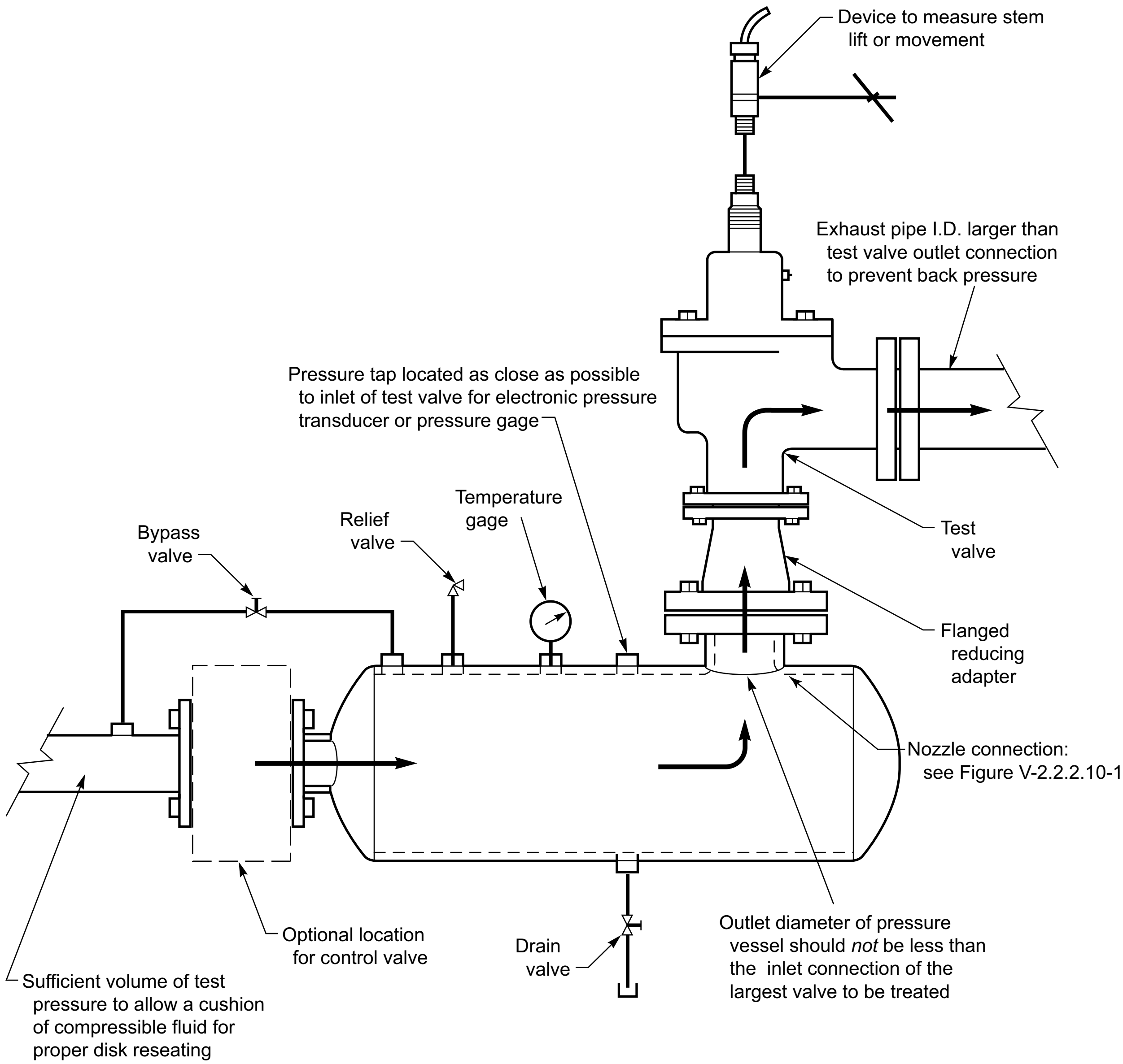


Figure V-3.2.2.2-2
Recommended Arrangement for Testing Valves With Incompressible Fluids

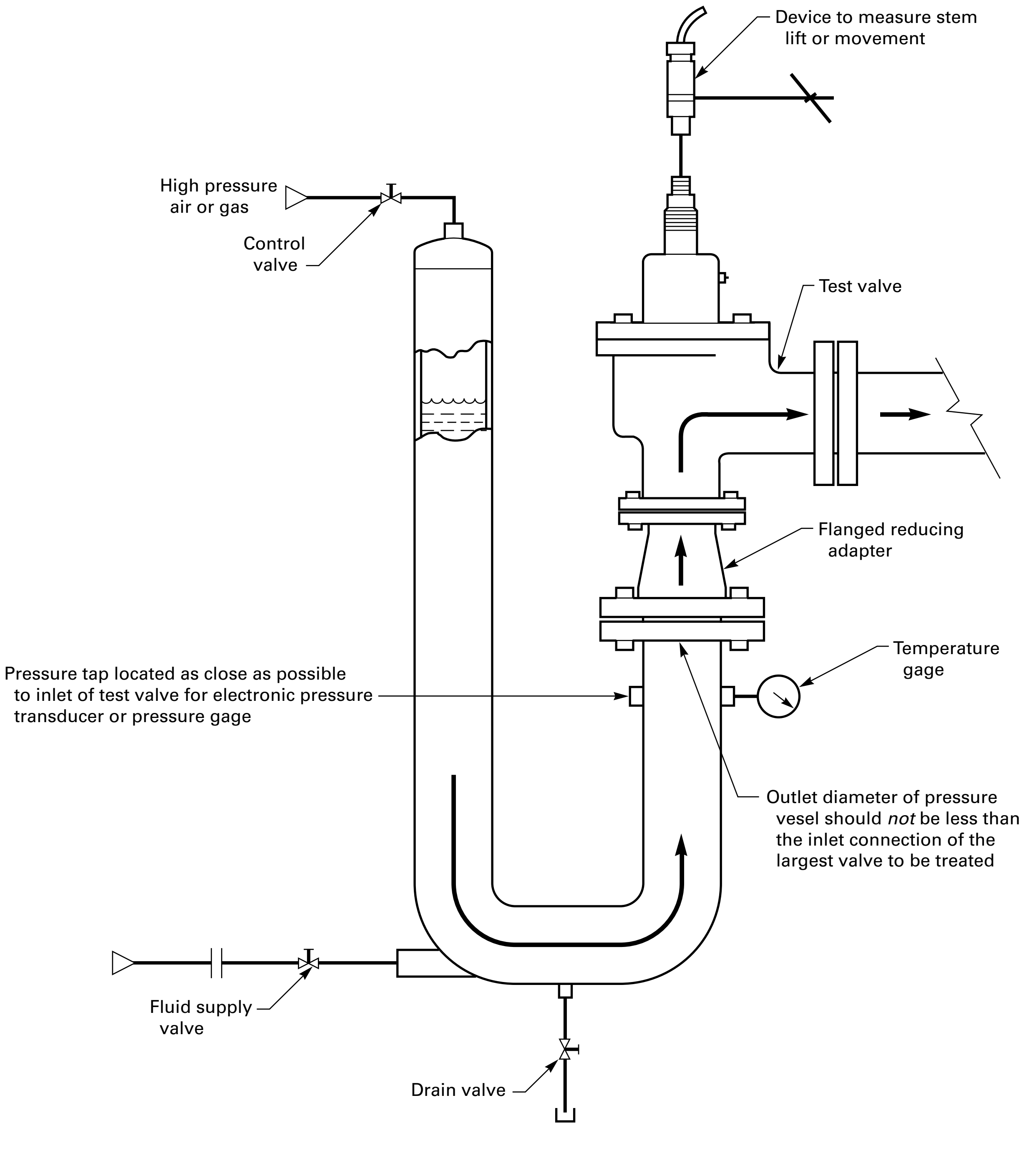
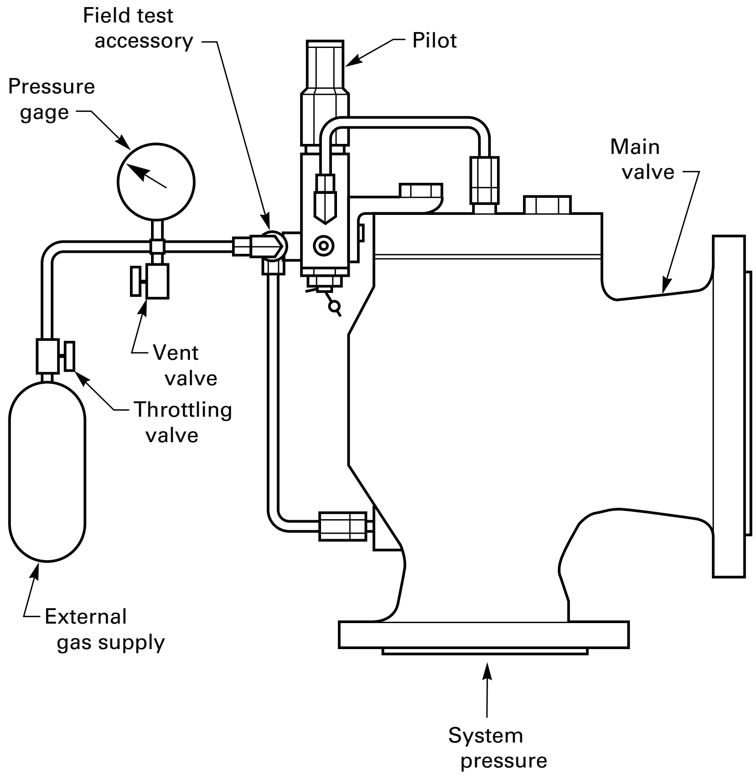


Figure V-3.2.3.2-1
Field Test Accessory for Pilot-Operated Pressure Relief Valve



Test conditions such as ambient temperature, valve temperature, fluid conditions, back pressures, and installation conditions should approximate the normal operating conditions under which the pressure relief valve would be exposed.

Seat leakage testing should be conducted per the requirements of V-3.2.5.

(b) Testing With Other Pressure Sources. On installations with pilot-operated pressure relief valves where increasing system pressure above normal operating pressure may not be desirable, a field test accessory may be used in accordance with the valve manufacturer's recommendations to determine set pressure. See Figure V-3.2.3.2-1 for a typical arrangement using a field test accessory.

Tests by this method shall be repeated such that the operational characteristics can be computed in accordance with the requirements of V-3.3.3.

(c) Testing With Auxiliary Lift-Assist Devices. On valve installations where increasing system pressure above normal operating pressure may not be desirable, auxiliary lift devices may be used in accordance with the valve lift-assist device manufacturer's procedure and the manufacturer's recommendations. The valve opening is characterized by an audible sound, momentary drop in assist load, or system fluid release. At the time of the opening, simultaneous readings of system pressure and applied load are recorded. The load is released from the lift-assist device. Valve set pressure may be presented graphically or be calculated using measured system pressure, measured lifting force, and the effective area of the valve seat. The effective area of the valve seat can be calculated from characterization tests or tests where the lift-assist test is performed and the results compared with a full pressure test. Before initial use of the lift-assist device, function and valve effective seat area shall be validated by demonstrating that the calculated set pressure determined by the lift-assist test compares with the actual set pressure determined by a full pressure test within an acceptable deviation agreed to by the parties of the test. Validation tests may be required for the specific valve design, size, and fluid conditions of the test. This test shall be repeated such that the operational characteristics can be computed in accordance with the requirements of V-3.3.3. Valve reseat pressure cannot be determined using this test method. Valve control elements shall be set to the valve manufacturer's specification.

CAUTION: Auxiliary lift devices can cause valve damage at inlet pressure too low relative to valve-set pressure. Auxiliary lift devices may not provide reliable results if there is damage to valve internal parts or if the valve has excessive leakage.

V-3.2.3.3 In-Service Verification of Pressure-Relieving Capacity

(a) If the parties of the test agree, an approximation of the relief valve flowing capacity can be determined in-service following completion of one of the tests described in V-3.2.3.2. In most cases, the purpose of such tests is to verify that the pressure-relieving devices in service are of adequate size to prevent an overpressure condition.

CAUTION: Precautions shall be taken during the tests to ensure that the maximum allowable working pressure of the system being protected is not exceeded beyond permissible safe limits. Therefore, the safety procedures noted in V-3.2.3.1(b) should be applied during the test.

(b) An accumulation test may be used if a quantitative value of capacity is not desired. Such a test is conducted by shutting off all the outlets from the vessel and maximizing the energy and mass flow input, which will be relieved by the pressure relief device. If the device is properly sized, the pressure in the vessel should not rise above a predetermined acceptable point. This method should not be used on a steam boiler with a superheater or reheater on a high-temperature water boiler.

(c) An estimated quantitative measure of flowing capacity can be determined for pressure relief valves mounted on steam boilers. As in the accumulation test described herein, all steam discharge outlets are shut while firing the boiler at a controlled rate sufficient to keep the valve open at a specified pressure. While maintaining steady steaming conditions over a long period of time, pressure relief valve capacity may be estimated from a measure of the rate of feed water input to the boiler.

(d) Other test arrangements may be used if agreed to by all interested parties. As an example, the arrangements may include the attachment of a vessel to the valve outlet for collection of the discharged fluid and release to atmosphere through a flowmetering device. Precautions should be taken to ensure that the built-up back pressure that may result does not affect the valve operation.

V-3.2.4 Bench Testing Procedures

V-3.2.4.1 General Features of Tests. There shall be assurance that the pressure relief devices are properly assembled with components that meet the design specification requirements. The pressure relief device shall be clean and ready for test.

The pressure relief device to be tested shall be installed on a test vessel with adapter fittings (flanged, screwed, welded, etc.). See Figure V-2.2.2.10-1 for acceptable adapter fitting contours for minimum inlet pressure drop. Other adapter fittings may be used provided the accuracy of the test is not affected. Operating and environmental conditions shall be maintained in accordance with the requirements of the procedure used. The duration of the test shall be that required to obtain the necessary performance data under stable conditions.

V-3.2.4.2 Compressible Fluids

(a) Valves marked for steam service shall be tested on steam. Valves marked for air, gas, or vapor service shall be tested with air or gas.

(b) Pressure relief valve-inlet pressure shall be the static pressure as measured with a pressure tap positioned as shown in Figure V-3.2.2.2-1.

NOTE: For steam testing, the quality of the steam may affect the operational characteristics of the valve. The steam quality may be affected by inadequate moisture separation, an underheated test vessel, or improper steam trap operation.

(c) Increase the pressure at the valve inlet to 90% of the expected set pressure. Then increase at a rate equal to 2% of set pressure per second or at a rate that permits accurate pressure readings. Observe and record the set pressure and other pertinent valve characteristics. Decrease the inlet pressure until the valve closes.

This test shall be repeated such that operational characteristics can be computed in accordance with V-3.3.3.

(d) To obtain an accurate reseat pressure measurement, an adequate volume of test medium is required at the valve inlet. When determining this volume, consideration shall be given to the cycle time and size of the device being tested relative to the rate of supply of the test medium.

V-3.2.4.3 Incompressible Fluids

(a) Valves marked for liquid service shall be tested with water or another suitable liquid.

(b) Pressure relief valve-inlet pressure shall be the static pressure as measured with a pressure tap positioned as shown in Figure V-3.2.2.2-2.

(c) Increase the pressure at the valve inlet to 90% of the expected set pressure. Then increase at a rate equal to 2% of set pressure per second or at a rate that permits accurate pressure readings. Observe and record the set pressure and other pertinent valve characteristics. Decrease the inlet pressure until the valve closes.

