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Document Name: API 2000: Venting Atmospheric and Low-Pressure Storage Tanks

CFR Section(s): 49 CFR 195.264(e)(2)

Standards Body: American Petroleum Institute

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Venting Atmospheric and Low-Pressure Storage Tanks

Nonrefrigerated and Refrigerated

API STANDARD 2000
FIFTH EDITION, APRIL 1998

STEP
Strategies for Today's Environmental Partnership

American Petroleum Institute

Strategies for Today's
Environmental Partnership

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Venting Atmospheric and Low-Pressure Storage Tanks

Nonrefrigerated and Refrigerated

Manufacturing, Distribution and Marketing Department

API STANDARD 2000
FIFTH EDITION, APRIL 1998

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Date of Issue: November 15, 1999
Affected Publication: API Standard 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*, Fifth Edition, April 1998

ERRATA

On page 8, Formula 1B, the key for "L" should read as follows:

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature in joules/kilogram (J/kg).

On page 20, Formula 5B, the key for "L" should read as follows:

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature, in J/kg.

On page 15, replace the first section of 4.6 as follows:

4.6 TESTING AND MARKING OF VENTING DEVICES

4.6.1 Testing of Venting Devices

4.6.1.1 Determination of Capacity

The capacity of venting devices shall be established by the test methods described in Sections 4.6.1.2, 4.6.1.2.1, or 4.6.1.2.2 or by the calculation method described in 4.6.1.2.3. For the test methods described in Sections 4.6.1.2, 4.6.1.2.1, and 4.6.1.2.2, the testing facilities, methods, and procedures and the person supervising the tests shall meet the applicable requirements described in this paragraph (4.6.1) and in ASME PTC 25; if there is a conflict, the requirements in this paragraph shall govern.

The test report shall describe how the venting device was mounted and tested as well as describe the inlet and outlet piping. If any fluid other than air is used in the test, the name of the fluid actually used along with the fluid's temperature and its specific gravity at standard conditions shall be noted on the test report.

FOREWORD

This standard covers the normal and emergency vapor venting requirements for aboveground liquid petroleum storage tanks and aboveground and underground refrigerated storage tanks designed for operation at pressures from vacuum through 15 pounds per square inch gauge (1.034 bar gauge). Discussed in this standard are the causes of overpressure or vacuum; determination of venting requirements; means of venting; selection, installation, and maintenance of venting devices; and testing and marking of relief devices.

This standard has been developed from the accumulated knowledge and experience of qualified engineers in the petroleum-processing industry and its related industries. The vapor venting requirements in this standard are based on studies using hexane. Intended for petroleum products, this standard may be applied to other materials; however, sound engineering analysis and judgment should be used whenever this standard is applied to other materials.

Engineering studies of a particular tank may indicate that the appropriate venting capacity for the tank is not the venting capacity estimated in accordance with this standard. The many variables associated with tank venting requirements make it impractical to set forth definite, simple rules that are applicable to all locations and conditions. Larger venting capacities may be required on tanks in which liquid is heated, on tanks that receive liquid from wells or traps, and on tanks that are subjected to pipeline surges. Larger venting capacities may also be required on tanks that use flame arresters or have other restrictions that may build up pressure under certain conditions.

This standard does not apply to external floating roof tanks or free vented internal floating roof tanks.

Suggested revisions are invited and should be submitted to the director of the Manufacturing, Distribution and Marketing Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of extreme usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products (Sections 763.160-179).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

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The venting requirements provided in this standard are based on studies of hexane stored in steel tanks. Sound engineering judgment should be applied when extrapolating these results to other liquids and nonmetallic tanks.

Detailed engineering studies of a particular tank and its operating conditions may indicate that the appropriate venting capacity for the tank is not the venting capacity estimated in accordance with this standard. If a tank's operating conditions could deviate from those used in developing this standard, detailed engineering studies should be performed.

1 Scope

This standard covers the normal and emergency vapor venting requirements for aboveground liquid petroleum or petroleum products storage tanks and aboveground and underground refrigerated storage tanks designed for operation at pressures from vacuum through 15 pounds per square inch gauge (1.034 bar gauge). Discussed in this standard are the causes of overpressure or vacuum; determination of venting requirements; means of venting; selection, installation, and maintenance of venting devices; and testing and marking of relief devices.

2 References

Unless otherwise specified, the referenced sections of the most recent editions or revisions of the following standards, codes, and specifications shall, to the extent specified herein, form a part of this standard.

2.1 STANDARDS

API

Std 620	*Design and Construction of Large, Welded, Low-Pressure Storage Tanks*
Std 650	*Welded Steel Tanks for Oil Storage*
Std 2510	*Design and Construction of Liquefied Petroleum Gas (LPG) Installations*

ASME[1]

PTC 19.5	*Fluid Meters: Interim Supplement on Instruments and Apparatus, Part II—"Application"*
PTC 25	*Pressure Relief Devices*
	Boiler & Pressure Vessel Code, Section VIII, Division 1, Rules for Construction of Pressure Vessels

[1]American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017

2.2 OTHER REFERENCES

API

RP 520	*Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part I — "Sizing and Selection"*
RP 521	*Guide for Pressure-Relieving and Depressuring Systems*
RP 576	*Inspection of Pressure-Relieving Devices*
Publ 2210	*Flame Arresters for Vents of Tanks Storing Petroleum Products*
RP 2350	*Overfill Protection for Petroleum Storage Tanks*
Bull 2521	*Use of Pressure-Vacuum Vent Valves for Atmospheric Pressure Tanks to Reduce Evaporation Loss*

3 Definition of Terms

For the purposes of this standard, the following definitions apply:

3.1 accumulation: The pressure increase in a tank over its maximum allowable working pressure when the vent valve is relieving (expressed in pressure units or percentage of the maximum allowable working pressure). Maximum allowable accumulations are typically established by applicable codes for operating and fire contingencies.

3.2 barrel: A liquid unit of measure equal to 42 US gallons (0.159 cubic meters).

3.3 BTU: British Thermal Unit, a unit of heat that will increase the temperature of one pound of water one degree Fahrenheit.

3.4 emergency venting: The venting required when an abnormal condition, such as ruptured internal heating coils or an external fire, exists either inside or outside of a tank.

3.5 nonrefrigerated tank: A container that stores material in a liquid state without the aid of refrigeration either by evaporation of the tank contents or by a circulating refrigeration system. Generally, the storage temperature will be close to or higher than ambient temperature.

3.6 normal venting: The venting required because of operational requirements or atmospheric changes.

3.7 overpressure: The pressure increase at the valve inlet above the set pressure, when the valve is relieving, expressed in pressure units or as a percentage of the set pressure. It is the same as accumulation when the valve is set at the maximum allowable working pressure and the inlet piping losses are zero.

3.8 petroleum: Crude oil.

3.9 petroleum products: Hydrocarbon materials or other products derived from crude oil.

3.10 PV valve: A weight-loaded, pilot-operated, or spring-loaded valve, used to relieve excess pressure and/or vacuum that has developed in a tank.

3.11 rated relieving capacity: The flow capacity of a relief device expressed in terms of air flow at standard conditions (SCFH or Nm^3/h) at a designated pressure or vacuum.

3.12 refrigerated tank: A container that stores liquid at a temperature below atmospheric temperature with or without the aid of refrigeration either by evaporation of the tank contents or by a circulating refrigeration system.

3.13 relief device: Any device used to relieve excess pressure and/or vacuum that has developed in a tank.

3.14 relieving pressure: The pressure at the inlet of a relief device when it is flowing at the required relieving capacity.

3.15 required flow capacity: The flow capacity of a relief device required to prevent excessive overpressure or vacuum in a tank under the most severe operating or emergency conditions.

3.16 SCFH: Standard cubic feet of air or gas per hour (same as free air or free gas) at a temperature of 60°F (15.6°C) and a pressure of 14.7 pounds per square inch absolute (1.014 bar absolute).

3.17 Nm^3/h: Normal cubic meters of air or gas per hour at a temperature of 0°C and pressure of 1.014 bar

3.18 set pressure: The gauge pressure at the device inlet at which the relief device is set to start opening under service conditions (measurable lift begins).

3.19 thermal inbreathing: The movement of air or blanketing gas into a tank when vapors in the tank contract or condense as a result of weather changes conditions (e.g., a decrease in atmospheric temperature).

3.20 thermal outbreathing: The movement of vapors out of a tank when vapors in the tank expand and liquid in the tank vaporizes as a result of weather changes (e.g., an increase in atmospheric temperature).

3.21 wetted area: The surface area of a tank exposed to liquid on the interior and heat from a fire on the exterior.

