สำนักหอสมุดกลาง พระจอมเกล้าลาดกระบัง

Report of Cooperative Education

Sizing of Pressure Safety Valve for Light Hydrocarbon at Supercritical Region in Fire Case

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A Report Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Engineering (Petrochemical Engineering), Department of Chemical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang

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Co-operative Title: Sizing of a Pressure Safety Valve for Light Hydrocarbon at Supercritical Region in Fire Case

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Abstract

Pressure safety valve (PSV) is one of pressure relief devices for preventing pressure vessel from an overpressure by relieving the excess pressure. A fire case of 1-hexene fluid that can cause overpressure was studied intensively in this project. If the relieving pressure is higher than fluid critical pressure, the fluid will reach the supercritical region. The purpose of this project is sizing of the orifice area of the pressure safety valve for light hydrocarbons such as 1-hexene at the supercritical region in fire case. Two methods were applied. The API 521 recommended method is based on ideal gas law. Since the properties of ideal gas deviate from fluid properties at the supercritical region, and therefore the calculated orifice area (0.1287 in^2, J – type) of the pressure safety valve by API 521 was larger than required (0.1011 in^2). In case of the thermodynamic principles method, the calculation templates were provided to calculate the orifice area. Pro/II simulation (Version 9.3) was additionally used to calculate fluid physical properties, e.g., enthalpy, entropy, and specific volume. These physical properties were used to calculate mass relief rate, volumetric relief rate and the orifice area. The orifice area is 0.3508 in^2 indicating that the calculation templates are reliable because the resulting orifice area was closely to the orifice area simulated by Aspen Hysys (0.3711 in^2). The percent deviation of the orifice area by the calculation templates and by Aspen Hysys is 5%, and thus the orifice area and the orifice type are the same (0.503, G-type).

Keywords: Pressure Safety Valve, Light Hydrocarbon, Supercritical Region, Fire Case

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Nattapat Isarankura Na Ayudhya

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TABLE OF CONTENTS

Page

ABSTRACT I

ACKNOWLEDGEMENTS II

TABLE OF CONTENTS III

LIST OF FIGURES V

LIST OF TABLES VII

NOMENCLATURE IX

CHAPTER I. INTRODUCTION

1.1 Background 1

1.2 Objective 1

1.3 Scopes of Work 2

1.4 Expected Output 2

CHAPTER II. LITERATURE REVIEW

2.1 Terms and Definitions 3

2.2 Pressure Relief Devices 6

2.3 Pressure Vessels 10

2.4 Scenarios 13

2.5 Supercritical Fluid 16

2.6 Lee-Kesler Method 17

2.7 Isentropic Flow Through Nozzle 18

2.8 Sizing Orifice Area 20

CHAPTER III. RESEARCH METHODOLOGY

3.1 Relieving Pressure Calculation 26

3.2 Wetted Surface Area Calculation 26

3.3 Heat Absorption Calculation 27

3.4 Physical Properties Calculation 28

3.5 Required Relief Rates Calculation 28

3.6 Isentropic Nozzle Mass Flux Calculation 29

3.7 Orifice Area Calculation 29

3.8 Relief Valve Size Selection 29

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CHAPTER IV. RESULTS AND DISCUSSION

4.1 Relieving Pressure Calculation 30

4.2 Wetted Surface Area Calculation 31

4.3 Heat Absorption Calculation 32

4.4 Physical Properties for Required Relief Rates Calculation 33

4.5 Required Relief Rates Calculation 36

4.6 Physicals Properties for Isentropic Nozzle Mass Flux 37
by Pro/II Simulation

4.7 Isentropic Nozzle Mass Flux Calculation 40

4.8 Orifice Area Calculation and Relief Valve Size Selection 41

CHAPTER V. CONCLUSION

5.1 Conclusion 44

5.2 Suggestion 44

REFERENCES 45

APPENDIX

APPENDIX A RAW DATA 47

APPENDIX B EXAMPLE OF CALCULATION 49

APPENDIX C PRO/II SIMULATION SETTING (VERSION 9.3) 52

APPENDIX D OTHER METHODS 54

APPENDIX F EFFECTIVE ORIFICE AREA AND 56
LETTER DESIGNATION

BIBLIOGRAPHY 84

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LIST OF FIGURES

Figure **Page**

2.1 Pressure-level Relationships for Pressure Relief Valve 5
2.2 Conventional Pressure Relief Valve 6
2.3 Balanced Pressure Relief Valve 7
2.4 Pilot-operated Pressure Relief Valve 8
2.5 Rupture Disk 9
2.6 Rupture Disk Device in Combination with a Pressure Relief Valve 9
2.7 Buckling Pin Valve 10
2.8 Flat Head 11
2.9 Ellipsoidal Head 11
2.10 Hemispherical Head 12
2.11 Torispherical Head 12
2.12 Phase Diagram 16
2.13 The Effect of Back Pressure on The Pressure Distribution Along a Converging Nozzle 18
2.14 The Effect of Back Pressure on The Mass Flow Rate 19
3.1A Path of Liquid Conditions into The Supercritical 20
3.1B Typical Vessel Subjected to Fire Case Study 20
3.2 Trend Curve 21
4.1 Design Criteria for Using this Template (Available) 30
4.2 Design Criteria for Using this Template (Unavailable) 31
4.3 Wetted Surface Area Calculation 31
4.4 Heat Absorption Calculation 32
4.5 Operating Conditions 32
4.6 Orifice Area Correction Factors 33
4.7 Input Data into Pro/II Simulation I 33
4.8 Waring from Pro/II Simulation I 33
4.9 Input 1-Hexene Into Pro/II Simulation 34
4.10 Input Operating Temperature and Relieving Pressure into Pro/II Simulation 34

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Forbidden to modify the content, and cite the document when use

4.11 Input Different Temperature into Pro/II Simulation 35
4.12 Physical Properties from Pro/II Simulation I 35
4.13 Paste Data from Pro/II Simulation I 36
4.14 Find Out the Maximum Volumetric Relief Rate 36
and the Maximum Mass Relief Rate
4.15 Input Data into Pro/II Simulation II 37
4.16 Waring from Pro/II Simulation II 37
4.17 Input 1-Hexene Into Pro/II Simulation II 38
4.18 Input Operating Temperature and Relieving Pressure into Upstream Line 38
4.19 Input Relieving Pressure into Flash Drum 39
4.20 Physical Properties from Pro/II Simulation II 39
4.21 Paste Data from Pro/II Simulation 40
4.22 Find Out the Maximum Mass Flux 40
4.23 Orifice Area Calculation (Incomplete) 41
4.24 Orifice Area Calculation (Complete) 41
4.25 Final Results 42
4.26 Trend Curve of Case Study 42
C.1 The Case Study of Physical Properties Calculation 52
C.2 The Case Study of Isentropic Nozzle Mass Flux Calculation 53
D.2 The Flowsheet of Aspen Hysys 54

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Forbidden to modify the content, and cite the document when use

LIST OF TABLES

Table	Page
4.1 Calculation Results from 1-Hexene	43
A.1 Required Input Data	47
A.2 Environmental Factor	47
A.3 Determination of Portion of Liquid Level	48
A.4 Standard Effective Orifice Areas and Letter Designations	48
D.1 Results of Aspen Hysys Simulation	54
D.2 Values of API 521 Recommended Method	55
F.1 Spring-loaded Pressure Relief Valves "D" Orifice	56
F.2 Spring-loaded Pressure Relief Valves "E" Orifice	57
F.3 Spring-loaded Pressure Relief Valves "F" Orifice	58
F.4 Spring-loaded Pressure Relief Valves "G" Orifice	59
F.5 Spring-loaded Pressure Relief Valves "H" Orifice	60
F.6 Spring-loaded Pressure Relief Valves "J" Orifice	61
F.7 Spring-loaded Pressure Relief Valves "K" Orifice	62
F.8 Spring-loaded Pressure Relief Valves "L" Orifice	63
F.9 Spring-loaded Pressure Relief Valves "M" Orifice	64
F.10 Spring-loaded Pressure Relief Valves "N" Orifice	65
F.11 Spring-loaded Pressure Relief Valves "P" Orifice	66
F.12 Spring-loaded Pressure Relief Valves "Q" Orifice	67
F.13 Spring-loaded Pressure Relief Valves "R" Orifice	68
F.14 Spring-loaded Pressure Relief Valves "T" Orifice	69
F.15 Pilot-operated Pressure Relief Valves "D" Orifice	70
F.16 Pilot-operated Pressure Relief Valves "E" Orifice	71
F.17 Pilot-operated Pressure Relief Valves "F" Orifice	72
F.18 Pilot-operated Pressure Relief Valves "G" Orifice	73
F.19 Pilot-operated Pressure Relief Valves "H" Orifice	74
F.20 Pilot-operated Pressure Relief Valves "J" Orifice	75
F.21 Pilot-operated Pressure Relief Valves "K" Orifice	76

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F.22 Pilot-operated Pressure Relief Valves "L" Orifice 77
F.23 Pilot-operated Pressure Relief Valves "M" Orifice 78
F.24 Pilot-operated Pressure Relief Valves "N" Orifice 79
F.25 Pilot-operated Pressure Relief Valves "P" Orifice 80
F.26 Pilot-operated Pressure Relief Valves "Q" Orifice 81
F.27 Pilot-operated Pressure Relief Valves "R" Orifice 82
F.28 Pilot-operated Pressure Relief Valves "T" Orifice 83

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NOMENCLATURE

A_H	=	Surface Area of Vessel Head (ft^2)
A_C	=	Surface Area of Vessel (ft^2)
A_W	=	Wetted Surface Area (ft^2)
A	=	Required Orifice Area (in^2)
D	=	Vessel Diameter (ft)
F_2	=	Coefficient of Subcritical Flow
f	=	Environmental Factor (Btu/h·ft^2)
G	=	Mass Flux (lb/h·in^2)
$\widehat{H}$	=	Enthalpy (Btu/lb)
H	=	Vessel Tangent-to-tangent Height for Vertical Tank (ft)
K_b	=	Correction Factor for Back Pressure
K_c	=	Correction Factor for Installation with A Rupture Disk
K_d	=	Correction Factor for Discharge
K_N	=	Correction Factor for Napier Equation
K_{SH}	=	Superheat Steam Correction Factor
k	=	Ratio of The Specific Heat
L	=	Vessel Tangent-to-tangent Height for Horizontal Tank (ft)
M_W	=	Molecular Weight (lb/lbmol)
$\dot{m}$	=	Mass Relief Rate (lb/h)
P_a	=	Atmospheric Pressure (psia)
P_b	=	Back Pressure (psia)
P_C	=	Critical Pressure of Fluid (psia)
P_{Set}	=	Set Pressure (psig)
$P_{Relieving}$	=	Relieving Pressure (psia)
P_0	=	Upstream Pressure (psia)
P^*	=	Choke Pressure (psia)
$\dot{Q}$	=	Heat Absorption (Btu/h)
R	=	Vessel Radius (ft)
T_C	=	Critical Temperature of Fluid (R)

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T_2	=	High Temperature (R)
T_1	=	Low Temperature (R)
V_C	=	Molar Critical Volume (cm^3/mol)
$\dot{V}$	=	Volumetric Relief Rate (ft^3/h)
$\widehat{V}$	=	Specific Volume (ft^3/lb)
$\frac{\Delta\widehat{V}}{\Delta\widehat{H}}$	=	Volumetric Expansion (ft^3/Btu)
ω	=	Acentric Factor
Z	=	Compressibility Factor

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CHAPTER I
INTRODUCTION

1.1 Background

TTCL Public Company Limited possesses experience and expertise in providing an integrated EPC (Design and engineering, procurement of machinery and equipment, and construction) of turnkey projects for industrial and processing plants, mainly in energy, petrochemical, chemical and power industries. The company prepares a convenient calculation templates for designing equipment, which is used for providing materials according to specification.

A pressure safety valve (PSV) is a safety device which is designed to protect a pressurized vessel or system during an overpressure event. An overpressure event refers to any condition which causes the pressure in a vessel or a system to increase beyond the specified design pressure or maximum allowable working pressure (MAWP). The scenarios which can cause an overpressure are divided into 2 categories: unfired case (Block discharge, hydraulic expansion and utility failure), and exposure to external flames (Fire case). The purpose of this project is to design a pressure safety valve for light hydrocarbon at supercritical region in fire case.

The typical method for sizing an orifice area for supercritical fluid is presented in API 521, Section 4.4.13.2.4.3. As stated in the API 521 text, this method is based on the ideal-gas law. The API-recommended method with ideal-gas behavior may lead to improperly sized valve with larger orifice area than the required size. The main concern is over-sized valves.

The thermodynamic principles method, which is presented by Ryan Ouderkirk, can solve the problem. The method is based on the physical properties of the supercritical fluid which are calculated by using an equation of state. Computer simulation is very valuable for property calculations. The size of orifice acquired by using this method can be smaller than the size gained by the API 521 recommended method.

1.2 Objective

To calculate pressure safety valve for light hydrocarbon at supercritical region in fire case

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1.3 Scopes of Work

1.3.1 Study principles of pressure safety valve sizing for scenario which causes overpressure, for instance, block discharge, hydraulic expansion, utility failure and fire case

1.3.2 Provide the calculation template and manual of pressure safety valve sizing for light hydrocarbon in fire case

1.3.3 Compare the calculation results from Aspen Hysys Simulation, the API 521 recommended method and the PSV calculation template

1.4 Expected Output

Calculation template and manual of pressure safety valve sizing for light hydrocarbon at supercritical region in fire case

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CHAPTER II
LITERATURE REVIEW

An overpressure can be caused by scenarios which are divided into 2 categories: fire case and unfired cases. According to API Standard 521, there are many unfired cases including closed outlets on vessels (as known as Block discharge), failure of automatic control, and hydraulic expansion. For fire case, it depends on the phase of the fluid within the internal vessel whether they are in liquid phase, vapor phase, or supercritical fluid phase. If the pressure is higher than the maximum strength of pressure vessel, the pressure vessel may be ruptured and may cause a catastrophe as a result. A protection against an overpressure is an important system to prevent a disaster. Therefore, pressure relief devices are installed to ensure that a process system is not subjected to pressure that exceeds the maximum allowable accumulated pressure. The purpose of this project is sizing of pressure safety valve for light hydrocarbon at supercritical region in fire case.

2.1 Terms and Definitions [API Standard 520, 2000]

2.1.1 Maximum Allowable Working Pressure

The maximum allowable working pressure (MAWP) is the maximum gauge pressure permissible at the top of a completed vessel in its normal operating position at the designated coincident temperature specified for that pressure. The maximum allowable working pressure is the basis for the pressure setting of the pressure relief devices that protects the vessel. The MAWP is normally greater than the design pressure but must be equal to the design pressure when the design rules are used only to calculate the minimum thickness for each element and calculations are not made to determine the value of the MAWP.

2.1.2 Set Pressure

The set pressure is the inlet gauge pressure at which the pressure relief device is set to open under service conditions.

2.1.3 Design Pressure

The design pressure of the vessel along with the design temperature is used to determine the minimum permissible thickness or physical characteristic of each vessel component as determined by the vessel design rules. The design pressure is selected by the user

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to provide a suitable margin above the most severe pressure expected during normal operation at a coincident temperature. It is the pressure specified on the purchase order. This pressure may be used in place of the maximum allowable working pressure in all cases where the MAWP has not been established. The design pressure is equal to or less than the MAWP.

2.1.4 Overpressure

Overpressure is the pressure increase over the set pressure of the relieving device allowed to achieve rated flow. Overpressure is expressed in pressure units or as a percentage of set pressure. It is the same as accumulation only when the relieving device is set to open at the maximum allowable working pressure of the vessel.

2.1.5 Back Pressure

Back pressure is the pressure that exists at the outlet of a pressure relief device as a result of the pressure in the discharge system. It is the sum of the superimposed and built-up back pressures.

2.1.6 Accumulation

Accumulation is the pressure increase over the maximum allowable working pressure of the vessel allowed during discharge through the pressure relief device, expressed in pressure units or as a percentage of MAWP or design pressure. Maximum allowable accumulations are established by applicable codes for emergency operating and fire contingencies.

2.1.7 Superimposed Back Pressure

Superimposed back pressure is the static pressure that exists 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 coming from other sources and may be constant or variable.

2.1.8 Built-up Back Pressure

Built-up back pressure is the increase in pressure at the outlet of a pressure relief device that develops as a result of flow after the pressure relief device opens.

2.1.9 Relieving Conditions

The term relieving conditions is used to indicate the inlet pressure and temperature on a pressure relief device during an overpressure condition. The relieving pressure is equal to the valve set pressure plus the overpressure. The temperature of the flowing fluid at relieving conditions may be higher or lower than the operating temperature.

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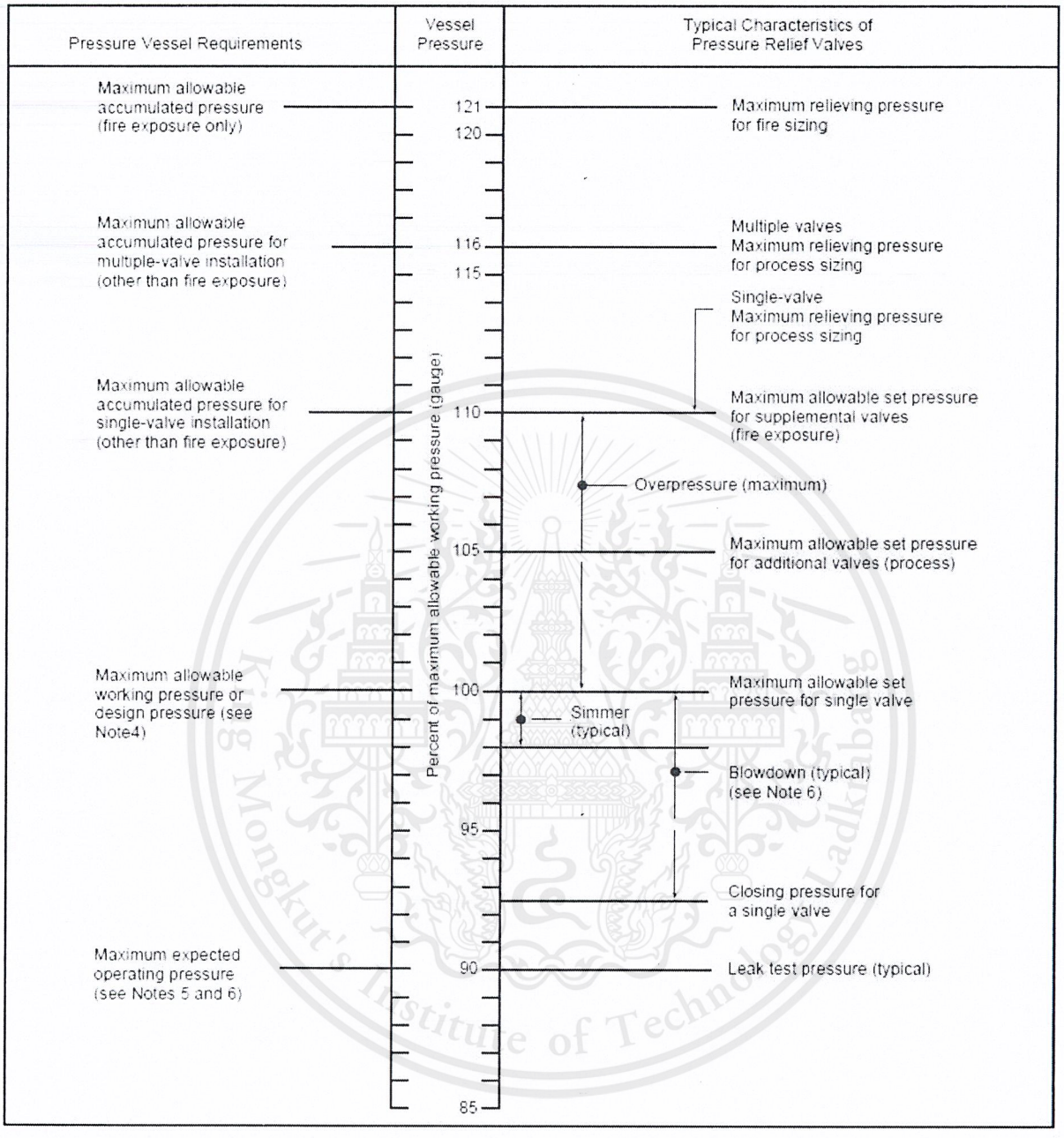

Figure 2.1 Pressure-level Relationships for Pressure Relief Valve [API Standard 520, 2000]

As shown in Figure 2.1, The maximum relieving pressure for sizing pressure safety valve is equal to 121 % of set pressure in fire case. In other than fire case, the maximum relieving pressure for sizing pressure relieving valves is equal to 110% of set pressure.

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2.2 Pressure Relief Devices [API Standard 520, 2000]

This section describes the basic principles, operational characteristics, applications, and selection of pressure relief devices used independently or in combination. These devices include spring loaded, pilot operated pressure relief valves, rupture disk devices and pin-actuated devices.

2.2.1 Pressure Relief Valves

2.2.1.1 Conventional Pressure Relief Valve

A conventional pressure relief valve (see Figure 2.2) is a self-actuated spring-loaded pressure relief valve which is designed to open at a predetermined pressure and protect a vessel or system from excess pressure by removing or relieving fluid from that vessel or system. The basic elements of a spring-loaded pressure relief valve include an inlet nozzle connected to the vessel or system to be protected, a movable disc which controls flow through the nozzle, and a spring which controls the position of the disc. In a conventional pressure relief valve application, built-up back pressure should not exceed 10% of the set pressure at 10% allowable overpressure. Excessive built-up back pressure can cause the valve to operate in an unstable manner. This instability may occur as flutter or chatter. Chatter refers to the abnormally rapid reciprocating motion of the pressure relief valve disc where the disc contacts the pressure relief valve seat during cycling.

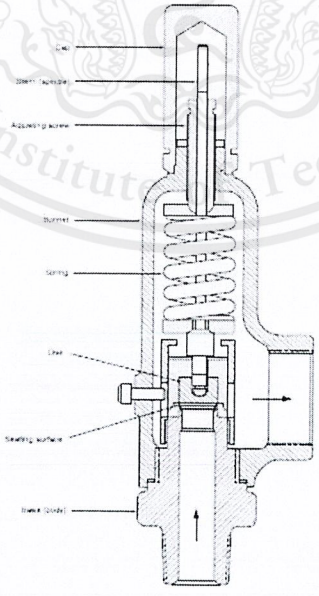

Figure 2.2 Conventional Pressure Relief Valve
[API Standard 520, 2000]

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2.2.1.2 Balanced Pressure Relief Valve

A balanced pressure relief valve is a spring-loaded pressure relief valve which incorporates a bellow or other means of balancing the valve disc to minimize the effects of back pressure on the performance characteristics of the valve (see Figure 2.3). The balanced pressure relief valves should be considered where the built-up back pressure, which is caused by flow through the downstream piping after the relief valve lifts, is too high for a conventional pressure relief. Balanced pressure relief valve may also be used as a mean to isolate the guide, spring, bonnet and other top works parts within the valve from the relieving fluid. This may be important if there is a concern that the fluid will cause corrosive damage to these parts. The balanced pressure relief valve should be used where the built-up back pressure is too high for conventional pressure relief valves or where the superimposed back pressure varies widely compared to the set pressure. The balanced pressure relief valve can typically be applied where the total back pressure (superimposed plus built-up) does not exceed approximately 50% of the set pressure.

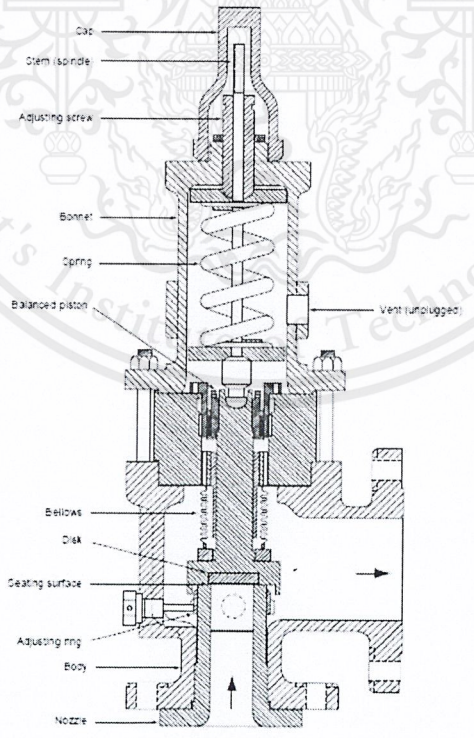

Figure 2.3 Balanced Pressure Relief Valve
[API Standard 520, 2000]

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2.2.1.3 Pilot-operated Pressure Relief Valve

A pilot-operated pressure relief valve consists of the main valve, which normally encloses a floating unbalanced piston assembly, and an external pilot (see Figure 2.4). The pilot-operated pressure relief valve is a spring-loaded valve that senses the process pressure and opens the main valve by lowering the pressure on the top of an unbalanced piston, diaphragm, or bellows of the main valve. Once the process pressure is lowered to the blowdown pressure, the pilot closes the main valve by permitting the pressure in the top of the main valve to increase. The pilot-operated relief valve is commonly used in clean, low-pressure services and in services where a large relieving area at high set pressures is required. The set pressure of this type of valve can be close to the operating pressure. The pilot-operated valve is frequently chosen when operating pressures are within 5 percent of set pressures and a close tolerance valve is required.