This test shall be repeated such that operational characteristics can be computed in accordance with V-3.3.3.

V-3.2.5 Seat Tightness Test

Seat tightness can be determined, when required, using API Standard 527 or another method agreed to by the parties of the test. These methods may include wet paper towel, soap bubble, cold bar, mirror, or fluid collection tests.

V-3.3 COMPUTATION OF RESULTS

V-3.3.1 Correction of Measured Variables

The values of measured variables shall be corrected in accordance with instrument calibrations. No other corrections to the data are permitted.

V-3.3.2 Review of Instrument Readings

Before calculations are undertaken, the instrument readings recorded in the log shall be reviewed for inconsistency and large fluctuation in accordance with ASME PTC 19.1.

V-3.3.3 Computation of Operational Characteristics

When specified in V-3.2 to determine specific operational characteristics, the result will be computed as per V-3.3.3.1 through V-3.3.3.3.

V-3.3.3.1 Set Pressure. The computed set pressure will be the average of at least the last three measured set pressures once established and stabilized. A set pressure is considered stable when the measured set pressures show no significant upward or downward trend whereby all are within ±1% or ±0.5 psi (4 kPa), whichever is greater, of the computed set pressure.

V-3.3.3.2 Blowdown. The computed blowdown shall be the average of the individual blowdowns of those tests used to determine the computed set pressure in V-3.3.3.1.

V-3.3.3.3 Lift. The computed lift shall be the average of the individual lift measurements of those tests used to determine the computed set pressure.

V-3.4 TEST SUMMARY REPORT FORM

V-3.4.1 General Instructions

(a) The Report of Test shall be prepared for the purpose of formally recording observed data and computed results. It shall contain sufficient supporting information to prove that all objectives of any tests conducted in accordance with this Appendix have been attained.

(b) The procedures described in V-3.3 are recommended for use in computing the test results.

(c) The Report of Test shall include Parts I to IV as listed in (1) through (4) herein and may include any of the remaining parts as agreed to by the contracting parties.

(1) Part I: General Information

(2) Part II: Summary of Results

(3) Part III: Description of Valve Under Test

(4) Part IV: Observed Data and Computed Results

(5) Part V: Test Conditions and Corrections Agreements

(6) Part VI: Test Methods and Procedures

(7) Part VII: Supporting Data

Paragraphs V-3.4.2 through V-3.4.8 give a discussion of each Part of the Test Report.

V-3.4.2 Part I: General Information

Part I shall include the following items:

(a) date of test
(b) location of test facilities
(c) valve manufacturer's name
(d) valve type or model number
(e) valve identification
(f) marked set pressure
(g) inlet and outlet connection sizes
(h) person conducting test
(i) operational characteristics to be measured
(j) test fluid

V-3.4.3 Part II: Summary of Results

Part II shall include those computed values with units of measurement and characteristics listed in V-3.4.2 that describe the performance of the valve at test conditions.

V-3.4.4 Part III: Description of Valve Under Test

Part III may include assembly drawings, manufacturing drawings, and measured dimensions. Manufacturing drawings for these parts may be submitted with the assembly drawing. The dimensions of these parts shall include the following, if applicable:

(a) bore diameter, in. (mm)
(b) seat diameter, in. (mm)
(c) seat angle, deg
(d) inlet opening diameter, in. (mm)
(e) ratio of throat diameter to the diameter of the inlet opening
(f) actual discharge area, in.^{2} (mm^2)

V-3.4.5 Part IV: Observed Data and Computed Results

Part IV shall include a record of data and calculations required for the results of the tests. The data shall have been corrected for instrument calibrations and conditions prevailing for each test run.

V-3.4.6 Part V: Test Conditions and Corrections Agreements

Operating conditions, such as the following, that have been agreed upon prior to the test shall be reported for each test:

(a) valve-inlet maximum pressure
(b) valve-inlet temperature
(c) valve temperature profile

V-3.4.7 Part VI: Test Methods and Procedures

Part VI shall include a description of the instruments and apparatus used to measure the various quantities and procedures for observing the mechanical characteristics of the valve under test.

V-3.4.8 Part VII: Supporting Data

Part VII shall include pertinent material supplementing data presented elsewhere in the report, whereby an independent verification of the report results can be made. This material may include, but not necessarily be limited to, the following:

(a) instrument calibration records
(b) detailed log sheets
(c) sample calculations
(d) graphical presentation of data

NONMANDATORY APPENDIX A
GUIDANCE FOR THE USE OF U.S. CUSTOMARY AND SI UNITS IN THE ASME BOILER AND PRESSURE VESSEL CODE

A-1 USE OF UNITS IN EQUATIONS

The equations in this Section are suitable for use with either the U.S. Customary or the SI units provided in 1.5, or with the units provided in the nomenclatures associated with the equations. It is the responsibility of the individual and organization performing the calculations to ensure that appropriate units are used. Either U.S. Customary or SI units may be used as a consistent set. When it is necessary to convert from one system of units to another, the units shall be converted to at least three significant figures for use in calculations and other aspects of construction.

A-2 GUIDELINES USED TO DEVELOP SI EQUIVALENTS

The following guidelines were used to develop SI equivalents:

(a) U.S. Customary units are placed in parentheses after the SI units in the text.

(b) In general, both SI and U.S. Customary tables are provided if interpolation is expected. The table designation (i.e., table number) is the same for both the SI and U.S. Customary tables, with the addition of an "M" after the table number for the SI table. In the text, references to a table use the primary table number followed by the secondary table number in parentheses. For some small tables, where interpolation is not required, U.S. Customary units are placed in parentheses after the SI units.

(c) Separate SI versions of graphical information (charts) are provided, except that if both axes are dimensionless, a single figure (chart) is used.

(d) In most cases, conversions of units in the text were done using hard SI conversion practices, with some soft conversions on a case-by-case basis, as appropriate. This was implemented by rounding the SI values to the number of significant figures of implied precision in the existing U.S. Customary units. For example, 3,000 psi has an implied precision of one significant figure. Therefore, the conversion to SI units would typically be to 20 000 kPa. This is a difference of about 3% from the "exact" or soft conversion of 20 684.27 kPa. However, the precision of the conversion was determined by the Committee on a case-by-case basis. More significant digits were included in the SI equivalent if there was any question. The values of allowable stress in Section II, Part D generally include three significant figures.

(e) Minimum thickness and radius values that are expressed in fractions of an inch were generally converted according to the following table:

Fraction, in.	Proposed SI Conversion, mm	Difference, %
1/32	0.8	−0.8
3/64	1.2	−0.8
1/16	1.5	5.5
3/32	2.5	−5.0
1/8	3	5.5
5/32	4	−0.8
3/16	5	−5.0
7/32	5.5	1.0
1/4	6	5.5
5/16	8	−0.8
3/8	10	−5.0
7/16	11	1.0
1/2	13	−2.4
9/16	14	2.0
5/8	16	−0.8
11/16	17	2.6
3/4	19	0.3
7/8	22	1.0
1	25	1.6

(f) For nominal sizes that are in even increments of inches, even multiples of 25 mm were generally used. Intermediate values were interpolated rather than converting and rounding to the nearest mm. See examples in the following table. [Note that this table does not apply to nominal pipe sizes (NPS), which are covered below.]

Size, in.	Size, mm
1	25
1 1/8	29
1 1/4	32
1 1/2	38
2	50

Table continued

Size, in.	Size, mm
2¼	57
2½	64
3	75
3½	89
4	100
4½	114
5	125
6	150
8	200
12	300
18	450
20	500
24	600
36	900
40	1 000
54	1 350
60	1 500
72	1 800

Size or Length, ft	Size or Length, m
3	1
5	1.5
200	60

(g) For nominal pipe sizes, the following relationships were used:

U.S. Customary Practice	SI Practice	U.S. Customary Practice	SI Practice
NPS ⅛	DN 6	NPS 20	DN 500
NPS ¼	DN 8	NPS 22	DN 550
NPS ⅜	DN 10	NPS 24	DN 600
NPS ½	DN 15	NPS 26	DN 650
NPS ¾	DN 20	NPS 28	DN 700
NPS 1	DN 25	NPS 30	DN 750
NPS 1¼	DN 32	NPS 32	DN 800
NPS 1½	DN 40	NPS 34	DN 850
NPS 2	DN 50	NPS 36	DN 900
NPS 2½	DN 65	NPS 38	DN 950
NPS 3	DN 80	NPS 40	DN 1 000
NPS 3½	DN 90	NPS 42	DN 1 050
NPS 4	DN 100	NPS 44	DN 1 100
NPS 5	DN 125	NPS 46	DN 1 150
NPS 6	DN 150	NPS 48	DN 1 200
NPS 8	DN 200	NPS 50	DN 1 250
NPS 10	DN 250	NPS 52	DN 1 300
NPS 12	DN 300	NPS 54	DN 1 350
NPS 14	DN 350	NPS 56	DN 1 400
NPS 16	DN 400	NPS 58	DN 1 450
NPS 18	DN 450	NPS 60	DN 1 500

(h) Areas in square inches (in.^{2}) were converted to square millimeters (mm^2), and areas in square feet (ft^2) were converted to square meters (m^2). See examples in the following table:

Area (U.S. Customary)	Area (SI)
1 in.^{2}	650 mm^2
6 in.^{2}	4 000 mm^2
10 in.^{2}	6 500 mm^2
5 ft^2	0.5 m^2

(i) Volumes in cubic inches (in.^{3}) were converted to cubic millimeters (mm^3), and volumes in cubic feet (ft^3) were converted to cubic meters (m^3). See examples in the following table:

Volume (U.S. Customary)	Volume (SI)
1 in.^{3}	16 000 mm^3
6 in.^{3}	100 000 mm^3
10 in.^{3}	160 000 mm^3
5 ft^3	0.14 m^3

(j) Although the pressure should always be in MPa for calculations, there are cases where other units are used in the text. For example, kPa is used for small pressures. Also, rounding was to one significant figure (two at the most) in most cases. See examples in the following table. (Note that 14.7 psi converts to 101 kPa, while 15 psi converts to 100 kPa. While this may seem at first glance to be an anomaly, it is consistent with the rounding philosophy.)

Pressure (U.S. Customary)	Pressure (SI)
0.5 psi	3 kPa
2 psi	15 kPa
3 psi	20 kPa
10 psi	70 kPa
14.7 psi	101 kPa
15 psi	100 kPa
30 psi	200 kPa
50 psi	350 kPa
100 psi	700 kPa
150 psi	1 MPa
200 psi	1.5 MPa
250 psi	1.7 MPa
300 psi	2 MPa
350 psi	2.5 MPa
400 psi	3 MPa
500 psi	3.5 MPa
600 psi	4 MPa
1,200 psi	8 MPa
1,500 psi	10 MPa

(k) Material properties that are expressed in psi or ksi (e.g., allowable stress, yield and tensile strength, elastic modulus) were generally converted to MPa to three significant figures. See example in the following table:

Strength (U.S. Customary)	Strength (SI)
95,000 psi	655 MPa

(l) In most cases, temperatures (e.g., for PWHT) were rounded to the nearest 5°C. Depending on the implied precision of the temperature, some were rounded to the nearest 1°C or 10°C or even 25°C. Temperatures colder than 0°F (negative values) were generally rounded to the nearest 1°C. The examples in the table below were created by rounding to the nearest 5°C, with one exception:

Temperature, °F	Temperature, °C
70	20
100	38
120	50
150	65
200	95
250	120
300	150
350	175
400	205
450	230
500	260
550	290
600	315
650	345
700	370
750	400
800	425
850	455
900	480
925	495
950	510
1,000	540
1,050	565
1,100	595
1,150	620
1,200	650
1,250	675
1,800	980
1,900	1 040
2,000	1 095
2,050	1 120

A-3 SOFT CONVERSION FACTORS

The following table of "soft" conversion factors is provided for convenience. Multiply the U.S. Customary value by the factor given to obtain the SI value. Similarly, divide the SI value by the factor given to obtain the U.S. Customary value. In most cases it is appropriate to round the answer to three significant figures.

U.S. Customary	SI	Factor	Notes
in.	mm	25.4	...
ft	m	0.3048	...
in.^{2}	mm^2	645.16	...
ft^2	m^2	0.09290304	...
in.^{3}	mm^3	16,387.064	...
ft^3	m^3	0.02831685	...
U.S. gal	m^3	0.003785412	...
U.S. gal	liters	3.785412	...
psi	MPa (N/mm^2)	0.0068948	Used exclusively in equations
psi	kPa	6.894757	Used only in text and for nameplate
psi	bar	0.06894757	...
ft-lb	J	1.355818	...
°F	°C	$\frac{5}{9}$ × (°F − 32)	Not for temperature difference
°F	°C	$\frac{5}{9}$	For temperature differences only
°R	K	$\frac{5}{9}$	Absolute temperature
lbm	kg	0.4535924	...
lbf	N	4.448222	...
in.-lb	N·mm	112.98484	Use exclusively in equations
ft-lb	N·m	1.3558181	Use only in text
$\text{ksi}\sqrt{\text{in.}}$	$\text{MPa}\sqrt{\text{m}}$	1.0988434	...
Btu/hr	W	0.2930711	Use for boiler rating and heat transfer
lb/ft^3	kg/m^3	16.018463	...

NONMANDATORY APPENDIX B
STOP VALVES USED IN PRESSURE RELIEF SYSTEMS

B-1 INTRODUCTION

This Appendix provides guidance for the installation and use of stop valves in pressure relief systems. The use of stop valves in pressure relief systems is determined by the equipment's code or standard. Where their use is permitted, stop valves shall be installed in accordance with the equipment's code or standard unless the code or standard has also adopted by reference this Appendix. In addition, the use of stop valves may involve jurisdictional approval. Where a code, standard, or jurisdictional authority does not address the use of stop valves, the guidance in this Appendix may be used. In these situations, substitute the term "pressurized equipment" for "vessel(s)."

B-2 STOP VALVES LOCATED IN THE RELIEF PATH

(a) Stop valves may be located within the relief path as provided for in B-6 through B-9 but only when specified by the user. The responsibilities of the user are summarized in B-4. The specific requirements in B-6 through B-9 are not intended to allow for normal operation above the pressurized equipment's maximum allowable working pressure (MAWP).

(b) The pressure relief path shall be designed such that the pressure in the equipment being protected does not exceed its MAWP before the pressure at the pressure relief device reaches its set pressure and the pressure does not exceed the pressurized equipment's maximum permissible relief pressure of the governing code.

B-3 DEFINITIONS

administrative controls: procedures that, in combination with mechanical locking elements, are intended to ensure that personnel actions do not compromise the overpressure protection of the equipment. They include, as a minimum, documented operation and maintenance procedures, and the training of operator and maintenance personnel in these procedures.

full-area stop valve: a valve in which the flow area of the valve is equal to or greater than the inlet flow area of the pressure relief device.

management system: the collective application of administrative controls, valve operation controls, and valve failure controls in accordance with the applicable requirements of this Section.

mechanical locking elements: elements that when installed on a stop valve provide a physical barrier to the operation of the stop valve such that the stop valve is not capable of being operated unless a deliberate action is taken to remove or disable the element. Such elements, when used in combination with administrative controls, ensure that the equipment overpressure protection is not compromised by personnel actions. Examples of mechanical locking elements include locks (with or without chains) on the stop valve handwheels, levers, or actuators, and plastic or metal straps (car seals) that are secured to the valve in such a way that the strap must be broken to operate the stop valve.

pressure relief path: path consisting of all equipment, pipe, fittings, and valves in the flow path between any protected equipment and its pressure-relieving device, and between the pressure-relieving device and the discharge point of the relieving stream. Stop valves within a pressure relief path include, but are not limited to, those located directly upstream and downstream of the pressure relief device (PRD) that may be provided exclusively for PRD maintenance.

valve failure controls: measures taken in valve design, configuration, and/or orientation for the purpose of preventing an internal failure of a stop valve from closing and blocking the pressure relief path. An example of valve failure controls is the installation of gate valves with the valve stem oriented at or below the horizontal position.

valve operation controls: devices used to ensure that stop valves within the pressure relief path are in their proper (open/closed) position. They include the following:

(a) mechanical interlocks designed to prevent valve operations that could result in the blocking of a pressure relief path before an alternative pressure relief path is put into service. Mechanical interlocks include physical linkages such as shafts or levers between stop valves and key-based interlocking systems.