4 Nonrefrigerated Aboveground Tanks

4.1 GENERAL

This section covers the normal and emergency venting requirements for nonrefrigerated aboveground liquid petroleum or petroleum products storage tanks. Discussed in this section are the causes of overpressure or vacuum; determination of venting requirements; means of venting; selection, installation, and maintenance of venting devices; and testing and marking of relief devices.

4.2 CAUSES OF OVERPRESSURE OR VACUUM

4.2.1 General

When the possible causes of overpressure or vacuum in a tank are being determined, the following circumstances must be considered:

a. Liquid movement into or out of the tank.

b. Tank breathing due to weather changes (e.g., pressure and temperature changes).

c. Fire exposure.

d. Other circumstances resulting from equipment failures and operating errors.

Some of these circumstances are described more fully in Sections 4.2.2 through 4.2.5. There may be additional circumstances that should be considered by the designer but are not included in this standard.

4.2.2 Liquid Movement Into or Out of a Tank

Inbreathing will result from the outflow of liquid from a tank. Outbreathing will result from the inflow of liquid into a tank and from the vaporization, including flashing of the feed liquid, that will occur because of the inflow of the liquid. Flashing of the feed liquid can be significant for feed that is near or above its boiling point at the pressure in the tank.

4.2.3 Weather Changes

Inbreathing will result from the contraction or condensation of vapors that is caused by a decrease in atmospheric temperature or other weather changes, such as wind changes, precipitation, etc. Outbreathing will result from the expansion and vaporization that is caused by an increase in atmospheric temperature or weather changes (thermal breathing).

4.2.4 Fire Exposure

Outbreathing will result from the expansion of the vapors and vaporization of the liquid that occurs when a tank absorbs heat from an external fire.

4.2.5 Other Circumstances

4.2.5.1 General

When the possible causes of overpressure or vacuum in a tank are being determined, other circumstances resulting from equipment failures and operating errors must be considered and evaluated by the designer. Calculation methods for these other circumstances have not been provided in this standard.

4.2.5.2 Pressure Transfer Blowoff

Liquid transfer from other vessels, tank trucks, and tank cars may be aided or accomplished entirely by pressurization of the supply vessel with a gas, but the receiving tank may encounter a flow surge at the end of the transfer due to vapor breakthrough. Depending on the pre-existing pressure and free head space in the receiving tank, the additional gas volume may be sufficient to overpressure the tank. The controlling case is a transfer that fills the receiving tank so that little head space remains to absorb the pressure surge. A similar situation can be encountered during line pigging if a vapor chaser is used after the pigging device.

4.2.5.3 Inert Pads and Purges

Inert pads and purges are provided on tanks to protect the contents of the tanks from contamination, maintain nonflammable atmospheres in the tanks, and suppress vapor emissions from the tanks. An inert pad and purge system normally has a supply regulator and a back pressure regulator to maintain interior tank pressure within a narrow range. Failure of the supply regulator can result in unrestricted gas flow into the tank, reduced gas flow, or complete loss of the gas flow. Failure of the back pressure regulator could result in overpressure.

4.2.5.4 External Heat Transfer Devices

Steam, tempered water, and hot oil are common heating media for tanks whose contents must be maintained at elevated temperatures. If failure of a tank's supply control valve, temperature sensing element, or control system causes the flow of heating medium to the tank's jacket to increase, vaporization of the liquid stored in the tank can occur. When vaporization occurs, the resulting overpressure must be relieved.

If a tank maintained at elevated temperatures is empty, excessive feed vaporization may result when the tank is filled. If the temperature control system of the tank is active with the sensing element exposed to vapor, the tank's heating medium may be circulating at maximum rate with the tank wall at maximum temperature. Filling during such conditions may result in excessive feed vaporization. The excessive feed vaporization would stop as soon as the walls cooled and the fluid level covered the sensing element.

For a tank with a cooling jacket or coils, liquid vaporization as a result of the loss of coolant flow must be considered.

4.2.5.5 Internal Heat Transfer Devices

Mechanical failure of a tank's internal heating or cooling device can expose the contents of the tank to the heating or cooling medium used in the device. In low-pressure tanks, it can be assumed that the flow direction of the heat transfer medium will be into the tank when the device fails. Chemical compatibility of the tank contents and the heat transfer medium must be considered. Relief of the heat transfer medium (e.g., steam) may be necessary. The disposition of the tank contents until the device can be repaired or replaced must also be considered.

4.2.5.6 Vent Treatment Systems

If vapor from a tank is collected for treatment or disposal by a vent treatment system, the vent collection system may fail. This failure must be evaluated. Failures affecting the safety of a tank can include back pressure developed from problems in the piping (liquid-filled pockets and solids build-up), other equipment relieving into the header, or blockage due to equipment failure. An emergency venting device that relieves to atmosphere, set at a higher pressure than the vent treatment system, is normally used. For toxic or hazardous vapors, a fail-safe vent treatment system should be considered.

4.2.5.7 Utility Failure

Local and plant-wide power and utility failures must be considered as possible causes of overpressure or vacuum. Loss of electrical power will directly affect any motorized valves or controllers and may also shut down the instrument air supply. Also, cooling and heating fluids may be lost during an electrical failure.

4.2.5.8 Change in Temperature of the Input Stream to a Tank

A change in the temperature of the input stream to a tank brought about by a loss of cooling or an increase in heat input may cause overpressure in the tank.

4.2.5.9 Chemical Reactions

The contents of some tanks may be subject to chemical reactions, which may generate heat and/or vapors. Some examples of chemical reactions may include inadvertently adding water to acid or spent acid tanks thereby generating steam and/or vaporizing light hydrocarbons, runaway reactions of phenol tanks, etc. In some cases, the material may foam, causing two phase relief. Technology developed by the Design Institute for Emergency Relief (DIERS) may be used to evaluate these cases.

4.2.5.10 Liquid Overfill Protection

For information on liquid overfill protection, see API Standards 620, 2510, and API Recommended Practice 2350. Liquid overfill shall be prevented by providing positive design and operation steps, such as two reliable and repairable level instruments and an independent high-level alarm that independently stop the filling operation by closing the filling valves.

4.2.5.11 Atmospheric Pressure Changes

A rise or drop in barometric pressure is a possible cause of vacuum or overpressure in a tank.

4.2.5.12 Control Valve Failure

Failure of a control valve on the liquid line to a tank must be considered because such a failure may overload heat exchange equipment and cause high temperature material to be admitted to the tank. A control valve failure may also cause the liquid level in a pressurized vessel feeding liquid to a tank to drop below the vessel outlet nozzle, allowing high pressure vapor to enter the tank.

4.2.5.13 Steam Out

If an uninsulated tank is filled with steam, the condensing rate due to ambient cooling may exceed the venting rates specified in this standard. Other steps, including large vents (open manways) and slowly cooling the tank, are necessary to prevent excessive internal vacuum.

4.2.5.14 Uninsulated Tanks

Uninsulated tanks with exceptionally hot vapor spaces may exceed the venting requirements in this standard during a rainstorm. Vapor contraction may cause excessive vacuum. An engineered review of heated uninsulated tanks with vapor space temperatures above 120°F (48.9°C) is recommended.

4.3 DETERMINATION OF VENTING REQUIREMENTS

4.3.1 General

Venting requirements are given for the following conditions:

a. Inbreathing resulting from maximum outflow of liquid from the tank.

b. Inbreathing resulting from contraction or condensation of vapors caused by maximum decrease in vapor space temperature (thermal breathing).

c. Outbreathing resulting from maximum inflow of liquid into the tank and maximum vaporization caused by such inflow.

d. Outbreathing resulting from expansion and vaporization that result from maximum increase in vapor space temperature (thermal breathing).

e. Outbreathing resulting from fire exposure.

Although design guidelines are not presented in this standard for other circumstances discussed in Section 4.2.5, they should be considered.

4.3.2 Requirements for Normal Venting Capacity

The total normal venting capacity shall be at least the sum of the venting requirements for liquid movement and thermal effect; however, the required capacity may be reduced for products whose volatility is such that vapor generation or condensation within the permissible operating range of tank pressure will provide all or part of the venting requirements. In cases in which noncondensables are present, this should be taken into account. A summary of the venting requirements for inbreathing and outbreathing due to liquid movement out of and into a tank and thermal effects are shown in Tables 1 and 2. These requirements are discussed in Sections 4.3.2.1 and 4.3.2.2.

Table 1A—Normal Venting Requirements
(SCFH of Air per Barrel per Hour of Liquid Flow)
A. English Units

Flash Point/Boiling Point[a]	Inbreathing		Outbreathing	
	Liquid Movement Out	Thermal	Liquid Movement In	Thermal
Flash Point ≥ 100°F	5.6	See Table 2A	6	See Table 2A
Boiling Point ≥ 300°F	5.6	" "	6	" "
Flash Point < 100°F	5.6	" "	12	" "
Boiling Point < 300°F	5.6	" "	12	" "

[a] Data on flash point or boiling point may be used. Where both are available, use flash point (See Appendix A).