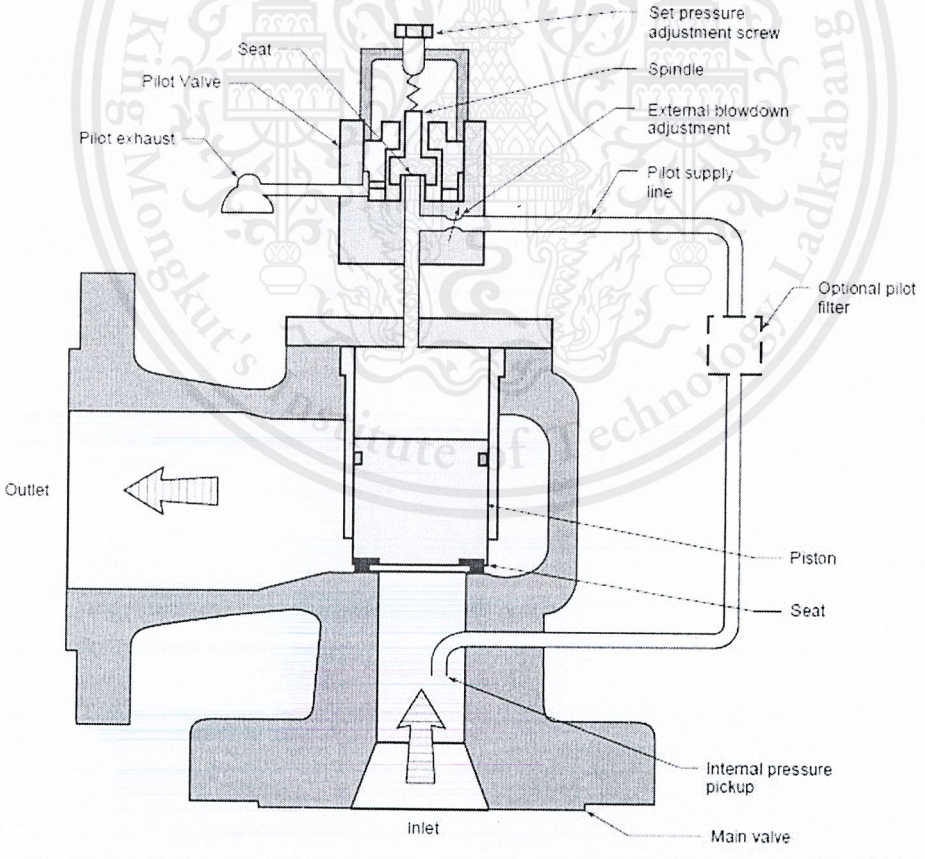

Figure 2.4 Pilot-operated Pressure Relief Valve
[API Standard 520, 2000]

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2.2.2 Rupture Disk Devices

Rupture disk is non-reclosing pressure relief devices used to protect vessels, piping and other pressure containing components from excessive pressure or vacuum (see Figure 2.5). Rupture disks are used in single and multiple relief device installations. Rupture disk is also used as redundant pressure relief devices (see Figure 2.6). Rupture disks can be specified for systems with vapor (gas) or liquid pressure relief requirements. Additionally, rupture disk designs are available for processes with high viscosity fluid, including nonabrasive slurries, where fluid flow is directed across the rupture disk inlet to prevent product build-up which may otherwise adversely affect rupture disk performance.

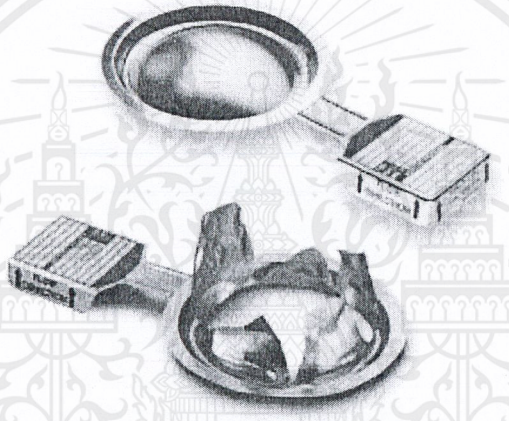

Figure 2.5 Rupture Disk
[API Standard 520, 2000]

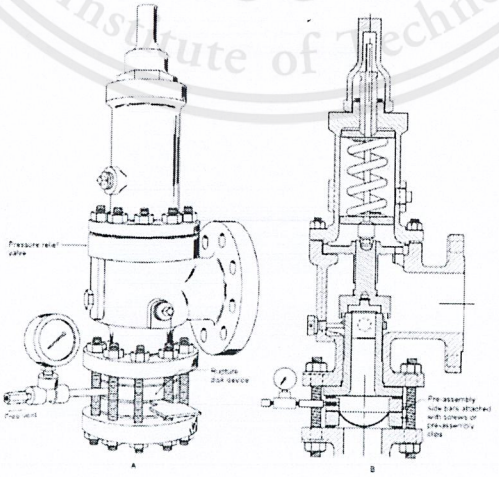

Figure 2.6 Rupture Disk Device in Combination with a Pressure Relief Valve
[API Standard 520, 2000]

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2.2.3 Pin-actuated Devices

Pin-actuated pressure relief devices are non-reclosing devices consisting of a moving disc exposed to the pressure system, and an external mechanism housing a pin which is mechanically linked to the disc. Pins may be loaded in tension (breaking pins) or in compression (buckling pins, see Figure 2.7). The pin restrains the movement of the disc until the specified set pressure is reached. At this point the pin fails and the disc opens.

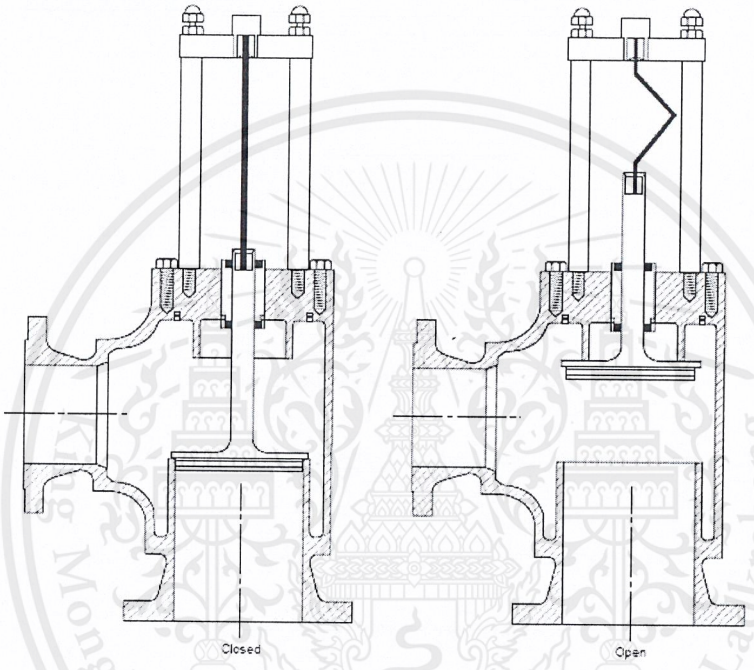

Figure 2.7 Buckling Pin Valve
[API Standard 520, 2000]

2.3 Pressure Vessels [B.S.Thakkar and S.A.Thakkar, 2012]

Some physical and chemical processes must be operated at high pressure. Therefore, pressure vessels are required because they are durable enough to contain the fluid in high pressure conditions. The fluids which are used in the operation may be hazardous substances. If pressure vessels cannot persevere in high pressure, the vessels may be ruptured and the hazardous fluid will leak to the environment. Therefore, pressure vessels must be carefully designed in order to cope with high operating temperature and pressure. Moreover, pressure safety devices are installed to prevent pressure vessels from overpressure. Pressure vessels are used in several industries; for example, the power generation industry, the petrochemical industry, and the chemical industry.

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2.3.1 Head of Pressure Vessels [Lois Orthez, 2014]

When choosing a head of pressure vessel, the pressure of the liquid which is stored has to be determined. If the incorrect head is purchased, it may be hard to maintain and prevent dangerous situations. There are four main types of head of pressure vessel: flat head, ellipsoidal head, hemispherical head and torispherical head.

2.3.1.1 Flat Head

Flat head is used for vessels which contain liquid at low pressure. If it is used at high pressure, the structure of head will crack. Flat head is quite cheap and easy to create. Therefore, flat head is often used for the storage liquid at low pressure.

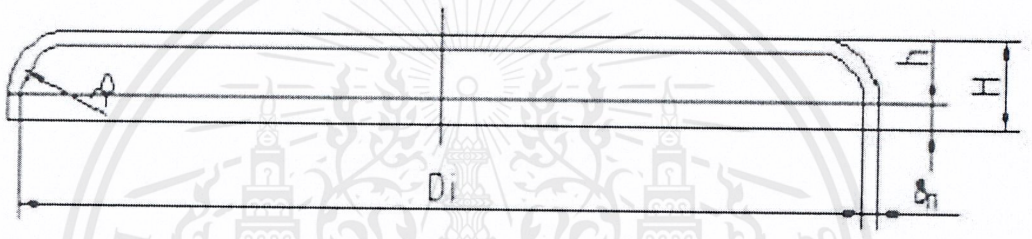

Figure 2.8 Flat Head
[Wermac, 2008]

2.3.1.2 Ellipsoidal Head

For pressures over 10 bar, ellipsoidal head is often used. In cross-section, the head resembles an ellipse, its radius varying continuously. This results in a smooth transition between the dome and the cylindrical part of the vessel. Ellipsoidal head is deeper than the comparable torispherical heads. The shape of the ellipsoidal head is defined by the ratio of the major and minor axis. A standard arrangement on vessels is the 2:1 elliptical head. The depth of the head is a quarter of the vessels internal diameter.

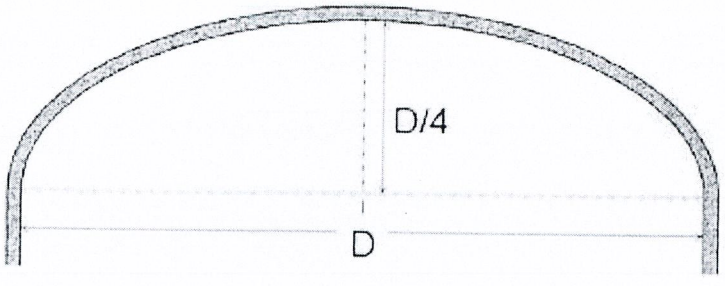

Figure 2.9 Ellipsoïdal Head
[Wermac, 2008]

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2.3.1.3 Hemispherical Head

A hemispherical head is the strongest of all heads; capable of resisting about twice the pressure of a torispherical head of the same thickness. The cost of forming a hemispherical head is, however, higher than that of a shallow torispherical head. The additional amount of forming required to produce hemispherical shape results in its increased forming cost. As they are the most expensive head to create, they are reserved for high pressure applications.

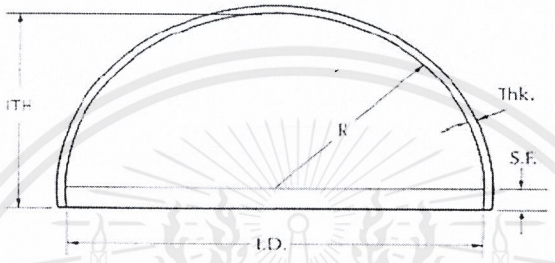

Figure 2.10 Hemispherical Head
[Wermac, 2008]

2.3.1.4 Torispherical Head

A torispherical head is extensively used as the end closure for a large variety of cylindrical pressure vessels. The heads are formed from a part of a torus and a part of a sphere. The shape is close to that of an ellipse but is easier and cheaper to fabricate. Torispherical head is made of a dish, with a constant radius. Joining the dish directly to the cylindrical section of the vessel would lead to a rapid change in geometry, resulting in excessive local stresses. To avoid this, a transition section (the "knuckle") is used between the dish and the cylinder. Normally, producing torispherical head with pressure ratings much above 10 bar is uneconomical. The torispherical head is actually very similar to the ellipsoid in shape and benefits. However, it is easier to manufacture because of availability regular circular curves on the edges then a larger curve as it heads.

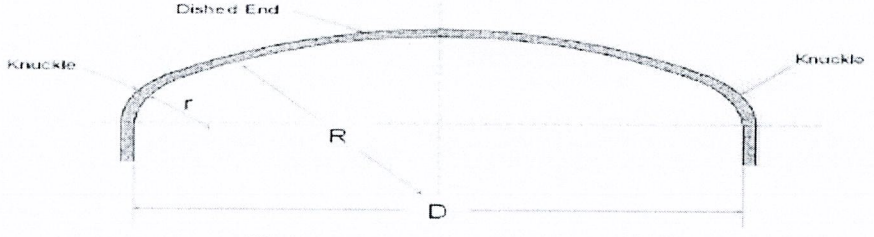

Figure 2.11 Torispherical Head
[Wermac, 2008]

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2.4 Scenarios [API Standard 521, 2014]

The most difficult part of designing an adequate emergency pressure relief system lies in determining the emergency events (credible design scenarios) for which to design. The difficulty arises primarily because the identification of credible design scenarios usually involves highly subjective judgments, which are often influenced by economic situations. Unfortunately, there exists no universally accepted list of credible design scenarios. Relief systems must be designed for the credible chain of events that results in the most severe venting requirements (worst credible scenario).

2.4.1 Unfired Cases

2.4.1.1 Close Outlets on Vessel (Block discharge)

The inadvertent closure of a valve on the outlet of pressure equipment while the equipment is on stream can expose the equipment to a pressure that exceeds the MAWP. Every valve should be considered as being subject to inadvertent operation. If closure of an outlet valve can result in pressure in excess of that allowed by the design code, a PRD is required. If the equipment is designed to the maximum source pressure, then closure of an outlet valve will not result in overpressure, so a PRD is not required for the closed outlet scenario.

2.4.1.2 Failure of Automatic Control

Automatic control devices directly actuated from the process or indirectly actuated from a process variable such as pressure, flow, liquid level, or temperature used at inlets and outlets of vessels or systems. When the transmission signal or operating medium to a final control element such as a valve operator fails, the control devices should assume either a fully open or fully closed position according to their basic design. Final control elements that fail in a stationary position should be assumed to fail fully open or fully closed. The failure of a process measuring element in a transmitter or controller without coincidental failure of the operating power to the final controlled element should be reviewed to determine the effect on the final controlled element.

2.4.1.3 Hydraulic Expansion

Hydraulic expansion is the increase in liquid volume caused by an increase in temperature. It can result from several causes, the most common of which are the following: Piping or vessels are blocked in while they are filled with cold liquid and are subsequently heated by heat tracing, coils, ambient heat gain, or fire. An exchanger is blocked in on the cold

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side with flow in the hot side. Piping or vessels are blocked in while they are filled with liquid at near-ambient temperatures and are heated by direct solar radiation.

2.4.1.4 Absorbent Flow Failure

For lean-oil absorption of hydrocarbons, generally no relief requirement results from lean-oil failure. However, in an acid gas removal unit in which large quantities (25 % or more) of the inlet vapor can be removed in the absorber, loss of absorbent can cause a pressure rise to relief pressure, since the downstream system might not be adequate to handle the increased vapor flow.

2.4.1.5 Accumulation of Noncondensables

Noncondensables do not accumulate under normal conditions because they are released with the process streams. If the noncondensables accumulate to the point of blanketing (vapor-locking) the overhead condenser, the effect may be equal to a total loss of cooling. In addition, some relief scenarios may introduce noncondensables that may have the same effect.

2.4.1.6 Cooling Water Failure

The failure of electrical or mechanical equipment that provides cooling or condensation in process streams can cause overpressure in process vessels. The loss of reflux as a result of pump or instrument failure can cause overpressure in a column because of condenser flooding or loss of coolant in the fractionating process. Fans on air-cooled heat exchangers or cooling towers occasionally become inoperative because of a loss of power or a mechanical breakdown. On cooling towers and air-cooled exchangers where independent operation of the louvers can be maintained, credit for the cooling effect may be obtained by convection and radiation.

2.4.2 Fire Case

Fire exposure on equipment can result in overpressure due to vapor generation or fluid expansion. Fire exposure can also cause overheating of the vessel walls resulting in a reduction in material strength. For the purpose of API 521 Standard, fires are characterized as open pool fires, confined pool fires, or jet fires. A pool fire typically results from an ignited liquid spill while a jet fire results from an ignited pressurized leak. The heat flux from jet fires is very high and localized whereas the heat flux from pool fires is lower and not localized. Confined pool fires are those that occur inside a structure or are confined by embankments

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thereby causing higher heat fluxes than open pool fires in some cases. Fire heat intensities can vary dramatically depending on fuel, ventilation, release rate, and other factors.

2.4.2.1 Open Pool Fire

For the purposes of PRD sizing for equipment within the scope of API 521 standard, the design fire scenario has been and continues to be an open pool fire. The recommended method was empirically derived to size PRDs for open pool fires involving hydrocarbons in a refinery environment that is typical for the facilities within the scope of API 521 standard. The intensity of open pool fire is around 50 kW/m^2 to 150 kW/m^2.

2.4.2.2 Confined Pool Fire

Confined fires are divided into fuel-controlled fires and ventilation-controlled fires. A ventilation-controlled fire is in shortage of air, hence the available air—the ventilation—controls the heat release rate. A fire inside compact process modules or in buildings may result in a ventilation-controlled fire. Confined fires typically have higher heat fluxes than open fires but their size can be limited due to lack of ventilation. The intensity of confined pool fire is around 100 kW/m^2 to 250 kW/m^2.

2.4.2.3 Jet Fire

Protection from jet fire exposure is typically addressed through means other than PRDs because failure often occurs due to localized overheating for which a PRD is ineffective. Jet fire characteristics include unpredictability of the source (leak) and flame impingement locations, unpredictability of the jet flame length, and significantly increased heat loading to the vessel's wetted and unwetted surfaces relative to a pool fire. Jet fires can occur when almost any flammable fluid under pressure is released to atmosphere. The primary concern with jet fire impingement is that the equipment can fail due to intense, localized overheating of the metal wall where the jet fire impinges. Failure can occur even without increasing the pressure in the equipment to the set point of the relief device. This is due to the localized nature of heating whereby the bulk fluid temperature might not increase appreciably. Hence, a relief device might not prevent vessel failure from jet fire impingement. The intensity of jet fire varies from 100 kW/m^2 to 400 kW/m^2.

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2.5 Supercritical Fluid [Unit operation of chemical engineering, 2005]

Supercritical fluids are gases at pressure and temperatures slightly above those of the vapour-liquid critical point as shown in Figure 2.12. At this point, liquid and vapor become indistinguishable, and the vapor pressure curve of the liquid ends. The main distinctive characteristic of the supercritical fluid condition is that the density of the fluid is very sensitive to small changes in pressure and temperature. At the critical point, the compressibility is infinite. Density is directly related to many other physical (and chemical) properties of a fluid. The most important in supercritical fluid applications is the solvent power, that is, the ability to dissolve other substances. At gas-like densities, a supercritical fluid can hardly dissolve anything. When mixed with a liquid or a solid, the partial pressure of the condensed substance in the gas phase is limited to its vapor pressure, because the density of the supercritical fluid is too small to allow the interactions that lead to dissolution. On the contrary, at liquid-like densities, the molecules of the fluid can cluster around the molecules of the other substance and bring them into the gas phase. So, with small variations of pressure or temperature, a supercritical fluid can be brought to a density where it dissolves (reasonably) high amounts of a solute or to another one where it precipitates (almost) everything it had dissolved before

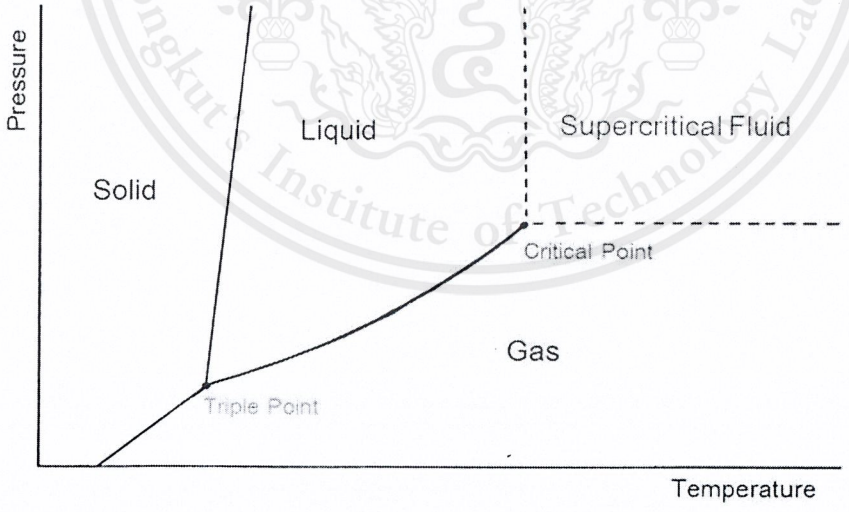

Figure 2.12 Phase Diagram
[Physics.stackexchange, 2004]

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2.6 Lee-Kesler Method (Lee, B. I., and M. G. Kesler, 1975)

The Lee-Kesler method may be used to predict both liquid and vapor enthalpies, entropies and densities. This method uses the three-parameter corresponding-states theory, which essentially states that all fluids having the same acentric factor must have the same properties at the same reduced temperature and pressure. Special mixing rules have been used to calculate the mixture reduced properties. For most fluids, the Lee-Kesler method is accurate in predicting the gas-phase compressibility factors. The method also gives reasonable results for slightly polar mixtures. This method is not recommended for highly polar mixtures, or those which form strongly associative hydrogen bonds. However, the Lee-Kesler method provides accurate results for polar fluids at low temperatures near the saturated-vapor region. Moreover, this method can apply to the critical and retrograde region. The Lee-Kesler method is not recommended for calculating liquid densities of hydrocarbon heavier than C8. Compressibility factor can calculate by using equation 2.1.

$$Z = Z_o + \left(\frac{\omega}{\omega_r}\right)(Z_r - Z_o) \tag{2.1}$$

The mixing rules proposed here are:

$$T_{c,mix} = \frac{1}{V_{c,mix}} \sum_j \sum_k x_j x_k V_{cjk} T_{cjk} \tag{2.2}$$

$$V_{c,mix} = \sum_j \sum_k x_j x_k V_{cjk} \tag{2.3}$$

$$\omega_{mix} = \sum_j x_j \omega_j \tag{2.4}$$

The cross coefficients are given by:

$$T_{cjk} = (T_{cj} T_{ck})^{1/2} K_{jk} \tag{2.5}$$

$$V_{cjk} = \frac{1}{8}\left({V_{cj}}^{1/3} + {V_{ck}}^{1/3}\right)^3 \tag{2.6}$$

The pseudo-critical pressure is found by:

$$P_{c,mix} = (0.2905 - 0.085\omega_{mix}) R \frac{T_{c,mix}}{V_{c,mix}} \tag{2.7}$$

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2.7 Isentropic Flow Through Nozzle (Thermodynamic an Engineering Approach, 2004)

Converging is found in many engineering applications including steam and gas turbines, aircraft and spacecraft propulsion systems, and even industrial blasting nozzles and torch nozzles. In this section, the effects of back pressure are considered on the exit velocity, the mass flow rate, and the pressure distribution along the nozzle. In this project, the fluid flows through the orifice which is assumed be the nozzle.

2.7.1 Converging

To consider the subsonic flow through a converging nozzle as shown in Figure 2.13, the nozzle inlet is attached to a reservoir at pressure P_r and temperature T_r. The reservoir is sufficiently large so that the nozzle inlet velocity is negligible. Since the fluid velocity in the reservoir is zero and the flow through the nozzle is approximated as isentropic, the stagnation pressure and stagnation temperature of the fluid at any cross section through the nozzle are equal to the reservoir pressure and temperature, respectively. The back pressure is gradually decreased to observe the resulting effects on the pressure distribution along the length of the nozzle, as shown in Figure 2.13.