(b) instrumented interlocks that function in a way similar to mechanical interlocks, except that instrument permissives and/or overrides are used instead of

mechanical linkages or devices to prevent valve positions that block the pressure relief path.

(c) three-way valves designed to prevent a flow path from being blocked unless another flow path is simultaneously opened.

B-4 RESPONSIBILITIES

The user has the responsibility to establish and maintain a management system that ensures a vessel is not operated without overpressure protection. These responsibilities include, but are not limited to, the following:

(a) deciding and specifying whether the overpressure protection system will allow the use of stop valve(s) located in the relief path

(b) establishing the pressure relief philosophy and the administrative controls requirements

(c) establishing the required level of reliability, redundancy, and maintenance of instrumented interlocks, if used

NOTE: The procedures contained in IEC 61508 or ISA S-84 may be used for the purpose and analysis described in (c).

(d) establishing procedures to ensure that the equipment is adequately protected against overpressure

(e) ensuring that authorization to operate identified valves is clear and that personnel are adequately trained for this task

(f) establishing management systems to ensure that administrative controls are effective

(g) establishing the analysis procedures and basis to be used in determining the potential levels of pressure if the stop valves were closed

(h) ensuring that the analysis described in (g) is conducted by personnel who are qualified and experienced with the analysis procedure

(i) ensuring that the other system components are acceptable for the potential levels of pressure established in (g)

(j) ensuring that the results of the analysis described in (g) are documented and are reviewed and accepted in writing by the individual responsible for operation of the vessel and valves

(k) ensuring that the administrative controls are reviewed and accepted in writing by the individual responsible for operation of the vessel and valves

B-5 PROCEDURES AND MANAGEMENT SYSTEMS

(a) Procedures shall specify that valves requiring mechanical locking elements and/or valve operation controls and/or valve failure controls shall be documented and clearly identified as such.

(b) The management system shall document the administrative controls (training and procedures), the valve controls, and the performance of the administrative controls in an auditable form for management review.

B-6 STOP VALVES IN SYSTEMS WITH PRESSURE FROM AN OUTSIDE SOURCE

A vessel or system for which the pressure originates from an outside source exclusively may have individual pressure-relieving devices on each vessel or connected to any point on the connecting piping, or on any one of the vessels to be protected. Under any such arrangement, there may be stop valve(s) between any vessel and the pressure-relieving devices, and these stop valves need not have any administrative controls, valve operation controls, or valve failure controls, provided that the stop valves also isolate the vessel from the source of pressure.

B-7 STOP VALVES UPSTREAM OR DOWNSTREAM OF THE PRESSURE RELIEF DEVICE

Full-area stop valves may be provided upstream and/or downstream of the pressure-relieving device exclusively for the purpose of inspection, testing, and repair of the pressure-relieving device or discharge header isolation, provided that, as a minimum, the following requirements are met:

(a) Administrative controls are provided to prevent unauthorized valve operation.

(b) Valves are provided with mechanical locking elements.

(c) Valve failure controls are provided to prevent accidental valve closure due to mechanical failure.

(d) Procedures are in place to provide pressure relief protection during the time when the system is isolated from its pressure relief path. These procedures shall ensure that when the system is isolated from its pressure relief path, an authorized person shall continuously monitor the pressure conditions of the vessel and shall be capable of responding promptly with documented, predefined actions, either stopping the source of overpressure or opening alternative means of pressure relief. This authorized person shall be dedicated to this task and shall have no other duties when performing this task.

(e) The system shall be isolated from its pressure relief path only for the time required to test, repair, and/or replace the pressure relief device.

B-8 STOP VALVES IN THE PRESSURE RELIEF PATHS HANDLING PROCESS FLOW

Stop valves, excluding remotely operated valves and process control valves, may be provided in the relief path where there is normally a process flow, provided the requirements in (a) through (c), as a minimum, are met. These requirements are based on the potential overpressure scenarios involving accidental closure of a single stop valve within the relief path [see B-3.4(g)]. The accidental closure of these stop valves in the pressure relief system need not be considered as a condition for establishing the pressurized equipment's design pressure in accordance with the referencing Code or Standard.

(a) The flow resistance of the valve in the full open position does not reduce the relieving capacity below that required by the requirements of the referencing Code or Standard.

(b) The closure of the valve will be readily apparent to the operators such that corrective action, in accordance with documented operating procedures, is required.

(c) One of the following conditions shall be met:

(1) If the pressure due to closure of the valve cannot exceed the multiple relief device maximum allowed relief pressure, such as 116% of MAWP for Section VIII, Division 1 or Division 2 vessels, then no administrative controls, mechanical locking elements, valve operation controls, or valve failure controls are required.

(2) If the pressure due to closure of the valve cannot exceed the value calculated in (-a) or (-b), then administrative controls and mechanical locking elements are required as a minimum.

(-a) the documented vessel test pressure multiplied by the ratio of the stress value at the design temperature to the stress value at the test temperature

(-b) if the governing code or standard permits the vessel test pressure to be calculated on a value greater than the vessel design pressure, then, in addition to being multiplied by the ratio in (-a), the test pressure shall be multiplied by the ratio of nominal thickness minus the corrosion allowance to the nominal thickness

(3) If the pressure due to closure of the valve could exceed the pressure indicated in (2), then the user shall do one of the following:

(-a) Eliminate the stop valve.

(-b) Apply administrative controls, mechanical locking elements, valve failure controls, and valve operation controls.

(-c) Provide a pressure relief device to protect the equipment that could be overpressured due to closure of the stop valve.

B-9 STOP VALVES IN THE RELIEF PATHS WHERE FIRE IS SOURCE OF OVERPRESSURE

Full-area stop valves located in the relief path of equipment where there is normally process flow and where fire is the only potential source of overpressure do not require physical elements such as locks or car seals, valve operation controls, or valve failure controls, provided the user has documented operating procedures requiring that equipment isolated from its pressure relief path is depressurized and free of liquids.

NONMANDATORY APPENDIX C
GUIDE TO MANUFACTURER'S AND ASSEMBLER'S CERTIFICATES OF CONFORMANCE FOR PRESSURE RELIEF DEVICES

C-1 INTRODUCTION

This Appendix contains copies of the Manufacturer's and Assembler's Certificate of Conformance forms (see Table C-1-1) and associated guides for completing the forms. The instructions in the guides are keyed to the forms in the following manner:

(a) Circled numbers on each form refer to the items listed in the associated guide. The parenthesized numbers in the guide correspond to the circled numbers on the form.

(b) Numbers without circles appearing in the guide identify specific lines on the associated Manufacturer's or Assembler's Certificate of Conformance form.

Forms in this Appendix may be obtained from the ASME website at https://www.asme.org/codes-standards/publications-information/asme-data-report-forms.

C-2 CERTIFICATE OF CONFORMANCE FORMS

The Certificate of Conformance forms begin on the next page.

Table C-1-1
Summary of Certificate of Conformance Forms (25)

Certification Designator	Type of Certificate of Conformance	Form	Guide
HV	Manufacturer	HV-1	Table C-2-1
UV	Manufacturer or Assembler	UV-1	Table C-2-2
UD	Manufacturer	UD-1	Table C-2-2
UV3	Manufacturer or Assembler	K-4	Table C-2-3
UD3	Manufacturer	K-5	Table C-2-4
TV	Manufacturer or Assembler	TV-1	Table C-2-5
TD	Manufacturer	TD-1	Table C-2-5

(25)

FORM HV-1 MANUFACTURER'S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

1. Manufactured by ______ (1) ______

2. Table of Code symbol stamped items:

I.D. #	Date	Cert. #	Qty.	Type	Size (NPS)	Set Pressure	Capacity	Test Fluid	Date Code	CI Name	CI Signature
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

3. Remarks ______ (18) ______

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 XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

HV Certificate of Authorization No. ______ (14) ______ Expires ______ (15) ______

Date ______ (16) ______ Signed ______ (17) ______ (responsible representative) Name ______ (17) ______ (Manufacturer)

(07/25)

(25)

Table C-2-1
Guide for the Preparation of Manufacturer's Certificate of Conformance Form HV-1

Reference to Circled Numbers in Form HV-1	Instructions
(1)	Name and address of Manufacturer.
(2)	Pressure relief valve Manufacturer's unique identification number, such as serial number, work order number, or lot number.
(3)	The date of completion of production of the pressure relief valve.
(4)	The NB Certification Number.
(5)	The quantity of identical valves for this line item.
(6)	The Manufacturer's Design or Type Number as marked on the nameplate.
(7)	The inlet size of the pressure relief valve (NPS).
(8)	The nameplate set pressure of the pressure relief valve.
(9)	The nameplate capacity of the pressure relief valve.
(10)	The fluid used for testing the pressure relief valve.
(11)	The year built or the pressure relief valve Manufacturer's date code.
(12)	The name of the Certified Individual.
(13)	The signature of the Certified Individual. Required for each line item.
(14)	The number of the pressure relief valve Manufacturer's Certificate of Authorization.
(15)	Expiration date of the pressure relief valve Manufacturer's Certificate of Authorization.
(16)	Date signed by the pressure relief valve Manufacturer's authorized representative.
(17)	The Certificate of Shop Compliance block shall show the name of the Manufacturer as it appears on the ASME Code Certificate of Authorization and shall be signed in accordance with the organizational authority defined in the quality control system (see Mandatory Appendix III).
(18)	Include any applicable remarks (referencing the identification number) that may pertain, such as identification of a Code Case that requires marking on the device.

GENERAL NOTE: Any quantity to which units apply shall be entered with the chosen units.

FORM UV-1 MANUFACTURER’S OR ASSEMBLER’S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

1. Manufactured (or assembled) by ______ (1) ______

2. Table of Certification Mark stamped items:

I.D. #	Year Built	NB Cert. #	Qty.	Type	Size	Set Pressure	Capacity	Test Fluid	Date	CI Name	CI Signature
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

3. Remarks ______ (14) ______

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 devices conform with the requirements of Section XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

UV Certificate of Authorization No. ______ (15) ______ Expires ______ (16) ______

Date ______ (17) ______ Signed ______ (18) ______ (Responsible representative) Name ______ (18) ______ (Manufacturer or Assembler)

(07/21)

(25)

FORM UD-1 MANUFACTURER'S CERTIFICATE OF CONFORMANCE FOR NON-RECLOSING PRESSURE RELIEF DEVICES

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

1. Manufactured by ______________________ ① ______________________

2A. Table of Certification Mark stamped activation components:

Lot #	Year Built	NB Cert. #	Qty.	Activation Component Material	Type	Size	Marked Burst or Set Pressure	Specified Temp.	Min. Net Flow Area	Certified Flow Resistance	Capacity	Date	CI Name	CI Signature
②	③	④	⑤	⑲	⑥	⑦	⑳	㉑	㉒	㉓	⑨	⑪	⑫	⑬

2B. Table of Certification Mark stamped non-reclosing pressure relief device holder or body:

Year Built	Qty.	Holder or Body Material	Type	Size	Pin to Pin Device Identifier	Date	CI Name	CI Signature
③	⑤	⑲	⑥	⑦	㉔	⑪	⑫	⑬

3. Remarks ______________________ ⑭ ______________________

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 or pin devices conform with the requirements of Section XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

UD Certificate of Authorization No. ________ ⑮ ________ Expires ____ ⑯ ____

Date ____ ⑰ ____ Signed ________ ⑱ ________ Name ________ ⑱ ________
(Responsible representative) (Manufacturer)

(07/25)

Table C-2-2
Supplementary Instructions for the Preparation of Manufacturer's or Assembler's Certificate of Conformance Forms UV-1 and UD-1 (25)

Reference to Circled Numbers in Forms UV-1 and UD-1	Instructions
(1)	Name and address of Manufacturer or Assembler.
(2)	Pressure relief device Manufacturer's or Assembler's unique identification number, such as serial number, work order number, or lot number.
(3)	The year built or the pressure relief device Manufacturer's or Assembler's date code.
(4)	The NB Certification Number.
(5)	The quantity of identical devices for this line item.
(6)	The Manufacturer's Design or Type Number as marked on the nameplate.
(7)	The inlet size of the pressure relief device.
(8)	The nameplate set pressure of the pressure relief device.
(9)	The nameplate capacity of the pressure relief device, as applicable.
(10)	The fluid used for testing the pressure relief device.
(11)	The date of completion of production of the pressure relief device.
(12)	The name or unique ID stamp of the Certified Individual.
(13)	The signature of the Certified Individual. Required for each line item.
(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.
(15)	The number of the pressure relief device Manufacturer's or Assembler's Certificate of Authorization.
(16)	Expiration date of the pressure relief device Manufacturer's or Assembler's Certificate of Authorization.
(17)	Date signed by the pressure relief device Manufacturer's or Assembler's authorized representative.
(18)	The Certificate of Compliance block shall show the name of the Manufacturer or Assembler as it appears on the ASME Code Certificate of Authorization and shall be signed in accordance with the organizational authority defined in the quality control system (see Mandatory Appendix III).
(19)	The material of the activation component and/or activation component holder or body, as applicable.
(20)	The marked burst or set pressure of the rupture disk or pin.
(21)	The specified temperature of the rupture disk or pin.
(22)	The minimum net flow area of the rupture disk or pin device, as applicable.
(23)	The certified flow resistance of the device, K_{RG}, K_{RL}, and/or K_{RGL} (one or more, as applicable).
(24)	Pin-to-pin device identifier, as applicable.

GENERAL NOTE: Any quantity to which units apply shall be entered with the chosen units.

FORM K-4 MANUFACTURER'S OR ASSEMBLER'S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

1. Manufactured (or assembled) by ______ ①

2. Table of Certification Marked items:

I.D. #	Date	Cert. #	Qty.	Type	Size	Set Pressure	Capacity	Test Fluid	Date Code	CI Name	CI Signature
②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬

3. Remarks ______ ⑭

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 XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

UV3 Certificate of Authorization No. ______ ⑮ Expires ______ ⑯

Date ______ ⑰ Signed ______ ⑱ (Responsible representative) Name ______ ⑱ (Manufacturer or Assembler)

(07/23)

Table C-2-3 Supplementary Instructions for the Preparation of Manufacturer's or Assembler's Certificate of Conformance Form K-4 (25)

Reference to Circled Numbers in Form K-4	Instructions
(1)	Name and address of Manufacturer or Assembler.
(2)	Pressure relief valve Manufacturer's or Assembler's unique number, such as serial number, work order number, or lot number.
(3)	The date of completion of production of the pressure relief valve.
(4)	The NB Certification Number.
(5)	The quantity of identical valves for this line item.
(6)	The Manufacturer's Design or Type Number as marked on the nameplate.
(7)	The inlet size of the pressure relief valve.
(8)	The nameplate set pressure of the pressure relief valve.
(9)	The nameplate capacity of the pressure relief valve.
(10)	The fluid used for testing the pressure relief valve.
(11)	The year built or the pressure relief valve Manufacturer's or Assembler's date code.
(12)	The name of the Certified Individual.
(13)	The signature of the Certified Individual. Required for each line item.
(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.
(15)	The number of the pressure relief valve Manufacturer's or Assembler's Certificate of Authorization.
(16)	Expiration date of the pressure relief valve Manufacturer's or Assembler's Certificate of Authorization.
(17)	Date signed by the pressure relief valve Manufacturer's or Assembler's responsible representative.
(18)	The Certificate of Compliance block shall show the name of the Manufacturer or Assembler as it appears on the ASME Code Certificate of Authorization and shall be signed in accordance with the organizational authority defined in the quality control system (see Mandatory Appendix III).