Table 1B—Normal Venting Requirements
(Nm^3/hr of Air per Cubic Meter per Hour of Liquid Flow)
B. Metric Units

Flash Point/Boiling Point[a]	Inbreathing		Outbreathing	
	Liquid Movement Out	Thermal	Liquid Movement In	Thermal
Flash Point ≥ 37.8°C	0.94	See Table 2B	1.01	See Table 2B
Boiling Point ≥ 148.9°C	0.94	" "	1.01	" "
Flash Point < 37.8°C	0.94	" "	2.02	" "
Boiling Point < 149°C	0.94	" "	2.02	" "

[a] Data on flash point or boiling point may be used. Where both are available, use flash point (See Appendix A).

4.3.2.1 Inbreathing (Vacuum Relief)

4.3.2.1.1 The requirement for venting capacity for maximum liquid movement out of a tank should be equivalent to 5.6 SCFH of air for each 42 US gallon barrel (0.94 Nm^3/h of air for each cubic meter) per hour of maximum emptying rate for liquids of any flash point.

4.3.2.1.2 The requirement for venting capacity for thermal inbreathing for a given tank capacity for liquids of any flash point should be at least that shown in Column 2 of Table 2. An engineering review should be conducted for heated uninsulated tanks where the vapor space temperature is maintained above 120°F (48.9°C) (see Section 4.2.5.14).

4.3.2.2 Outbreathing (Pressure Relief) for Liquid With a Flash Point Above 100°F (37.8°C)

4.3.2.2.1 The requirement for venting capacity for maximum liquid movement into a tank and the resulting vaporization for liquid with a flash point of 100°F (37.8°C) or above or a normal boiling point of 300°F (148.9°C) or above should be equivalent to 6 SCFH of air for each 42 US gallon barrel (1.01 Nm^3/h per cubic meter) per hour of maximum filling rate.

Note: Protection against liquid overfilling is not covered in this standard, but it is covered in API Standard 620 and in API Recommended Practice 2350.

4.3.2.2.2 The requirement for venting capacity for thermal outbreathing, including thermal vaporization, for a given tank capacity for liquid with a flash point of 100°F (37.8°C) or above or a normal boiling point of 300°F (148.9°C) or above should be at least that shown in Column 3 of Table 2.

4.3.2.3 Outbreathing (Pressure Relief) for Liquid With a Flash Point Below 100°F (37.8°C)

4.3.2.3.1 The requirement for venting capacity for maximum liquid movement into a tank and the resulting vaporization for liquid with a flash point below 100°F (37.8°C) or a normal boiling point below 300°F (148.9°C) should be equivalent to 12 SCFH of air for each 42 US gallon barrel (2.02 Nm^3/h per cubic meter) per hour of maximum filling rate (see Appendix A for the basis of this requirement).

A tank into which liquid is fed at or near the boiling point at the tank pressure may require an outbreathing capacity that is higher than the capacity indicated above or in Table 1. The values presented above and in Table 1 are based on vaporization of 0.5 percent of the feed liquid; significantly higher vaporization rates can occur if the feed is above the boiling point. For instance, with hexane, 0.4 percent of the feed can vaporize for every 1°F (0.56°C) above the boiling point at tank pressure.

Note: Protection against liquid overfilling is not covered in this standard, but it is covered in API Standard 620 and in API Recommended Practice 2350.

4.3.2.3.2 The requirement for venting capacity for thermal outbreathing, including thermal vaporization, for a given tank capacity for liquid with a flash point below 100°F (37.8°C) or a normal boiling point below 300°F (148.9°C) should be at least that shown in Column 4 of Table 2.

4.3.3 Requirements for Emergency Venting Capacity for Tanks Subject to Fire Exposure

When storage tanks are exposed to fire, the venting rate may exceed the rate resulting from a combination of normal thermal effects and liquid movement. In such cases, the construction of the tank will determine whether additional venting capacity must be provided.

4.3.3.1 Tanks With Weak Roof-to-Shell Attachment

On a fixed-roof tank with a weak (frangible) roof-to-shell attachment as described in API Standard 650, the roof-to-shell connection will fail preferentially to any other joint and the excess pressure will be safely relieved if the normal venting capacity should prove inadequate. For a tank built to these specifications, consideration need not be given to any additional requirements for emergency venting; however, additional

Table 2A—Requirements for Thermal Venting Capacity
A. English Units

Tank Capacity		Inbreathing (Vacuum)	Outbreathing	
Column 1[d]		Column 2[a]	Column 3[b]	Column 4[c]
			Flash Point ≥ 100°F or Normal Boiling Point ≥ 300°F	Flash Point < 100°F or Normal Boiling Point < 300°F
Barrels	Gallons	SCFH Air	SCFH Air	SCFH Air
60	2,500	60	40	60
100	4,200	100	60	100
500	21,000	500	300	500
1,000	42,000	1,000	600	1,000
2,000	84,000	2,000	1,200	2,000
3,000	126,000	3,000	1,800	3,000
4,000	168,000	4,000	2,400	4,000
5,000	210,000	5,000	3,000	5,000
10,000	420,000	10,000	6,000	10,000
15,000	630,000	15,000	9,000	15,000
20,000	840,000	20,000	12,000	20,000
25,000	1,050,000	24,000	15,000	24,000
30,000	1,260,000	28,000	17,000	28,000
35,000	1,470,000	31,000	19,000	31,000
40,000	1,680,000	34,000	21,000	34,000
45,000	1,890,000	37,000	23,000	37,000
50,000	2,100,000	40,000	24,000	40,000
60,000	2,520,000	44,000	27,000	44,000
70,000	2,940,000	48,000	29,000	48,000
80,000	3,360,000	52,000	31,000	52,000
90,000	3,780,000	56,000	34,000	56,000
100,000	4,200,000	60,000	36,000	60,000
120,000	5,040,000	68,000	41,000	68,000
140,000	5,880,000	75,000	45,000	75,000
160,000	6,720,000	82,000	50,000	82,000
180,000	7,560,000	90,000	54,000	90,000

Notes:

[a] For tanks with a capacity of 20,000 barrels (3,180 cubic meters) or more, the requirements for the vacuum condition are very close to the theoretically computed value of 2 SCFH of air per square foot (0.577 Nm^3/h per square meter) of total shell and roof area. For tanks with a capacity of less than 20,000 barrels (3,180 cubic meters), the requirements for the vacuum condition have been based on 1 SCFH of air for each barrel of tank capacity (0.169 Nm^3/h per cubic meter). This is substantially equivalent to a mean rate of temperature change of 100°F (37.8°C) per hour in the vapor space (see Appendix A). An engineering review should be conducted for uninsulated tanks where the vapor space temperature is maintained above 120°F (48.9°C) (see 4.2.5.14).

[b] For stocks with a flash point of 100°F (37.8°C) or above, the outbreathing requirement has been assumed to be 60 percent of the inbreathing requirement. The roof and shell temperatures of a tank cannot rise as rapidly under any condition as they fall, for example, during a sudden cold rain.

[c] For stocks with a flash point below 100°F (37.8°C), the outbreathing requirement has been assumed to be equal to the inbreathing requirement to allow for vaporization at the liquid surface and for the higher specific gravity of the tank vapors.

[d] Interpolate for intermediate tank sizes. Tanks with a capacity of more than 180,000 barrels (30,000 cubic meters) require individual study. Refer to Appendix A for additional information about the basis of this table.