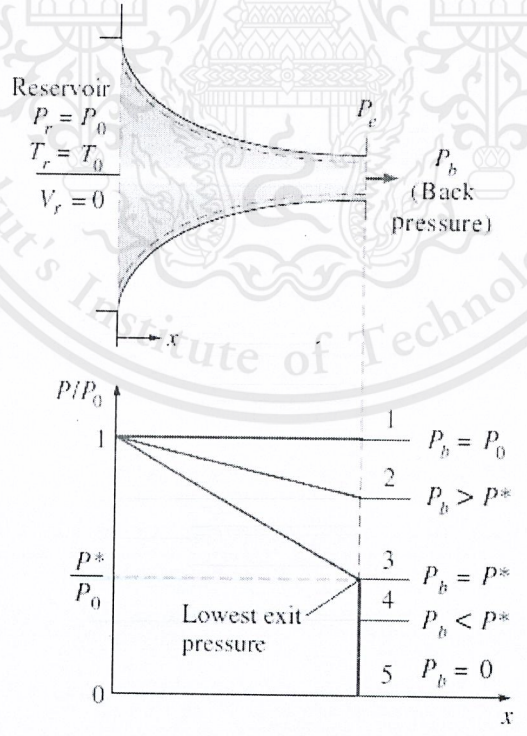

Figure 2.13 The Effect of Back Pressure on The Pressure Distribution along a Converging Nozzle [Yunus, A.C. and Michael A.B, 2004]

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If the back pressure P_b is equal to P_1, which is equal to P_r, there is no flow and the pressure distribution is uniform along the nozzle. When the back pressure is reduced to P_2, the exit plane pressure P_e also drops to P_2. This causes the pressure along the nozzle to decrease in the flow direction. When the back pressure is reduced to P_3 or P*, which is the pressure required to increase the fluid velocity to the speed of sound at the exit plane or throat, the mass flow reaches a maximum value and the flow is said to be choked as shown in Figure 2.14. Further reduction of the back pressure to level P_4 or below does not result in additional changes in the pressure distribution, or anything else along the nozzle length. To summarize, for all back pressures lower than the critical pressure P*, the pressure at the exit plane of the converging nozzle P_e is equal to P*, the Mach number at the exit plane is unity, and the mass flow rate is the maximum (or choked) flow rate. Because the velocity of the flow is sonic at the throat for the maximum flow rate, a back pressure lower than the critical pressure cannot be sensed in the nozzle upstream flow and does not affect the flow rate.

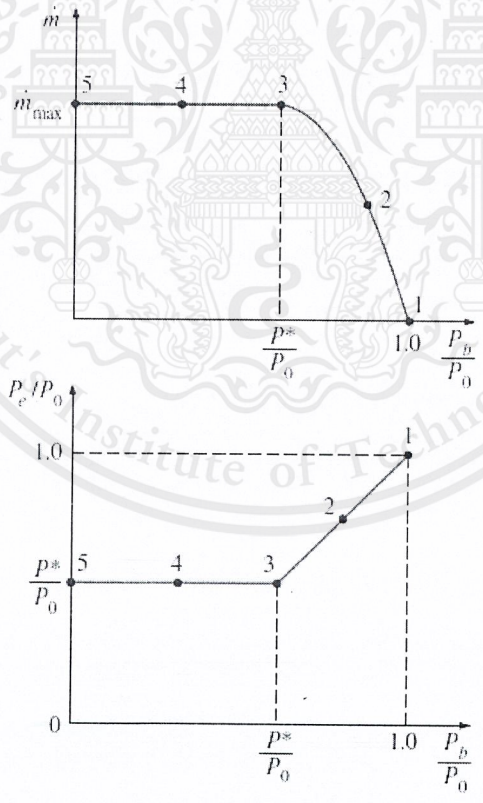

Figure 2.14 The Effect of Back Pressure on the Mass Flow Rate

[Yunus, A.C. and Michael A.B, 2004]

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2.8 Sizing Orifice Area [API Standard 520, 2002]

2.8.1 Sizing for Vapor or Gas Relief

The sizing equations for pressure relief devices in vapor or gas service fall into two general categories depending on whether the flow is critical (Choked) or subcritical. If the pressure downstream of the nozzle is less than, or equal to, the critical flow pressure, P*, then critical flow will occur, and the equations in 2.8.1.2 should be applied. If the downstream pressure exceeds the critical flow pressure, P*, then subcritical flow will occur, and the procedures in 2.8.1.3 should be applied.

$$\frac{P^*}{P_1} = \left[\frac{2}{k+1}\right]^{k/(k-1)} \tag{2.8}$$

2.8.1.2 Sizing for Critical Flow

Pressure relief devices in gas or vapor service that operate at critical flow conditions may be sized using Equations 2.9 – 2.11. Each of the equations may be used to calculate the effective discharge area, A, required to achieve a required flow rate through a pressure relief device. A pressure relief valve that has an effective discharge area equal to or greater than the calculated value of A is then chosen for the application from API Std 526.

$$A = \frac{W}{CP_1K_dK_cK_b}\sqrt{\frac{ZT}{M}} \tag{2.9}$$

$$A = \frac{V\sqrt{TZM}}{6.32CK_dP_1K_cK_b} \tag{2.10}$$

$$A = \frac{V\sqrt{TZG}}{1.175CK_dP_1K_cK_b} \tag{2.11}$$

2.8.1.3 Sizing for Subcritical Flow

The flow through the pressure relief device is subcritical. Equations 2.12 – 2.14 may be used to calculate the required effective discharge area for a conventional pressure relief valve that has its spring setting adjusted to compensate for superimposed back pressure. Equations 2.12 – 2.14 may also be used for sizing a pilot-operated relief valve.

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$$A = \frac{W}{735F_2K_dK_c}\sqrt{\frac{ZT}{MP_1(P_1-P_2)}} \quad (2.12)$$

$$A = \frac{V}{4645F_2K_dK_c}\sqrt{\frac{ZTM}{P_1(P_1-P_2)}} \quad (2.13)$$

$$A = \frac{V}{864F_2K_dK_c}\sqrt{\frac{ZTG}{P_1(P_1-P_2)}} \quad (2.14)$$

2.8.2 Sizing for Steam Relief

Pressure relief devices in steam service that operate at critical flow conditions may be sized using Equation 2.15.

$$A = \frac{W}{51.5P_1K_dK_bK_cK_NK_{SH}} \quad (2.15)$$

2.8.3 Sizing for Liquid Relief

2.8.3.1 Pressure Relief Valves Requiring Capacity Certification

Section VIII, Division I, of the ASME Code requires that capacity certification be obtained for pressure relief valves designed for liquid service. The procedure for obtaining capacity certification includes testing to determine the rated coefficient of discharge for the liquid relief valves at 10% overpressure. Valves in liquid service that are designed in accordance with the ASME Code which require a capacity certification may be initially sized using Equation 2.16.

$$A = \frac{Q}{38K_dK_wK_cK_v}\sqrt{\frac{G}{p_1-p_2}} \quad (2.16)$$

2.8.3.2 Pressure Relief Valves Not Requiring Capacity Certification

Before the ASME Code incorporated requirements for capacity certification, valves were generally sized for liquid service using Equation 2.17.

$$A = \frac{Q}{38K_dK_wK_cK_vK_p}\sqrt{\frac{G}{1.25(p_1-p_2)}} \quad (2.17)$$

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2.8.4 Two-phase Liquid/Vapor Relief

The method presented in this section can be used for sizing pressure relief valves handling either flashing or nonflashing flow. For flashing flow, the two-phase system must consist of a saturated liquid and saturated vapor and contain no noncondensable gas. For nonflashing flow, the two-phase system must consist of a highly subcooled liquid and either a noncondensable gas, condensable vapor or both. Fluids both above and below the thermodynamic critical point in condensing two-phase flow can be handled as well. The following procedure can be used.

$$A = \frac{W}{GK_dK_c} \tag{2-18}$$

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CHAPTER III
RESEARCH METHODOLOGY

The purpose of this project is sizing of pressure safety valve (PSV) for light hydrocarbon at supercritical region in fire case. The PSV calculation template and Pro/II simulation are necessary to design pressure safety valve in this case. From the summary of the literature review, the pressure vessel contains liquid hydrocarbon (see Figure 3.1A) and the case considered here is heat from a fire. Therefore, the liquid hydrocarbon expands because of absorbing the heat input, which then leads to an overpressurization. If relieving pressure of pressure safety valve is higher than the critical pressure of the fluid, the phase of the fluid will go to supercritical. As shown in Figure 3.2B, the fluid at its initial condition is liquid phase and its physical properties gradually changes because of absorbing the heat input from fire until being above its critical point, and then it reaches the relieving pressure.

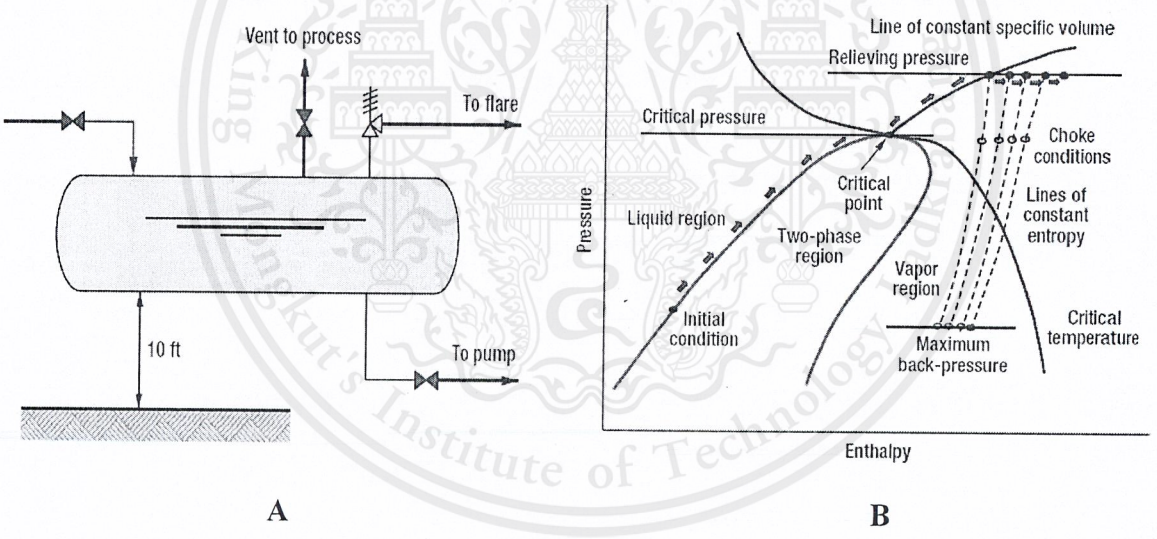

Figure 3.1A Path of Liquid Conditions into The Supercritical
3.1B Typical Vessel Subjected to Fire Case Study
[Richard Doane, 2010]

However, the latent heat cannot be calculated in this relieving condition. In contrast, the difference of enthalpy must be calculated instead. The fluid flows through an orifice area based on isentropic flow at choke condition. The choke condition is the limiting velocity of the fluid which is equal to the velocity of sound, which leads to the maximum back-pressure as well. Thermodynamic principle method is required to calculate the physical properties at supercritical

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region. Lee-Kesler method is the proper equation of state to calculate these physical properties. However, this method is not recommended for hydrocarbon which is heavier than C_8. Therefore, Pro/II simulation program is needed in order to calculate the physical properties such as enthalpy, entropy and specific volume. Theses physical properties are used in order to calculate the required relief rates: volumetric relief rate and mass relief rate. The region between the maximum volumetric relief rate and the maximum mass relief rate must be found out because the maximum orifice area appears in between these value (see Figure 3.2).

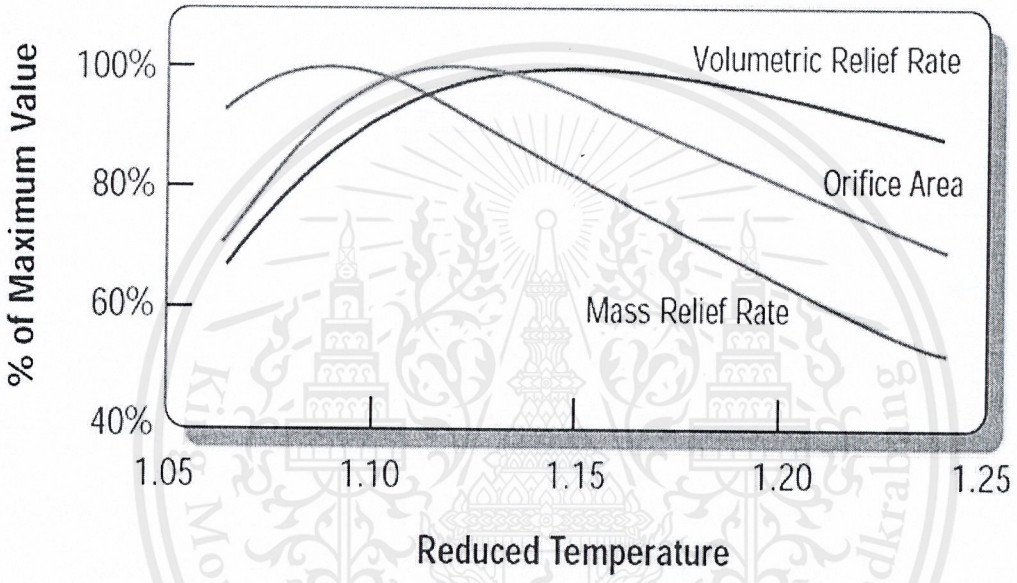

Figure 3.2 Trend Curve [Ryan Ouderkirk, 2002]

The raw data of case study are shown in Table A.1. The steps for sizing pressure safety valve for light hydrocarbon at supercritical region in fire case are shown in Figure 3.3.

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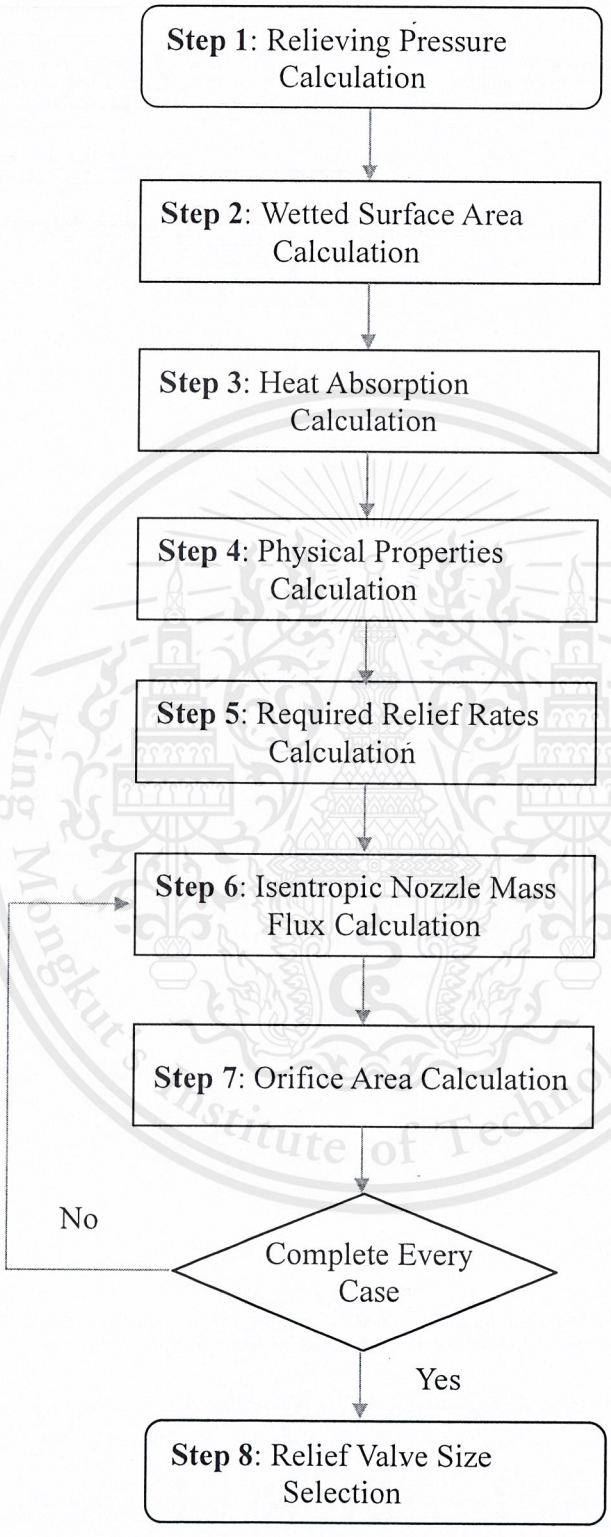

Figure 3.3 A Simplified Logic Diagram for Sizing Pressure Safety Valve for Light Hydrocarbon at Supercritical Region in Fire Case [Ryan Ouderkirk, 2002]

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3.1 Relieving Pressure Calculation [API Standard 520, 2002]

According to API Standard 520, the maximum relieving pressure for sizing PSV is equal to set pressure with 21% allowable pressure for fire case. To obtain a supercritical fluid, the relieving pressure must be higher than the critical pressure of the fluid (see Figure 3.1B).

$$P_{Relieving} = P_{Set} \times 1.21 + P_a \tag{3.1}$$

$$P_{Relieving} > P_c$$

3.2 Wetted Surface Area Calculation [API Standard 521, 2014]

Wetted surface area is considered a portion of the vessel that is wetted by its internal liquid and is equal to or less than 7.6 m (25 ft) above the source of flame. Wetted surface area can be calculated from the surface area of the tank and the head. The geometry of a tank is divided into 2 categories: cylindrical and spherical. Moreover, there are two types of cylindrical tank, including vertical and horizontal. The types of head are flat, 2:1 ellipsoidal and hemispherical.

3.2.1 Vertical Cylindrical Tank Surface Area

$$A_c = \pi \times D \times h \tag{3.2}$$

3.2.2 Horizontal Cylindrical Tank Surface Area

$$A_c = 2 \times L \times R \times \cos^{-1}\left(\frac{R-h}{R}\right) \tag{3.3}$$

3.2.3 Spherical Tank Surface Area

$$A_c = 2 \times \pi \times R \times h \tag{3.4}$$

3.2.4 Flat head for Vertical Cylindrical Tank Surface Area

$$A_H = \pi \times R^2 \tag{3.5}$$

3.2.5 2:1 Ellipsoidal Head for Vertical Cylindrical Tank Surface Area

$$A_H = \frac{\pi \times D^2}{8}\left(2 + \frac{1}{4\varepsilon}\ln\left(\frac{2\varepsilon+2}{2-\sqrt{3}}\right)\right) \tag{3.6}$$

$$\varepsilon = 0.866 \; for \; 2{:}1 \; elleipsoidal$$

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3.2.6 Hemispherical Head for Vertical Cylindrical Tank Surface Area

$$A_H = 2\times\pi\times R\times h \tag{3.7}$$

3.2.7 Flat Head for Horizontal Cylindrical Tank Surface Area

$$A_H = \begin{cases} \frac{\pi\times R^2}{2},\ for\ h = R \\ (h-R)\times(R^2-(h-R)^2)^{0.5} - R^2\times\tan^{-1}\left(\frac{\left(R^2-(h-R)^2\right)^{0.5}}{h-R}\right) + \pi\times R^2, for\ h > R \\ -(R-h)\times(R^2-(R-h)^2)^{0.5} + R^2\times\tan^{-1}\left(\frac{\left(R^2-(R-h)^2\right)^{0.5}}{R-h}\right), for\ h < R \end{cases} \tag{3.8}$$

3.2.8 2:1 Ellipsoidal Head for Horizontal Cylindrical Tank Surface Area

$$A_H = \frac{\pi\times D^2}{8}\left(\left(\frac{h}{D}-0.5\right)B + 1 + \frac{1}{4\varepsilon}\ln\left(\frac{4\varepsilon\left(\frac{h}{D}-0.5\right)+B}{2-\sqrt{3}}\right)\right) \tag{3.9}$$

$$B = \sqrt{1+12\left(\frac{h}{D}-0.5\right)^2}$$

$$\varepsilon = 0.866\ for\ 2:1\ elleipsoidal$$

3.2.9 Hemispherical Head for Horizontal Cylindrical Tank Surface Area

$$A_H = \pi\times R\times h \tag{3.10}$$

3.3 Heat Absorption Calculation [API Standard 521, 2014]

The heat absorption calculation depends on the system of drainage and firefighting according to API Standard 521. The drainage system is to carry flammable liquid hydrocarbon away from a vessel. The firefighting system is to extinguish a fire. For environmental factor (F), it depends on the insulation of thermal conductivity and this factor are shown in Table A.2.

3.3.1 The drainage and firefighting are present

$$\dot{Q} = 21{,}000\times f\times A^{0.82} \tag{3.11}$$

3.3.2 The drainage and firefighting are absent

$$\dot{Q} = 34{,}500\times f\times A^{0.82} \tag{3.12}$$

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3.4 Physical Properties Calculation [Ryan Ouderkirk, 2002]

Pro/II simulation is used significantly to simplify calculations. The Lee-Kesler method is used because this method can calculate physical properties for light hydrocarbon at supercritical region. However, this method is not recommended for hydrocarbon which is heavier than C_8. According to Table A.1, the fluid of the case study is 1-Hexene which is lighter than C_8. Therefore, Lee-Kesler can calculate physical properties of 1-Hexene at supercritical region. Physical properties, which are required to be calculated by Pro/II simulation, are shown in Appendix B. To set up a Pro/II simulation, Appendix C shows the case study of Pro/II simulation in order to calculate physical properties. However, volumetric expansion may need to be acquired outside of the simulator. Volumetric expansion is calculated by specific volume and enthalpy at the relieving pressure, and after the temperature increase.

3.4.1 Volumetric Expansion

$$\frac{\Delta\hat{V}}{\Delta\hat{H}} = \frac{(\hat{V}_{T_2} - \hat{V}_{T_1})}{(\hat{H}_{T_2} - \hat{H}_{T_1})} \tag{3.13}$$

3.5 Required Relief Rates Calculation [Ryan Ouderkirk, 2002]

Required relief rates are volumetric relief rate and mass relief rate. Volumetric relief rate is equal to heat absorption multiplied by volumetric expansion. Mass relief rate is equal to volumetric expansion divided by specific volume. According to Figure 3.2, the maximum orifice appears between the maximum of volumetric relief rate and mass relief rate. Therefore, the maximum of volumetric relief rate and mass relief rate need to be obtained in order to calculate the maximum orifice area.

3.5.1 Volumetric Relief Rate

$$\dot{V} = \dot{Q} \times \frac{\Delta\hat{V}}{\Delta\hat{H}} \tag{3.14}$$

3.5.2 Mass Relief Rate

$$\dot{m} = \frac{\dot{V}}{\hat{V}} \tag{3.15}$$

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3.6 Isentropic Nozzle Mass Flux Calculation [Ryan Ouderkirk, 2002]

Due to choked or critical flow, we have to find the choked mass flux by maximizing the mass flux. The pressure at which this maximum mass flux occurs is the choking pressure. We need to calculate the mass flux for multiple backpressures by keeping the entropy constant and starting with a backpressure that is equal to the relief-valve inlet pressure and then decreasing the inlet pressure by 1%. Once the maximum mass flux is found, the choked condition will be solved and no further calculations are required. When generating these mass flux values, the property package should be set up to indicate two-phase flow of the fluid being relieved. A Pro/II simulation is necessary to calculate physical properties which are needed to calculate the mass flux. Appendix C shows the case study of Pro/II simulation in order to calculate physical properties by using equation 3.16.

$$G = \frac{\sqrt{2(\hat{H}_a - \hat{H}_b)}}{\hat{V}_b} \times 3{,}955.77 \tag{3.16}$$

3.7 Orifice Area Calculation [API Standard 520, 2002]

Based on the maximum mass flux and the required relief rate, the required orifice area can finally be calculated. To correct this calculation for system nonidealities, we need to use the correction factor for discharge and correction factor for installation with a rupture disk. According to Figure 3.2, the maximum orifice area appears between the maximum mass relief rate and the maximum volumetric flow rate.

$$A = \frac{\dot{m}}{GK_dK_c} \tag{3.17}$$

3.8 Relief Valve Size Selection [API Standard 526, 2000]

The required orifice area is the maximum orifice which can be calculated in the previous step. As shown in Table A.3, the effective orifice area must be larger than the maximum orifice area. The material and valve selection can be found from Appendix F.

$$Effective\ orifice\ area > The\ maximum\ orifice\ area$$

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CHAPTER IV
RESULTS AND DISCUSSION

The calculation template of pressure safety valve sizing for light hydrocarbon at supercritical region in fire case is divided into 8 steps.

- Relieving pressure calculation
- Wetted surface area calculation
- Heat absorption calculation
- Physicals properties for required relief rates by Pro/II simulation
- Required relief rates calculation
- Physicals properties for isentropic nozzle mass flux by Pro/II simulation
- Isentropic nozzle mass flux calculation
- Orifice area calculation and relief valve size selection

The raw data of case study and examples of calculation are shown in Appendix A and Appendix B, respectively.

4.1 Relieving Pressure Calculation

As shown in Figure 4.1, Set pressure and critical pressure of fluid are filled into yellow cells, and then selecting the proper units according to Table A.1. Relieving pressure is automatically calculated by using equation 3.1. The template automatically considers between relieving pressure and critical pressure of fluid to define this information. If define is available, this template can be applied to design the orifice area of pressure safety valve.