GENERAL NOTE: Any quantity to which units apply shall be entered with the chosen units.

FORM K-5 MANUFACTURER'S CERTIFICATE OF CONFORMANCE FOR RUPTURE DISK DEVICES
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

1. Manufactured by ______ (1) ______

2A. Table of Certification Marked rupture disks:

Lot #	Year Built	NB Cert. #	Qty.	Disk Material	Type	Size	Marked Burst Pressure	Specified Disk Temp.	Holder Type	Date	CI Name	CI Signature
(2)	(3)	(4)	(5)	(18)	(6)	(7)	(8)	(9)	(6)	(10)	(11)	(12)

2B. Table of Certification Marked rupture disk holders:

Year Built	NB Cert. #	Qty.	Holder Material	Type	Size	Date	CI Name	CI Signature
(3)	(4)	(5)	(18)	(6)	(7)	(10)	(11)	(12)

3. Remarks ______ (13) ______

______

______

______

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 XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

UD3 Certificate of Authorization No. ______ (14) ______ Expires ______ (15) ______

Date ______ (16) ______ Signed ______ (17) ______ Name ______ (17) ______
(Responsible representative) (Manufacturer)

(07/23)

Table C-2-4
Supplementary Instructions for the Preparation of Manufacturer's Certificate of Conformance Form K-5

(25)

Reference to Circled Numbers in Form K-5	Instructions
(1)	Name and address of Manufacturer.
(2)	Pressure relief device Manufacturer's unique number, such as serial number, work order number, or lot number.
(3)	The year built or the device Manufacturer's date code.
(4)	The NB Certification Number.
(5)	The quantity of identical devices for this line item.
(6)	The Manufacturer's Design or Type Number as marked on the nameplate.
(7)	The inlet size of the device.
(8)	The marked burst pressure of the device.
(9)	The specified disk temperature.
(10)	The date of completion of production of the pressure relief device.
(11)	The name or unique ID stamp of the Certified Individual.
(12)	The signature of the Certified Individual. Required for each line item.
(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.
(14)	The number of the pressure relief device Manufacturer's Certificate of Authorization.
(15)	Expiration date of the pressure relief device Manufacturer's Certificate of Authorization.
(16)	Date signed by the pressure relief device Manufacturer's authorized representative.
(17)	The Certificate of Compliance block shall show the name of the Manufacturer as it appears on the ASME Code Certificate of Authorization and shall be signed in accordance with the organizational authority defined in the quality control system (see Mandatory Appendix III).
(18)	The material of the rupture disk and/or holder, as applicable.

GENERAL NOTE: Any quantity to which units apply shall be entered with the chosen units.

FORM TV-1 MANUFACTURER'S OR ASSEMBLER'S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

Page ______ of ______

1. Manufactured (or assembled) by ______ ① ______

2. Table of Certification Mark stamped items:

I.D. #	Year Built	NB Cert. #	Qty.	Type	Size	Set Pressure	Capacity	Test Fluid	Date	CI Name	CI Signature
②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬

3. Remarks ______ ⑭ ______

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 devices conform with the requirements of Section XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

TV Certificate of Authorization No. ______ ⑮ ______ Expires ______ ⑯ ______

Date ______ ⑰ ______ Signed ______ ⑱ ______ (Responsible representative) Name ______ ⑱ ______ (Manufacturer or Assembler)

(07/21)

(25)

FORM TD-1 MANUFACTURER'S CERTIFICATE OF CONFORMANCE FOR NON-RECLOSING PRESSURE RELIEF DEVICES
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section XIII

Page ______ of ______

1. Manufactured by ______ ①

2A. Table of Certification Mark stamped activation components:

Lot #	Year Built	NB Cert. #	Qty.	Activation Component Material	Type	Size	Marked Burst or Set Pressure	Specified Temp.	Min. Net Flow Area	Certified Flow Resistance	Capacity	Date	CI Name	CI Signature
②	③	④	⑤	⑲	⑥	⑦	⑳	㉑	㉒	㉓	⑨	⑪	⑫	⑬

2B. Table of Certification Mark stamped non-reclosing pressure relief device holder or body:

Year Built	Qty.	Holder or Body Material	Type	Size	Pin to Pin Device Identifier	Date	CI Name	CI Signature
③	⑤	⑲	⑥	⑦	㉔	⑪	⑫	⑬

3. Remarks ______ ⑭

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 or pin devices conform with the requirements of Section XIII of the ASME BOILER AND PRESSURE VESSEL CODE.

TD Certificate of Authorization No. ______ ⑮ Expires ______ ⑯

Date ______ ⑰ Signed ______ ⑱ (Responsible representative) Name ______ ⑱ (Manufacturer)

(07/25)

(25)

Table C-2-5
Supplementary Instructions for the Preparation of Manufacturer's or Assembler's Certificate of Conformance Forms TV-1 and TD-1

Reference to Circled Numbers in Forms TV-1 and TD-1	Instructions
(1)	Name and address of Manufacturer or Assembler.
(2)	Pressure relief device Manufacturer's or Assembler's unique identification number, such as serial number, work order number, or lot number.
(3)	The year built or the pressure relief device Manufacturer's or Assembler's date code.
(4)	The NB Certification Number.
(5)	The quantity of identical devices for this line item.
(6)	The Manufacturer's Design or Type Number as marked on the nameplate.
(7)	The inlet size of the pressure relief device.
(8)	The nameplate set pressure of the pressure relief device.
(9)	The nameplate capacity of the pressure relief device, as applicable.
(10)	The fluid used for testing the pressure relief device.
(11)	The date of completion of production of the pressure relief device.
(12)	The name or unique ID stamp of the Certified Individual.
(13)	The signature of the Certified Individual. Required for each line item.
(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.
(15)	The number of the pressure relief device Manufacturer's or Assembler's Certificate of Authorization.
(16)	Expiration date of the pressure relief device Manufacturer's or Assembler's Certificate of Authorization.
(17)	Date signed by the pressure relief device Manufacturer's or Assembler's authorized representative.
(18)	The Certificate of Compliance block shall show the name of the Manufacturer or Assembler as it appears on the ASME Code Certificate of Authorization and shall be signed in accordance with the organizational authority defined in the quality control system (see Mandatory Appendix III).
(19)	The material of the activation component and/or activation component holder or body, as applicable.
(20)	The marked burst or set pressure of the rupture disk or pin.
(21)	The specified temperature of the rupture disk or pin.
(22)	The minimum net flow area of the rupture disk or pin device, as applicable.
(23)	The certified flow resistance of the device, K_{RG}, K_{RL}, and/or K_{RGL} (one or more, as applicable).
(24)	Pin-to-pin device identifier, as applicable.

GENERAL NOTE: Any quantity to which units apply shall be entered with the chosen units.

NONMANDATORY APPENDIX D EXAMPLES OF DETERMINING FLOW RATE UNCERTAINTIES (25)

D-1 PURPOSE

The purpose of this Mandatory Appendix is to present an example of the various methods used to establish meaningful estimates for the limits of uncertainty of the final flow measurement specified in V-1.3. The terms and methods described in ASME PTC 19.1-2013 were used in this example to establish the estimate of measurement uncertainty. The techniques and procedures specified in Nonmandatory Appendix V and ASME PTC 19.5 were used in this example for determination of valve flow rates. This Appendix is not intended to be definitive, and the latest editions of ASME PTC 19.1 and ASME PTC 19.5 should be consulted for possible updates to equations and terminology.

D-2 EXAMPLE DETERMINATION

Meter type:	ASME concentric thin-plate square-edged orifice with flange taps
Purpose:	Establish estimate for limits of uncertainty for flow test results
Medium:	Water
Assumption:	The coefficient for the meter has not been calibrated against a standard.

The following is a typical set of test data:

Diameter of meter:	D = 3.117 in. (79.17 mm)
Diameter of orifice plate:	d_o = 0.935 in. (23.75 mm)
Pressure drop across meter:	ΔP = 387.8 in. (9 850 mm) water
Temperature:	T = 77°F (26°C)
Beta ratio:	$\beta = d_o/D$ = 0.300

Define the functional relationship

(U.S. Customary Units)

$$m = \frac{358.93\, C\, d_o^2 F_a \sqrt{\rho(\Delta P)}}{\sqrt{1 - \left(\frac{d_o}{D}\right)^4}} \tag{D-2-1}$$

(SI Units)

$$m = \frac{12\,510\, C\, d_o^2 F_a \sqrt{\rho(\Delta P)}}{\sqrt{1 - \left(\frac{d_o}{D}\right)^4}}$$

where

C = discharge coefficient, dimensionless
D = diameter of meter, in. (mm)
d_o = diameter of orifice plate, in. (mm)
F_a = thermal expansion number, dimensionless
m = mass flow rate, lbm/hr (kg/h)
ΔP = differential pressure head across meter, in. water (mm water)
ρ = water density, lbm/ft^3 (kg/m^3)

List elemental error sources, and list estimated systematic and precision errors for each [see Table D-2-1 (Table D-2-1M)].

D-2.1 Discharge Coefficient, *C*

Per Benedict (1977), the discharge coefficient for orifice plate meters is characterized by a systematic error of ±0.55% for pipes 2 in. (50 mm) and greater with Reynolds numbers exceeding

(a) 5,000 × D, where D is in inches
(b) 200 × D, where D is in millimeters

Also, ASME PTC 19.5 recommends that a 0.5% margin be added to all other identified systematic errors to account for installation variations.

The total relative systematic error for C is determined as follows:

$$B_{C\%} = 0.5\% + 0.55\% = 1.05\%$$

The coefficient of discharge is calculated based on the equations listed in ASME PTC 19.5.

The calculated value for C is 0.599.

The absolute value for the systematic limit is

$$B_C = (0.0105)\,(0.599) = 0.00627 \approx 0.007$$

The absolute precision error for the coefficient of discharge is zero.

Table D-2-1
Table of Uncertainty Parameters — U.S. Customary Units

Parameter	Absolute Systematic Error, *B*	Absolute Precision Error, *S*	Nominal Value (Based on Test Data)	Relative Systematic Error, B_R	Relative Precision Error, S_R	Relative Sensitivity Coefficient, θ^1
C	±0.007	0	0.599	$\frac{0.007}{0.599} = \pm 0.0117$	0	1
d_o	±0.001 in.	0	0.935 in.	$\frac{0.001}{0.935} = \pm 0.00107$	0	$\frac{2}{1-\beta^4} = 2.0163$
D	±0.003 in.	0	3.117 in.	$\frac{0.003}{3.117} = \pm 0.00096$	0	$\frac{2\beta^4}{1-\beta^4} = 0.0163$
F_a	0	0	1.00002	0	0	1
ρ	±0.04 lbm/ft^3	±0.02 lbm/ft^3	62.25 lbm/ft^3	$\frac{0.04}{62.25} = \pm 0.00064$	$\frac{0.02}{62.25} = \pm 0.00032$	0.5
ΔP	11 in. water	5 in. water	387.8 in. water	$\frac{11}{387.8} = \pm 0.02836$	$\frac{5}{387.8} = \pm 0.01290$	0.5

Table D-2-1M
Table of Uncertainty Parameters — SI Units

Parameter	Absolute Systematic Error, *B*	Absolute Precision Error, *S*	Nominal Value (Based on Test Data)	Relative Systematic Error, B_R	Relative Precision Error, S_R	Relative Sensitivity Coefficient, θ^1
C	±0.007	0	0.599	$\frac{0.007}{0.599} = \pm 0.0117$	0	1
d_o	±0.025 mm	0	23.75 mm	$\frac{0.025}{23.75} = \pm 0.00105$	0	$\frac{2}{1-\beta^4} = 2.0163$
D	±0.075 mm	0	79.19 mm	$\frac{0.075}{79.19} = \pm 0.00095$	0	$\frac{2\beta^4}{1-\beta^4} = 0.0163$
F_a	0	0	1.0001	0	0	1
ρ	±0.64 kg/m^3	±0.32 kg/m^3	997.1 kg/m^3	$\frac{0.64}{997.1} = \pm 0.00064$	$\frac{0.32}{997.1} = \pm 0.00032$	0.5
ΔP	260 mm water	125 mm water	9 850 mm water	$\frac{260}{9\,850} = \pm 0.0264$	$\frac{125}{9\,850} = \pm 0.01269$	0.5

D-2.2 Diameter of Orifice Plate, d_o

The estimated systematic error for the orifice plate diameter is ±0.001 in. (±0.025 mm). This absolute systematic error estimate accounts for the inaccuracies in the measurement device and the potential personnel error in reading the measurement device.

The absolute precision error for the orifice plate diameter is zero.

D-2.3 Diameter of Meter, D

The estimated systematic error for the meter diameter is ±0.003 in. (±0.075 mm). This estimate in absolute systematic error accounts for both measurement device and personnel inaccuracies.

The absolute precision error for the meter diameter is zero.

D-2.4 Thermal Expansion Number, F_a

$$F_a = \int(T)$$

where

T = water temperature, °F (°C)

Per ASME MFC-3M–1989, Appendix E, F_a is determined from the following equation:

$$F_a = 1 + \frac{2}{1 - \beta^4}(\alpha_{\text{PE}} - \beta^4\alpha_p)(T - T_{\text{ref}})$$

where

β = 0.300 from the test data (see D-2)
T_{ref} = 68°F (20°C)
α_P = mean coefficient of thermal expansion for carbon steel pipe
= 6.05×10^{-6} (1.089×10^{-5})
α_{PE} = mean coefficient of thermal expansion for 316 orifice plate
= 9.08×10^{-6} (1.635×10^{-5})

The coefficients of thermal expansion are referenced from ASME PTC 19.5-2004, Tables F-1-1 and F-1-2 and are assumed to be constant for the range in allowable temperature error used for the following derivation:

(U.S. Customary Units)

$$F_a = 1 + \frac{2}{1 - (0.300)^4}\left[9.08 \times 10^{-6} - 0.300^4\left(6.05 \times 10^{-6}\right)\right](T - 68)$$

$$F_a = 1 + (2.0163)\left(9.031 \times 10^{-6}\right)(T - 68)$$

$$F_a = \left(1.8209 \times 10^{-5}\right)(T) + 0.9988$$

$$B_{Fa} = \frac{\partial F_a}{\partial T}(B_T)$$

$$\frac{\partial F_a}{\partial T} = \frac{dF_a}{dT} = 1.8209 \times 10^{-5}$$

where

B_{Fa} = $(1.8209 \times 10^{-5})(5)$ = ±0.00009
B_T = assumed to be ±5°F
F_a = $(1.8209 \times 10^{-5})(77) + 0.9988$ based on a nominal temperature of 77°F
= 1.0002 at 77°F

(SI Units)

$$F_a = 1 + \frac{2}{1 - (0.300)^4}\left[1.635 \times 10^{-5} - 0.300^4\left(1.089 \times 10^{-5}\right)\right](T - 20)$$

$$F_a = 1 + (2.0163)\left(1.6262 \times 10^{-5}\right)(T - 20)$$

$$F_a = \left(3.2789 \times 10^{-5}\right)(T) + 0.9993$$

$$B_{Fa} = \frac{\partial F_a}{\partial T}(B_T)$$

$$\frac{\partial F_a}{\partial T} = \frac{dF_a}{dT} = 3.2789 \times 10^{-5}$$

where

B_{Fa} = $(3.2789 \times 10^{-5})(3)$ = ±0.00010
B_T = assumed to be ±3°C
F_a = $(3.2789 \times 10^{-5})(26) + 0.9993$ based on a nominal temperature of 26°C
= 1.0001 at 26°C

The relative variation in F_a for a 5°F (3°C) error in water temperature would equate to

(U.S. Customary Units)

$$\%\ \text{error}\ F_a = \frac{0.00009}{1.00002} = 0.01\%$$

(SI Units)

$$\%\ \text{error}\ F_a = \frac{0.00010}{1.00001} = 0.01\%$$

Therefore, the absolute systematic error is considered zero.