Table 2B —Requirements for Thermal Venting Capacity
B. Metric Units

Tank Capacity	Inbreathing (Vacuum)	Outbreathing	
Column 1[d]	Column 2[a]	Column 3[b]	Column 4[c]
		Flash Point ≥ 37.8°C or Normal Boiling Point ≥ 148.9°C	Flash Point < 37.8°C or Normal Boiling Point < 148.9°C
Cubic Meters	Nm^3/h	Nm^3/h	Nm^3/h
10	1.69	1.01	1.69
20	3.37	2.02	3.37
100	16.9	10.1	16.9
200	33.7	20.2	33.7
300	50.6	30.3	50.6
500	84.3	50.6	84.3
700	118	70.8	118
1,000	169	101	169
1,500	253	152	253
2,000	337	202	337
3,000	506	303	506
3,180	536	388	536
4,000	647	472	647
5,000	787	537	787
6,000	896	602	896
7,000	1,003	646	1,003
8,000	1,077	682	1,077
9,000	1,136	726	1,136
10,000	1,210	807	1,210
12,000	1,345	888	1,345
14,000	1,480	969	1,480
16,000	1,615	1,047	1,615
18,000	1,745	1,126	1,745
20,000	1,877	1,307	1,877
25,000	2,179	1,378	2,179
30,000	2,495	1,497	2,495

Notes:

[a] For tanks with a capacity of 20,000 barrels (3,180 cubic meters) or more, the requirements for the vacuum condition are very close to the theoretically computed value of 2 SCFH of air per square foot (0.577 Nm^3/h per square meter) of total shell and roof area. For tanks with a capacity of less than 20,000 barrels (3,180 cubic meters), the requirements for the vacuum condition have been based on 1 SCFH of air for each barrel of tank capacity (0.169 Nm^3/h per cubic meter). This is substantially equivalent to a mean rate of temperature change of 100°F (37.8°C) per hour in the vapor space (see Appendix A). An engineering review should be conducted for uninsulated tanks where the vapor space temperature is maintained above 120°F (48.9°C) (see 4.2.5.14).

[b] For stocks with a flash point of 100°F (37.8°C) or above, the outbreathing requirement has been assumed to be 60 percent of the inbreathing requirement. The roof and shell temperatures of a tank cannot rise as rapidly under any condition as they fall, for example, during a sudden cold rain.

[c] For stocks with a flash point below 100°F (37.8°C), the outbreathing requirement has been assumed to be equal to the inbreathing requirement to allow for vaporization at the liquid surface and for the higher specific gravity of the tank vapors.

[d] Interpolate for intermediate tank sizes. Tanks with a capacity of more than 180,000 barrels (30,000 cubic meters) require individual study. Refer to Appendix A for additional information about the basis of this table.

emergency vents may be used to avoid failure of the joint. Care should be taken to ensure that the requirements for a frangible roof-to-shell attachment are met, particularly on a smaller tank.

4.3.3.2 Tanks Without Weak Roof-to-Shell Attachment

When a tank is not provided with a weak roof-to-shell attachment as described in 4.3.1.1, the procedure given in 4.3.3.2.1 through 4.3.3.2.6 shall govern in evaluating the required venting capacity for fire exposure.

4.3.3.2.1 For tanks subject to fire exposure, the required venting capacity shall be determined by Equation 1A or 1B.

A. English Units

$$SCFH = 3.091 \times \frac{QF}{L} \times \left(\frac{T}{M}\right)^{0.5} \qquad (1A)$$

where

$SCFH$ = venting requirement, in standard cubic feet per hour of air,

Q = heat input from fire exposure, in BTU per hour. Heat input is provided in Figure B-1 of Appendix B or the following summary:

Wetted Surface Area (square feet)	Design Pressure (psig)	Heat Input (Btu/hr)
<200	≤15	$Q = 20{,}000A$
≥200 and <1000	≤15	$Q = 199{,}300A^{0.566}$
≥1000 and <2800	≤15	$Q = 963{,}400A^{0.338}$
≥2800	between 1 psig and 15	$Q = 21{,}000A^{0.82}$
≥2800	≤1	$Q = 14{,}090{,}000$

A = wetted surface area of the tank, in square feet (see Table 3A, Footnotes a and b),

F = environmental factor from Table 4A. Credit may be taken for only one environmental factor,

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature, in BTU per pound,

T = temperature of the relieving vapor, in degrees Rankine. It is normally assumed that the temperature of the relieving vapor corresponds to the boiling point of the stored fluid at the relieving pressure,

M = molecular weight of the vapor being relieved.

B. Metric Units

$$Nm^3/h = 881.55 \times \frac{QF}{L} \times \left(\frac{T}{M}\right)^{0.5} \qquad (1B)$$

where

Nm^3/h = venting requirement, in normal cubic meters per hour of air,

Q = heat input from fire exposure, in Watts. Heat input is provided in the following summary:

Wetted Surface Area (square mm)	Design Pressure (barg)	Heat Input (Watts)
<18.6	≤1.034	$Q = 63{,}150A$
≥18.6 and <93	≤1.034	$Q = 224{,}200A^{0.566}$
≥93 and <260	≤1.034	$Q = 630{,}400A^{0.338}$
≥260	between 0.07 and 1.034	$Q = 43{,}200A^{0.82}$
≥260	≤0.07	$Q = 4{,}129{,}700$

A = wetted surface area of the tank, in square meters (see Table 3B, Footnotes a and b),

F = environmental factor from Table 4B. Credit may be taken for only one environmental factor,

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature, in kilojoules/kilogram (kJ/kg),

T = temperature of the relieving vapor, in degrees Kelvin. It is normally assumed that the temperature of the relieving vapor corresponds to the boiling point of the stored fluid at the relieving pressure,

M = molecular weight of the vapor.

4.3.3.2.2 Where a lesser degree of accuracy can be tolerated, the required venting capacity can be determined from Table 3 or Equation 2A or 2B, as indicated in the following summary:

For English Units:

Wetted Surface Area (square feet)	Design Pressure (psig)	Required Venting Capacity (SCFH)
<2800	≤15	See Table 3A and 4.3.3.2.3
≥2800	≤1	742,000 (see 4.3.3.2.3)
≥2800	Between 1 and 15	Equation 2A

$$SCFH = 1107FA^{0.82} \qquad (2A)$$

Table 3A—Emergency Venting Required for Fire Exposure Versus Wetted Surface Area[c]
A. English Units

Wetted Area[a] (square feet)	Venting Requirement (SCFH)	Wetted Area[a] (square feet)	Venting Requirement (SCFH)
20	21,100	350	288,000
30	31,600	400	312,000
40	42,100	500	354,000
50	52,700	600	392,000
60	63,200	700	428,000
70	73,700	800	462,000
80	84,200	900	493,000
90	94,800	1,000	524,000
100	105,000	1,200	557,000
120	126,000	1,400	587,000
140	147,000	1,600	614,000
160	168,000	1,800	639,000
180	190,000	2,000	662,000
200	211,000	2,400	704,000
250	239,000	2,800	742,000
300	265,000	>2,800[b]	—

Table 3B—Emergency Venting Required for Fire Exposure Versus Wetted Surface Area[c]
B. Metric Units

Wetted Area[a] (square meters)	Venting Requirement (Nm^3/h)	Wetted Area[a] (square meters)	Venting Requirement (Nm^3/h)
2	608	35	8086
3	913	40	8721
4	1,217	45	9322
5	1,521	50	9895
6	1,825	60	10,971
7	2,130	70	11,971
8	2,434	80	12,911
9	2,738	90	13,801
11	3,347	110	15,461
13	3,955	130	15,751
15	4,563	150	16,532
17	5,172	175	17,416
19	5,780	200	18,220
22	6,217	230	19,102
25	6,684	260	19,910
30	7,411	>260[b]	—

[a]The wetted area of a tank or storage vessel shall be calculated as follows:

Sphere and Spheroids—The wetted area is equal to 55 percent of the total surface area or the surface area to a height of 30 feet (9.14 meters) above grade, whichever is greater.

Horizontal Tanks—The wetted area is equal to 75 percent of the total surface area or the surface area to a height of 30 feet (9.14 meters) above grade, whichever is greater.

Vertical Tanks—The wetted area is equal to the total surface area of the vertical shell to a height of 30 feet (9.14 meters) above grade. For a vertical tank setting on the ground, the area of the ground plates is not to be included as wetted area. For a vertical tank supported above grade, a portion of the area of the bottom is to be included as additional wetted surface. The portion of the bottom area exposed to a fire depends on the diameter and elevation of the tank above grade. Engineering judgment is to be used in evaluating the portion of the area exposed to fire.

[b]For wetted surfaces larger than 2,800 square feet (260 square meters), see Sections 4.3.3.2.2 and 4.3.3.2.3.

Note:

Table 3 and the constants 1107 and 208.2 in Equations 2A and 2B respectively were derived from Equation 1 and Figure B-1 by using the latent heat of vaporization of hexane (144 BTU per pound or 334,900 J/kg) at atmospheric pressure and the molecular weight of hexane (86.17) and assuming a vapor temperature of 60°F (15.6°C). This method will provide results within an acceptable degree of accuracy for many fluids having similar properties (see Appendix B).