P_{Set}	=	Set Pressure	=	41.50	kg/cm²g
			=	590.25	psig
$P_{Relieving}$	=	Relieving Pressure	=	728.70	psia
P_c	=	Critical Pressure of Fluid	=	455.40	psia
			=	455.40	psia
Define				Available	

Figure 4.1 Design Criteria for Using this Template (Available)

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If define is unavailable, this template cannot be applied to design the orifice area of pressure safety valve because the relieving pressure is less than the critical pressure of fluid, and the fluid does not become supercritical fluid as shown in Figure 4.2.

P_{Set}	=	Set Pressure	=	10.00	kg/cm²g
			=	142.23	psig
$P_{Relieving}$	=	Relieving Pressure	=	186.70	psia
P_c	=	Critical Pressure of Fluid	=	455.40	psia
			=	455.40	psia
Define				Unavailable	

Figure 4.2 Design Criteria for Using this Template (Unavailable)

4.2 Wetted Surface Area Calculation

According to Table A.1, there are many dimension data: vessel type, head type, diameter, vessel TL/TL, liquid level and elevation of vessel. These parameters are inputted into yellow cells and then selecting the proper units. The template automatically calculates the wetted surface area by using equation 3.2 and 3.9. Table A.3 gives recommended portion of liquid inventory for using in calculation.

Wetted Surface Calculation

Input Data

Unit	=	m	
Vessel Type	=	Vertical	
Head Type	=	2:1 Ellipsoidal	
Diameter	=	1.90	m
Vessel TL/TL	=	8.13	m
Vessel Elevation	=	1.39	m
Liquid Level	=	Full	m
Fire Source Elevation at Ground	=	Yes	
Wetted Surface Area	=	38.16	m²

Back

Figure 4.3 Wetted Surface Area Calculation

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4.3 Heat Absorption Calculation

For drainage and firefighting selection, this case is assumed that drainage and firefighting are present. The environmental factor can be found from Table A.2 and bare vessel is chosen because of giving the highest heat absorption. The unit of wetted surface area is automatically converted to square feet for using in the equation 3.11 and then the template calculates the heat absorption automatically.

Case	=	Drainage and Firefighting		Present	
F	=	Environment Factor	=	1	See Data
A	=	Wetted Surface Area	=	Wetted Surface Area Calculation	
			=	410.74	ft^2
Q	=	Heat Absorption	=	2,919,762	Btu/h

Figure 4.4 Heat Absorption Calculation

Before going to the next step, the operating temperature and critical temperature of the fluid are required in order to calculate different temperature and reduced temperature which are required to use in further steps (see Figure 4.5).

T_o	=	Operating Temperature	=	40.00	°C
			=	564.00	R
T_c	=	Critical Temperature of Fluid	=	907.00	R
			=	907.00	R

Figure 4.5 Operating Conditions

If the manufacturer's correction factor for discharge is unknown, the estimation value recommended by API 520 is used instead. Rupture disk is not installed in pressure safety valve. Therefore, 'without rupture disk' is selected for correction factor for installation with a rupture disk. These correction factors are used to calculate the orifice area by using the equation 3.17.

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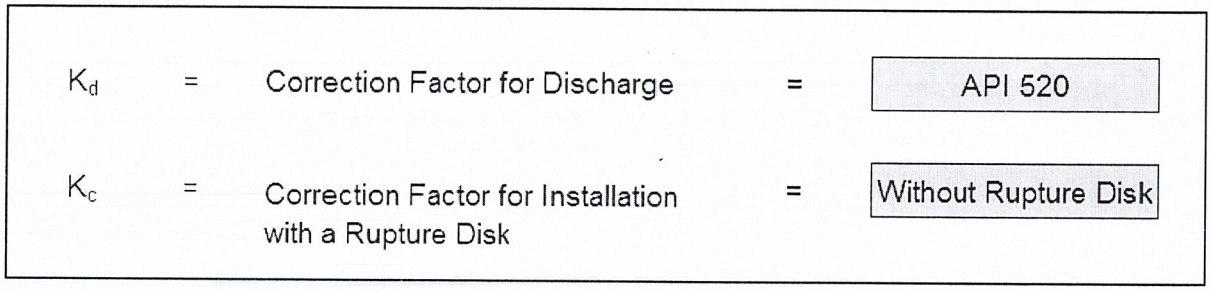

Figure 4.6 Orifice Area Correction Factors

4.4 Physical Properties for Required Relief Rates Calculation

The template automatically reveals parameters in green cells which are operating temperature, relieving pressure and different temperature. Pro/II simulations is necessary for calculating the physical properties such as density, enthalpy, and entropy. These physical properties are needed in order to calculate the required relief rates in the next step. Pro/II simulation files can be opened by pressing the "Go to Pro/II simulation" button.

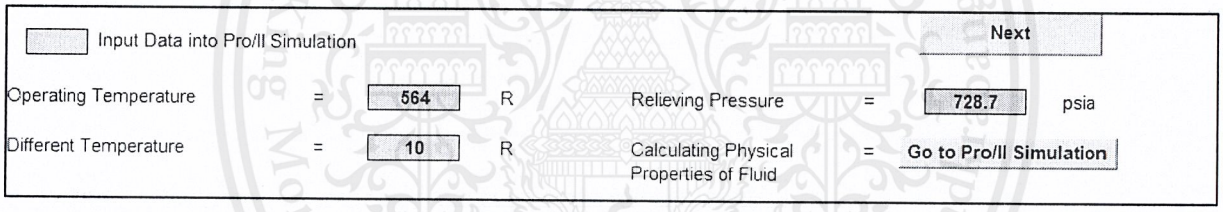

Figure 4.7 Input Data into Pro/II Simulation I

Firstly, Pro/II simulation show the red rectangles and warns that there is no fluid in this file (see Figure 4.8). Therefore, 1-hexene is added into component selection (see Figure 4.9).

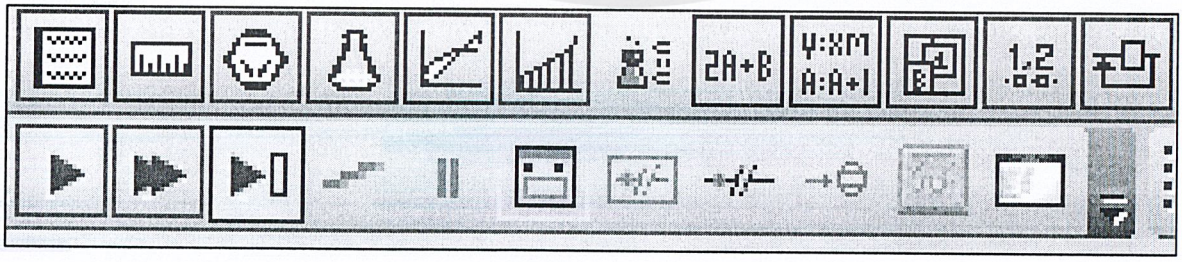

Figure 4.8 Waring from Pro/II Simulation I

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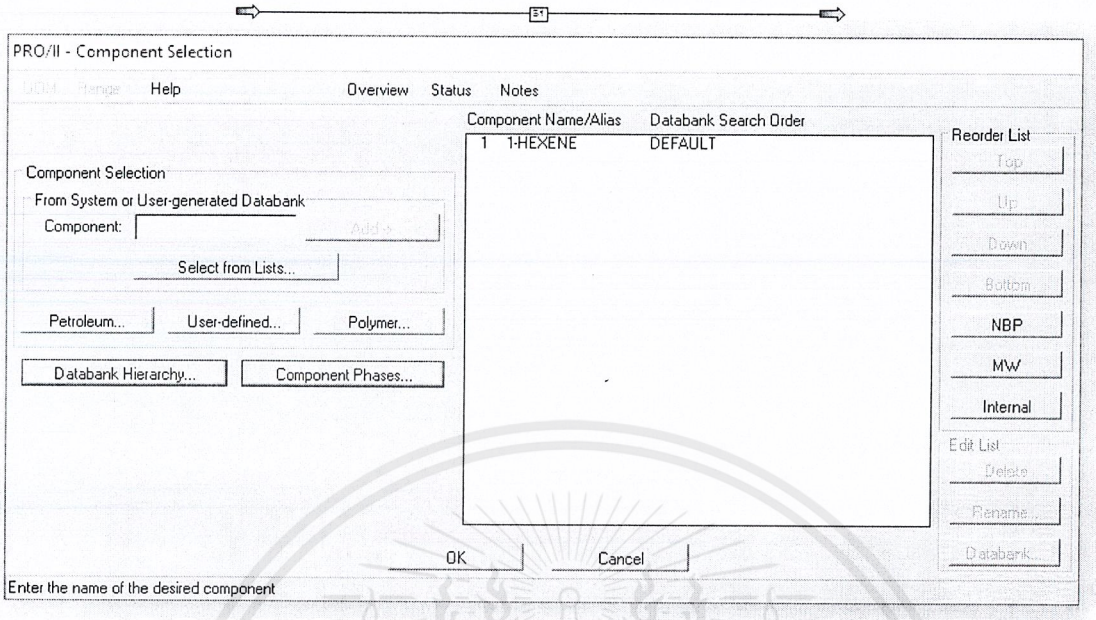

Figure 4.9 Input 1-Hexene into Pro/II Simulation

After that, operating temperature and relieving pressure from template are inputted into thermal condition as shown in Figure 4.10.

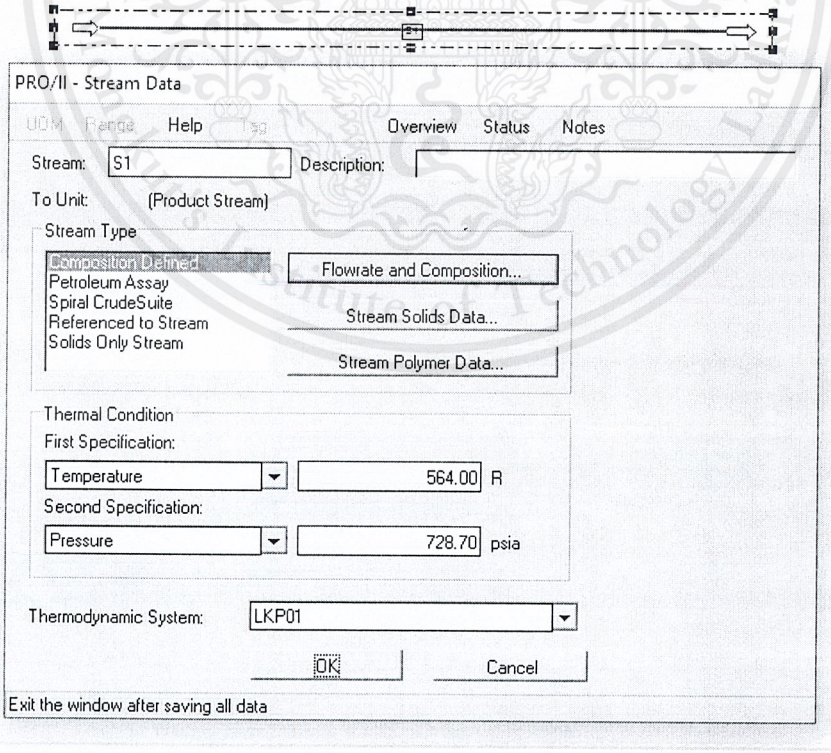

Figure 4.10 Input Operating Temperature and Relieving Pressure into Pro/II Simulation

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We need to open the case study in order to know the step size which is equal to different temperature as an input (see Figure 4.11) and then run the simulation to calculate the physical properties.

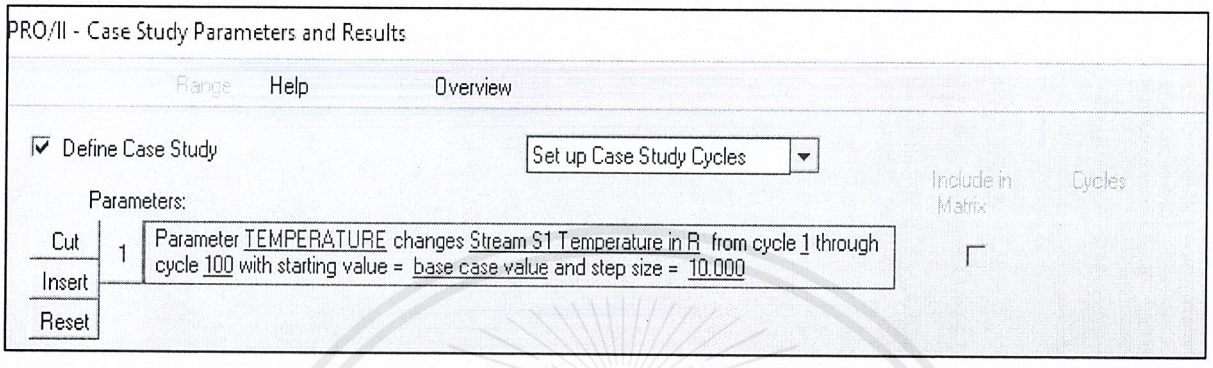

Figure 4.11 Input Different Temperature into Pro/II Simulation

Pro/II simulation calculates 100 cases of physical properties such as density, enthalpy, and entropy by varying temperature and fixing relieving pressure (see Figure 4.12). These physical properties are required to be used in required relief rates calculation. The case study is shown in Appendix C.

Cycles	Pressure (psia)	Temperature (R)	Density (lb/ft^3)	Enthalpy (x 10^6 Btu/h)	Entropy (Btu/lb-R)
1	728.70	564.00	40.061	0.33771	1.56
2	728.70	574.00	39.728	0.38315	1.57
3	728.70	584.00	39.394	0.42902	1.58
4	728.70	594.00	39.059	0.47531	1.59
5	728.70	604.00	38.722	0.52204	1.59
6	728.70	614.00	38.384	0.56920	1.60
7	728.70	624.00	38.044	0.61680	1.61
8	728.70	634.00	37.703	0.66483	1.62
9	728.70	644.00	37.359	0.71330	1.63
10	728.70	654.00	37.013	0.76221	1.64

Figure 4.12 Physical Properties from Pro/II Simulation I

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4.5 Required Relief Rates Calculation

The physical properties from Pro/II simulation are inputted into "Paste" cell and then specific volume, enthalpy, volumetric expansion, volumetric relief rate and mass relief rate are automatically calculated by using equation 3.13-3.15.

Paste Data from Pro/II for Required Relief Rates Calculation

Input Data

Paste	Pressure (psia)	Temperature (R)	Density (lb/ft³)	Enthalpy (x 10⁶ Btu/h)	Entropy (Btu/lb-R)	Basis Flow (lb/h)	Specific Volume (ft³/lb)	Enthalpy (Btu/lb)	ΔV/ΔH (ft³/Btu)	Volumetric Relief Rate (ft³/h)	Mass Relief Rate (lb/h)
1	728.7	564	40.0612	0.3377	1.5620	8416	0.0250	40.13	0.00004	113	4,534
2	728.7	574	39.7281	0.3832	1.5715	8416	0.0252	45.53	0.00004	114	4,543
3	728.7	584	39.3940	0.4290	1.5809	8416	0.0254	50.98	0.00004	116	4,555
4	728.7	594	39.0588	0.4753	1.5903	8416	0.0256	56.48	0.00004	117	4,570
5	728.7	604	38.7222	0.5220	1.5995	8416	0.0258	62.03	0.00004	119	4,589
6	728.7	614	38.3842	0.5692	1.6087	8416	0.0261	67.63	0.00004	120	4,610
7	728.7	624	38.0445	0.6168	1.6179	8416	0.0263	73.29	0.00004	122	4,636
8	728.7	634	37.7028	0.6648	1.6269	8416	0.0265	78.99	0.00004	124	4,666
9	728.7	644	37.3590	0.7133	1.6360	8416	0.0268	84.75	0.00004	126	4,700
10	728.7	654	37.0128	0.7622	1.6449	8416	0.0270	90.57	0.00004	128	4,738
11	728.7	664	36.6639	0.8116	1.6538	8416	0.0273	96.43	0.00004	130	4,782
12	728.7	674	36.3119	0.8614	1.6627	8416	0.0275	102.35	0.00005	133	4,832
13	728.7	684	35.9566	0.9116	1.6715	8416	0.0278	108.32	0.00005	136	4,887
14	728.7	694	35.5975	0.9623	1.6802	8416	0.0281	114.35	0.00005	139	4,950
15	728.7	704	35.2342	1.0135	1.6889	8416	0.0284	120.43	0.00005	142	5,020
16	728.7	714	34.8662	1.0652	1.6976	8416	0.0287	126.57	0.00005	146	5,097
17	728.7	724	34.4931	1.1173	1.7062	8416	0.0290	132.76	0.00005	150	5,184

Figure 4.13 Paste Data from Pro/II Simulation I

The template automatically highlights the row where the maximum volumetric relief rate and mass relief rate are at in orange (see Figure 4.14). According to Figure 3.1B, the maximum orifice area appears in between the maximum volumetric relief rate and mass relief rate. This region is focused for sizing the orifice area of pressure safety valve.

Paste Data from Pro/II for Required Relief Rates Calculation

Input Data

Paste	Pressure (psia)	Temperature (R)	Density (lb/ft³)	Enthalpy (x 10⁶ Btu/h)	Entropy (Btu/lb-R)	Basis Flow (lb/h)	Specific Volume (ft³/lb)	Enthalpy (Btu/lb)	ΔV/ΔH (ft³/Btu)	Volumetric Relief Rate (ft³/h)	Mass Relief Rate (lb/h)
34	728.7	894	26.1609	2.1025	1.8508	8416	0.0382	249.81	0.00015	438	11,447
35	728.7	904	25.3560	2.1706	1.8598	8416	0.0394	257.91	0.00017	510	12,924
36	728.7	914	24.4441	2.2415	1.8691	8416	0.0409	266.34	0.00021	611	14,925
37	728.7	924	23.3833	2.3162	1.8788	8416	0.0428	275.21	0.00026	756	17,688
38	728.7	934	22.1110	2.3962	1.8890	8416	0.0452	284.71	0.00033	967	21,384
39	728.7	944	20.5549	2.4832	1.9000	8416	0.0487	295.05	0.00042	1,238	25,448
40	728.7	954	18.7278	2.5774	1.9118	8416	0.0534	306.24	0.00052	1,507	28,230
41	728.7	964	16.8443	2.6747	1.9238	8416	0.0594	317.81	0.00059	1,718	28,939
42	728.7	974	15.1402	2.7703	1.9356	8416	0.0660	329.16	0.00064	1,860	28,163
43	728.7	984	13.7041	2.8617	1.9467	8416	0.0730	340.03	0.00066	1,939	26,575
44	728.7	994	12.5236	2.9484	1.9571	8416	0.0798	350.33	0.00067	1,968	24,652
45	728.7	1,004	11.5750	3.0306	1.9668	8416	0.0864	360.09	0.00067	1,960	22,682
46	728.7	1,014	10.7942	3.1090	1.9761	8416	0.0926	369.41	0.00066	1,928	20,811
47	728.7	1,024	10.1479	3.1842	1.9848	8416	0.0985	378.34	0.00064	1,883	19,104
48	728.7	1,034	9.6054	3.2568	1.9932	8416	0.1041	386.97	0.00063	1,830	17,582
49	728.7	1,044	9.1434	3.3274	2.0013	8416	0.1094	395.36	0.00061	1,776	16,239

Figure 4.14 Find Out the Maximum Volumetric Relief Rate and the Maximum Mass Relief Rate

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4.6 Physicals Properties for Isentropic Nozzle Mass Flux by Pro/II Simulation

The calculation template shows relieving pressure, temperature and mass relief rate, which are between the maximum volumetric relief rate and the maximum mass relief rate (see Figure 4.14). Relieving pressure and temperature are required as an input for a Pro/II simulation for calculating physical properties such as density, enthalpy, and entropy. These physical properties are required to calculate the mass flux by using equation 3.16. The Pro/II simulation can be opened by pressing "Go to Pro/II simulation" button.

Input Data into Pro/II Simulation — Next

Relieving Pressure = 728.70 psia — Calculating Physical Properties of Fluid = Go to Pro/II Simulation

Number of Required Cases to Simulate by Pro/II Simulation

Cases	Temperature (R)	Mass Relief Rate (lb/h)	Mass Flux (lb/h-in^2)	Orifice Area (in^2)	Status
1	964	28,939			
2	974	28,163			
3	984	26,575			
4	994	24,652			

Figure 4.15 Input Data into Pro/II Simulation II

Pro/II simulation shows the red rectangles and warns that there is no fluid in this file (see Figure 4.16). Therefore, 1-hexene is added into component selection as shown in Figure 4.17. This Pro/II simulation file is not the same as previous file.

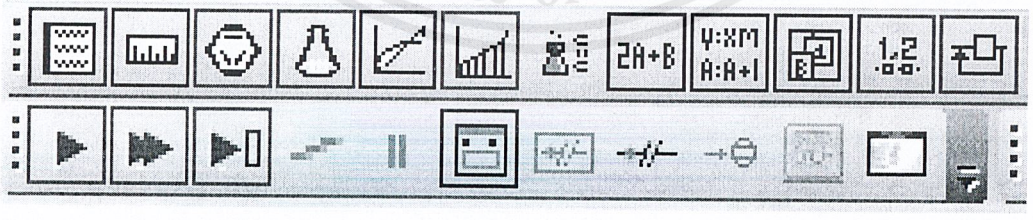

Figure 4.16 Waring from Pro/II Simulation II

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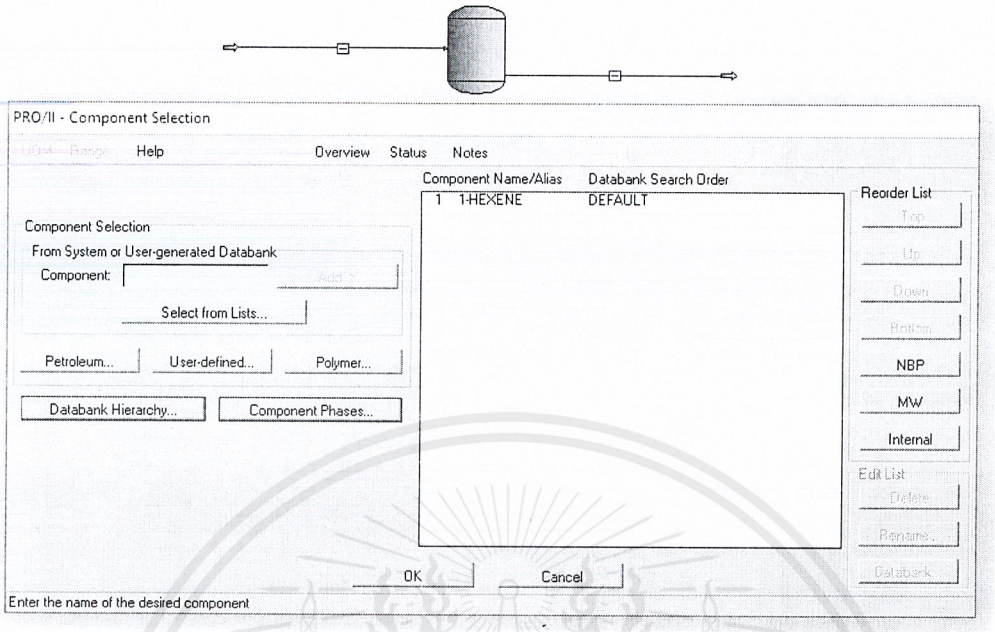

Figure 4.17 Input 1-Hexene into Pro/II Simulation II

After that, temperature, which is the first case, and relieving pressure (see Figure 4.15) are inputted into thermal condition of upstream line as shown in Figure 4.18.

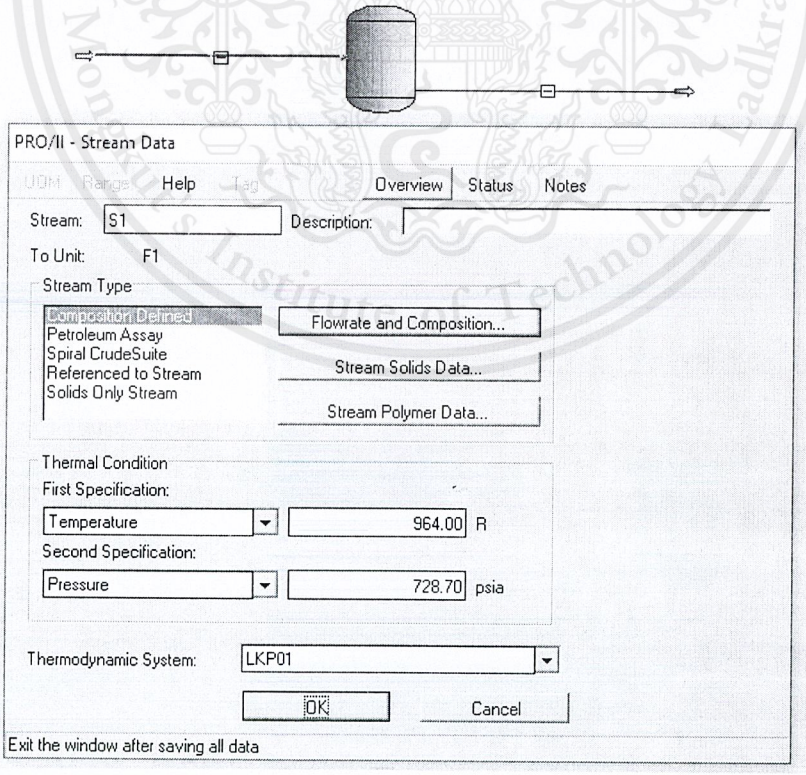

Figure 4.18 Input Operating Temperature and Relieving Pressure into Upstream Line

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Relieving pressure is inputted in flash drum as shown in Figure 4.18 then running Pro/II simulation in order to calculate physical properties which are necessary in isentropic nozzle mass flux calculation (see Figure 4.19). The case study is shown in Appendix C.