The absolute precision error for the thermal expansion number, F_a, is zero.

D-2.5 Density of Water, ρ

$$\rho = \int(TP)$$

where

P = pressure, psia (kPa)

T = water temperature, °F (°C)

Water density, ρ, is determined from Table 3 of the ASME Steam Tables (1971).

The variation in ρ due to pressure is negligible and not considered.

The variation in ρ due to a ±5% error in water temperature would equate to

$$B_\rho = \pm\ 0.03875$$

The absolute systematic error for ρ is taken as ±0.04 lb/ft^3 (±0.64 kg/m^3).

The absolute precision error, S_ρ, for water density is estimated from past experience to be ±0.02 lbm/ft^3 (±0.32 kg/m^3).

D-2.6 Parameter Δ*P* — Differential Pressure Head Across Meter, in. (mm) Water

ΔP is measured on a strip chart recorder that is calibrated using a transfer gage with a range of 0 in. (0 mm) water to 1,000 in. (25 400 mm) water. The transfer gage is in turn calibrated using a deadweight tester.

The systematic error limit for the strip chart recorder is based on one-half the smallest subdivision, which is ±10 in. (±250 mm) water.

The accepted tolerance for the transfer gage is ±0.25% of full scale, which equates to an absolute systematic error of ±2.5 in. (±63.5 mm) water.

The calibrator (deadweight tester) for the transfer gage is two times as accurate as the transfer gage, and the systematic error induced is ±0.3 in. (±7.6 mm) water. See Taylor (1988), pages 54 to 55.

The RSS technique for combining the systematic errors in water yields

(U.S. Customary Units)

$$B_{\Delta P} = \left[(10)^2 + (2.5)^2 + (0.3)^2\right]^{1/2} = 10.3 \approx 11.0$$

(SI Units)

$$B_{\Delta P} = \left[(250)^2 + (63.5)^2 + (7.6)^2\right]^{1/2} = 258 \approx 260$$

The absolute precision error $S_{\Delta P}$ for the meter differential pressure is estimated based on previous experience to be ±5 in. (±125 mm) water.

D-2.7 Uncertainty Calculation

All the absolute and relative systematic and precision errors are tabulated in the following equations. Also tabulated for each parameter are the relative sensitivity coefficients, θ', which were determined in accordance with ASME PTC 19.1-2005.

The individual parameter errors are propagated separately for systematic and precision into the result according to a Taylor (1988) series expansion.

The relative systematic error for the flow rate is

$$\frac{B_m}{m} = \left[\left(1 \times \frac{B_c}{C}\right)^2 + \left(\frac{2}{1-\beta^4} \times \frac{B_{d_o}}{d_o}\right)^2 + \left(\frac{2\beta^4}{1-\beta^4} \times \frac{B_D}{D}\right)^2 + \left(1 \times \frac{B_{F_a}}{F_a}\right)^2 + \left(0.5 \times \frac{B_\rho}{\rho}\right)^2 + \left(0.5 \times \frac{B_{\Delta P}}{\Delta P}\right)^2\right]^{1/2} \quad \text{(D-2-2)}$$

The relative precision error for the flow rate is

$$\frac{S_m}{m} = \left[\left(1 \times \frac{S_c}{C}\right)^2 + \left(\frac{2}{1-\beta^4} \times \frac{S_{d_o}}{d_o}\right)^2 + \left(\frac{2\beta^4}{1-\beta^4} \times \frac{S_D}{D}\right)^2 + \left(1 \times \frac{S_{F_a}}{F_a}\right)^2 + \left(0.5 \times \frac{S_\rho}{\rho}\right)^2 + \left(0.5 \times \frac{S_{\Delta P}}{\Delta P}\right)^2\right]^{1/2} \quad \text{(D-2-3)}$$

Substituting the appropriate values into eqs. (D-2-2) and (D-2-3)

(U.S. Customary Units)

$$\frac{B_m}{m} = \left[(0.0117)^2 + (2.016 \times 0.00107)^2 + (0.0163 \times 0.00096)^2 + (0) + (0.5 \times 0.00064)^2 + (0.5 \times 0.02836)^2\right]^{1/2} \quad \text{(D-2-4)}$$

$$= \left(0.0001370 + 0.0000046 + 2.45 \times 10^{-10} + 0 + 1.02 \times 10^{-7} + 0.0002011\right)^{1/2}$$

$$\pm\ 0.0185$$

(SI Units)

$$\frac{B_m}{m} = \Big[(0.0117)^2 + (2.016 \times 0.00105)^2\Big] + (0.0163 \times 0.00095)^2 + (0) + (0.5 \times 0.00064)^2 + (0.5 \times 0.0264)^2\Big]^{1/2}$$
$$= \Big(0.0001370 + 0.0000045 + 2.398 \times 10^{-10} + 0 + 1.02 \times 10^{-7} + 0.0001742\Big)^{1/2}$$
$$\pm 0.0178$$

(U.S. Customary Units)

$$\frac{S_m}{m} = \pm[(0) + (0) + (0) + (0) + (0.5 \times 0.00032)^2 + (0.5 \times 0.01290)^2\Big]^{1/2} \quad \text{(D-2-5)}$$
$$= \pm\Big(2.5 \times 10^{-8} + 0.0000416\Big)^{1/2}$$
$$= \pm 0.0065$$

(SI Units)

$$\frac{S_m}{m} = \pm[(0) + (0) + (0) + (0) + (0.5 \times 0.00032)^2 + (0.5 \times 0.01289)^2\Big]^{1/2}$$
$$= \pm\Big(2.5 \times 10^{-8} + 0.0000415\Big)^{1/2}$$
$$= \pm 0.0065$$

Examination of the individual factors for each parameter in eqs. (D-2-4) and (D-2-5) clearly indicates which parameters contribute most to the systematic and precision error limits of the result. In this example, the largest contributors to the systematic error limit are the differential pressure, ΔP, and the discharge coefficient, C. The largest contributor to the precision error limit is the differential pressure measurement, ΔP.

Since all the estimates for precision errors of the independent parameters are based on experience, the degrees of freedom can be assumed to be greater than 30, so that the t value can be taken as 2. Therefore, the relative precision error limit is (2)(0.0065) = ±0.013.

The total uncertainty in the flow rate can be obtained by combining the systematic and precision errors as follows:

(U.S. Customary Units)

$$\frac{U_{RSS}}{m} = \left[\left(\frac{B_m}{m}\right)^2 + \left(2 \times \frac{S_m}{m}\right)^2\right]^{1/2} \quad \text{(D-2-6)}$$
$$= \Big[(0.0185)^2 + (2 \times 0.0065)^2\Big]^{1/2}$$
$$= \pm 2.26\% \text{ at} \sim 95\% \text{ coverage}$$

(SI Units)

$$\frac{U_{RSS}}{m} = \left[\left(\frac{B_m}{m}\right)^2 + \left(2 \times \frac{S_m}{m}\right)^2\right]^{1/2}$$
$$= \Big[(0.0178)^2 + (2 \times 0.0065)^2\Big]^{1/2}$$
$$= \pm 2.20\% \text{ at} \sim 95\% \text{ coverage}$$

Note that the requirement of ASME PTC 25 for $m \pm 2\%$ has not been achieved.

The largest contributor to uncertainty is the differential pressure, ΔP. The first step is to eliminate the transfer gage for calibration of the strip chart recorder. The strip chart recorder will be calibrated directly using a deadweight tester.

The systematic error limit for the deadweight tester is ±0.1% of full scale. The full scale range for the deadweight tester is 0 in. (0 mm) water to 500 in. (12 700 mm) water. The absolute systematic error limit is 0.001 × 500 = 0.5 in. water (0.001 × 12 700 = 12.7 mm water).

In addition, the calibration range for ΔP is changed to reduce the smallest subdivision on the strip chart recorder from 20 in. (500 mm) water to 10 in. (250 mm) water. The systematic error limit is based on one-half the smallest subdivision, which results in a reduction of the bias error limit from 10 in. (250 mm) water to 5 in. (125 mm) water.

The RSS technique for combining systematic errors is used to recalculate the absolute systematic error for ΔP:

(U.S. Customary Units)

$$B_{\Delta P} = \Big[(5)^2 + (0.5)^2\Big]^{1/2} = 5.02 \text{ in. water}$$

(SI Units)

$$B_{\Delta P} = \Big[(125)^2 + (12.7)^2\Big]^{1/2} = \pm 125.6 \text{ mm water}$$

Round up to 6 in. (150 mm) water.

The revised relative systematic error is

(U.S. Customary Units)

$$(B_{\Delta P})_R = \frac{6}{387.8} = 0.01547$$

(SI Units)

$$(B_{\Delta P})_R = \frac{150}{9\,850} = 0.01523$$

The revised value for $\frac{B_m}{m}$ is

(U.S. Customary Units)

$$\frac{B_m}{m} = 0.0145$$

(SI Units)

$$\frac{B_m}{m} = \pm 0.0136$$

Combining systematic and precision errors yields

(U.S. Customary Units)

$$\frac{U_{\text{RSS}}}{m} = 1.959 \text{ at} \sim 95\% \text{ coverage}$$

(SI Units)

$$\frac{U_{\text{RSS}}}{m} = \pm 1.881 \text{ at} \sim 95\% \text{ coverage}$$

The mass flow rate, m, based on the nominal values noted herein is 29,300 lbm/hr (13 290 kg/h).

The following test was conducted to verify the estimate for the precision error index.

All instruments were calibrated in accordance with the tolerance limits stated herein.

A steady-state flow test was conducted with the 0.935-in. (23.75-mm) diameter orifice plate. The temperature was a constant 77°F (26°C) for the entire test. During the test, ten separate sets of data were taken to establish the precision error limit of uncertainty. The results of the test are as follows:

Data Set	*m*
1	29,410 (13 340)
2	29,280 (13 280)
3	29,170 (13 230)
4	29,320 (13 300)
5	29,190 (13 240)
6	29,450 (13 360)
7	29,305 (13 290)
8	29,260 (13 270)
9	29,380 (13 330)
10	29,350 (13 310)

$\bar{x}$, average value m for sample, is

(U.S. Customary Units)

$$\bar{x} = \frac{1}{N}\sum_{k=1}^{N} X_k = \frac{1}{10}(293{,}115) = 29{,}311 \text{ lbm/hr}$$

(SI Units)

$$\bar{x} = \frac{1}{N}\sum_{k=1}^{N} X_k = \frac{1}{10}(132\,950) = 13\,295 \text{ kg/h}$$

The sample standard deviation is

(U.S. Customary Units)

$$S = \left[\frac{\sum_{k=1}^{N}(X_k - \bar{x})^2}{N-1}\right]^{1/2} = 90.4 \text{ lbm/hr}$$

(SI Units)

$$S = \left[\frac{\sum_{k=1}^{N}(X_k - \bar{x})^2}{N-1}\right]^{1/2} = \pm 42.0 \text{ kg/h}$$

Degrees of freedom $N - 1 = 10 - 1 = 9$.

The t value for the 95 percentile point for a two-tailed Student's t distribution with 9 degrees of freedom is 2.262.

Relative precision error limit is calculated as follows:

(U.S. Customary Units)

$$\frac{S_m}{m} = \pm \frac{90.4}{29{,}311}(2.262) = \pm 0.0069$$

(SI Units)

$$\frac{S_m}{m} = \pm \frac{42.0}{13\,295}(2.262) = \pm 0.0071$$

This value is roughly half the original estimated. Combining the new precision error limit obtained by test with the systematic error estimate yields

(U.S. Customary Units)

$$\begin{aligned}\frac{U_{\text{RSS}}}{m} &= \pm\left[(0.0145)^2 + (0.0069)^2\right]^{1/2} = \pm 0.016 \\ &= \pm 1.6\% \text{ at} \sim 95\% \text{ coverage, precision (process) error}\end{aligned}$$

(SI Units)

$$\begin{aligned}\frac{U_{\text{RSS}}}{m} &= \pm\left[(0.0136)^2 + (0.0071)^2\right]^{1/2} = \pm 0.015 \\ &= \pm 1.5\% \text{ at} \sim 95\% \text{ coverage, precision (process) error}\end{aligned}$$

Note that the test objective of ±2% has been achieved; however, the uncertainty error limits can be further reduced by conducting calibration tests to better define the meter coefficient of discharge.

The report summary is as follows:

(U.S. Customary Units)

$$\frac{B_m}{m} = \pm 0.0145\text{, systematic error}$$

$$\frac{S_m}{m} = \pm 0.0069\text{, uncertainty of mass flow rate}$$

$$\frac{U_{\mathrm{RSS}}}{m} = \pm 1.6\%\text{ at ~95\% coverage, precision (process) error}$$

(SI Units)

$$\frac{B_m}{m} = \pm 0.0136\text{, systematic error}$$

$$\frac{S_m}{m} = \pm 0.0071\text{, uncertainty of mass flow rate}$$

$$\frac{U_{\mathrm{RSS}}}{m} = \pm 1.5\%\text{ at ~95\% coverage, precision (process) error}$$

NONMANDATORY APPENDIX E
(25) # EXAMPLE OF PRESSURE TAP PROFILE COMPARISON

E-1 PURPOSE

This Appendix presents an example of the calibration procedure described in V-2.1.9.2 for flow resistance test rigs.

E-2 EXAMPLE DETERMINATION

E-2.1 Sample Data

Table E-2.1-1 lists sample data from a flow resistance test conducted according to V-2.2.9. Calculated values were determined using Form V-2.2.5.7-1 (Form V-2.2.5.7-1M).