Table 4A—Environmental Factors for Nonrefrigerated Aboveground Tanks
A. English Units

Tank Design/Configuration	Insulation Conductance (BTU/hr ft^2 °F)	Insulation Thickness (in)	*F* Factor
Bare metal tank	—	0	1.0
Insulated tank[a]	4.0	1	0.3[b]
" "	2.0	2	0.15[b]
" "	1.0	4	0.075[b]
" "	0.67	6	0.05[b]
" "	0.5	8	0.0375[b]
" "	0.4	10	0.03[b]
" "	0.33	12	0.025[b]
Concrete tank or fireproofing	—	—	(see note c)
Water-application facilities[d]	—	—	1.0
Depressuring and emptying facilities[e]	—	—	1.0
Underground storage	—	—	0
Earth-covered storage above grade	—	—	0.03
Impoundment away from tank[f]	—	—	0.5

Notes:

[a]The insulation shall resist dislodgment by fire-fighting equipment, shall be noncombustible, and shall not decompose at temperatures up to 1000°F (537.8°C). The user is responsible to determine if the insulation will resist dislodgment by the available fire-fighting equipment. If the insulation does not meet these criteria, no credit for insulation shall be taken. The conductance values are based on insulation with a thermal conductivity of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness). The user is responsible for determining the actual conductance value of the insulation used. The conservative value of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness) for the thermal conductivity is used.

[b]These *F* factors are based on the thermal conductance values shown and a temperature differential of 1600°F (888.9°C) when using a heat input value of 21,000 BTU per hour per square foot (66,200 Watts per square meter) in accordance with the conditions assumed in API Recommended Practice 521. When these conditions do not exist, engineering judgment should be used to select a different *F* factor or to provide other means for protecting the tank from fire exposure.

[c]Use the *F* factor for an equivalent conductance value of insulation.

[d]Under ideal conditions, water films covering the metal surfaces can absorb most incident radiation. The reliability of water application depends on many factors. Freezing weather, high winds, clogged systems, undependable water supply, and tank surface conditions can prevent uniform water coverage. Because of these uncertainties, no reduction in environmental factors is recommended; however, as stated previously, properly applied water can be very effective.

[e]Depressuring devices may be used, but no credit shall be allowed in sizing the venting device for fire exposure.

[f]The following conditions must be met: A slope of not less than 1 percent away from the tank shall be provided for at least 50 feet (15 meters) toward the impounding area; the impounding area shall have a capacity that is not less than the capacity of the largest tank that can drain into it; the drainage system routes from other tanks to their impounding areas shall not seriously expose the tank; and the impounding area for the tank as well as the impounding areas for the other tanks (whether remote or with dikes around the other tanks) shall be located so that when the area is filled to capacity, its liquid level is no closer than 50 feet (15 meters) to the tank.

Table 4B—Environmental Factors for Nonrefrigerated Aboveground Tanks
B. Metric Units

Tank Design/Configuration	Insulation Conductance (Watts/m² °K)	Insulation Thickness (cm)	*F* Factor
Bare metal tank	—	0	1.0
Insulated tank[a]	22.7	2.5	0.3[b]
" "	11.4	5	0.15[b]
" "	5.7	10	0.075[b]
" "	3.8	15	0.05[b]
" "	2.8	20	0.0375[b]
" "	2.3	25	0.03[b]
" "	1.9	30	0.025[b]
Concrete tank or fireproofing	—	—	(see note c)
Water-application facilities[d]	—	—	1.0
Depressuring and emptying facilities[e]	—	—	1.0
Underground storage	—	—	0
Earth-covered storage above grade	—	—	0.03
Impoundment away from tank[f]	—	—	0.5

Notes:
[a]The insulation shall resist dislodgment by fire-fighting equipment, shall be noncombustible, and shall not decompose at temperatures up to 1000°F (537.8°C). The user is responsible to determine if the insulation will resist dislodgment by the available fire-fighting equipment. If the insulation does not meet these criteria, no credit for insulation shall be taken. The conductance values are based on insulation with a thermal conductivity of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness). The user is responsible for determining the actual conductance value of the insulation used. The conservative value of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness) for the thermal conductivity is used.
[b]These *F* factors are based on the thermal conductance values shown and a temperature differential of 1600°F (888.9°C) when using a heat input value of 21,000 BTU per hour per square foot (66,200 Watts per square meter) in accordance with the conditions assumed in API Recommended Practice 521. When these conditions do not exist, engineering judgment should be used to select a different *F* factor or to provide other means for protecting the tank from fire exposure.
[c]Use the *F* factor for an equivalent conductance value of insulation.
[d]Under ideal conditions, water films covering the metal surfaces can absorb most incident radiation. The reliability of water application depends on many factors. Freezing weather, high winds, clogged systems, undependable water supply, and tank surface conditions can prevent uniform water coverage. Because of these uncertainties, no reduction in environmental factors is recommended; however, as stated previously, properly applied water can be very effective.
[e]Depressuring devices may be used, but no credit shall be allowed in sizing the venting device for fire exposure.
[f]The following conditions must be met: A slope of not less than 1 percent away from the tank shall be provided for at least 50 feet (15 meters) toward the impounding area; the impounding area shall have a capacity that is not less than the capacity of the largest tank that can drain into it; the drainage system routes from other tanks to their impounding areas shall not seriously expose the tank; and the impounding area for the tank as well as the impounding areas for the other tanks (whether remote or with dikes around the other tanks) shall be located so that when the area is filled to capacity, its liquid level is no closer than 50 feet (15 meters) to the tank.

where

$SCFH$ = venting requirement, in standard cubic feet per hour of air,

F = environmental factor from Table 4A. Credit may be taken for only one environmental factor,

A = wetted surface area, in square feet (see Table 3A, Footnote a).

Note: Equation 2A is based on

$$Q = 21{,}000A^{0.82}$$

or

For Metric Units:

Wetted Surface Area (square mm)	Design Pressure (barg)	Required Venting Capacity (Nm^3/h)
<260	≤1.034	See Table 3B and 4.3.3.2.3
≥260	≤0.07	19910 (see 4.3.3.2.3)
≥260	Between 0.07 and 1.034	Equation 2B

$$Nm^3 / h = 208.2FA^{0.82} \qquad (2B)$$

where

Nm^3 / h = venting requirement, in normal cubic meters per hour of air,

F = environmental factor from Table 4B. Credit may be taken for only one environmental factor,

A = wetted surface area, in square meters (see Table 3B, Footnote a).

Note: Equation 2B is based on

$$Q = 43{,}200A^{0.82}$$

The total heat absorbed, Q, is in BTU per hour for Equation 2A and in Watts for Equation 2B. Table 3 and the constants 1107 and 208.2 in Equations 2A and 2B, respectively, were derived from Equation 1A and Figure B-1 by using the latent heat of vaporization of hexane (144 BTU per pound or 335,000 J/kg) at atmospheric pressure and the molecular weight of hexane (86.17) and assuming a vapor temperature of 60°F (15.6°C). This method will provide results within an acceptable degree of accuracy for many fluids having similar properties (see Appendix B).

4.3.3.2.3 The total rate of venting determined from Table 3 may be multiplied by an appropriate environmental factor, F, selected from Table 4, but credit may be taken for only one environmental factor.

4.3.3.2.4 Full credit may be taken for the venting capacity provided for normal venting, since the normal thermal effect can be disregarded during a fire. Also, it can be assumed that there will be no liquid movement into the tank.

4.3.3.2.5 If normal venting devices are inadequate, additional emergency venting devices of the type described in Section 4.4.2 shall be provided so that the total venting capacity is at least equivalent to that required by Table 3 or Equation 1 or 2.

4.3.3.2.6 The total venting capacity shall be based on the pressure indicated in Section 4.5.1.

4.4 MEANS OF VENTING

4.4.1 Normal Venting

Normal venting for pressure and vacuum shall be accomplished by a PV valve or an open vent with or without a flame-arresting device in accordance with the requirements of Sections 4.4.1.1 through 4.4.1.5. Relief devices equipped with a weight and lever are not recommended.

4.4.1.1 Any relief device, shall be designed so that it will protect the tank in the event of failure of any essential part.

4.4.1.2 PV valves are recommended for use on atmospheric storage tanks in which petroleum or petroleum products with a flash point below 100°F (37.8°C) are stored and for use on tanks containing petroleum or petroleum products where the fluid temperature may exceed the flash point. A flame arrester is not considered necessary for use in conjunction with a PV valve venting to atmosphere because flame speeds are less than vapor velocities across the seats of PV valves (see API Publication 2210).

4.4.1.3 Open vents with a flame-arresting device may be used in place of PV valves on tanks in which petroleum or petroleum products with a flash point below 100°F (37.8°C) are stored and on tanks containing petroleum and petroleum products where the fluid storage temperature may exceed the flash point.