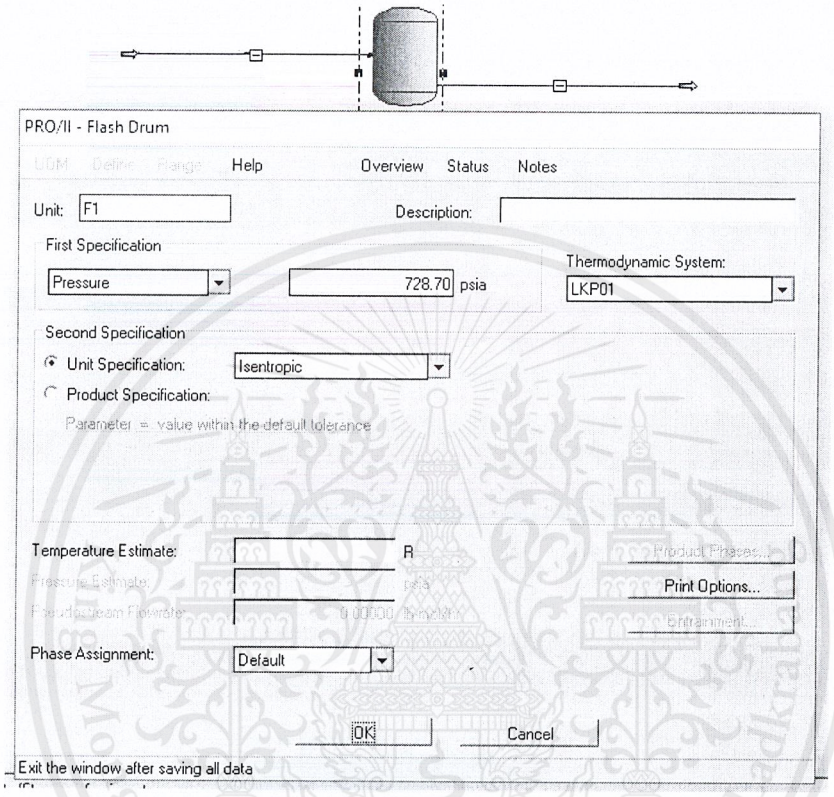

Figure 4.19 Input Relieving Pressure into Flash Drum

Cycles	Pressure (psia)	Temperature (R)	Density (lb/ft^3)	Enthalpy (x 10^6 Btu/h)	Entropy (Btu/lb-R)
1	728.70	964.00	16.844	2.6747	1.92
2	721.41	963.27	16.699	2.6740	1.92
3	714.13	962.52	16.551	2.6733	1.92
4	706.84	961.75	16.400	2.6727	1.92
5	699.55	960.96	16.245	2.6720	1.92
6	692.27	960.15	16.087	2.6713	1.92
7	684.98	959.32	15.925	2.6706	1.92
8	677.69	958.47	15.760	2.6698	1.92
9	670.40	957.59	15.591	2.6691	1.92
10	663.12	956.69	15.419	2.6684	1.92

Figure 4.20 Physical Properties from Pro/II Simulation II

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4.7 Isentropic Nozzle Mass Flux Calculation

The physical properties from Pro/II simulation are inputted into "Paste" cell (see Figure 4.21). By pressing the "Calculation" button, specific volume, enthalpy and mass flux are automatically calculated.

Input Data

Calculation

*Paste Data from Pro/II Simulation and then Pressing "Calculation" Case by Case

Paste	Pressure (psia)	Temperature (R)	Density (lb/ft^3)	Enthalpy (x 10^5 Btu/h)	Entropy (Btu/lb-R)	Basis Flow (lb/h)	Specific Volume (ft^3/lb)	Enthalpy (Btu/lb)	Mass Flux ($lb/h\text{-}in^2$)
1	728.70	964.00	16.8443	2.6747	1.9238	8,416			
2	721.41	963.27	16.6994	2.6740	1.9238	8,416			
3	714.13	962.52	16.5513	2.6733	1.9238	8,416			
4	706.84	961.75	16.4000	2.6727	1.9238	8,416			
5	699.55	960.96	16.2453	2.6720	1.9238	8,416			
6	692.27	960.15	16.0871	2.6713	1.9238	8,416			
7	684.98	959.32	15.9255	2.6706	1.9238	8,416			
8	677.69	958.47	15.7602	2.6698	1.9238	8,416			
9	670.40	957.59	15.5913	2.6691	1.9238	8,416			
10	663.12	956.69	15.4185	2.6684	1.9238	8,416			
11	655.83	955.76	15.2419	2.6676	1.9238	8,416			
12	648.54	954.81	15.0613	2.6669	1.9238	8,416			
13	641.26	953.83	14.8769	2.6661	1.9238	8,416			
14	633.97	952.82	14.6882	2.6654	1.9238	8,416			
15	626.68	951.79	14.4952	2.6646	1.9238	8,416			
16	619.40	950.72	14.2978	2.6638	1.9238	8,416			
17	612.11	949.61	14.0961	2.6630	1.9238	8,416			
18	604.82	948.48	13.8898	2.6622	1.9238	8,416			
19	597.53	947.31	13.6790	2.6614	1.9238	8,416			
20	590.25	946.10	13.4635	2.6605	1.9238	8,416			

Figure 4.21 Paste Data from Pro/II Simulation

The choke condition can be found the mass flux. The template automatically highlights the maximum mass flux in orange (see Figure 4.22).

Input Data

Calculation

*Paste Data from Pro/II Simulation and then Pressing "Calculation" Case by Case

Paste	Pressure (psia)	Temperature (R)	Density (lb/ft^3)	Enthalpy (x 10^6 Btu/h)	Entropy (Btu/lb-R)	Basis Flow (lb/h)	Specific Volume (ft^3/lb)	Enthalpy (Btu/lb)	Mass Flux ($lb/h\text{-}in^2$)
22	575.67	943.56	13.0181	2.6588	1.9238	8,416	0.0768	315.92	100,094
23	568.39	942.23	12.7881	2.6579	1.9238	8,416	0.0782	315.81	101,011
24	561.10	940.85	12.5532	2.6570	1.9238	8,416	0.0797	315.71	101,771
25	553.81	939.43	12.3132	2.6561	1.9238	8,416	0.0812	315.60	102,371
26	546.53	937.95	12.0681	2.6552	1.9238	8,416	0.0829	315.49	102,818
27	539.24	936.43	11.8178	2.6542	1.9238	8,416	0.0846	315.37	103,109
28	531.95	934.85	11.5623	2.6533	1.9238	8,416	0.0865	315.26	103,245
29	524.66	933.21	11.3016	2.6523	1.9238	8,416	0.0885	315.14	103,225
30	517.38	931.52	11.0357	2.6513	1.9238	8,416	0.0906	315.02	103,048
31	510.09	929.77	10.7648	2.6502	1.9238	8,416	0.0929	314.90	102,722
32	502.80	927.97	10.4896	2.6492	1.9238	8,416	0.0953	314.77	102,248
33	495.52	926.11	10.2110	2.6481	1.9238	8,416	0.0979	314.64	101,642
34	488.23	924.20	9.9304	2.6469	1.9238	8,416	0.1007	314.51	100,937
35	480.94	922.25	9.6487	2.6458	1.9238	8,416	0.1036	314.37	100,082
36	473.66	920.27	9.3681	2.6446	1.9238	8,416	0.1067	314.23	99,160

Figure 4.22 Find Out the Maximum Mass Flux

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4.8 Orifice Area Calculation and Relief Valve Size Selection

The template automatically calculates the orifice area by using equation 3.17 and shows the message box to inform that it has to calculate all cases (see Figure 4.23). Therefore, we have to turn back to calculate mass flux and orifice area in the next temperature.

Number of Required Cases to Simulate by Pro/II Simulation

Cases	Temperature (R)	Mass Relief Rate (lb/h)	Mass Flux (lb/h-in^2)	Orifice Area (in^2)	Status
1	964	28,939	103,245	0.3298	DONE
2	974	28,163			
3	984	26,575			
4	994	24,652			

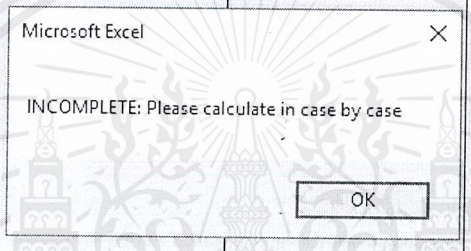

Figure 4.23 Orifice Area Calculation (Incomplete)

If the orifice area is calculated all cases, the massage box pops up to inform the user that the calculation is complete (see Figure 4.24).

Number of Required Cases to Simulate by Pro/II Simulation

Cases	Temperature (R)	Mass Relief Rate (lb/h)	Mass Flux (lb/h-in^2)	Orifice Area (in^2)	Status
1	964	28,939	103,245	0.3298	DONE
2	974	28,163	94,811	0.3495	DONE
3	984	26,575	89,137	0.3508	DONE
4	994	24,652	85,322	0.3399	DONE

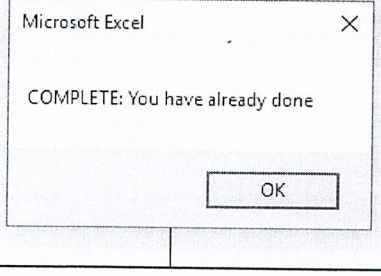

Figure 4.24 Orifice Area Calculation (Complete)

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Final results are relieving pressure, relieving temperature, mass relief rate, required orifice area, selected orifice area and selected orifice type.

Relieving Pressure	=	714.00	psig
Relieving Temperature	=	524.33	°F
Mass Relief Rate	=	26,575	lb/h
Required Orifice Area	=	0.3508	in^2
Selected Orifice Area	=	0.503	in^2
Selected Orifice Type	=	G	
Note: Please Check Material for Sizing of Pressure Safety Valve According to API 526		API 526	

Graph

Figure 4.25 Final Results

The Figure 4.26 explains the reason why we need to determine this region because the maximum orifice area appears in between the maximum volumetric relief rate and the maximum mass relief rate. This Figure 4.26 is similar to Figure 3.2.

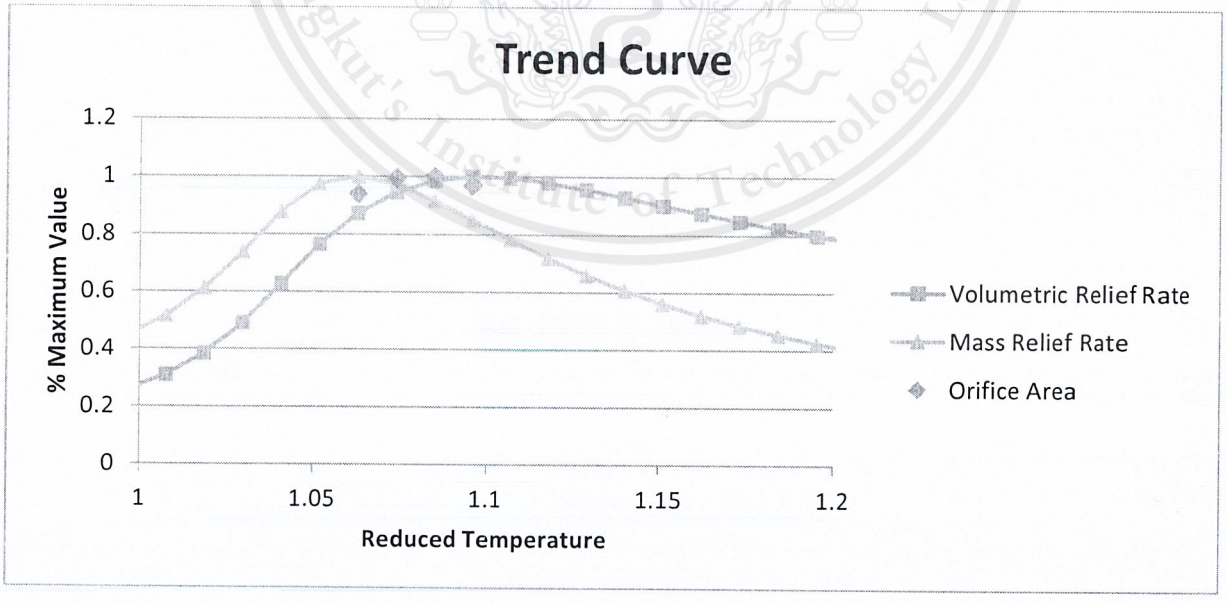

Figure 4.26 Trend curve of case study

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Table 4.1 Calculation Design Results from 1-Hexene

Methods	Required Orifice Area (in^2)	% Deviation	Selected Orifice Area (in^2)	Selected Orifice Type
Aspen Hysys Simulation	0.3711	-	0.503	G
PSV Calculation Template	0.3508	5.53	0.503	G
API 521 Recommended Method	1.011	172.43	1.287	J

Table 4.1 shows the calculation design results from three methods including Aspen Hysys Simulation, PSV calculation template and API 521 recommended method. Aspen Hysys Simulation and API 521 recommended method are shown in Appendix D. The orifice area between Aspen Hysys database (simulation) and Pro/II database (Template) is quite similiar and the selected orifice type is the same. However, the result from the API 521 recommended method is quite larger than the results of the other methods.

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CHAPTER V

CONCLUSION

The reliable method for sizing of pressure safety valve for 1-hexene at supercritical region in fire case is the thermodynamic principles method. For API 521 recommended method, the calculated orifice area is larger than necessary. The percent deviation of the orifice area by the calculation templates and by Aspen Hysys is 5%, and thus the PSV calculation templates are more reliable for calculating the orifice area than API 521 recommended method. The resulting orifice area and the orifice type are the same (0.503, G-type). The materials for sizing pressure safety valve can be found from Appendix F.

SUGGESTIONS

Lee-Kesler EOS, which is used in Pro/II simulation (Version 9.3) to calculate the physical properties of 1-hexene in this project, is not recommended for hydrocarbons which are heavier than C_8. However, there are no suitable equations of state except Lee-Kesler to calculate the physical properties of the fluid at supercritical region. Although Soave-Redlich-Kwong (SRK EOS) is recommended for supercritical region as stated in the phase equilibria in Walas' Chemical Engineering Textbook, there are some errors in fluid density nearby the critical region in Pro/II simulation. The recommended method is generalized volume translation SRK EOS (VTSRK EOS). This method is modified from SRK EOS and it may solve the problem. However, there is no VTSRK EOS in Pro/II simulation. It is necessary to provide the templates in order to calculate the physical properties of heavy hydrocarbons at the supercritical region instead of using Pro/II simulation.

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APPENDIX

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APPENDIX A
Raw Data

Table A.1 Required Input Data [TTCL Plc., 2016]

Parameters	Required Data
Fluid	1-Hexene
Set Pressure (kg/cm^2g)	41.50
Operating Temperature (°C)	40.00
Vessel Type	Vertical
Head Type	2:1 Ellipsoidal
Diameter (m)	1.90
Vessel TL/TL (m)	8.13
Liquid Level (m)	Full
Elevation (m)	1.39
Critical Temperature of Fluid (R)	907.25
Critical Pressure of Fluid (psia)	455.40

Table A.2 Environmental Factor [API Standard 521, 2014]

Type of Equipment		Environment Factor *F*
Bare vessel		1.0
Insulated vessel with insulation conductance values (i.e. insulation therma conductivity divided by thickness) for fire exposure conditions in $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$)	22.71 (4)	0.3
	11.36 (2)	0.15
	5.68 (1)	0.075
	3.80 (0.67)	0.05
	2.84 (0.5)	0.0376
	2.27 (0.4)	0.03
	1.87 (0.33)	0.026
Water application facilities, on bare vessel		1.0
Depressurizing and emptying facilities		1.0
Earth-covered storage		0.03
Below-grade storage		0.00

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Table A.3 Determination of Portion of Liquid Level [API Satndard 521, 2014]

Class of Vessel	Portion of Liquid Inventory	Remarks
Liquid-full, such as treaters	All up to the height of 7.6 m (25 ft)	—
Surge drums, knockout drums, process vessels	Normal operating level up to the height of 7.6 m (25 ft)	—
Fractionating columns	Normal level in bottom plus liquid holdup from all trays dumped to the normal level in the column bottom; total wetted surface up to the height of 7.6 m (25 ft)	Level in reboiler is to be included if the reboiler is an integral part of the column
Working storage	Maximum inventory level up to the height of 7.6 m (25 ft) (portions of the wetted area in contact with foundations or the ground are normally excluded)	For low-pressure [i.e. <103 kPa (15 psig)] storage tanks and process tanks, see API 2000
Spheres and spheroids	Up to the maximum horizontal diameter or up to the height of 7.6 m (25 ft), whichever is greater	—

Table A.4 Standard Effective Orifice Areas and Letter Designations [API Standard 526, 2002]

Designation	Effective Orifice Area (in^2)
D	0.110
E	0.10 6
F	0.307
G	0.503
H	0.785
J	1.287
K	1.838
L	2.853
M	3.60
N	4.34
P	6.38
Q	11.05
R	16.00
T	26.00

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APPENDIX B
EXAMPLE OF CALCULATION

1. Relieving Pressure Calculation

$$P_{Relieving}\ (psia) = P_{Set} \times 1.21 + P_a \quad (3.1)$$

$$= 590.25\ psig \times 1.21 + 14.7 psia$$

$$= 728.70\ psia$$

2. Wetted Surface Area Calculation

2.1 Wetted Level

$$\text{W (m)} = F - E - H \quad (B.1)$$

$$= 7.6\ m - 1.39\ m - 0.475\ m$$

$$= 5.735\ \text{m}$$

2.2 Wetted Surface Area

$$\text{A (ft)} = A_C + A_W \quad (B.2)$$

$$= \pi \times D \times W + \frac{\pi \times D^2}{8}\left(2 + \frac{1}{4\varepsilon}\ln\left(\frac{2\varepsilon+2}{2-\sqrt{3}}\right)\right)$$

$$= \frac{22}{7} \times 1.9\ m \times 5.735\ m + \frac{22}{7} \times \frac{1.9^2}{8} m^2 \left(2 + \frac{1}{4 \times 0.866}\ln\left(\frac{2 \times 0.866 + 2}{2-\sqrt{3}}\right)\right)$$

$$= 38.16\ m^2 \times 10.739\ \frac{\text{ft}^2}{m^2}$$

$$= 410.74\ ft^2$$

3. Heat Absorption Calculation

For Drainage and Firefighting System

$$\dot{Q}\ (Btu/h) = 21{,}000 \times f \times A^{0.82} \quad (3.11)$$

$$= 21{,}000 \times 1\ \frac{Btu}{h \cdot ft^2} \times 410.74^{0.82}\ ft^2$$

$$= 2{,}919{,}762\ Btu/h$$

4. Physical Properties Calculation

4.1 Different Temperature

$$T_{diff}\ (R) = \frac{T_{wall} - T_O}{n} \quad (B.3)$$

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$$= \frac{1560\,R - 564\,R}{100}$$

$$= 9.96\ \text{R}$$

This value is rounded up easily to input intó Pro/II simulation.

$$= 10\ \text{R}$$

where

T_{wall} = The Maximum Wall Temperature According to API Standard 521 (R)

T_O = Operating Temperature (R)

n = Iterative Number

4.2 Specific Volume at 564 R and 728.7 psia

$$\hat{V}\ (ft^3/lb) = \frac{1}{D}$$

$$= \frac{1}{40.061}\frac{ft^3}{lb}$$

$$= 0.0250\ ft^3/lb$$

4.3 Enthalpy at 564 R and 728.7 psia

$$\hat{H}\ (Btu/lb) = \frac{\dot{H}}{\dot{m}}$$

$$= 0.3377\times10^6\frac{Btu}{h} \times \frac{1}{8416}\frac{h}{lb}$$

$$= 40.13\ Btu/lb$$

4.4 Volumetric Expansion

Specific Volume and Enthalpy at 564 and 728.7 psia

$\hat{V}_{T_1}$ = $0.0250\ ft^3/lb$

$\hat{H}_{T_1}$ = $40.13\ Btu/lb$

Specific Volume and Enthalpy at 574 and 728.7 psia

$\hat{V}_{T_2}$ = $0.0252\ ft^3/lb$

$\hat{H}_{T_2}$ = $45.53\ Btu/lb$

$$\frac{\Delta\hat{V}}{\Delta\hat{H}}\ (ft^3/Btu) = \frac{(\hat{V}_{T_2} - \hat{V}_{T_1})}{(\hat{H}_{T_2} - \hat{H}_{T_1})} \qquad (3.13)$$

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$$\frac{\Delta\hat{V}}{\Delta\hat{H}} = \frac{(0.0252 - 0.0250)ft^3/lb}{(45.53 - 40.13)\ Btu/lb}$$

$$= 3.8766 \times 10^{-5}\ ft^3/Btu$$

4.5 Volumetric Relief Rate at 564 R and 728.7 psia

$$\dot{V}\ (ft^3/h) = \dot{Q} \times \frac{\Delta\hat{V}}{\Delta\hat{H}} \quad (3.14)$$

$$= 2{,}919{,}762 \frac{Btu}{h} \times 3.8766 \times 10^{-5} \frac{ft^3}{Btu}$$

$$= 113\ ft^3/h$$

4.6 Mass Relief Rate at 564 R and 728.7 psia

$$\dot{m}\ (lb/h) = \frac{\dot{V}}{\hat{V}_{T_1}} \quad (3.15)$$

$$= 113\ \frac{ft^3}{h} \times \frac{1}{0.0250}\frac{lb}{ft^3}$$

$$= 4{,}534\ lb/h$$

Isentropic Nozzle Mass Flux Calculation

Enthalpy at Upstream Line

$$\hat{H}_a = 340.03\ Btu/lb$$

Enthalpy and Specific Volume at Downstream Line

$$\hat{H}_b = 336.02\ Btu/lb$$

$$\hat{V}_b = 0.1158\ ft^3/lb$$

$$G\ (lb/h \cdot in^2) = \frac{\sqrt{2(\hat{H}_a - \hat{H}_b)}}{\hat{V}_b} \times 3{,}955.77 \quad (3.16)$$

$$= \frac{\sqrt{2(340.03\ Btu/lb - 336.02\ Btu/lb)}}{0.1158\ ft^3/lb} \times 3{,}955.77$$

$$= 89{,}137\ lb/h \cdot in^2$$

Orifice Area Calculation

$$A\ (in^2) = \frac{\dot{m}}{GK_dK_c} \quad (3.17)$$

$$= \frac{26575\ lb/h}{89{,}137\ lb/h \cdot in^2 \times 0.85 \times 1}$$

$$= 0.3508\ in^2$$

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APPENDIX C
PRO/II SIMULATION SETTING (VERSION 9.3)

1. Physical Properties Calculation

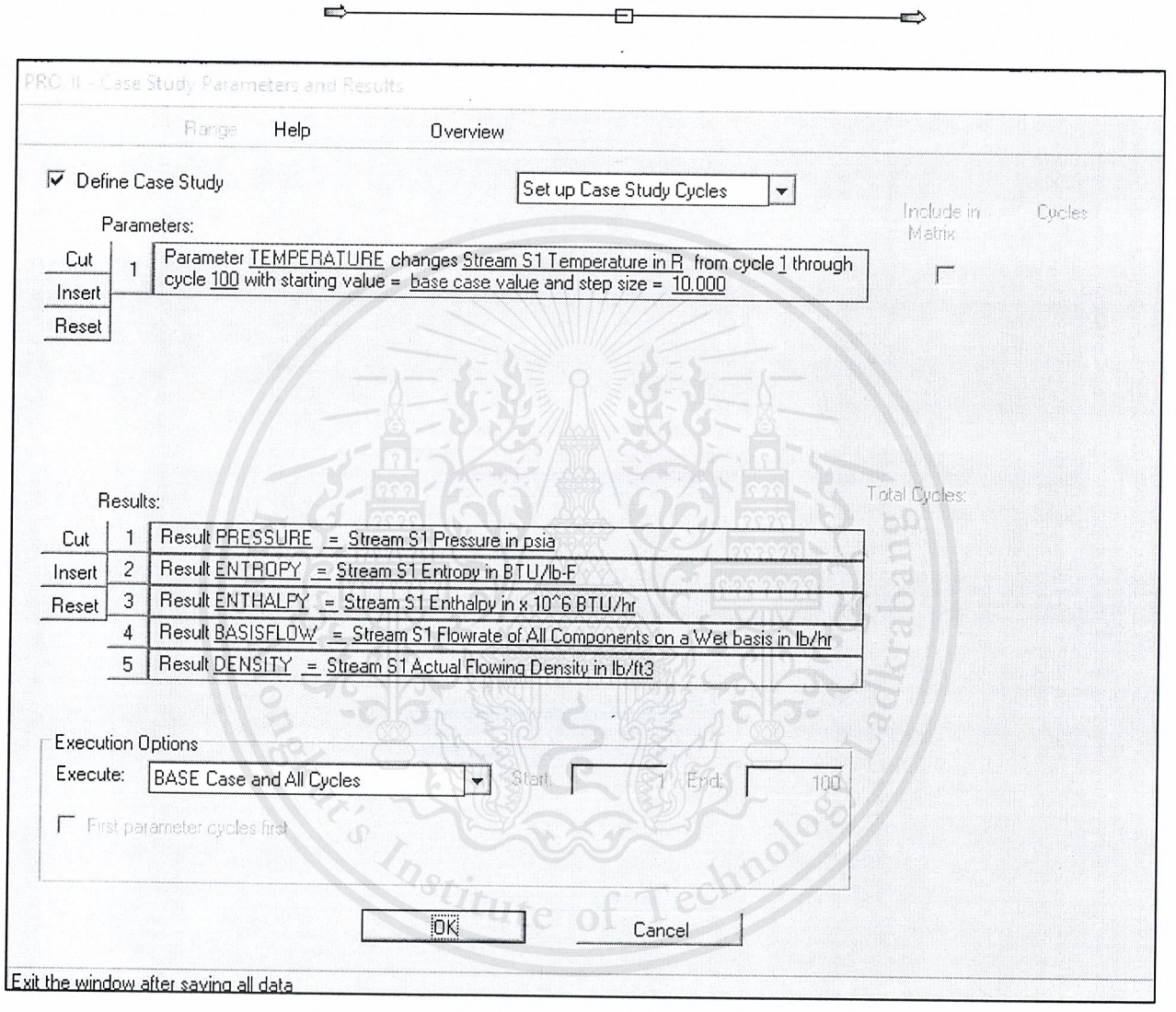

Figure C.1 The Case Study of Physical Properties Calculation

The parameter, which is varied, is only temperature. The cycle of calculation is set 100 cycles. The step size of case study depends on different temperature in Microsoft Excel. The results are pressure, entropy, enthalpy, basis flow, and density. The order of results must not be changed because it relates to formula in Microsoft Excel. An Appendix B shows an example of calculation by using these results.