Table E-2.1-1
Sample Test Data

Parameter	Value
Ratio of specific heats, k	1.405
Test rig inside diameter, D	0.085 ft (0.025908 m)
Actual pipe length to tap A, L_A	5.608 ft (1.709 m)
Actual pipe length to tap B, L_B	8.223 ft (2.506 m)
Actual pipe length to tap C, L_C	9.457 ft (2.882 m)
Actual pipe length to tap D, L_D	12.082 ft (3.683 m)
Actual length between taps A and B, $L_{\text{A-B}}$	2.615 ft (0.79705 m)
Actual length between taps C and D, $L_{\text{C-D}}$	2.625 ft (0.8001 m)
Mach number at pipe entrance, M_1	0.375094230450
Expansion factor at pipe entrance, Y_1	1.02849087555
Pressure at pipe entrance, P_1	52.92760355 psia (364.923 kPa)
Tap A pressure, P_A	43.0240195 psia (296.6402 kPa)
Tap B pressure, P_B	38.561844 psia (265.8746 kPa)
Tap C pressure, P_C	36.0269315 psia (248.3969 kPa)
Tap D pressure, P_D	28.9483255 psia (199.5917 kPa)
Total resistance factor to tap A, K_A	1.3389762771
Total resistance factor to tap B, K_B	1.8082572438
Total resistance factor to tap C, K_C	2.0365010346
Total resistance factor to tap D, K_D	2.5214688060
Resistance between taps A and B, $K_{\text{A-B}}$	0.469280967
Resistance between taps C and D, $K_{\text{C-D}}$	0.484967771

E-2.2 Calculations

Step 1 (From V-2.1.9.2, Step 1)

(a) Calculate the friction factor, f, for the pipe segment from tap A to tap B:

(U.S. Customary Units)

$$\begin{aligned} f_{\text{A-B}} &= \frac{K_{\text{A-B}}D}{4L_{\text{A-B}}} \\ &= \frac{0.469280967 \times 0.085}{4 \times 2.615} \\ &= 0.003813469 \end{aligned}$$

(SI Units)

$$\begin{aligned} f_{\text{A-B}} &= \frac{K_{\text{A-B}}D}{4L_{\text{A-B}}} \\ &= \frac{0.469280967 \times 0.025908}{4 \times 0.79705} \\ &= 0.003813469 \end{aligned}$$

(b) Repeat (a) for the pipe segment between tap C and tap D:

(U.S. Customary Units)

$$\begin{aligned} f_{\text{C-D}} &= \frac{K_{\text{C-D}}D}{4L_{\text{C-D}}} \\ &= \frac{0.484967771 \times 0.085}{4 \times 2.625} \\ &= 0.003925930 \end{aligned}$$

(SI Units)

$$\begin{aligned} f_{\text{C-D}} &= \frac{K_{\text{C-D}}D}{4L_{\text{C-D}}} \\ &= \frac{0.484967771 \times 0.025908}{4 \times 0.8001} \\ &= 0.003925930 \end{aligned}$$

(c) Average the values from (a) and (b):

$$\begin{aligned} f &= \frac{f_{\text{A-B}} + f_{\text{C-D}}}{2} \\ &= \frac{0.003813469 + 0.003925930}{2} \\ &= 0.003869699 \end{aligned}$$

Step 2 (From V-2.1.9.2, Step 2). Paragraph V-2.1.9.2 calls for the use of the Lapple (1943) and Levenspiel (1977) model to calculate equivalent pipe length in this step. The total resistance to tap A based on measured flow rate and tap pressure has already been determined using the formulas in Form V-2.2.5.7-1 (Form V-2.2.5.7-1M), which conform to the Lapple and Levenspiel model. Calculate the equivalent length to tap A, ℓ_A, from the total resistance using the average friction factor from Step 1(c):

(U.S. Customary Units)

$$\begin{aligned}\ell_A &= \frac{K_A D}{4f}\\ &= \frac{1.3389762771 \times 0.085}{4 \times 0.003869699}\\ &= 7.352831578 \text{ ft}\end{aligned}$$

(SI Units)

$$\begin{aligned}\ell_A &= \frac{K_A D}{4f}\\ &= \frac{1.3389762771 \times 0.025908}{4 \times 0.003869699}\\ &= 2.241143065 \text{ m}\end{aligned}$$

Step 3 (From V-2.1.9.2, Step 3). The equivalent length from Step 2 should exceed the actual pipe length to the tap. The excess resistance can be attributed to energy loss in the nozzle connecting the test rig to the vessel shown in Figure V-2.1.9-1. Estimate the equivalent pipe length of the nozzle, $\ell_{0,A}$, by subtracting the actual length to tap A from the equivalent length:

(U.S. Customary Units)

$$\begin{aligned}\ell_{0,A} &= \ell_A - L_A\\ &= 7.352831578 - 5.608\\ &= 1.744831578 \text{ ft}\end{aligned}$$

(SI Units)

$$\begin{aligned}\ell_{0,A} &= \ell_A - L_A\\ &= 2.241143065 - 1.7093184\\ &= 0.531824665 \text{ m}\end{aligned}$$

Step 4 (From V-2.1.9.2, Step 4). Repeat Steps 2 and 3 for the remaining taps.

(a) Tap B

(U.S. Customary Units)

$$\begin{aligned}\ell_B &= \frac{K_B D}{4f}\\ &= \frac{1.8082572438 \times 0.085}{4 \times 0.003869699}\\ &= 9.929833414 \text{ ft}\end{aligned}$$

$$\begin{aligned}\ell_{0,B} &= \ell_B - L_B\\ &= 9.92833414 - 8.223\\ &= 1.706833414 \text{ ft}\end{aligned}$$

(SI Units)

$$\begin{aligned}\ell_B &= \frac{K_B D}{4f}\\ &= \frac{1.8082572438 \times 0.025908}{4 \times 0.003869699}\\ &= 3.026613225 \text{ m}\end{aligned}$$

$$\begin{aligned}\ell_{0,B} &= \ell_B - L_B\\ &= 3.020753385 - 2.506\\ &= 0.520242825 \text{ m}\end{aligned}$$

(b) Tap C

(U.S. Customary Units)

$$\ell_C = \frac{K_C D}{4f} = \frac{2.0365010346 \times 0.085}{4 \times 0.003869699} = 11.18320753 \text{ ft}$$

$$\ell_{0,C} = \ell_C - L_C = 11.18320753 - 9.457 = 1.726207527 \text{ ft}$$

(SI Units)

$$\ell_C = \frac{K_C D}{4f} = \frac{2.0365010346 \times 0.025908}{4 \times 0.003869699} = 3.408641655 \text{ m}$$

$$\ell_{0,C} = \ell_C - L_C = 3.408641655 - 2.882 = 0.526148054 \text{ m}$$

(c) Tap D

(U.S. Customary Units)

$$\ell_D = \frac{K_D D}{4f} = \frac{2.5214688060 \times 0.085}{4 \times 0.003869699} = 13.84635139 \text{ ft}$$

$$\ell_{0,D} = \ell_D - L_D = 13.84635139 - 12.082 = 1.764350956 \text{ ft}$$

(SI Units)

$$\ell_D = \frac{K_D D}{4f} = \frac{2.5214688060 \times 0.025908}{4 \times 0.003869699} = 4.220367904 \text{ m}$$

$$\ell_{0,D} = \ell_D - L_D = 4.220367904 - 3.683 = 0.537774171 \text{ m}$$

Step 5 (From V-2.1.9.2, Step 5). Average the estimates for the nozzle equivalent length:

(U.S. Customary Units)

$$\begin{aligned} \ell_0 &= \frac{\ell_{0,A} + \ell_{0,B} + \ell_{0,C} + \ell_{0,D}}{4} \\ &= \frac{1.744831578 + 1.706833414 + 1.726207527 + 1.764350956}{4} \\ &= 1.735555869\ \text{ft} \end{aligned}$$

(SI Units)

$$\begin{aligned} \ell_0 &= \frac{\ell_{0,A} + \ell_{0,B} + \ell_{0,C} + \ell_{0,D}}{4} \\ &= \frac{0.531824665 + 0.520242825 + 0.526148054 + 0.537774171}{4} \\ &= 0.528997429\ \text{m} \end{aligned}$$

Step 6 (From V-2.1.9.2, Step 6)

(a) Using the average nozzle equivalent length, ℓ_0, recalculate the equivalent length to tap A:

(U.S. Customary Units)

$$\begin{aligned} \ell'_A &= \ell_0 + L_A \\ &= 1.735555869 + 5.608 \\ &= 7.343555869\ \text{ft} \end{aligned}$$

(SI Units)

$$\begin{aligned} \ell'_A &= \ell_0 + L_A \\ &= 0.528997429 + 1.709 \\ &= 2.238315829\ \text{m} \end{aligned}$$

(b) Determine the corresponding total resistance to tap A:

(U.S. Customary Units)

$$\begin{aligned} K'_A &= \frac{4f\ell'_A}{D} \\ &= \frac{4 \times 0.003869699 \times 7.343555869}{0.085} \\ &= 1.337287097 \end{aligned}$$

(SI Units)

$$\begin{aligned} K'_A &= \frac{4f\ell'_A}{D} \\ &= \frac{4 \times 0.003869699 \times 2.238315829}{0.025908} \\ &= 1.337287097 \end{aligned}$$

(c) From the Lapple (1943) and Levenspiel (1977) model, for any of the four taps

$$K = \frac{Y_1}{kM_1^2}(1 - r^2) + \frac{k + 1}{k}\ln r \tag{E-2-1}$$

$$P = P_1\left(\frac{1 - Y_1}{r} + Y_1 r\right) \tag{E-2-2}$$

where

K = total flow resistance to the tap

P = tap pressure, psia (kPa)

r = density ratio at the tap

Given the total resistance upstream of the tap, simultaneous solution of eqs. (E-2-1) and (E-2-2) will yield the theoretical tap pressure required in this step by V-2.1.9.2.

NOTE: Equations (E-2-1) and (E-2-2) were reduced from eqs. 65 and 66 in Appendix I of Lapple (1943) with the following substitutions:

$$Y_1 = 1 + \frac{k-1}{2} M_1^2$$

$$r = \frac{v_1}{v_2}$$

Since $v_1/v_2 = \rho_2/\rho_1$, where ρ is the fluid density and subscripts are assigned as in Lapple, the parameter r is referred to here as the density ratio.

(d) Solve eq. (E-2-1) for the tap A density ratio, r_A, given the resistance, K'_A, from (b). Fixed-point iteration is used in this example by rearranging eq. (E-2-1) as shown in eq. (E-2-3); the first two iterations are provided for illustration.

$$r = \sqrt{1 + \frac{kM_1^2}{Y_1}\left(\frac{k+1}{k}\ln r - K\right)} \quad \text{(E-2-3)}$$

Initial approximation is $r_A = 1$.

(1) Iteration 1

$$\begin{aligned} r_A &= \sqrt{1 + \frac{kM_1^2}{Y_1}\left(\frac{k+1}{k}\ln r_A - K'_A\right)} \\ &= \sqrt{1 + \frac{1.405 \times 0.375094230450^2}{1.02849087555}\left(\frac{1.405+1}{1.405}\ln 1 - 1.337287097\right)} \\ &= 0.8619579381 \end{aligned}$$

(2) Iteration 2

$$\begin{aligned} r_A &= \sqrt{1 + \frac{1.405 \times 0.375094230450^2}{1.02849087555}\left(\frac{1.405+1}{1.405}\ln 0.8619579381 - 1.337287097\right)} \\ &= 0.8331260322 \end{aligned}$$

After 16 iterations, the solution converges within 10^{-10} to r_A = 0.8242451311.

(e) Evaluate eq. (E-2-2) to calculate the pressure predicted at tap A:

(U.S. Customary Units)

$$\begin{aligned} P'_A &= P_1\left(\frac{1 - Y_1}{r_A} + Y_1 r_A\right) \\ &= 52.92760355\left(\frac{1 - 1.02849087555}{0.8242451311} + 1.02849087555 \times 0.8242451311\right) \\ &= 43.03874635 \text{ psia} \end{aligned}$$

(SI Units)

$$
\begin{aligned}
P'_A &= P_1\left(\frac{1 - Y_1}{r_A} + Y_1 r_A\right) \\
&= 364.923\left(\frac{1 - 1.02849087555}{0.8242451311} + 1.02849087555 \times 0.8242451311\right) \\
&= 296.7417\ \text{kPa}
\end{aligned}
$$

Step 7 (From V-2.1.9.2, Step 7). Repeat Step 6 for the remaining taps. The density ratio at each tap is found numerically as described in Step 6(c); the calculation steps are omitted here.

(a) Tap B

(U.S. Customary Units)

$$
\begin{aligned}
\ell'_B &= \ell_0 + L_B \\
&= 1.735555869 + 8.223 \\
&= 9.9585555869\ \text{ft}
\end{aligned}
$$

$$
\begin{aligned}
K'_B &= \frac{4f\ell'_B}{D} \\
&= \frac{4 \times 0.003869699 \times 9.9585555869}{0.085} \\
&= 1.813487652
\end{aligned}
$$

$$
r_B = 0.7445916279
$$

$$
\begin{aligned}
P'_B &= P_1\left(\frac{1 - Y_1}{r_B} + Y_1 r_B\right) \\
&= 52.92760355\left(\frac{1 - 1.02849087555}{0.7445916279} + 1.02849087555 \times 0.7445916279\right) \\
&= 38.5070511\ \text{psia}
\end{aligned}
$$

(SI Units)

$$
\begin{aligned}
\ell'_B &= \ell_0 + L_B \\
&= 0.528997429 + 2.506 \\
&= 3.035367743\ \text{m}
\end{aligned}
$$

$$
\begin{aligned}
K'_B &= \frac{4f\ell'_B}{D} \\
&= \frac{4 \times 0.003869699 \times 3.035367743}{0.025908} \\
&= 1.813487652
\end{aligned}
$$

$$
r_B = 0.7445916279
$$

$$
\begin{aligned}
P'_B &= P_1\left(\frac{1 - Y_1}{r_B} + Y_1 r_B\right) \\
&= 364.923\left(\frac{1 - 1.02849087555}{0.7445916279} + 1.02849087555 \times 0.7445916279\right) \\
&= 265.4968\ \text{kPa}
\end{aligned}
$$

(b) Tap C

(U.S. Customary Units)

$$\begin{aligned} \ell'_C &= \ell_0 + L_C \\ &= 1.735555869 + 9.457 \\ &= 11.19255587 \text{ ft} \end{aligned}$$

$$K'_C = \frac{4f\ell'_C}{D} = \frac{4 \times 0.003869699 \times 11.19255587}{0.085} = 2.0382034$$

$$r_C = 0.7009754472$$

$$\begin{aligned} P'_C &= P_1\left(\frac{1 - Y_1}{r_C} + Y_1 r_C\right) \\ &= 52.92760355\left(\frac{1 - 1.02849087555}{0.7009754472} + 1.02849087555 \times 0.7009754472\right) \\ &= 36.01296771 \text{ psia} \end{aligned}$$

(SI Units)

$$\begin{aligned} \ell'_C &= \ell_0 + L_C \\ &= 0.528997429 + 2.882 \\ &= 3.411491029 \text{ m} \end{aligned}$$

$$\begin{aligned} K'_C &= \frac{4f\ell'_C}{D} \\ &= \frac{4 \times 0.003869699 \times 3.411491029}{0.025908} \\ &= 2.0382034 \end{aligned}$$

$$r_C = 0.7009754472$$

$$\begin{aligned} P'_C &= P_1\left(\frac{1 - Y_1}{r_C} + Y_1 r_C\right) \\ &= 364.923\left(\frac{1 - 1.02849087555}{0.7009754472} + 1.02849087555 \times 0.7009754472\right) \\ &= 248.3007 \text{ kPa} \end{aligned}$$

(c) Tap D

(U.S. Customary Units)

$$\begin{aligned} \ell'_D &= \ell_0 + L_D \\ &= 1.735555869 + 12.082 \\ &= 13.81755587 \text{ ft} \end{aligned}$$

$$\begin{aligned} K'_D &= \frac{4f\ell'_D}{D} \\ &= \frac{4 \times 0.003869699 \times 13.81755587}{0.085} \\ &= 2.516225041 \end{aligned}$$

$$r_D = 0.5812828536$$

$$
\begin{aligned}
P'_D &= P_1\left(\frac{1-Y_1}{r_D} + Y_1 r_D\right)\\
&= 52.92706355\left(\frac{1-1.02849087555}{0.5812828536} + 1.02849087555 \times 0.5812828536\right)\\
&= 29.04827366\ \text{psia}
\end{aligned}
$$

(SI Units)

$$
\begin{aligned}
\ell'_D &= \ell_0 + L_D\\
&= 0.528997429 + 3.683\\
&= 4.211591029\text{m}
\end{aligned}
$$

$$
\begin{aligned}
K'_D &= \frac{4f\ell'_D}{D}\\
&= \frac{4 \times 0.003869699 \times 4.211591029}{0.025908}\\
&= 2.516225041
\end{aligned}
$$

$$
r_D = 0.5812828536
$$

$$
\begin{aligned}
P'_D &= P_1\left(\frac{1-Y_1}{r_D} + Y_1 r_D\right)\\
&= 364.923\left(\frac{1-1.02849087555}{0.5812828536} + 1.02849087555 \times 0.5812828536\right)\\
&= 200.2808\ \text{kPa}
\end{aligned}
$$

Step 8 (From V-2.1.9.2, Step 8). Find the error, ε, between the measured and calculated pressure at each tap as a percentage of the calculated pressure.