4.4.1.4 Open vents without flame arresters may be used to provide venting capacity for any of the following:

a. For tanks in which petroleum or petroleum products with a flash point of 100°F (37.8°C) or above are stored, provided the contents are not heated and the fluid temperature remains below the flash point.

b. For heated tanks in which the storage temperature of the petroleum and petroleum products is below the flash point.

c. For tanks with a capacity of less than 59.5 barrels (9.46 cubic meters) [2,500 US gallons (9,460 liters)] used for storing any product.

d. For tanks with a capacity of less than 3,000 barrels (477 cubic meters) [126,000 US gallons (477,000 liters)] used for storing crude oil.

4.4.1.5 In the case of viscous oils, such as cutback and penetration-grade asphalts, where the danger of tank collapse resulting from sticking pallets or from plugging of flame arresters is greater than the possibility of flame transmission into the tank, open vents may be used as an exception to the requirements of Sections 4.4.1.2 and 4.4.1.3 for PV valves or flame-arresting devices.

4.4.1.6 A discussion of the types and operating characteristics of venting devices can be found in Appendix C.

4.4.1.7 In areas with strict fugitive emissions regulations, open vents may not be acceptable and vent device selection should consider maximum leakage requirements during periods of normal tank operation.

4.4.2 Emergency Venting

Emergency venting may be accomplished by the use of the following:

a. Larger or additional open vents as limited by Sections 4.4.1.2 and 4.4.1.3.

b. Larger or additional PV valves.

c. A gauge hatch that permits the cover to lift under abnormal internal pressure.

d. A manhole cover that lifts when exposed to abnormal internal pressure.

e. A connection between the roof and the shell that is weaker than the weakest vertical joint in the shell or the shell-to-bottom connection.

Note: A tank with a frangible roof-to-shell attachment, as described in API Standard 650, does not require emergency venting devices. Care should be taken to ensure that the requirements for a frangible roof-to-shell attachment are met, particularly on a smaller tank, before this method of emergency venting is used.

f. Other forms of construction that can be proven to be comparable for the purposes of pressure relief.

g. A rupture disk device.

4.5 SELECTION, INSTALLATION, AND MAINTENANCE OF VENTING DEVICES

4.5.1 Total Venting Requirements

4.5.1.1 Pressure

4.5.1.1.1 The pressure relief device or emergency venting device shall be suitable to relieve the flow capacity required for the largest single contingency or any reasonable and probable combination of contingencies; however, the required capacity may be reduced for products whose volatility is such that vapor condensation within the permissible operating range of tank pressure will provide all or part of the venting requirements. In cases in which noncondensables are present, this should be taken into account.

4.5.1.1.2 Consultation between the tank designer, the person specifying the venting devices, and the venting device manufacturer is strongly recommended to ensure that the venting devices are compatible with the tank design. The set or start-to-open pressure often must be lower than the design pressure of the tank to allow for adequate flow capacity of the devices. The operating pressure should be lower than the set pressure to allow for normal variations in pressure caused by changes in temperature and by other factors that affect pressure in the tank vapor space. The set pressure and relieving pressure must be consistent with the requirements of the standard according to which the tank was designed and fabricated. Some standards present specific requirements, but others may not.

4.5.1.1.3 Requirements for pressure relieving devices for tanks that are designed and fabricated in accordance with API Standard 620 are provided in Section 6 of API Standard 620. The pressure setting of a pressure-relieving device shall not exceed the maximum pressure that can exist at the level where the device is located when the pressure at the top of the tank equals the nominal pressure rating for the tank and the liquid contained in the tank is at the maximum design level.

Under normal conditions, pressure-relieving devices must have sufficient flow capacity to prevent the pressure from rising more than 10 percent above the maximum allowable working pressure. Under fire emergency conditions, the devices shall be capable of preventing the pressure from rising more than 20 percent above the maximum allowable working pressure.

4.5.1.1.4 API Standard 650 is not as definitive as API Standard 620 in presenting venting requirements. Appendix F of API Standard 650 states that the pressure relief devices for tanks designed for low internal pressures shall be sized and set so that at the rated capacity of the devices, the internal pressure of each tank under any normal operating condition shall not exceed the internal design pressure or the maximum design pressure. These pressures are defined specifically in Appendix F of API Standard 650.

For other API Standard 650 tanks, the pressure relief devices selected should limit the pressure in the tanks to prevent excessive lifting and flexing of the roofs of the tanks. Lifting and flexing of the roof of a tank is a condition that is determined by the weight of the roof. The total force caused by internal pressure should not exceed the weight of the roof and attachments, such as platforms and handrails. For example, the pressure should be limited to approximately 1.4 inches of water column (3.5 mbarg) for a $^3/_{16}$ inch (4.76 mm) carbon steel roof.

4.5.1.2 Vacuum

A vacuum relief device shall be installed to permit the entry of air, or another gas or vapor, to avoid excessive vacuum that may result; however, the required capacity may be reduced for products whose volatility is such that vapor generation within the permissible operating range of tank pressure will provide all or part of the venting requirements. In cases in which noncondensables are present, this should be taken into account.

The vacuum relief device shall be suitable to relieve the flow capacity required for the largest single contingency or any reasonable and probable combination of contingencies. It is permissible to reduce the requirement for vacuum relief capacity by the rate of vaporization that results from minimum normal heat gain to the contents. A gas-repressuring line with a suitable control and source of gas may be provided to avoid drawing air into the tank. The design of a gas-repressuring system to eliminate the requirement for vacuum relief valves is beyond the scope of this standard and should be considered only when the induction of air represents a hazard equal to or greater than failure of the tank.

In general, the set and relieving pressures for vacuum relief are established to prevent damage to a tank and must limit vacuum to a level no greater than that for which a tank has been designed. The vacuum relieving devices of a tank shall be set to open at a pressure or vacuum that will ensure that the vacuum in the tank will not exceed the vacuum for which the tank has been designed when the inflow of air through the devices is at its maximum specified rate.

4.5.2 Installation of Pressure and Vacuum Relief Devices

Pressure and vacuum relief devices shall be installed to:

a. Provide direct communication with the vapor space and not be sealed off by the liquid contents of the tank.

b. Protect the tank from the closure of a block valve or valves installed between the tank and the pressure or vacuum relief device or between the pressure or vacuum relief device and the discharge outlet. This may be done by locking or sealing the block valves open without installing excess relief capacity or by providing excess pressure or vacuum relief capacity with multiple-way valves, interlocked valves, or sealed block valves arranged so that isolating one pressure or vacuum relief device will not reduce the remaining relief capacity below the required relief capacity.

c. Ensure that the inlet and outlet assemblies, including any block valves, will permit the relief device to provide the required flow capacity. Inlet pressure losses developed during relief conditions must be taken into account when sizing the pressure and vacuum relief devices. The inlet pipe penetration into the vessel, the pressure drop across any block valves used upstream of the venting device, and the inlet piping must be considered when determining these losses.

4.5.3 Discharge Piping

4.5.3.1 Discharge piping from the relief devices or common discharge headers shall be installed to:

a. Lead to a safe location.

b. Be protected against mechanical damage.

c. Exclude or remove atmospheric moisture and condensate from the relief devices and associated piping. This may be done by the use of loose-fitting rain caps or drains, but an accounting must be made of the pressure loss effects of these items. Drains, if provided, shall be installed to prevent possible flame impingement on the tanks, piping, equipment, and structures.

d. Discharge in areas that (1) will prevent flame impingement on personnel, tanks, piping, equipment, and structures, and (2) will prevent vapor entry into enclosed spaces.

e. Prevent air from recirculating into the valve body during relief conditions to prevent ice from forming when the relief temperature is below 32°F (0°C).

f. Prevent vapor from the tank from freezing.

4.5.3.2 When a tank is located inside a building, the tank's venting devices shall discharge to the outside of the building. A weak roof-to-shell connection shall not be used as a means for emergency venting a tank inside a building.

4.5.3.3 Relief device discharge lines from one or more tanks may be connected to a common discharge header, provided the header complies with the other provisions of this paragraph. Liquid traps that can introduce sufficient back pressure to prevent relief devices from functioning properly shall be avoided. Other vents, drains, bleeders, and relief devices shall not be tied into the common discharge header if back pressures can be developed that prevent the relief devices on the tank from functioning properly. Back pressures developed during relief conditions must be taken into account when sizing the discharge header, sizing the relief devices, and compensating the set pressure of unbalanced relief devices (see API Recommended Practice 521).

4.5.4 Set Pressure Verification

The set pressure of all pressure and vacuum relief devices should be verified by testing before the devices are placed in operation.

4.5.5 Materials of Construction

Materials for a relief device and its associated piping shall be selected for the stored-product service temperatures and pressures at which the device and its piping are intended to operate. Also, the materials should be compatible with the product stored in the tank and with any products formed in the vicinity of the relief device during discharge.

4.5.6 Maintenance

For recommended maintenance and inspection procedures, see API Bulletin 2521 and API Recommended Practice 576.