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2. Isentropic Nozzle Mass Flux Calculation

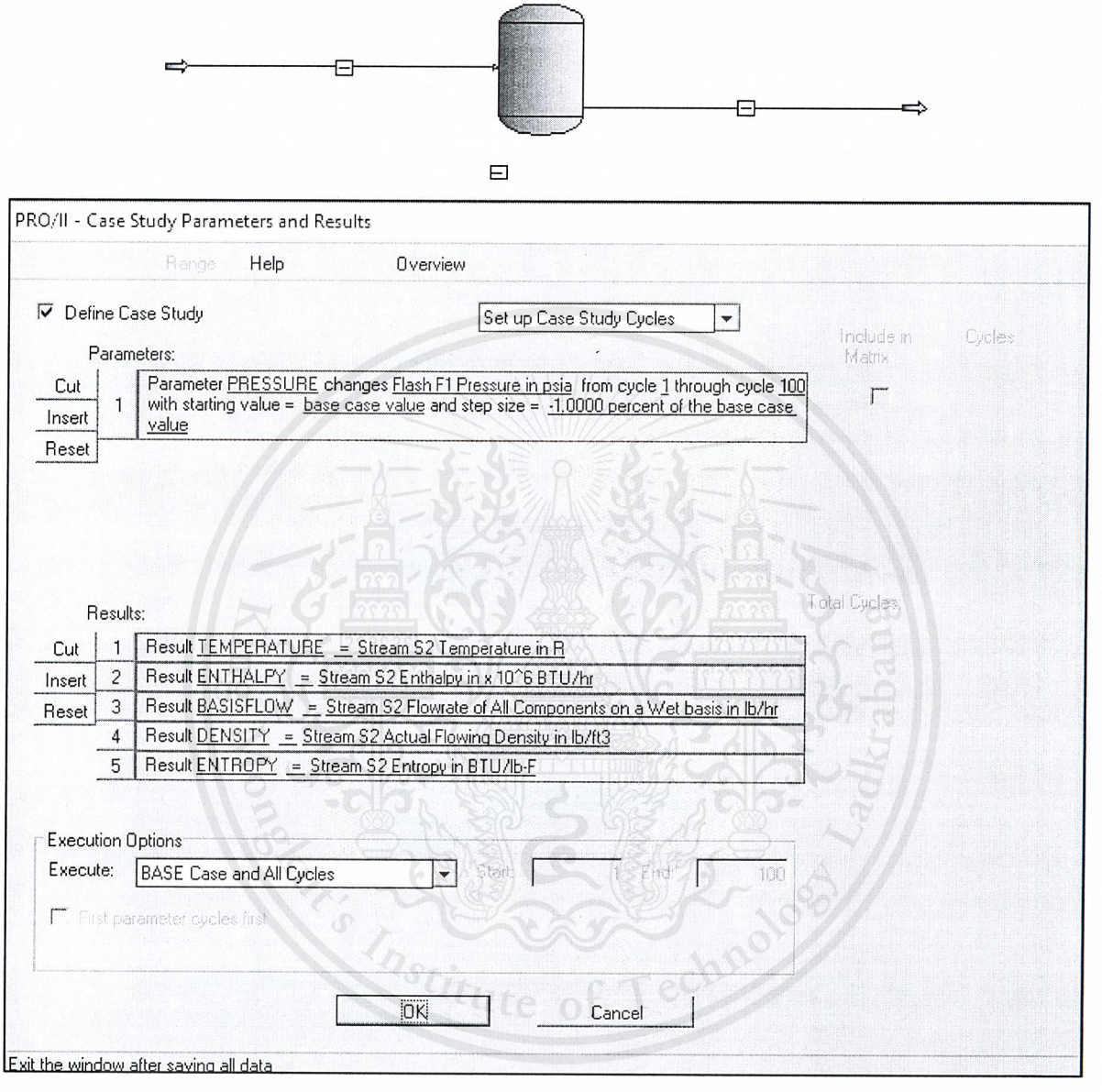

Figure C.2 The Case Study of Isentropic Nozzle Mass Flux Calculation

The parameter, which is varied, is only pressure in flash drum. The flash drum is used because this unit can select an isentropic condition. The cycle of calculation is set 100 cycles. The step size of case study is 1% decrease of pressure in flash drum. The results of downstream line are temperature, enthalpy entropy, basis flow, and density. The order of results must not be changed because it relates to formula in Microsoft Excel. An Appendix B shows an example of calculation by using these results.

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APPENDIX D
OTHER METHODS

1. Aspen Hysys Simulation (Version 8.8)

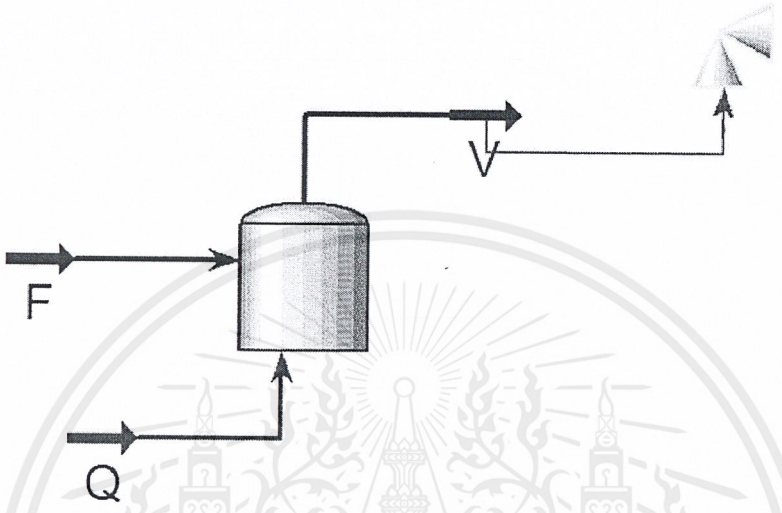

Figure D.1 The Flowsheet of Aspen Hysys

F is represented as 1-Hexene liquid feed. Q is represented as the heat input from fire. V is represented as the stream line that relieves to pressure safety valve.

Table D.1 Results of Aspen Hysys Simulation

Parameters	Values
Relieving Pressure (psig)	714.2
Relieving Temperature (°F)	524.4
Mass Relief Rate (lb/h)	27,360
Required Orifice Area (in^2)	0.3711
Selected Orifice Area (in^2)	0.503
Selected Orifice Type	G

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2. API 521 Recommended Method (API Standard 521, 2014)

The discharge area for pressure safety valve on vessels containing supercritical fluid, gases or vapors exposed to open fires can be estimated using Equation (D.1). In certain cases, the normal operating pressure can be below the thermodynamic critical conditions but the relieving pressure is supercritical. In such cases, the guidance below can be used to size the relief device. In the use of Equation (D.1), This equation is related to ideal gas law.

$$A = \frac{F' \cdot A'}{\sqrt{p_1}} \quad \text{(D.1)}$$

where

A = Required Orifice Area (in^2)

A' = Exposed Surface Area of Vessel (ft^2)

p_1 = Relieving Pressure(psia)

F' = If insufficient information is available to use then F ' = 0.045.

Note: The phase of 1-Hexene is liquid phase at normal operation, therefore, F' must be assumed as per API Standard 521.

Table D.2 Values of API 521 Recommended Method

Parameters	Values
Expose Surface Area of Vessel (ft^2)	606.55
Relieving Pressure (psia)	728.7
F'	0.045
Required Orifice Area (in^2)	1.011
Selected Orifice Area (in^2)	1.287
Selected Orifice Type	J

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APPENDIX F
EFFECTIVE ORIFICE AREA AND LETTER DESIGNATION
[API Standard 526, 200]

Table F.1 Spring-loaded Pressure Relief Valves "D" Orifice (Effective Orifice Area = 0.110 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	− 450°F to − 76°F	− 75°F to − 21°F	− 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, − 20°F to 800°F Inclusive													
Carbon Steel	1D2	150	150			285	185	80		285	230	$4^1/_8$	$4^1/_2$
	1D2 (4)	300	150			285	285	285		285	230	$4^1/_8$	$4^1/_2$
	1D2	300	150			740	615	410		285	230	$4^1/_8$	$4^1/_2$
	1D2	600	150			1480	1235	825		285	230	$4^1/_8$	$4^1/_2$
	$1^1/_2$D2	900	300			2220	1845	1235		600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D2	1500	300			3705	3080	2060		600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D3	2500	300			6000	5135	3430		740	500	$5^1/_2$	7
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	1D2	300	150					510	215	285	230	$4^1/_8$	$4^1/_2$
	1D2	600	150					1015	430	285	230	$4^1/_8$	$4^1/_2$
	$1^1/_2$D2	900	300					1525	650	600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D2	1500	300					2540	1080	600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D3	2500	300					4230	1800	740	500	$5^1/_2$	7
Temperature Range, − 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	1D2	150	150	275	275	275	180	80	20	275	230	$4^1/_8$	$4^1/_2$
	1D2 (4)	300	150	275	275	275	180	80	20	275	230	$4^1/_8$	$4^1/_2$
	1D2	300	150	720	720	720	495	420	350	275	230	$4^1/_8$	$4^1/_2$
	1D2	600	150	1440	1440	1440	990	845	700	275	230	$4^1/_8$	$4^1/_2$
	$1^1/_2$D2	900	300	2160	2160	2160	1485	1265	1050	600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D2	1500	300	3600	3600	3600	2480	2110	1750	600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D3	2500	300	4000	6000	6000	4130	3520	2915	720	500	$5^1/_2$	7
Temperature Range, − 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	1D2	150	150			140	140	140		140	140	$4^1/_8$	$4^1/_2$
	1D2 (4)	300	150			140	140	140		140	140	$4^1/_8$	$4^1/_2$
	1D2	300	150			360	360	360		140	140	$4^1/_8$	$4^1/_2$
	1D2	600	150			720	720	720		140	140	$4^1/_8$	$4^1/_2$
Temperature Range, − 20°F to 300°F Inclusive													
Alloy 20 (6)	1D2	150	150			230	180			230	230	$4^1/_8$	$4^1/_2$
	1D2 (4)	300	150			230	180			230	230	$4^1/_8$	$4^1/_2$
	1D2	300	150			600	465			230	230	$4^1/_8$	$4^1/_2$
	1D2	600	150			1200	930			230	230	$4^1/_8$	$4^1/_2$
	$1^1/_2$D2	900	300			1800	1395			600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D2	1500	300			3000	2330			600	500	$4^1/_8$	$5^1/_2$
	$1^1/_2$D3	2500	300			5000	3880			600	500	$5^1/_2$	7

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Table F.2 Spring-loaded Pressure Relief Valves "E" Orifice (Effective Orifice Area = 0.196 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	1E2	150	150			285	185	80		285	230	4 1/8	4 1/2
	1E2 (4)	300	150			285	285	285		285	230	4 1/8	4 1/2
	1E2	300	150			740	615	410		285	230	4 1/8	4 1/2
	1E2	600	150			1480	1235	825		285	230	4 1/8	4 1/2
	1 1/2E2	900	300			2220	1845	1235		600	500	4 1/8	5 1/2
	1 1/2E2	1500	300			3705	3080	2060		600	500	4 1/8	5 1/2
	1 1/2E3	2500	300			6000	5135	3430		740	500	5 1/2	7
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	1E2	300	150					510	215	285	230	4 1/8	4 1/2
	1E2	600	150					1015	430	285	230	4 1/8	4 1/2
	1 1/2E2	900	300					1525	650	600	500	4 1/8	5 1/2
	1 1/2E2	1500	300					2540	1080	600	500	4 1/8	5 1/2
	1 1/2E3	2500	300					4230	1800	740	500	5 1/2	7
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	1E2	150	150	275	275	275	180	80	20	275	230	4 1/8	4 1/2
	1E2 (4)	300	150	275	275	275	180	80	20	275	230	4 1/8	4 1/2
	1E2	300	150	720	720	720	495	420	350	275	230	4 1/8	4 1/2
	1E2	600	150	1440	1440	1440	990	845	700	275	230	4 1/8	4 1/2
	1 1/2E2	900	300	2160	2160	2160	1485	1265	1050	600	500	4 1/8	5 1/2
	1 1/2E2	1500	300	3600	3600	3600	2480	2110	1750	600	500	4 1/8	5 1/2
	1 1/2E3	2500	300	4000	6000	6000	4130	3520	2 15	720	500	5 1/2	7
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	1E2	150	150			140	140	140		140	140	4 1/8	4 1/2
	1E2 (4)	300	150			140	140	140		140	140	4 1/8	4 1/2
	1E2	300	150			360	360	360		140	140	4 1/8	4 1/2
	1E2	600	150			720	720	720		140	140	4 1/8	4 1/2
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	1E2	150	150			230	180			230	230	4 1/8	4 1/2
	1E2 (4)	300	150			230	180			230	230	4 1/8	4 1/2
	1E2	300	150			600	465			230	230	4 1/8	4 1/2
	1E2	600	150			1200	930			230	230	4 1/8	4 1/2
	1 1/2E2	900	300			1800	1395			600	500	4 1/8	5 1/2
	1 1/2E2	1500	300			3000	2330			600	500	4 1/8	5 1/2
	1 1/2E3	2500	300			5000	3880			600	500	5 1/2	7

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Table F.3 Spring-loaded Pressure Relief Valves "F" Orifice (Effective Orifice Area = 0.307 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, -20°F to 800°F Inclusive													
Carbon Steel	1 1/2F2	150	150			285	185	80		285	230	4 7/8	4 3/4
	1 1/2F2 (4)	300	150			285	285	285		285	230	4 7/8	4 3/4
	1 1/2F2	300	150			740	615	410		285	230	4 7/8	6
	1 1/2F2	600	150			1480	1235	825		285	230	4 7/8	6
	1 1/2F3	900	300			2220	1845	1235		740	500	4 7/8	6 1/2
	1 1/2F3	1500	300			3705	3080	2060		740	500	4 7/8	6 1/2
	1 1/2F3	2500	300			5000	5000	3430		740	500	5 1/2	7
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	1 1/2F2	300	150					510	215	285	230	4 7/8	6
	1 1/2F2	600	150					1015	430	285	230	4 7/8	6
	1 1/2F3	900	300					1525	650	740	500	4 7/8	6 1/2
	1 1/2F3	1500	300					2540	1080	740	500	4 7/8	6 1/2
	1 1/2F3	2500	300					4230	1800	740	500	5 1/2	7
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	1 1/2F2	150	150	275	275	275	180	80	20	275	230	4 7/8	4 3/4
	1 1/2F2 (4)	300	150	275	275	275	180	80	20	275	230	4 7/8	4 3/4
	1 1/2F2	300	150	720	720	720	49 5	420	350	275	230	4 7/8	6
	1 1/2F2	600	150	1440	1440	1440	975	845	700	275	230	4 7/8	6
	1 1/2F3	900	300	2160	2160	2160	1485	1265	1050	600	500	4 7/8	6 1/2
	1 1/2F3	1500	300	2200	3600	3600	2480	2110	1750	600	500	4 7/8	6 1/2
	1 1/2F3	2500	300	3400	5000	5000	4130	3520	29 15	720	500	5 1/2	7
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	1 1/2F2	150	150			140	140	140		140	140	4 7/8	4 3/4
	1 1/2F2 (4)	300	150			140	140	140		140	140	4 7/8	4 3/4
	1 1/2F2	300	150			360	360	360		140	140	4 7/8	6
	1 1/2F2	600	150			720	720	720		140	140	4 7/8	6
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	1 1/2F2	150	150			230	180			230	230	4 7/8	4 3/4
	1 1/2F2 (4)	300	150			230	180			230	230	4 7/8	4 3/4
	1 1/2F2	300	150			600	465			230	230	4 7/8	6
	1 1/2F2	600	150			1200	930			230	230	4 7/8	6
	1 1/2F3	900	300			1800	139 5			600	500	4 7/8	6 1/2
	1 1/2F3	1500	300			3000	2330			600	500	4 7/8	6 1/2
	1 1/2F3	2500	300			5000	3880			600	500	5 1/2	7

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Table F.4 Spring-loaded Pressure Relief Valves "G" Orifice (Effective Orifice Area = 0.503 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	Low Temperature Alloy Steel - 450°F to - 76°F	Carbon Steel or Chrome Alloy Steel - 75°F to - 21°F	Carbon Steel or Chrome Alloy Steel - 20°F to 100°F	Carbon Steel or Chrome Alloy Steel 101°F to 450°F	High Temperature Alloy Steel 451°F to 800°F	High Temperature Alloy Steel 801°F to 1000°F	Outlet Pressure Limit (1) Conventional Valves 100°F	Outlet Pressure Limit (1) Bellows Valves 100°F	Center to Face Dimensions (in.) Inlet	Center to Face Dimensions (in.) Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	1 1/2G3	150	150			285	185	80		285	230	4 7/8	4 3/4
	1 1/2G3	300	150			285	285	285		285	230	4 7/8	4 3/4
	(4)	300	150			740	615	410		285	230	4 7/8	6
	1 1/2G3	600	150			1480	1235	825		285	230	4 7/8	6
	1 1/2G3	900	300			2220	1845	1235		740	470	4 7/8	6 1/2
	1 1/2G3	1500	300			3705	3080	2060		740	470	6 1/8	6 3/4
	2G3	2500	300			3705	3705	3430		740	470	6 1/8	6 3/4
	2G3												
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	1 1/2G3	300	150					510	215	285	230	4 7/8	6
	1 1/2G3	600	150					1015	430	285	230	4 7/8	6
	1 1/2G3	900	300					1525	650	740	470	4 7/8	6 1/2
	2G3	1500	300					2540	1080	740	470	6 1/8	6 3/4
	2G3	2500	300					3705	1800	740	470	6 1/8	6 3/4
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	1 1/2G3	150	150	275	275	275	180	80	20	275	230	4 7/8	4 3/4
	1 1/2G3	300	150	275	275	275	180	80	20	275	230	4 7/8	4 3/4
	(4)	300	150	720	720	720	495	420	350	275	230	4 7/8	6
	1 1/2G3	600	150	1440	1440	1440	975	845	700	275	230	4 7/8	6
	1 1/2G3	900	300	2160	2160	2160	1485	1265	1050	600	470	4 7/8	6 1/2
	1 1/2G3	1500	300	2450	3600	3600	2480	2110	1750	600	470	6 1/8	6 3/4
	2G3	2500	300	2600	3600	3600	3600	3520	29 15	720	470	6 1/8	6 3/4
	2G3												
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	1 1/2G3	150	150			140	140	140		140	140	4 7/8	4 3/4
	1 1/2G3	300	150			140	140	140		140	140	4 7/8	4 3/4
	(4)	300	150			360	360	360		140	140	4 7/8	6
	1 1/2G3	600	150			720	720	720		140	140	4 7/8	6
	1 1/2G3												
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	1 1/2G3	150	150			230	180			230	230	4 7/8	4 3/4
	1 1/2G3	300	150			230	180			230	230	4 7/8	4 3/4
	(4)	300	150			600	465			230	230	4 7/8	6
	1 1/2G3	600	150			1200	930			230	230	4 7/8	6
	1 1/2G3	900	150			1800	139 5			600	470	4 7/8	6 1/2
	1 1/2G3	1500	150			3000	2330			600	470	6 1/8	6 3/4
	2G3	2500	150			5000	3880			600	470	6 1/8	6 3/4
	2G3												

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Table F.5 Spring-loaded Pressure Relief Valves "H" Orifice (Effective Orifice Area = 0.785 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F - 800°F Inclusive													
Carbon Steel	$1\frac{1}{2}$H3	150	150			285	185	80		285	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	$1\frac{1}{2}$H3	300	150			285	285	285		285	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	(4)	300	150			740	615	410		285	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	2H3	600	150			1480	1235	825		285	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	900	150			2220	1845	1235		285	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	1500	300			2750	2750	2060		740	415	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3												
Temperature Range, 801°F - 1000°F Inclusive													
Chrome Molybdenum Steel	2H3	300	150					510	215	285	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	2H3	600	150					1015	430	285	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	900	150					1525	650	285	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	1500	300					2540	1080	740	415	$6\frac{1}{16}$	$6\frac{3}{8}$
Temperature Range, - 450°F - 1000°F Inclusive													
Austenitic Stainless Steel	$1\frac{1}{2}$H3	150	150	275	275	275	180	80	20	275	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	$1\frac{1}{2}$H3	300	150	275	275	275	180	80	20	275	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	(4)	300	150	720	720	720	49 5	420	350	275	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	2H3	600	150	1440	1440	1440	975	845	700	275	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	900	150	1485	2160	2160	1485	1265	1050	600	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	1500	300	1600	2750	2750	2480	2110	1750	600	415	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3												
Temperature Range, - 20°F - 600°F Inclusive													
Nickel/Copper Alloy (5)	$1\frac{1}{2}$H3	150	150			140	140	140		140	140	$5\frac{1}{8}$	$4\frac{7}{8}$
	$1\frac{1}{2}$H3	300	150			140	140	140		140	140	$5\frac{1}{8}$	$4\frac{7}{8}$
	(4)	300	150			360	360	360		140	140	$5\frac{1}{8}$	$4\frac{7}{8}$
	2H3	600	150			720	720	720		140	140	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3												
Temperature Range, - 20°F - 300°F Inclusive													
Alloy 20 (6)	$1\frac{1}{2}$H3	150	150			230	180			230	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	$1\frac{1}{2}$H3	300	150			230	180			230	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	(4)	300	150			600	465			230	230	$5\frac{1}{8}$	$4\frac{7}{8}$
	$1\frac{1}{2}$H3	600	150			1200	930			230	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	900	150			1800	139 5			230	230	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3	1500	300			3000	2330			600	415	$6\frac{1}{16}$	$6\frac{3}{8}$
	2H3												