(U.S. Customary Units)

$$
\begin{aligned}
\varepsilon_A &= 100\% \times \frac{P_A - P'_A}{P'_A}\\
&= 100\% \times \frac{43.0240195 - 43.03874635}{43.03874635}\\
&= -0.043\%
\end{aligned}
$$

$$
\begin{aligned}
\varepsilon_B &= 100\% \times \frac{P_B - P'_B}{P'_B}\\
&= 100\% \times \frac{38.561844 - 38.5070511}{38.5070511}\\
&= 0.142\%
\end{aligned}
$$

$$
\begin{aligned}
\varepsilon_C &= 100\% \times \frac{P_C - P'_C}{P'_C}\\
&= 100\% \times \frac{36.0269315 - 36.01296771}{36.01296771}\\
&= 0.039\%
\end{aligned}
$$

$$
\begin{aligned}
\varepsilon_D &= 100\% \times \frac{P_D - P'_D}{P'_D}\\
&= 100\% \times \frac{28.9483255 - 29.04827366}{29.04827366}\\
&= -0.344\%
\end{aligned}
$$

(SI Units)

$$\begin{aligned}\varepsilon_A &= 100\% \times \frac{P_A - P'_A}{P'_A}\\ &= 100\% \times \frac{296.6402 - 296.7417}{296.7417}\\ &= -0.034\%\end{aligned}$$

$$\begin{aligned}\varepsilon_B &= 100\% \times \frac{P_B - P'_B}{P'_B}\\ &= 100\% \times \frac{265.8746 - 265.4968}{265.4968}\\ &= 0.142\%\end{aligned}$$

$$\begin{aligned}\varepsilon_C &= 100\% \times \frac{P_C - P'_C}{P'_C}\\ &= 100\% \times \frac{248.3969 - 248.3007}{248.3007}\\ &= 0.039\%\end{aligned}$$

$$\begin{aligned}\varepsilon_D &= 100\% \times \frac{P_D - P'_D}{P'_D}\\ &= 100\% \times \frac{199.5917 - 200.2808}{200.2808}\\ &= -0.344\%\end{aligned}$$

Since the percent error is within ±6% for all four taps, the test rig in this example is calibrated successfully by pressure tap profile comparison.

NONMANDATORY APPENDIX F
(25) DESIGN GUIDELINES FOR PRESSURE-CONTAINING AND PRESSURE-RETAINING SHELL PARTS OF PRESSURE RELIEF DEVICES

F-1 INTRODUCTION

This Appendix contains nonmandatory guidelines for designing the pressure-containing and pressure-retaining shell parts of pressure relief devices such as bodies, bonnets, yokes, nozzles, caps, body-to-bonnet joints, cover-to-body joints, and rupture disk holders (see Figures F-1-1 through F-1-5). This Appendix does not address all aspects or methods of designing pressure relief devices; engineering judgment consistent with the philosophy of this Section should be applied. This Appendix does not address the design guidelines for the pilot of a pilot-operated pressure relief valve.

The symbols used for wall thickness, t_m; inside diameter, d; and allowable stress value, S, in these guidelines might vary from those used in other standards referenced herein.

F-2 ALLOWABLE STRESS VALUES

The allowable stress value, S, for material specified in these guidelines is referenced from Section II, Part D. For materials not listed in Section II, Part D, the allowable stress value, S, should be calculated according to the referencing code or Code case, as applicable. See Section II, Part D, Table 3 for the allowable stress values for bolting materials. The allowable stresses of material may be exceeded during the device pressure relief event.

F-3 BODY

Pressure relief device bodies can have either one (primary) or two (primary and secondary) pressure zones. The pressure class rating for primary and secondary pressure zones may be the same or different, depending on the design of the pressure relief device.

(a) The minimum wall thickness, t_m, of the body shall be determined for the primary and secondary pressure zones based on the pressure class of the respective pressure zone or an otherwise specified design pressure. The secondary pressure zone shall be designed for the total maximum allowable back pressure, established by the manufacturer, that includes the combined effects of static head, built-up back pressure, and superimposed back pressure permissible for that design.

(b) The rating temperatures for the primary and secondary pressure zones shall be the design temperature for the primary pressure zone and secondary pressure zone, respectively.

(c) The minimum wall thickness, t_m, of the body shall be determined using one of the following methods:

(1) Determine the wall thickness per ASME B16.34, para. 6.1.1, using the applicable inside diameter, d, of the primary and secondary pressure zones and the respective pressure class. The inside diameter, d, for applicable pressure zones of the body shall be determined per requirements of ASME B16.34, para. 6.1.2.

(2) Calculate the wall thickness per Section VIII, Division 1, UG-27, using the applicable inside diameter, d, and design pressure of the primary or secondary pressure zone.

(3) Determine the wall thickness using classic bending and direct stress equations, with appropriate free-body diagrams. The general membrane stress shall not exceed the allowable stress value, S, and the general membrane stress plus bending stress shall not exceed 1.5 S.

(d) The minimum wall thickness, t_m, for the body neck shall be determined using one of the following methods:

(1) Determine the wall thickness per ASME B16.34, para. 6.1.3 corresponding to the applicable pressure zone pressure class and body neck inside diameter, d.

(2) Calculate the wall thickness per Section VIII, Division 1, UG-27 by evaluating for circumferential and longitudinal stress value due to internal pressure as defined in Section VIII, Division 1, UG-23.

(e) Inlet neck wall thickness, t_m, shall be adequate to support both internal pressure and an imposed bending load due to the discharge reaction force of the flowing fluid. The device body inlet neck wall thickness, t_m, shall be analyzed for horizontal reaction forces due to steady-state discharge of the pressure relief device at maximum allowable overpressure. The reaction force on the pressure relief device shall be evaluated as shown in ASME B31.1, Nonmandatory Appendix II. Bending and direct stress equations with the appropriate

free-body diagram shall be used. When the nozzle of the device acts as the inlet neck, the nozzle shall meet the requirements of (d) and F-7.

(f) Additional metal thickness might be needed for operating stresses, shapes other than circular, stress concentrations, and adequate structural strength of device body crotch areas for bending stresses and installation stress.

(g) Local areas with less than minimum wall thickness are acceptable provided that all of the requirements of ASME B16.34, para. 6.1.6 are satisfied.

(h) Dimensions for flanged inlet and outlet connections shall be per ASME B16.34, para. 6.2.2 and the applicable pressure class, or per API 6A or an applicable standard from Deutsches Institut für Normung e. V., Japanese Industrial Standards, or another organization. Bodies with special connections shall be designed considering all relevant loads specific to the application. ASME B16.34, Table 4 requirements apply for threaded and socket-welding end wall thickness where applicable.

(i) It is recommended to have a gradual transition for wall thickness between the primary and secondary pressure zones.

(j) Body flange pressure limits may be exceeded for short durations when the pressure relief device is relieving up to the maximum allowable overpressure by the referencing Code or Standard.

F-4 PRESSURE-CONTAINING BONNET

The bonnet shall be analyzed as a secondary pressure zone part.

(a) The threaded section of bonnet top for a spring-adjusting screw or bolt shall be analyzed for the condition when it is subjected to full-lift spring load at maximum allowable overpressure for the maximum permitted set pressure and maximum secondary zone pressure. The thread shear stress shall not exceed 0.6*S*. The bonnet top may be analyzed using classic direct tensile and shear stress equations with appropriate free-body diagrams. The general membrane stress shall not exceed the allowable stress value, *S*, and shear stress shall not exceed 0.6*S*.

(b) The minimum wall thickness, t_m, of the bonnet shall be determined using one of the following methods:

(1) Determine the wall thickness per ASME B16.34, para. 6.1.1, using the applicable inside diameter, *d*, of the primary and secondary pressure zones and the respective pressure class. The inside diameter, *d*, for applicable pressure zones of the body shall be determined per requirements of ASME B16.34, para. 6.1.2.

(2) Calculate the wall thickness per Section VIII, Division 1, UG-27, using the applicable inside diameter, *d*, and design pressure of the primary or secondary pressure zone.

(c) Additional metal thickness might be needed for operating stresses, shapes other than circular, stress concentrations, and adequate structural strength of bonnet crotch areas for bending stresses and installation stress.

(d) Local areas with less than minimum wall thickness are acceptable provided that all of the requirements of ASME B16.34, para. 6.1.6 are satisfied.

(e) The minimum wall thickness of the bonnet end having pipe threads shall be as per ASME B16.34, Table 4 where applicable.

(f) The bonnet-to-body and bonnet-to-cap threaded joints shall be analyzed for thread shear stress, which shall not exceed 0.6*S*.

(g) The bonnet flange dimensions are not required to meet the ASME B16.5 flange dimensions for secondary pressure class.

(h) See F-9 for body-to-bonnet and yoke-bolted joints for the bonnet flange design.

F-5 NON-PRESSURE-CONTAINING YOKE OR OPEN BONNET

(a) The yoke threaded section for the spring-adjusting screw or bolt shall be analyzed for the condition when it is subjected to full-lift spring load at maximum allowable overpressure for the maximum permitted set pressure. The thread shear stress shall not exceed 0.6*S*. The yoke may be analyzed using classic bending and direct stress equations, with appropriate free-body diagrams. The general membrane stress shall not exceed *S*, and the general membrane stress plus bending stress shall not exceed 1.5*S*.

(b) See F-9 for body-to-bonnet and yoke-bolted joints for the yoke flange design.

F-6 COVER OF A PILOT-OPERATED PRESSURE RELIEF VALVE

The cover of a pilot-operated pressure relief valve is subjected to primary and secondary zone pressures.

(a) The thickness of the cover shall be determined using one of the following methods:

(1) Calculate the cover thickness as per Section VIII, Division 1, UG-34(c)(2). The cover shall be considered to be a blind flange attached by bolts causing an edge moment.

(2) Determine the cover thickness by considering the total force acting under the cover and using the appropriate free-body diagram. The bending stress shall not exceed 1.5*S*. The shear stress shall not exceed 0.6*S*.

(b) See F-10 for body-to-cover bolted joints for the cover design.

F-7 NOZZLE

(a) The minimum wall thickness, t_m, of the nozzle shall be determined using one of the following methods:

(1) Determine the wall thickness based on general membrane stress limits. If the nozzle is a pressure-containing part of the shell, the general membrane stress value shall not exceed the stress value, *S*. For nozzle designs that are not pressure-containing, the general membrane stress shall not exceed 1.5*S* or the yield strength of the material at the design temperature.

(2) Calculate the wall thickness per Section VIII, Division 1, UG-27.

(b) The requirements of (a) are not applicable to the transition region to the seat-contacting area of the nozzle defined by dimension *L* (see Figure F-1-5), provided dimension *L* is less than the nominal wall thickness, t_m.

(c) The primary pressure zone hydrostatic test pressure shall be considered when designing the nozzle seat area and material thickness of the seat and adjacent area that separates the primary pressure zone from the secondary pressure zone.

(d) The minimum wall thickness of the nozzle end having pipe threads shall be as per ASME B16.34, Table 4 where applicable.

(e) The nozzle threads shall be analyzed for thread shear stress, which shall not exceed 0.6*S*.

F-8 CAP

(a) The minimum wall thickness of the cap shall be determined at the maximum secondary zone pressure using one of the following methods:

(1) Determine the thickness by using the appropriate free-body diagram for membrane stress. The general membrane stress shall not exceed *S*, and shear stress shall not exceed 0.6*S*.

(2) Calculate the thickness per Section VIII, Division 1, UG-27.

(b) The minimum wall thickness of the cap end having pipe threads shall be as per ASME B16.34, Table 4 where applicable.

(c) The cap threads shall be analyzed for thread shear stress, which shall not exceed 0.6*S*.

(d) A bolted cap flange joint shall be designed per Section VIII, Division 1, Mandatory Appendix 2. The bolted cap flange shall be designed to resist the maximum secondary design pressure.

(1) The bolt stresses shall not exceed the allowable stress value, *S*.

(2) The thread shear stress shall not exceed 0.6*S*.

(3) For flange stresses

(-a) longitudinal hub stress shall not exceed 1.5*S* except for cast iron, which shall be the allowable stress value, *S*

(-b) the radial and tangential stresses shall not exceed allowable stress, *S*

(-c) the average of the combined (longitudinal hub stress + radial stress) or the average of the combined (longitudinal hub stress + tangential stress) shall not exceed the allowable stress value, *S*

F-9 BODY-TO-BONNET AND YOKE-BOLTED JOINTS IN A SPRING-LOADED PRESSURE RELIEF VALVE

The body-to-bonnet or yoke-bolted joint shall be designed using one of the following methods:

(a) Section VIII, Division 1, Mandatory Appendix 2 requirements. The body-to-bonnet bolting shall be designed to resist the hydrostatic end force of the rated maximum secondary design pressure combined with the total spring load to full lift at maximum allowable overpressure for the maximum permitted set pressure. The design shall also maintain sufficient compression for a tight joint on the gasket or joint contact surface.

(1) The bolt stresses for these loadings shall not exceed the allowable stress value, *S*.

(2) The thread shear stress shall not exceed 0.6*S*.

(3) For flange stresses

(-a) longitudinal hub stress shall not exceed 1.5*S* except for cast iron, which shall be the allowable stress value, *S*

(-b) the radial and tangential stresses shall not exceed allowable stress, *S*

(-c) the average of the combined (longitudinal hub stress + radial stress) or the average of the combined (longitudinal hub stress + tangential stress) shall not exceed the allowable stress value, *S*

(b) ASME B16.34, para. 6.4 requirements.

F-10 BODY-TO-COVER BOLTED JOINT IN A PILOT-OPERATED PRESSURE RELIEF VALVE

The body-to-cover bolted joint shall be designed using one of the following methods:

(a) Section VIII, Division 1, Mandatory Appendix 2, requirements. The body-to-cover bolting shall be designed to resist the hydrostatic end force of the rated maximum primary and, if applicable, secondary design pressures to maintain sufficient compression for a tight joint on the O-ring, gasket, or joint contact surface.

(1) The bolt stresses for these loadings shall not exceed the allowable stress value, *S*.

(2) The thread shear stress shall not exceed 0.6*S*.

(3) For flange stresses

(-a) longitudinal hub stress shall not exceed 1.5*S* except for cast iron, which shall be the allowable stress value, *S*

(-b) the radial and tangential stresses shall not exceed allowable stress, *S*

(-c) the average of the combined (longitudinal hub stress + radial stress) or the average of the combined (longitudinal hub stress + tangential stress) shall not exceed the allowable stress value, *S*

(b) ASME B16.34, para. 6.4 requirements.