4.6 TESTING AND MARKING OF VENTING DEVICES

4.6.1 Testing of Venting Devices

4.6.1.1 Determination of Capacity

The capacity of venting devices shall be established by the test methods described in Sections 4.6.1.1.1, 4.6.1.1.2, or 4.6.1.1.3 or by the calculation method described in 4.6.1.1.4. For the test methods described in, Sections 4.6.1.1.1, 4.6.1.1.2, and 4.6.1.1.3, the testing facilities, methods, and procedures and the person supervising the tests shall meet the applicable requirements described in this paragraph (4.6.1) and in ASME PTC 25; if there is a conflict, the requirements in this paragraph shall govern.

The test report shall describe how the venting device was mounted and tested as well as describe the inlet and outlet piping. If any fluid other than air is used in the test, the name of the fluid actually used along with the fluid's temperature and its specific gravity at standard conditions shall be noted on the test report.

4.6.1.2 Coefficient of Discharge Method: Specific Design of Three or More Sizes

For a specific design with geometrically similar flow paths, a coefficient of discharge may be established for the line of venting devices by using the following procedure.

At least three devices for each of three different sizes (a total of nine devices) shall be tested, each at a different pressure. At least one of the test pressures shall be the minimum design pressure or vacuum for the design, and one of the test pressures shall be the maximum design pressure or vacuum. The other test pressures shall be evenly distributed between the minimum and maximum design pressures. All of the test pressures shall be those where lift of the seat disk is sufficient for the nozzle to control the flow or where the seat disk lifts to a fixed stop.

The coefficient of discharge for each test shall be determined by Equation 3:

$$K = \frac{Actual\ Flow}{Theoretical\ Flow} \tag{3}$$

where

K = coefficient of discharge of the device.

Theoretical flow shall be determined by:

A. English Units

$$SCFH = 278{,}700\ P_1 A \sqrt{\frac{k}{MTZ(k-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{k}} - \left(\frac{P_2}{P_1}\right)^{\frac{k+1}{k}}\right]} \tag{4A}$$

where

$SCFH$ = theoretical flow rate, in standard cubic feet per hour of test medium (typically air),

A = minimum flow area of device, in square inches,

P_1 = pressure at device inlet, in pounds per square inch absolute,

P_2 = pressure at device outlet, in pounds per square inch absolute,

k = ratio of specific heats of test medium,

T = absolute temperature at device inlet (°F + 460),

M = molecular weight of test medium,

Z = compressibility factor, evaluated at inlet conditions (if unknown, use $Z = 1.0$).

B. Metric Units

$$Nm^3/h = 12{,}503 P_1 A \sqrt{\frac{k}{MTZ(k-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{k}} - \left(\frac{P_2}{P_1}\right)^{\frac{k+1}{k}}\right]} \tag{4B}$$

where

Nm^3/h = theoretical flow rate, in normal cubic meters per hour of test medium (typically air),

A = minimum flow area of device, in square centimeters,

P_1 = pressure at device inlet, in bar absolute,

P_2 = pressure at device outlet, in bar absolute,

k = ratio of specific heats of test medium,

T = absolute temperature at device inlet (°K),

M = molecular weight of test medium,

Z = compressibility factor, evaluated at inlet conditions (if unknown, use $Z = 1.0$).

A best fit curve of the coefficient of discharge of the devices tested versus the absolute pressure ratio across each device shall be plotted. All measured coefficients shall fall within ±5 percent of the curve (see Figure 1). The flow capacity for any pressure within the test pressure range shall be calculated by multiplying the theoretical flow for that pressure ratio by 95 percent of the corresponding coefficient of discharge for that pressure ratio as determined by the best fit curve.

4.6.1.2.1 Coefficient of Discharge Method: Individual Valve Method

A coefficient of discharge may be established for each size of device by using the following procedure.

Four devices for each combination of pipe size and orifice size shall be tested, each at a different pressure. At least one of the test pressures shall be the minimum design pressure or vacuum, and one of the test pressures shall be the maximum design pressure or vacuum. The other test pressures shall be evenly distributed between the minimum and maximum design pressures. All of the test pressures shall be those where lift of the seat disk is sufficient for the nozzle to control the flow or where the seat disk lifts to a fixed stop.

The coefficient of discharge for each device shall be determined as described in Section 4.6.1.1.1. A best fit curve of the coefficient of discharge of the devices tested versus the absolute pressure ratio across each device shall be plotted. All measured coefficients shall fall within ±5 percent of the curve. The flow capacity for any pressure within the test pressure range shall be calculated by multiplying the theoretical flow described in Section 4.6.1.1.1 for that pressure by 95 percent of the corresponding coefficient of discharge for that pressure ratio as determined by the best fit curve.

4.6.1.2.2 Flow Capacity Method: Specific Design Type

For a specific design type, at least one production venting device of every size shall be flow tested. Each venting device shall be set at its minimum design pressure or vacuum, and flow measurements shall be made at sufficient increments above set pressure or vacuum to establish a flow capacity curve. These measurements shall be made at pressures in the vicinity of the opening points, particularly at 1.10, 1.20, 1.50, and 2.0 times the opening pressure and 1.50 and 2.0 times the opening point on vacuum, to establish the flow capacity at these points. In addition, the flow capacity shall be measured where lift of the seat disk is just sufficient for the nozzle to control the flow or where the seat disk lifts to a fixed stop. This data may also be used to establish a flow capacity curve for set pressures or vacuums greater than the maximum pressure tested, provided it can be demonstrated that the extrapolation of the data is valid.

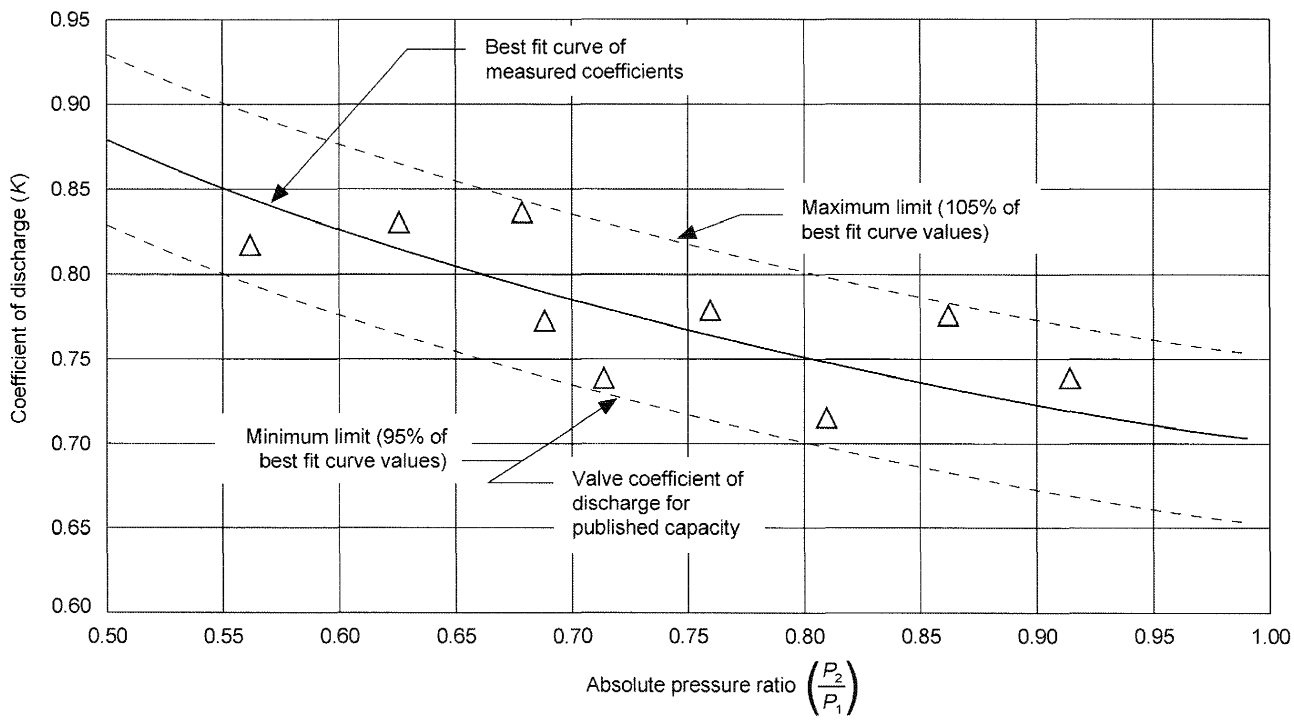


Figure 1—Typical Ratio Limits for Capacity Testing of Venting Devices Using the Coefficient of Discharge Method

4.6.1.2.3 Calculation Method: Manhole Covers

The flow capacity for any pressure in which full lift of a manhole cover occurs can be calculated by multiplying the theoretical flow described in Section 4.6.1.1.1 by 0.5.