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Table F.6 Spring-loaded Pressure Relief Valves "J" Orifice (Effective Orifice Area = 1.287 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F - 800°F Inclusive													
Carbon Steel	2J3	150	150			285	185	80		285	230	$5^3/_8$	$4^7/_8$
	2J3 (4)	300	150			285	285	285		285	230	$5^3/_8$	$4^7/_8$
	3J4	300	150			740	615	410		285	230	$7^1/_4$	$7^1/_8$
	3J4	600	150			1480	1235	825		285	230	$7^1/_4$	$7^1/_8$
	3J4	900	150			2220	1845	1235		285	230	$7^1/_4$	$7^1/_8$
	3J4	1500	300			2700	2700	2060		600	230	$7^1/_4$	$7^1/_8$
Temperature Range, 801°F - 1000°F Inclusive													
Chrome Molybdenum Steel	3J4	300	150					510	215	285	230	$7^1/_4$	$7^1/_8$
	3J4	600	150					1015	430	285	230	$7^1/_4$	$7^1/_8$
	3J4	900	150					1525	650	285	230	$7^1/_4$	$7^1/_8$
	3J4	1500	300					2540	1080	600	230	$7^1/_4$	$7^1/_8$
Temperature Range, - 450°F - 1000°F Inclusive													
Austenitic Stainless Steel	2J3	150	150	275	275	275	180	80	20	275	230	$5^3/_8$	$4^7/_8$
	2J3 (4)	300	150	275	275	275	180	80	20	275	230	$5^3/_8$	$4^7/_8$
	3J4	300	150	500	720	720	49 5	420	350	275	230	$7^1/_4$	$7^1/_8$
	3J4	600	150	625	1440	1440	975	845	700	275	230	$7^1/_4$	$7^1/_8$
	3J4	900	150	800	2160	2160	1485	1265	1050	275	230	$7^1/_4$	$7^1/_8$
	3J4	1500	300	800	2700	2700	2480	2110	1750	600	230	$7^1/_4$	$7^1/_8$
Temperature Range, - 20°F - 600°F Inclusive													
Nickel/Copper Alloy (5)	2J3	150	150		140	140	140	140		140	140	$5^3/_8$	$4^7/_8$
	2J3 (4)	300	150		140	140	140	140		140	140	$5^3/_8$	$4^7/_8$
	3J4	300	150		360	360	360	360		140	140	$7^1/_4$	$7^1/_8$
	3J4	600	150		720	720	720	720		140	140	$7^1/_4$	$7^1/_8$
Temperature Range, - 20°F - 300°F Inclusive													
Alloy 20 (6)	2J3	150	150		230	230	180			230	230	$5^3/_8$	$4^7/_8$
	2J3 (4)	300	150		230	230	180			230	230	$5^3/_8$	$4^7/_8$
	3J4	300	150		600	600	465			230	230	$7^1/_4$	$7^1/_8$
	3J4	600	150		1200	1200	930			230	230	$7^1/_4$	$7^1/_8$
	3J4	900	150		1800	1800	139 5			230	230	$7^1/_4$	$7^1/_8$
	3J4	1500	300		3000	3000	2330			600	230	$7^1/_4$	$7^1/_8$

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Table F.7 Spring-loaded Pressure Relief Valves "K" Orifice (Effective Orifice Area = 1.838 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F - 800°F Inclusive													
Carbon Steel	3K4	150	150			285	185	80		285	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4 (4)	300	150			285	285	285		285	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	300	150			740	615	410		285	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	600	150			1480	1235	825		285	200	$7\frac{1}{4}$	$7\frac{1}{8}$
	3K6	900	150			2220	1845	1235		285	200	$7\frac{13}{16}$	$8\frac{1}{2}$
	3K6	1500	300			2220	2220	2060		600	200	$7\frac{3}{4}$	$8\frac{1}{2}$
Temperature Range, 801°F - 1000°F Inclusive													
Chrome Molybdenum Steel	3K4	300	150					510	215	285	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	600	150					1015	430	285	200	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K6	900	150					1525	650	285	200	$7\frac{13}{16}$	$8\frac{1}{2}$
	3K6	1500	300					2220	1080	600	200	$7\frac{3}{4}$	$8\frac{1}{2}$
Temperature Range, - 450°F - 1000°F Inclusive													
Austenitic Stainless Steel	3K4	150	150	275	275	275	180	80	20	275	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4 (4)	300	150	275	275	275	180	80	20	275	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	300	150	525	720	720	49 5	420	350	275	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	600	150	600	1440	1440	975	845	700	275	200	$7\frac{1}{4}$	$7\frac{1}{8}$
	3K6	900	150	600	2160	2160	1485	1265	1050	275	200	$7\frac{13}{16}$	$8\frac{1}{2}$
	3K6	1500	300	750	2220	2220	2480	2110	1750	600	200	$7\frac{3}{4}$	$8\frac{1}{2}$
Temperature Range, - 20°F - 600°F Inclusive													
Nickel/Copper Alloy (5)	3K4	150	150			140	140	140		140	140	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4 (4)	300	150			140	140	140		140	140	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	300	150			360	360	360		140	140	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	600	150			720	720	720		140	140	$7\frac{1}{4}$	$7\frac{1}{8}$
Temperature Range, - 20°F - 300°F Inclusive													
Alloy 20 (6)	3K4	150	150			230	180			230	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4 (4)	300	150			230	180			230	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	300	150			600	465			230	150	$6\frac{1}{8}$	$6\frac{3}{8}$
	3K4	600	150			1200	930			230	200	$7\frac{1}{4}$	$7\frac{1}{8}$
	3K6	900	150			1800	139 5			230	200	$7\frac{13}{16}$	$8\frac{1}{2}$
	3K6	1500	300			3000	2330			600	200	$7\frac{3}{4}$	$8\frac{1}{2}$

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Table F.8 Spring-loaded Pressure Relief Valves "L" Orifice (Effective Orifice Area = 2.853 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	Low Temperature Alloy Steel - 450°F to - 76°F	Carbon Steel or Chrome Alloy Steel - 75°F to - 21°F	Carbon Steel or Chrome Alloy Steel - 20°F to 100°F	Carbon Steel or Chrome Alloy Steel 101°F to 450°F	High Temperature Alloy Steel 451°F to 800°F	High Temperature Alloy Steel 801°F to 1000°F	Outlet Pressure Limit (1) Conventional Valves 100°F	Outlet Pressure Limit (1) Bellows Valves 100°F	Center to Face Dimensions (in.) Inlet	Center to Face Dimensions (in.) Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	3L4	150	150			285	185	80		285	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	3L4 (4)	300	150			285	285	285		285	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	4L6	300	150			740	615	410		285	170	$7\frac{1}{16}$	$7\frac{1}{8}$
	4L6	600	150			1000	1000	825		285	170	$7\frac{1}{16}$	8
	4L6	900	150			1500	1500	1235		285	170	$7\frac{3}{4}$	$8\frac{3}{4}$
	4L6	1500	150					1500		285	170	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	4L6	300	150					510	215	285	170	$7\frac{1}{16}$	$7\frac{1}{8}$
	4L6	600	150					1000	430	285	170	$7\frac{1}{16}$	8
	4L6	900	150					1500	650	285	170	$7\frac{3}{4}$	$8\frac{3}{4}$
	4L6	1500	150					1500	1080	285	170	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	3L4	150	150	275	275	275	180	80	20	275	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	3L4 (4)	300	150	275	275	275	180	80	20	275	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	4L6	300	150	535	720	720	49 5	420	350	275	170	$7\frac{1}{16}$	$7\frac{1}{8}$
	4L6	600	150	535	1000	1000	975	845	700	275	170	$7\frac{1}{16}$	8
	4L6	00	150	700	1500	1500	1485	1265	1050	275	170	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	3L4	150	150			140	140	140		140	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	3L4 (4)	300	150			140	140	140		140	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	4L6	300	150			360	360	360		140	120	$7\frac{1}{16}$	$7\frac{1}{8}$
	4L6	600	150			720	720	720		140	120	$7\frac{1}{16}$	8
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	3L4	150	150			230	180			230	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	3L4 (4)	300	150			230	180			230	100	$6\frac{1}{8}$	$6\frac{1}{2}$
	4L6	300	150			600	465			230	170	$7\frac{1}{16}$	$7\frac{1}{8}$
	4L6	600	150			1200	930			230	170	$7\frac{1}{16}$	8
	4L6	900	150			1800	139 5			230	170	$7\frac{3}{4}$	$8\frac{3}{4}$
	4L6	1500	150			3000	2330			230	170	$7\frac{3}{4}$	$8\frac{3}{4}$

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Table F.9 Spring-loaded Pressure Relief Valves "M" Orifice (Effective Orifice Area = 3.60 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves						Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
				Spring Materials (3)									
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	Low Temperature Alloy Steel - 450°F to - 76°F	Carbon Steel or Chrome Alloy Steel - 75°F to - 21°F	Carbon Steel or Chrome Alloy Steel - 20°F to 100°F	Carbon Steel or Chrome Alloy Steel 101°F to 450°F	High Temperature Alloy Steel 451°F to 800°F	High Temperature Alloy Steel 801°F to 1000°F	Conventional Valves 100°F	Bellows Valves 100°F	Inlet	Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	4M6	150	150			285	185	80		285	80	7	$7^1/_4$
	4M6 (4)	300	150			285	285	285		285	80	7	$7^1/_4$
	4M6	300	150			740	615	410		285	160	7	$7^1/_4$
	4M6	600	150			1100	1100	825		285	160	7	8
	4M6	900	150					1100		285	160	$7^3/_4$	$8^3/_4$
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	4M6	300	150					510	215	285	160	7	$7^1/_4$
	4M6	600	150					1000	430	285	160	7	8
	4M6	900	150					1100	650	285	160	$7^3/_4$	$8^3/_4$
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	4M6	150	150	275	275	275	180	80	20	275	80	7	$7^1/_4$
	4M6 (4)	300	150	275	275	275	180	80	20	275	80	7	$7^1/_4$
	4M6	300	150	525	720	720	49 5	420	350	275	160	7	$7^1/_4$
	4M6	600	150	600	1000	1000	975	845	700	275	160	7	8
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	4M6	150	150			140	140	140		140	80	7	$7^1/_4$
	4M6 (4)	300	150			140	140	140		140	80	7	$7^1/_4$
	4M6	300	150			360	360	360		140	160	7	$7^1/_4$
	4M6	600	150			720	720	720		140	160	7	8
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	4M6	150	150			230	180			230	80	7	$7^1/_4$
	4M6 (4)	300	150			230	180			230	80	7	$7^1/_4$
	4M6	300	150			600	465			230	160	7	$7^1/_4$
	4M6	600	150			1100	930			230	160	7	8
	4M6	900	150			1100	1100			230	160	$7^3/_4$	$8^3/_4$

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Table F.10 Spring-loaded Pressure Relief Valves "N" Orifice (Effective Orifice Area = 4.34 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	– 450°F to – 76°F	– 75°F to – 21°F	– 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, – 20°F to 800°F Inclusive													
Carbon Steel	4N6	150	150			285	185	80		285	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6 (4)	300	150			285	285	285		285	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150			740	615	410		285	160	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150			1000	1000	825		285	160	$7\frac{3}{4}$	$8\frac{3}{4}$
	4N6	900	150					1000		285	160	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	4N6	300	150					510	215	285	160	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150					1000	430	285	160	$7\frac{3}{4}$	$8\frac{3}{4}$
	4N6	900	150					1000	650	285	160	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, – 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	4N6	150	150	275	275	275	180	80	20	275	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6 (4)	300	150	275	275	275	180	80	20	275	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150	450	720	720	49 5	420	350	275	160	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150	500	1000	1000	975	845	700	275	160	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, – 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	4N6	150	150			140	140	140		140	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6 (4)	300	150			140	140	140		140	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150			360	360	360		140	140	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150			720	720	720		140	140	$7\frac{3}{4}$	$8\frac{3}{4}$
Temperature Range, – 20°F to 300°F Inclusive													
Alloy 20 (6)	4N6	150	150			230	180			230	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6 (4)	300	150			230	180			230	80	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150			600	465			230	160	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150			1000	930			230	160	$7\frac{3}{4}$	$8\frac{3}{4}$
	4N6	900	150			1000	1000			230	160	$7\frac{3}{4}$	$8\frac{3}{4}$

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Table F.11 Spring-loaded Pressure Relief Valves "P" Orifice (Effective Orifice Area = 6.38 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	4P6	150	150			285	185	80		285	80	$7\frac{1}{8}$	
	4P6 (4)	300	150			285	285	285		285	80	$7\frac{1}{8}$	
	4P6	300	150			525	525	410		285	150	$8\frac{7}{8}$	10
	4P6	600	150			1000	1000	825		285	150	$8\frac{7}{8}$	10
	4P6	900	150					1000		285	150	$8\frac{7}{8}$	10
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	4P6	300	150					510	215	285	150	$8\frac{7}{8}$	10
	4P6	600	150					1000	430	285	150	$8\frac{7}{8}$	10
	4P6	900	150					1000	650	285	150	$8\frac{7}{8}$	10
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	4P6	150	150	175	275	275	180	80	20	275	80	$7\frac{1}{8}$	
	4P6 (4)	300	150	175	275	275	180	80	20	275	80	$7\frac{1}{8}$	
	4P6	300	150	300	525	525	49 5	420	350	275	150	$8\frac{7}{8}$	10
	4P6	600	150	480	1000	1000	975	845	700	275	150	$8\frac{7}{8}$	10
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	4P6	150	150			140	140	140		140	80	$7\frac{1}{8}$	
	4P6 (4)	300	150			140	140	140		140	80	$7\frac{1}{8}$	
	4P6	300	150			360	360	360		140	140	$8\frac{7}{8}$	10
	4P6	600	150			720	720	720		140	140	$8\frac{7}{8}$	10
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	4P6	150	150			230	180			230	80	$7\frac{1}{8}$	
	4P6 (4)	300	150			230	180			230	80	$7\frac{1}{8}$	
	4P6	300	150			525	465			230	150	$8\frac{7}{8}$	10
	4P6	600	150			1000	930			230	150	$8\frac{7}{8}$	10
	4P6	900	150			1000	1000			230	150	$8\frac{7}{8}$	10

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Table F.12 Spring-loaded Pressure Relief Valves "Q" Orifice (Effective Orifice Area = 11.05 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	6Q8	150	150			165	165	80		115	70	7/16	1/2
	6Q8 (4)	300	150			165	165	165		115	70	7/16	1/2
	6Q8	300	150			300	300	300		115	115	7/16	1/2
	6Q8	600	150			600	600	600		115	115	7/16	1/2
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	6Q8	300	150					165	165	115	115	7/16	1/2
	6Q8	600	150					600	430	115	115	7/16	1/2
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	6Q8	150	150	165	165	165	165	80	20	115	70	7/16	1/2
	6Q8 (4)	300	150	165	165	165	165	80	20	115	70	7/16	1/2
	6Q8	300	150	250	300	300	300	300	300	115	115	7/16	1/2
	6Q8	600	150	300	600	600	600	600	600	115	115	7/16	1/2
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	6Q8	150	150			140	140	140		115	70	7/16	1/2
	6Q8 (4)	300	150			140	140	140		115	70	7/16	1/2
	6Q8	300	150			360	360	360		115	115	7/16	1/2
	6Q8	600	150			720	720	720		115	115	7/16	1/2
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	6Q8	150	150			165	165			115	70	7/16	1/2
	6Q8 (4)	300	150			165	165			115	70	7/16	1/2
	6Q8	300	150			300	300			115	115	7/16	1/2
	6Q8	600	150			600	600			115	115	7/16	1/2

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Table F.13 Spring-loaded Pressure Relief Valves "R" Orifice (Effective Orifice Area = 16.00 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 76°F	- 75°F to - 21°F	- 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 800°F Inclusive													
Carbon Steel	6R8	150	150			100	100	80		60	60	7/16	1/2
	6R8 (4)	300	150			100	100	100		60	60	7/16	1/2
	6R10	300	150			230	230	230		100	100	7/16	10 1/2
	6R10	600	150			300	300	300		100	100	7/16	10 1/2
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	6R8	300	150					100	100	60	60	7/16	1/2
	6R10	600	150					300	300	100	100	7/16	10 1/2
Temperature Range, - 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	6R8	150	150	55	100	100	100	80	20	60	60	7/16	1/2
	6R8 (4)	300	150	55	100	100	100	80	20	60	60	7/16	1/2
	6R10	300	150	150	230	230	230	230	230	100	100	7/16	10 1/2
	6R10	600	150	200	300	300	300	300	300	100	100	7/16	10 1/2
Temperature Range, - 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	6R8	150	150			100	100	100		60	60	7/16	1/2
	6R8 (4)	300	150			100	100	100		60	60	7/16	1/2
	6R10	300	150			230	230	230		100	100	7/16	10 1/2
	6R10	600	150			300	300	300		100	100	7/16	10 1/2
Temperature Range, - 20°F to 300°F Inclusive													
Alloy 20 (6)	6R8	150	150			100	100			60	60	7/16	1/2
	6R8 (4)	300	150			100	100			60	60	7/16	1/2
	6R10	300	150			230	230			100	100	7/16	10 1/2
	6R10	600	150			300	300			100	100	7/16	10 1/2

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Table F.14 Spring-loaded Pressure Relief Valves "T" Orifice (Effective Orifice Area = 26.00 square in.)

Materials (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)									
				Conventional and Balanced Bellows Valves									
				Spring Materials (3)									
				Low Temperature Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	Carbon Steel or Chrome Alloy Steel	High Temperature Alloy Steel	High Temperature Alloy Steel	Outlet Pressure Limit (1)		Center to Face Dimensions (in.)	
										Conventional Valves	Bellows Valves		
Body/Bonnet	Inlet by Orifice by Outlet	Inlet	Outlet	− 450°F to − 76°F	− 75°F to − 21°F	− 20°F to 100°F	101°F to 450°F	451°F to 800°F	801°F to 1000°F	100°F	100°F	Inlet	Outlet
Temperature Range, − 20°F to 800°F Inclusive													
Carbon Steel	8T10	150	150			65	65	65		30	30	$10\frac{7}{8}$	11
	8T10 (4)	300	150			65	65	65		30	30	$10\frac{7}{8}$	11
	8T10	300	150			120	120	120		60	60	$10\frac{7}{8}$	11
	8T10	300	150			300	300	300		100	100	$10\frac{7}{8}$	11
Temperature Range, 801°F to 1000°F Inclusive													
Chrome Molybdenum Steel	8T10	300	150					120	100	60	60	$10\frac{7}{8}$	11
	8T10	300	150					300	225	100	100	$10\frac{7}{8}$	11
Temperature Range, − 450°F to 1000°F Inclusive													
Austenitic Stainless Steel	8T10	150	150	50	65	65	65	65	20	30	30	$10\frac{7}{8}$	11
	8T10 (4)	300	150	50	65	65	65	65	20	30	30	$10\frac{7}{8}$	11
	8T10	300	150	65	120	120	120	120	120	60	60	$10\frac{7}{8}$	11
Temperature Range, − 20°F to 600°F Inclusive													
Nickel/Copper Alloy (5)	8T10	150	150			65	65	65		30	30	$10\frac{7}{8}$	11
	8T10 (4)	300	150			65	65	65		30	30	$10\frac{7}{8}$	11
	8T10	300	150			120	120	120		60	60	$10\frac{7}{8}$	11
Temperature Range, − 20°F to 300°F Inclusive													
Alloy 20 (6)	8T10	150	150			65	65			30	30	$10\frac{7}{8}$	11
	8T10 (4)	300	150			65	65			30	30	$10\frac{7}{8}$	11
	8T10	300	150			120	120			60	60	$10\frac{7}{8}$	11

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Table F.15 Pilot-operated Pressure Relief Valves "D" Orifice (Effective Orifice Area = 0.110 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	1D2	150	150		285	170	285	$4\frac{1}{8}$	$4\frac{1}{2}$
	1D2	300	150		740	600	285	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	600	150		1480	1200	285	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	900	300		2220	1795	740	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	1500	300		3705	2995	740	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	2500	300		6170	4990	740	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	150	150		285	170	285	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	300	150		740	600	285	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	600	150		1480	1200	285	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	900	300		2220	1795	740	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	1500	300		3705	2995	740	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	2500	300		6170	4990	740	$5\frac{7}{8}$	$5\frac{1}{2}$
Temperature Range, - 450°F - 500°F									
Austenitic Stainless Steel	1D2	150	150	275	275	170	275	$4\frac{1}{8}$	$4\frac{1}{2}$
	1D2	300	150	720	720	480	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	600	150	1440	1440	955	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	900	300	2160	2160	1435	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	1500	300	3600	3600	2390	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	2500	300	6000	6000	3980	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	150	150	275	275	170	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	300	150	720	720	480	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	600	150	1440	1440	955	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	900	300	2160	2160	1435	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	1500	300	3600	3600	2390	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	2500	300	6000	6000	3980	720	$5\frac{7}{8}$	$5\frac{1}{2}$
Temperature Range, - 20°F - 500°F									
Nickel/Copper Alloy	1D2	150	150		140	140	275	$4\frac{1}{8}$	$4\frac{1}{2}$
	1D2	300	150		360	360	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	600	150		720	720	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	900	300		1080	1080	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	1500	300		1800	1800	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	2500	300		3000	3000	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	150	150		140	140	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	300	150		360	360	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	600	150		720	720	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	900	300		1080	1080	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	1500	300		1800	1800	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	2500	300		3000	3000	720	$5\frac{7}{8}$	$5\frac{1}{2}$
Temperature Range, - 20°F - 300°F									
Alloy 20 (3)	1D2	150	150		230	180	275	$4\frac{1}{8}$	$4\frac{1}{2}$
	1D2	300	150		600	465	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	600	150		1200	930	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1D2	900	300		1800	1395	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	1500	300		3000	2330	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1D2	2500	300		5000	3880	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	150	150		230	180	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	300	150		600	465	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	600	150		1200	930	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ D2	900	300		1800	1395	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	1500	300		3000	2330	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ D2	2500	300		5000	3880	720	$5\frac{7}{8}$	$5\frac{1}{2}$

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Table F.16 Pilot-operated Pressure Relief Valves "E" Orifice (Effective Orifice Area = 0.196 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)				Center to Face Dimensions (in.)	
				Set Pressure Limit			Outlet Pressure Limit (1)		
Body	Inlet by Orifice by Outlet	Inlet	Outlet	-450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	1E2	150	150		285	170	285	$4\frac{1}{8}$	$4\frac{1}{2}$
	1E2	300	150		740	600	285	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	600	150		1480	1200	285	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	900	300		2220	1795	740	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	1500	300		3705	2995	740	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	2500	300		6170	4990	740	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	150	150		285	170	285	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	300	150		740	600	285	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	600	150		1480	1200	285	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	900	300		2220	1795	740	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	1500	300		3705	2995	740	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	2500	300		6170	4990	740	$5\frac{7}{8}$	$5\frac{1}{2}$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	1E2	150	150	275	275	170	275	$4\frac{1}{8}$	$4\frac{1}{2}$
	1E2	300	150	720	720	480	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	600	150	1440	1440	955	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	900	300	2160	2160	1435	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	1500	300	3600	3600	2390	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	2500	300	6000	6000	3980	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	150	150	275	275	170	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	300	150	720	720	480	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	600	150	1440	1440	955	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	900	300	2160	2160	1435	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	1500	300	3600	3600	2390	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	2500	300	6000	6000	3980	720	$5\frac{7}{8}$	$5\frac{1}{2}$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	1E2	150	150		140	140	275	$4\frac{1}{8}$	$4\frac{1}{2}$
	1E2	300	150		360	360	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	600	150		720	720	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	900	300		1080	1080	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	1500	300		1800	1800	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	2500	300		3000	3000	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	150	150		140	140	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	300	150		360	360	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	600	150		720	720	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	900	300		1080	1080	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	1500	300		1800	1800	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	2500	300		3000	3000	720	$5\frac{7}{8}$	$5\frac{1}{2}$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	1E2	150	150		230	180	275	$4\frac{1}{8}$	$4\frac{1}{2}$
	1E2	300	150		600	465	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	600	150		1200	930	275	$4\frac{3}{8}$	$4\frac{1}{2}$
	1E2	900	300		1800	1395	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	1500	300		3000	2330	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	1E2	2500	300		5000	3880	720	$4\frac{15}{16}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	150	150		230	180	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	300	150		600	465	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	600	150		1200	930	275	$4\frac{7}{8}$	$4\frac{3}{4}$
	$1\frac{1}{2}$ E2	900	300		1800	1395	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	1500	300		3000	2330	720	$5\frac{7}{8}$	$5\frac{1}{2}$
	$1\frac{1}{2}$ E2	2500	300		5000	3880	720	$5\frac{7}{8}$	$5\frac{1}{2}$