F-11 RUPTURE DISK HOLDER

(a) The circumferential stress (basic hoop stress) shall be calculated at design pressure and temperature per Section VIII, Division 1, UG-27. The circumferential stress shall not exceed the allowable stress, *S*, of the material.

(b) The longitudinal stress (only if structural circumferential welding is performed) shall be calculated at design pressure and temperature per Section VIII, Division 1, UG-27. The longitudinal stress shall not exceed the allowable stress, *S*, of the material.

(c) The bite area of the rupture disk holder is exempt.

(d) The assembly bolting of the rupture disk holder is exempt.

F-12 FINITE ELEMENT ANALYSIS

Pressure-containing shell parts of pressure relief devices may be designed using finite element analysis.

F-13 EXCEPTIONS

(a) The localized stresses may exceed the allowable stress.

(b) The stresses may be greater than allowable stress when valves are gagged during the hydrostatic testing of parts.

(c) Previous designs that have been proven in service that may not meet all of the requirements in this Appendix are acceptable.

Figure F-1-1
Spring-Loaded Pressure Relief Valve

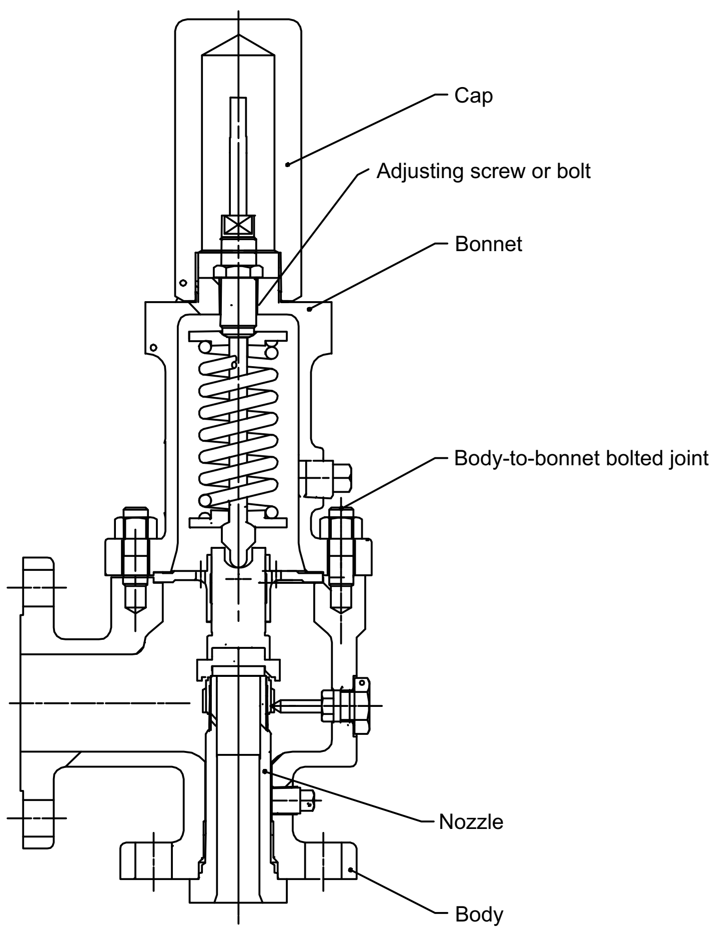


Figure F-1-2
Pilot-Operated Pressure Relief Valve

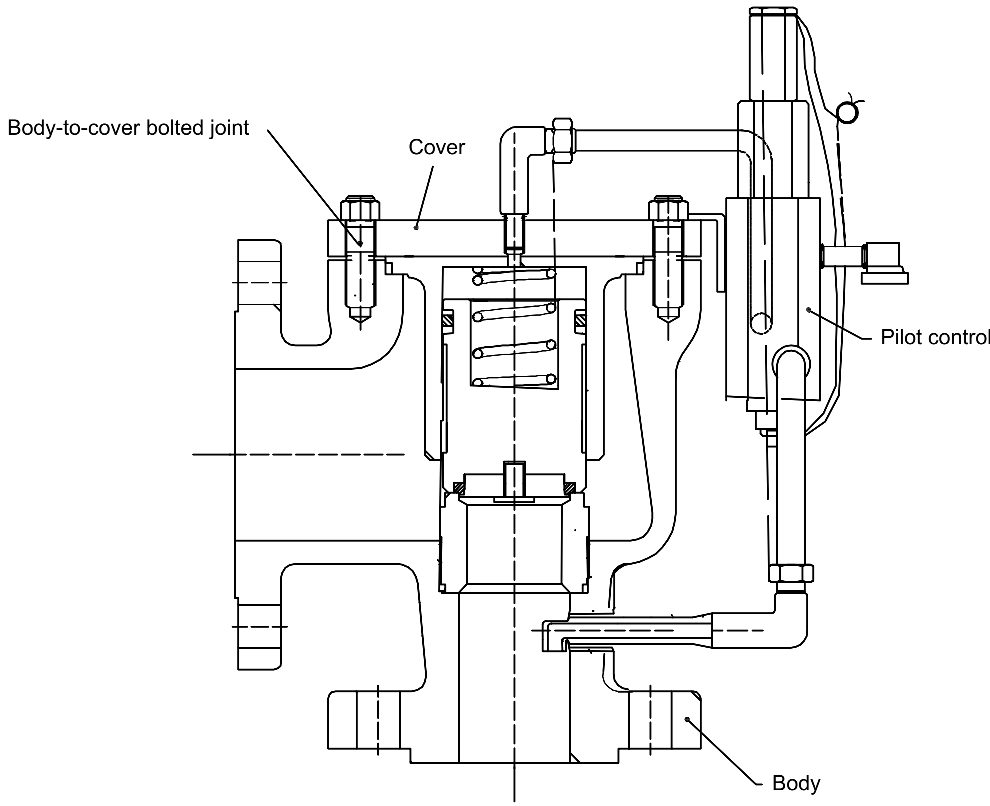


Figure F-1-3
Pressure Relief Valve (Yoke or Open Bonnet)

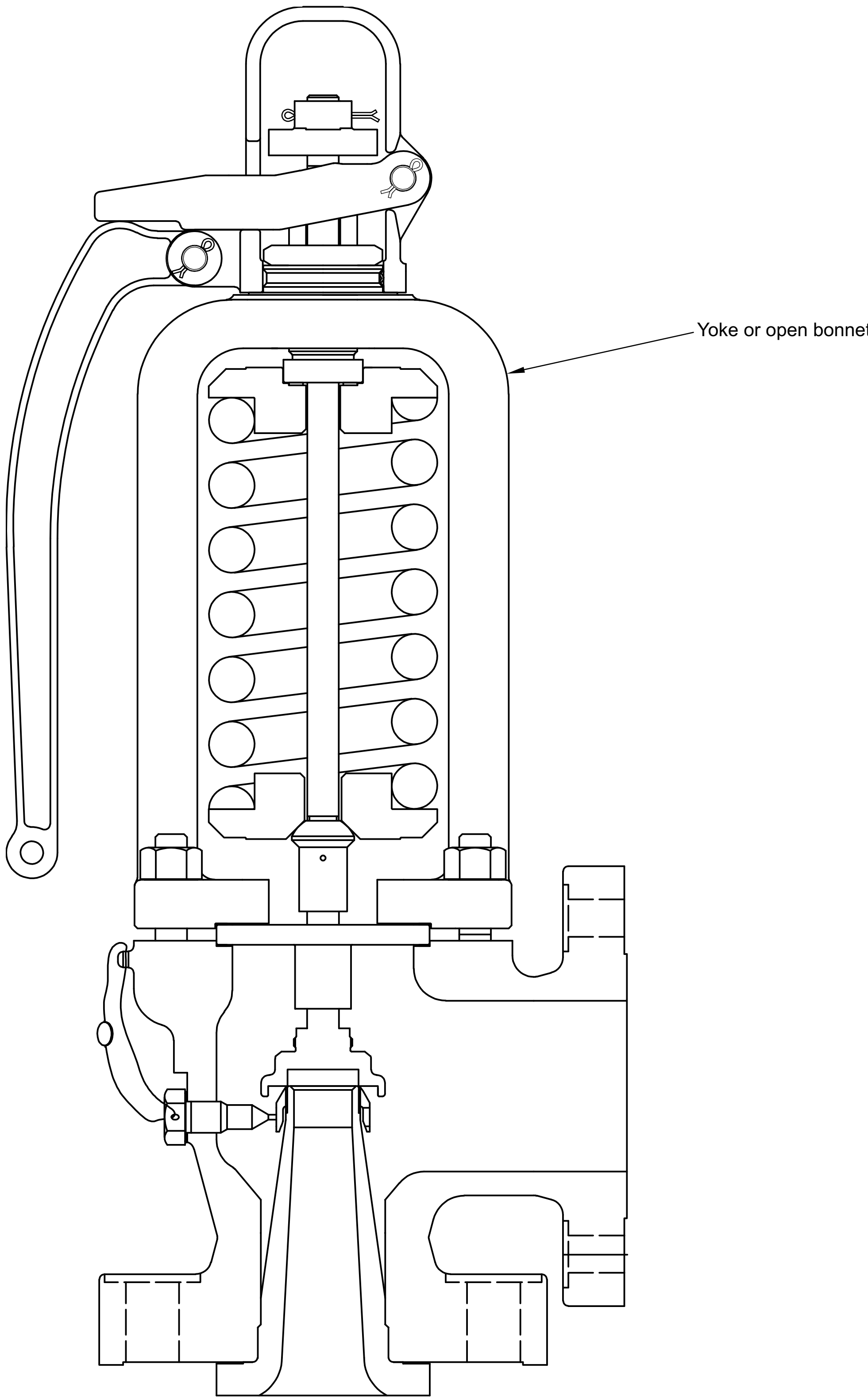


Figure F-1-4
Rupture Disk

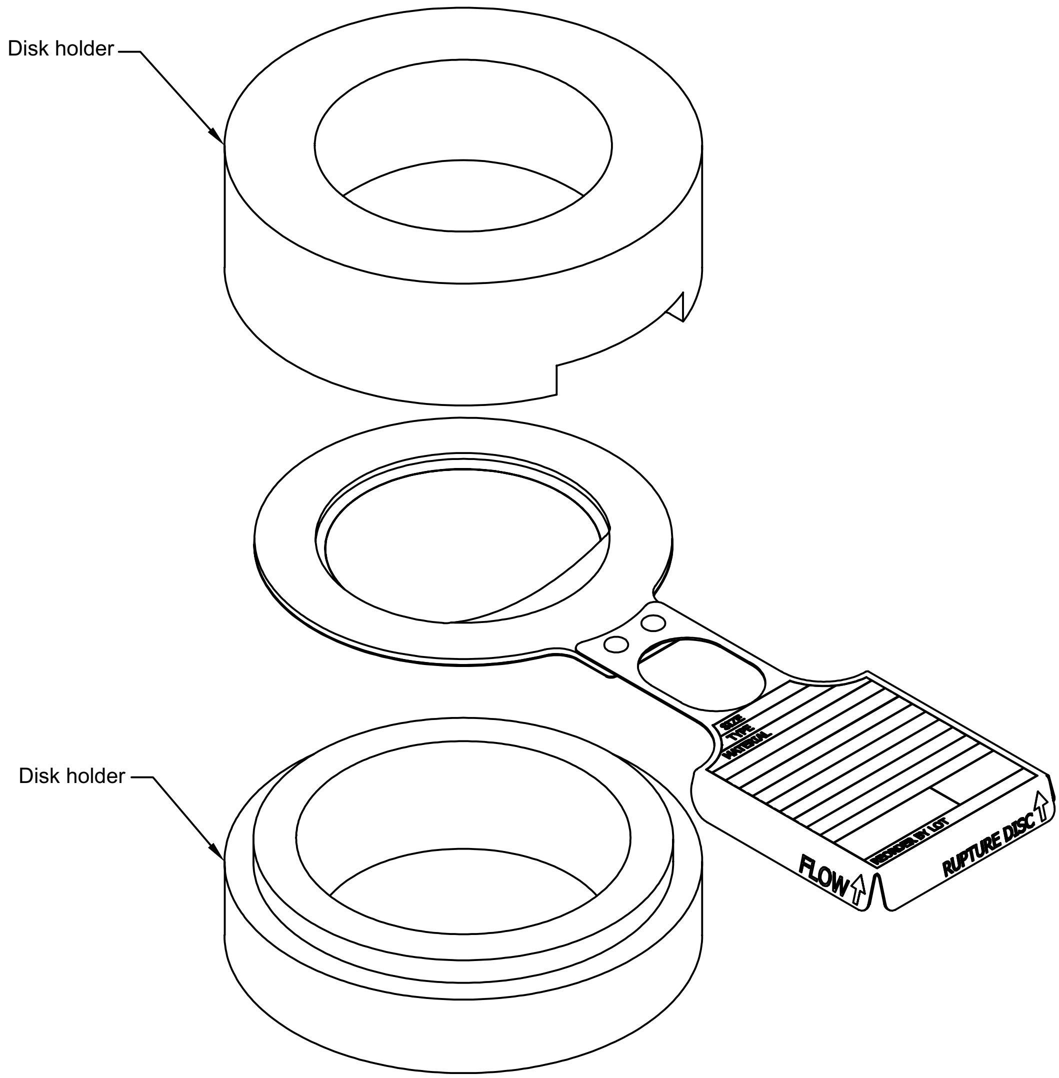
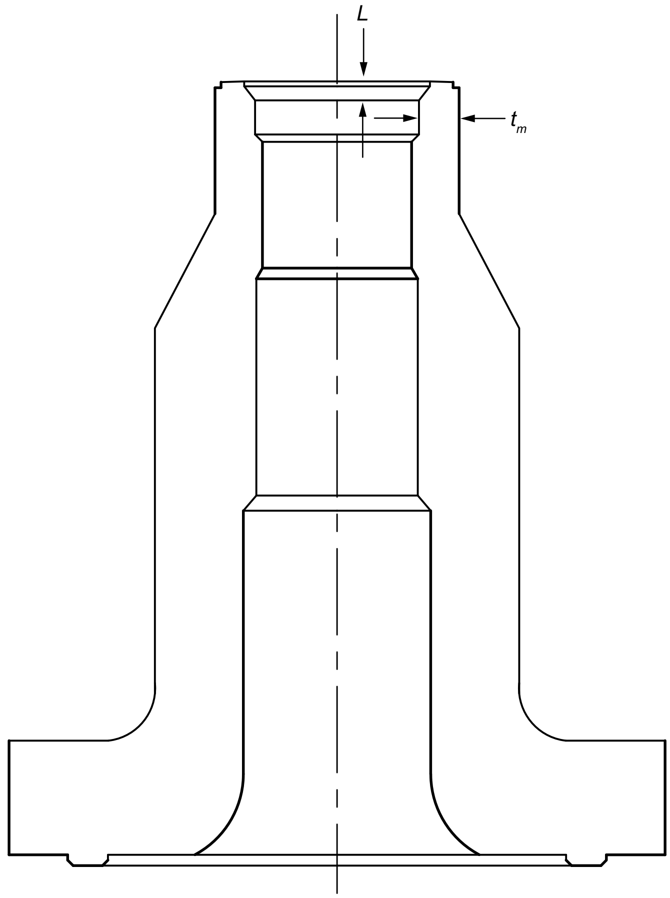


Figure F-1-5
Nozzle



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ISBN 978-0-7918-7730-2