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Table F.17 Pilot-operated Pressure Relief Valves "F" Orifice (Effective Orifice Area = 0.307 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)				Center to Face Dimensions (in.)	
				Set Pressure Limit			Outlet Pressure Limit (1)		
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	1F2	150	150		285	170	285	$4^{1}/_{8}$	$4^{1}/_{2}$
	1F2	300	150		740	600	285	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	600	150		1480	1200	285	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	900	300		2220	1795	740	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	1500	300		3705	2995	740	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	2500	300		6170	4990	740	$4^{15}/_{16}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	150	150		285	170	285	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	300	150		740	600	285	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	600	150		1480	1200	285	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	900	300		2220	1795	740	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	1500	300		3705	2995	740	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	2500	300		6170	4990	740	$5^{7}/_{8}$	$5^{1}/_{2}$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	1F2	150	150	275	275	170	275	$4^{1}/_{8}$	$4^{1}/_{2}$
	1F2	300	150	720	720	480	275	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	600	150	1440	1440	955	275	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	900	300	2160	2160	1435	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	1500	300	3600	3600	2390	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	2500	300	6000	6000	3980	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	150	150	275	275	170	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	300	150	720	720	480	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	600	150	1440	1440	955	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	900	300	2160	2160	1435	720	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	1500	300	3600	3600	2390	720	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	2500	300	6000	6000	3980	720	$5^{7}/_{8}$	$5^{1}/_{2}$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	1F2	150	150		140	140	275	$4^{1}/_{8}$	$4^{1}/_{2}$
	1F2	300	150		360	360	275	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	600	150		720	720	275	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	900	300		1080	1080	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	1500	300		1800	1800	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	2500	300		3000	3000	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	150	150		140	140	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	300	150		360	360	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	600	150		720	720	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	900	300		1080	1080	720	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	1500	300		1800	1800	720	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	2500	300		3000	3000	720	$5^{7}/_{8}$	$5^{1}/_{2}$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	1F2	150	150		230	180	275	$4^{1}/_{8}$	$4^{1}/_{2}$
	1F2	300	150		600	465	275	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	600	150		1200	930	275	$4^{3}/_{8}$	$4^{1}/_{2}$
	1F2	900	300		1800	1395	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	1500	300		3000	2330	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	1F2	2500	300		5000	3880	720	$4^{15}/_{16}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	150	150		230	180	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	300	150		600	465	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	600	150		1200	930	275	$4^{7}/_{8}$	$4^{3}/_{4}$
	$1^{1}/_{2}$ F2	900	300		1800	1395	720	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	1500	300		3000	2330	720	$5^{7}/_{8}$	$5^{1}/_{2}$
	$1^{1}/_{2}$ F2	2500	300		5000	3880	720	$5^{7}/_{8}$	$5^{1}/_{2}$

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Table F.18 Pilot-operated Pressure Relief Valves "G" Orifice (Effective Orifice Area = 0.503 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	1 1/2G3	150	150		285	170	285	5 1/8	4 7/8
	1 1/2G3	300	150		740	600	285	5 1/8	4 7/8
	1 1/2G3	600	150		1480	1200	285	5 1/8	4 7/8
	1 1/2G3	900	300		2220	1795	740	6 3/8	6 3/4
	1 1/2G3	1500	300		3705	2995	740	6 3/8	6 3/4
	1 1/2G3	2500	300		6170	4990	740	6 3/8	6 3/4
	2G3	150	150		285	170	285	5 3/8	4 7/8
	2G3	300	150		740	600	285	5 3/8	4 7/8
	2G3	600	150		1480	1200	285	5 3/8	4 7/8
	2G3	900	300		2220	1795	740	6 /16	6 3/4
	2G3	1500	300		3705	2995	740	6 /16	6 3/4
	2G3	2500	300		6170	4990	740	7	6 3/4
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	1 1/2G3	150	150	275	275	170	275	5 1/8	4 7/8
	1 1/2G3	300	150	720	720	480	275	5 1/8	4 7/8
	1 1/2G3	600	150	1440	1440	955	275	5 1/8	4 7/8
	1 1/2G3	900	300	2160	2160	1435	720	6 3/8	6 3/4
	1 1/2G3	1500	300	3600	3600	2390	720	6 3/8	6 3/4
	1 1/2G3	2500	300	6000	6000	3980	720	6 3/8	6 3/4
	2G3	150	150	275	275	170	275	5 3/8	4 7/8
	2G3	300	150	720	720	480	275	5 3/8	4 7/8
	2G3	600	150	1440	1440	955	275	5 3/8	4 7/8
	2G3	900	300	2160	2160	1435	720	6 /16	6 3/4
	2G3	1500	300	3600	3600	2390	720	6 /16	6 3/4
	2G3	2500	300	6000	6000	3980	720	7	6 3/4
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	1G2	150	150		140	140	275	4 1/8	4 1/2
	1G2	300	150		360	360	275	4 3/8	4 1/2
	1G2	600	150		720	720	275	4 3/8	4 1/2
	1G2	900	300		1080	1080	720	4 15/16	4 3/4
	1G2	1500	300		1800	1800	720	4 15/16	4 3/4
	1G2	2500	300		3000	3000	720	4 15/16	4 3/4
	1 1/2G2	150	150		140	140	275	4 7/8	4 3/4
	1 1/2G2	300	150		360	360	275	4 7/8	4 3/4
	1 1/2G2	600	150		720	720	275	4 7/8	4 3/4
	1 1/2G2	900	300		1080	1080	720	5 7/8	5 1/2
	1 1/2G2	1500	300		1800	1800	720	5 7/8	5 1/2
	1 1/2G2	2500	300		3000	3000	720	5 7/8	5 1/2
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	1G2	150	150		230	180	275	4 1/8	4 1/2
	1G2	300	150		600	465	275	4 3/8	4 1/2
	1G2	600	150		1200	930	275	4 3/8	4 1/2
	1G2	900	300		1800	1395	720	4 15/16	4 3/4
	1G2	1500	300		3000	2330	720	4 15/16	4 3/4
	1G2	2500	300		5000	3880	720	4 15/16	4 3/4
	1 1/2G2	150	150		230	180	275	4 7/8	4 3/4
	1 1/2G2	300	150		600	465	275	4 7/8	4 3/4
	1 1/2G2	600	150		1200	930	275	4 7/8	4 3/4
	1 1/2G2	900	300		1800	1395	720	5 7/8	5 1/2
	1 1/2G2	1500	300		3000	2330	720	5 7/8	5 1/2
	1 1/2G2	2500	300		5000	3880	720	5 7/8	5 1/2

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Table F.19 Pilot-operated Pressure Relief Valves "H" Orifice (Effective Orifice Area = 0.785 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	1 1/2H3	150	150		285	170	285	5 1/8	4 7/8
	1 1/2H3	300	150		740	600	285	5 1/8	4 7/8
	1 1/2H3	600	150		1480	1200	285	5 1/8	4 7/8
	1 1/2H3	900	300		2220	1795	740	6 3/8	6 3/4
	1 1/2H3	1500	300		3705	2995	740	6 3/8	6 3/4
	1 1/2H3	2500	300		6170	4990	740	6 3/8	6 3/4
	2H3	150	150		285	170	285	5 3/8	4 7/8
	2H3	300	150		740	600	285	5 3/8	4 7/8
	2H3	600	150		1480	1200	285	5 3/8	4 7/8
	2H3	900	300		2220	1795	740	6 /16	6 3/4
	2H3	1500	300		3705	2995	740	6 /16	6 3/4
	2H3	2500	300		6170	4990	740	7	6 3/4
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	1 1/2H3	150	150	275	275	170	275	5 1/8	4 7/8
	1 1/2H3	300	150	720	720	480	275	5 1/8	4 7/8
	1 1/2H3	600	150	1440	1440	955	275	5 1/8	4 7/8
	1 1/2H3	900	300	2160	2160	1435	720	6 3/8	6 3/4
	1 1/2H3	1500	300	3600	3600	2390	720	6 3/8	6 3/4
	1 1/2H3	2500	300	6000	6000	3980	720	6 3/8	6 3/4
	2H3	150	150	275	275	170	275	5 3/8	4 7/8
	2H3	300	150	720	720	480	275	5 3/8	4 7/8
	2H3	600	150	1440	1440	955	275	5 3/8	4 7/8
	2H3	900	300	2160	2160	1435	720	6 /16	6 3/4
	2H3	1500	300	3600	3600	2390	720	6 /16	6 3/4
	2H3	2500	300	6000	6000	3980	720	7	6 3/4
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	1H2	150	150		140	140	275	4 1/8	4 1/2
	1H2	300	150		360	360	275	4 3/8	4 1/2
	1H2	600	150		720	720	275	4 3/8	4 1/2
	1H2	900	300		1080	1080	720	4 15/16	4 3/4
	1H2	1500	300		1800	1800	720	4 15/16	4 3/4
	1H2	2500	300		3000	3000	720	4 15/16	4 3/4
	1 1/2H2	150	150		140	140	275	4 7/8	4 3/4
	1 1/2H2	300	150		360	360	275	4 7/8	4 3/4
	1 1/2H2	600	150		720	720	275	4 7/8	4 3/4
	1 1/2H2	900	300		1080	1080	720	5 7/8	5 1/2
	1 1/2H2	1500	300		1800	1800	720	5 7/8	5 1/2
	1 1/2H2	2500	300		3000	3000	720	5 7/8	5 1/2
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	1H2	150	150		230	180	275	4 1/8	4 1/2
	1H2	300	150		600	465	275	4 3/8	4 1/2
	1H2	600	150		1200	930	275	4 3/8	4 1/2
	1H2	900	300		1800	1395	720	4 15/16	4 3/4
	1H2	1500	300		3000	2330	720	4 15/16	4 3/4
	1H2	2500	300		5000	3880	720	4 15/16	4 3/4
	1 1/2H2	150	150		230	180	275	4 7/8	4 3/4
	1 1/2H2	300	150		600	465	275	4 7/8	4 3/4
	1 1/2H2	600	150		1200	930	275	4 7/8	4 3/4
	1 1/2H2	900	300		1800	1395	720	5 7/8	5 1/2
	1 1/2H2	1500	300		3000	2330	720	5 7/8	5 1/2
	1 1/2H2	2500	300		5000	3880	720	5 7/8	5 1/2

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Table F.20 Pilot-operated Pressure Relief Valves "J" Orifice (Effective Orifice Area = 1.287 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)				Center to Face Dimensions (in.)	
				Set Pressure Limit			Outlet Pressure Limit (1)		
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	2J3	150	150		285	170	285	5 3/8	4 7/8
	2J3	300	150		740	600	285	5 3/8	4 7/8
	2J3	600	150		1480	1200	285	5 3/8	4 7/8
	2J3	900	300		2220	1795	740	6 /16	6 3/4
	2J3	1500	300		3650	2995	740	6 /16	6 3/4
	2J3	2500	300		3650	3650	740	7	6 3/4
	3J4	150	150		285	170	285	6 1/8	6 3/8
	3J4	300	150		740	600	285	6 1/8	6 3/8
	3J4	600	150		1480	1200	285	6 3/8	6 3/8
	3J4	900	300		2220	1795	740	7 1/2	7 1/8
	3J4	1500	300		3705	2995	740	7 1/2	7 1/8
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	2J3	150	150	275	275	170	275	5 3/8	4 7/8
	2J3	300	150	720	720	480	275	5 3/8	4 7/8
	2J3	600	150	1440	1440	955	275	5 3/8	4 7/8
	2J3	900	300	2160	2160	1435	720	6 /16	6 3/4
	2J3	1500	300	3550	3550	2390	720	6 /16	6 3/4
	2J3	2500	300	3550	3550	3550	720	7	6 3/4
	3J4	150	150	275	275	170	275	6 1/8	6 3/8
	3J4	300	150	720	720	480	275	6 1/8	6 3/8
	3J4	600	150	1440	1440	955	275	6 3/8	6 3/8
	3J4	900	300	2160	2160	1435	720	7 1/2	7 1/8
	3J4	1500	300	3600	3600	2390	720	7 1/2	7 1/8
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	2J3	150	150		140	140	275	5 3/8	4 7/8
	2J3	300	150		360	360	275	5 3/8	4 7/8
	2J3	600	150		720	720	275	5 3/8	4 7/8
	2J3	900	300		1080	1080	720	6 /16	6 3/4
	2J3	1500	300		1800	1800	720	6 /16	6 3/4
	2J3	2500	300		3000	3000	720	7	6 3/4
	3J4	150	150		140	140	275	6 1/8	6 3/8
	3J4	300	150		360	360	275	6 1/8	6 3/8
	3J4	600	150		720	720	275	6 3/8	6 3/8
	3J4	900	300		1080	1080	720	7 1/2	7 1/8
	3J4	1500	300		1800	1800	720	7 1/2	7 1/8
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	2J3	150	150		230	180	275	5 3/8	4 7/8
	2J3	300	150		600	465	275	5 3/8	4 7/8
	2J3	600	150		1200	930	275	5 3/8	4 7/8
	2J3	900	300		1800	1395	720	6 /16	6 3/4
	2J3	1500	300		3000	2330	720	6 /16	6 3/4
	2J3	2500	300		5000	3880	720	7	6 3/4
	3J4	150	150		230	180	275	6 1/8	6 3/8
	3J4	300	150		600	465	275	6 1/8	6 3/8
	3J4	600	150		1200	930	275	6 3/8	6 3/8
	3J4	900	300		1800	1395	720	7 1/2	7 1/8
	3J4	1500	300		3000	2330	720	7 1/2	7 1/8

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Table F.21 Pilot-operated Pressure Relief Valves "K" Orifice (Effective Orifice Area = 1.838 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	3K4	150	150		285	170	285	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	300	150		740	600	285	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	600	150		1480	1200	285	$6^{3}/_{8}$	$6^{3}/_{8}$
	3K4	900	300		2220	1795	740	$7^{1}/_{2}$	$7^{1}/_{8}$
	3K4	1500	300		3705	2995	740	$7^{1}/_{2}$	$7^{1}/_{8}$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	3K4	150	150	275	275	170	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	300	150	720	720	480	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	600	150	1440	1440	955	275	$6^{3}/_{8}$	$6^{3}/_{8}$
	3K4	900	300	2160	2160	1435	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	3K4	1500	300	3600	3600	2390	720	$7^{1}/_{2}$	$7^{1}/_{8}$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	3K4	150	150		140	140	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	300	150		360	360	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	600	150		720	720	275	$6^{3}/_{8}$	$6^{3}/_{8}$
	3K4	900	300		1080	1080	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	3K4	1500	300		1800	1800	720	$7^{1}/_{2}$	$7^{1}/_{8}$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	3K4	150	150		230	180	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	300	150		600	465	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3K4	600	150		1200	930	275	$6^{3}/_{8}$	$6^{3}/_{8}$
	3K4	900	300		1800	1395	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	3K4	1500	300		3000	2330	720	$7^{1}/_{2}$	$7^{1}/_{8}$

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Table F.22 Pilot-operated Pressure Relief Valves "L" Orifice (Effective Orifice Area = 2.853 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)				Center to Face Dimensions (in.)	
				Set Pressure Limit			Outlet Pressure Limit (1)		
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	3L4	150	150		285	170	285	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	300	150		740	600	285	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	600	150		1240	1200	285	$6^{3}/_{8}$	$6^{3}/_{8}$
	3L4	900	300		2220	1795	740	$7^{1}/_{2}$	$7^{1}/_{8}$
	3L4	1500	300		2900	2900	740	$7^{1}/_{2}$	$7^{1}/_{8}$
	4L6	150	150		285	170	285	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	300	150		740	600	285	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	600	150		1480	1200	285	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	900	300		2220	1795	740	$^{13}/_{16}$	$^{3}/_{16}$
	4L6	1500	300		3705	2995	740	$^{13}/_{16}$	$^{3}/_{16}$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	3L4	150	150	275	275	170	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	300	150	720	720	480	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	600	150	1200	1200	955	275	$6^{3}/_{8}$	$6^{3}/_{8}$
	3L4	900	300	2160	2160	1435	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	3L4	1500	300	2825	2825	2390	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	4L6	150	150	275	275	170	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	300	150	720	720	480	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	600	150	1440	1440	955	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	900	300	2160	2160	1435	720	$^{13}/_{16}$	$^{3}/_{16}$
	4L6	1500	300	3600	3600	2390	720	$^{13}/_{16}$	$^{3}/_{16}$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	3L4	150	150		140	140	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	300	150		360	360	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	600	150		720	720	275	$6^{3}/_{8}$	$6^{3}/_{8}$
	3L4	900	300		1080	1080	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	3L4	1500	300		1800	1800	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	4L6	150	150		140	140	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	300	150		360	360	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	600	150		720	720	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	900	300		1080	1080	720	$^{13}/_{16}$	$^{3}/_{16}$
	4L6	1500	300		1800	1800	720	$^{13}/_{16}$	$^{3}/_{16}$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	3L4	150	150		230	180	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	300	150		600	465	275	$6^{1}/_{8}$	$6^{3}/_{8}$
	3L4	600	150		1200	930	275	$6^{3}/_{8}$	$6^{3}/_{8}$
	3L4	900	300		1800	1395	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	3L4	1500	300		3000	2330	720	$7^{1}/_{2}$	$7^{1}/_{8}$
	4L6	150	150		230	180	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	300	150		600	465	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	600	150		1200	930	275	$7^{3}/_{4}$	$8^{1}/_{4}$
	4L6	900	300		1800	1395	720	$^{13}/_{16}$	$^{3}/_{16}$
	4L6	1500	300		3000	2330	720	$^{13}/_{16}$	$^{3}/_{16}$

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Table F.23 Pilot-operated Pressure Relief Valves "M" Orifice (Effective Orifice Area = 3.60 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	4M6	150	150		285	170	285	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	300	150		740	600	285	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	600	150		1480	1200	285	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	00	300		2220	1795	740	$13/16$	$3/16$
	4M6	1500	300		3705	2995	740	$13/16$	$3/16$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	4M6	150	150	275	275	170	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	300	150	720	720	480	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	600	150	1440	1440	955	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	00	300	2160	2160	1435	720	$13/16$	$3/16$
	4M6	1500	300	3600	3600	2390	720	$13/16$	$3/16$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	4M6	150	150		140	140	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	300	150		360	360	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	600	150		720	720	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	00	300		1080	1080	720	$13/16$	$3/16$
	4M6	1500	300		1800	1800	720	$13/16$	$3/16$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	4M6	150	150		230	180	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	300	150		600	465	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	600	150		1200	930	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4M6	00	300		1800	1395	720	$13/16$	$3/16$
	4M6	1500	300		3000	2330	720	$13/16$	$3/16$

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Table F.24 Pilot-operated Pressure Relief Valves "N" Orifice (Effective Orifice Area = 4.34 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)				Center to Face Dimensions (in.)	
				Set Pressure Limit			Outlet Pressure Limit (1)		
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, -20°F to 500°F									
Carbon Steel	4N6	150	150		285	170	285	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150		740	600	285	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150		1480	1200	285	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	00	300		2220	1795	740	$13/16$	$3/16$
	4N6	1500	300		3705	2995	740	$13/16$	$3/16$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	4N6	150	150	275	275	170	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150	720	720	480	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150	1440	1440	955	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	00	300	2160	2160	1435	720	$13/16$	$3/16$
	4N6	1500	300	3600	3600	2390	720	$13/16$	$3/16$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	4N6	150	150		140	140	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150		360	360	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150		720	720	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	00	300		1080	1080	720	$13/16$	$3/16$
	4N6	1500	300		1800	1800	720	$13/16$	$3/16$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	4N6	150	150		230	180	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	300	150		600	465	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	600	150		1200	930	275	$7\frac{3}{4}$	$8\frac{1}{4}$
	4N6	00	300		1800	1395	720	$13/16$	$3/16$
	4N6	1500	300		3000	2330	720	$13/16$	$3/16$

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Table F.25 Pilot-operated Pressure Relief Valves "P" Orifice (Effective Orifice Area = 6.38 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, -20°F to 500°F									
Carbon Steel	4P6	150	150		285	170	285	$7^3/_4$	$8^1/_4$
	4P6	300	150		740	600	285	$7^3/_4$	$8^1/_4$
	4P6	600	150		1305	1200	285	$7^3/_4$	$8^1/_4$
	4P6	600	300		1480	1200	740	$^{13}/_{16}$	$^3/_{16}$
	4P6	00	300		2220	1795	740	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	300		3080	2995	740	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	600		3705	2995	1480	$^{13}/_{16}$	$10^3/_8$
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	4P6	150	150	275	275	170	275	$7^3/_4$	$8^1/_4$
	4P6	300	150	720	720	480	275	$7^3/_4$	$8^1/_4$
	4P6	600	300	1440	1440	955	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	00	300	2160	2160	1435	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	600	3600	3600	2390	1440	$^{13}/_{16}$	$10^3/_8$
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	4P6	150	150		140	140	275	$7^3/_4$	$8^1/_4$
	4P6	300	150		360	360	275	$7^3/_4$	$8^1/_4$
	4P6	600	150		720	720	275	$7^3/_4$	$8^1/_4$
	4P6	00	300		1080	1080	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	300		1800	1800	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	600		1800	1800	1440	$^{13}/_{16}$	$10^3/_8$
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	4P6	150	150		230	180	275	$7^3/_4$	$8^1/_4$
	4P6	300	150		600	465	275	$7^3/_4$	$8^1/_4$
	4P6	600	150		1200	930	275	$7^3/_4$	$8^1/_4$
	4P6	600	300		1200	930	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	00	300		1800	1395	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	300		3000	2330	720	$^{13}/_{16}$	$^3/_{16}$
	4P6	1500	600		3000	2330	1440	$^{13}/_{16}$	$10^3/_8$

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Table F.26 Pilot-operated Pressure Relief Valves "Q" Orifice (Effective Orifice Area = 11.05 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)				Center to Face Dimensions (in.)	
				Set Pressure Limit			Outlet Pressure Limit (1)		
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	6Q8	150	150		285	170	285	7/16	1/2
	6Q8	300	150		740	600	285	7/16	1/2
	6Q8	600	150		1330	1200	285	11/16	1/2
	6Q8	600	300		1480	1200	740	11/16	10 7/16
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	6Q8	150	150	275	275	170	275	7/16	1/2
	6Q8	300	150	720	720	480	275	7/16	1/2
	6Q8	600	150	1285	1285	955	275	11/16	1/2
	6Q8	600	300	1440	1440	955	720	11/16	10 7/16
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	6Q8	150	150		140	140	275	7/16	1/2
	6Q8	300	150		360	360	275	7/16	1/2
	6Q8	600	150		720	720	275	11/16	1/2
	6Q8	600	300		720	720	720	11/16	10 7/16
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	6Q8	150	150		230	180	275	7/16	1/2
	6Q8	300	150		600	465	275	7/16	1/2
	6Q8	600	150		1200	930	275	11/16	1/2
	6Q8	600	300		1200	930	720	11/16	10 7/16

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Table F.27 Pilot-operated Pressure Relief Valves "R" Orifice (Effective Orifice Area = 16.00 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	6R8	150	150		285	170	285	7/16	1/2
	6R8	300	150		740	600	285	7/16	1/2
	6R8	600	150		15	915	285	11/16	1/2
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	6R8	150	150	275	275	170	275	7/16	1/2
	6R8	300	150	720	720	480	275	7/16	1/2
	6R8	600	150	885	885	885	275	11/16	1/2
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	6R8	150	150		140	140	275	7/16	1/2
	6R8	300	150		360	360	275	7/16	1/2
	6R8	600	150		720	720	275	11/16	1/2
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	6R8	150	150		230	180	275	7/16	1/2
	6R8	300	150		600	465	275	7/16	1/2
	6R8	600	150		1200	930	275	11/16	1/2

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Table F.28 Pilot-operated Pressure Relief Valves "T" Orifice (Effective Orifice Area = 26.00 square in.)

Material (2)	Valve Size	ANSI Flange Class		Maximum Pressure (psig)					
				Set Pressure Limit			Outlet Pressure Limit (1)	Center to Face Dimensions (in.)	
Body	Inlet by Orifice by Outlet	Inlet	Outlet	- 450°F to - 21°F	- 20°F to 100°F	500°F	100°F	Inlet	Outlet
Temperature Range, - 20°F to 500°F									
Carbon Steel	8T10	150	150		285	170	285	$10^{7}/_{8}$	11
	8T10	300	150		740	600	285	$10^{7}/_{8}$	11
	8T10	600	150		00	900	285	$11^{11}/_{16}$	11
Temperature Range, - 450°F to 500°F									
Austenitic Stainless Steel	8T10	150	150	275	275	170	275	$10^{7}/_{8}$	11
	8T10	300	150	720	720	480	275	$10^{7}/_{8}$	11
	8T10	600	150	885	870	870	275	$11^{11}/_{16}$	11
Temperature Range, - 20°F to 500°F									
Nickel/Copper Alloy	8T10	150	150		140	140	275	$10^{7}/_{8}$	11
	8T10	300	150		360	360	275	$10^{7}/_{8}$	11
	8T10	600	150		720	720	275	$11^{11}/_{16}$	11
Temperature Range, - 20°F to 300°F									
Alloy 20 (3)	8T10	150	150		230	180	275	$10^{7}/_{8}$	11
	8T10	300	150		600	465	275	$10^{7}/_{8}$	11
	8T10	600	150		1200	930	275	$11^{11}/_{16}$	11

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