4.6.1.3 Test Tank

4.6.1.3.1 The test tank shall be constructed to prevent high velocity jets from impinging on the venting device.

4.6.1.3.2 Pulsations in the test medium supply shall be dampened to avoid errors in flow metering.

4.6.1.4 Mounting of the Venting Device for Testing

4.6.1.4.1 To minimize the effect of entrance losses, the venting device shall be mounted on the top of the test tank at a location near the center of an area that is essentially flat. The flat area shall have a diameter at least five times greater than the nominal diameter of the device tested.

4.6.1.4.2 The venting device shall be mounted for testing on a straight-pipe nipple that has the same nominal diameter as the venting device and a length 1.5 times the nominal pipe size. The pipe nipple shall squarely enter the top of the test tank near the center of the flat portion, with the end of the nipple machined to an angle of 90 degrees with the axis and flush with the inside of the tank. Rounding of the entrance edge shall not exceed a radius of 0.031 inch (0.80 millimeter).

4.6.1.5 Flow Metering

4.6.1.5.1 Air or another suitable gas shall be employed in testing the venting device.

4.6.1.5.2 The air or gas flow shall be measured in accordance with ASME PTC 19.5.

4.6.1.6 Capacity Data

4.6.1.6.1 The capacity data shall be presented in the form of curves or tables that give the volume of flow through the venting device versus pressure or vacuum at the tank connection. The data should indicate the pressure or vacuum at which lift of the seat disk is sufficient for flow through the venting device to be controlled by the nozzle or where the seat disk lifts to a fixed stop. The data should indicate the pressure or vacuum where the venting device closes. The capacity for a pilot-operated venting device that opens fully at set pressure or vacuum may be expressed as a coefficient that is the ratio of the flow of the venting device to the flow of a theoretically perfect device with the same minimum flow area.

4.6.1.6.2 The capacity shall be expressed in terms of SCFH at 60°F, or Nm^3/h at 0°C, of air.

4.6.1.6.3 Pressures shall be expressed in ounces per square inch, psig, inches of water, mbarg, barg, or millimeters of water.

4.6.2 Marking of Venting Devices

Each venting device shall be plainly marked by the manufacturer with the required data so that the marking will not be obliterated in service. The marking may be placed on the device or on a plate or plates securely fastened to the device. The required data may be stamped onto, etched in, impressed on, or cast in the device or nameplate. Although additional units may be shown, the marking shall, as a minimum, include the following:

a. The name or identifying trademark of the manufacturer.
b. The manufacturer's design or type number.
c. The pipe size of the device inlet.
d. The set pressure and/or vacuum, where applicable, shall be expressed in the units of measure specified in Section 4.6.1.6.3.
e. The rated capacity of air at the indicated relieving pressure in SCFH at 60°F or in Nm^3/h at 0°C.
f. The relieving pressure and/or vacuum, in the units of measure specified in 4.6.1.6.3.

5 Refrigerated Aboveground and Belowground Tanks

5.1 GENERAL

This section covers the normal and emergency vapor venting requirements for refrigerated liquid petroleum products storage tanks designed for operation at pressures from vacuum through 15 pounds per square inch gauge (1.034 barg). A refrigerated liquid petroleum products storage tank may be the inner tank of a double-roof, double-wall tank; a double-wall tank with a suspended deck; or a single-wall tank with or without a suspended deck. Discussed in this section are the causes of overpressure or vacuum; determination of venting requirements; means of venting; selection, installation, and maintenance of venting devices; and testing and marking of relief devices.

5.2 CAUSES OF OVERPRESSURE OR VACUUM

5.2.1 General

When the possible causes of overpressure or vacuum in a refrigerated tank are being determined, the following circumstances must be considered:

a. Liquid movement into or out of the tank.
b. Weather changes (e.g., temperature and pressure changes).
c. Fire exposure.
d. Other circumstances resulting from equipment failures and operating errors.

Some of these circumstances are described more fully in Sections 5.2.2 through 5.2.5. There may be additional circumstances that should be considered and evaluated by the designer but are not included in this standard.

5.2.2 Liquid Movement Into or Out of a Tank

Inbreathing may result from the outflow of liquid or vapor from a tank. Outbreathing may result from the inflow of liquid into a tank and from the vaporization, including flashing of the feed liquid, that will occur because of the inflow of the liquid. Flashing of the feed liquid can be significant for feed that is near or above its boiling point at the pressure in the tank. Vapors generated during the filling operation also may come from a warm fill, from inlet piping heat leak, inlet pump work, cool down of the tank and fill line, and vapors displaced by the incoming liquid.

5.2.3 Weather Changes

Vacuum can develop in a tank when the ambient conditions (temperature, wind, precipitation, etc.) change and cause a reduction in the temperature and vapor pressure of the liquid in the tank.

5.2.4 Fire Exposure

Outbreathing will result from the expansion of the vapors and evaporation of the liquid that occur when a tank absorbs heat from an external fire.

5.2.5 Other Circumstances

5.2.5.1 General

When the possible causes of overpressure or vacuum in a tank are being determined, other circumstances resulting from equipment failures and operating errors must be considered and evaluated by the designer. Calculation methods for these other circumstances have not been provided in this standard.

5.2.5.2 Pressure Transfer Blowoff

Liquid transfer from other vessels, tank trucks, and tank cars may be aided or accomplished entirely by pressurization of the supply vessel with a gas, but the receiving tank may encounter a flow surge at the end of the transfer due to vapor breakthrough. Depending on the preexisting pressure and free head space in the receiving tank, the additional gas volume may be sufficient to overpressure the tank. The controlling case is a transfer that fills the receiving tank so that little head space remains to absorb the pressure surge. A similar situation can be encountered during line pigging if a vapor chaser is used after the pigging device.

5.2.5.3 Inert Pads and Purges

Inert pads and purges are provided on tanks to protect the contents of the tanks from contamination, maintain nonflammable atmospheres in the tanks, and suppress vapor emissions from the tanks. An inert pad and purge system normally has both a supply regulator and a back-pressure regulator to maintain interior tank pressure within a narrow range. Failure of the supply regulator can result in unrestricted gas flow into the tank, reduced gas flow, or complete loss of the gas flow. Failure of the back pressure regulator could result in overpressure.

5.2.5.4 Heat Transfer Devices

For a tank with a cooling jacket or coils, liquid vaporization, resulting from the loss of coolant flow must be considered.

5.2.5.5 Internal Heat Transfer Devices

Mechanical failure of a tank's internal cooling device can expose the contents of the tank to the cooling medium used in the device. In low-pressure tanks, it can be assumed that the flow direction of heat transfer medium will be into the tank when the device fails. Chemical compatibility of the tank contents and the heat transfer medium must be considered. In addition to the consideration in Section 5.2.5.4, internal cooling devices have other potential causes for overpressure or vacuum that must be considered. The disposition of the tank contents until the device can be repaired or replaced must also be considered.

5.2.5.6 Vent Treatment Systems

If vapor from a tank is collected for treatment or disposal by a vent treatment system, the vent collection system may fail. This failure must be evaluated. Failures affecting the safety of a tank can include back pressure developed from problems in the piping (liquid-filled pockets and solids buildup), other equipment relieving into the header, or blockage due to equipment failure. An emergency venting device that relieves to atmosphere, set at a higher pressure than the vent treatment system, is normally used. For toxic or hazardous vapors, a fail-safe vent treatment system should be considered.

5.2.5.7 Utility Failure

Local and plant-wide power and utility failures must be considered as possible causes of overpressure or vacuum. Loss of electrical power will directly affect any motorized valves or controllers and may also shut down the instrument air supply. Also, cooling fluids may be lost during an electrical failure.

5.2.5.8 Change in Temperature of the Input Stream to a Tank

A change in the temperature of the input stream to a tank brought about by a loss of cooling or an increase in heat input may cause overpressure in the tank. A reduction in vapor pressure brought about by the introduction of subcooled product into the vapor space may create a vacuum condition.

Note: Relief valves are normally not sized to relieve vapors generated during "rollover." Although vapors generated during rollover are a source of potential overpressure, there are no generally recognized methods available for calculating the relieving requirements of these vapors. Proper design and operation of the storage system are essential whenever an attempt is made to prevent rollover (see Section 9 of API Standard 2510).

5.2.5.9 Chemical Reactions

The contents of some tanks may be subject to chemical reactions, which may generate heat and/or vapors. Some examples of chemical reactions may include inadvertently adding water to acid or spent acid tanks thereby generating steam and/or vaporizing light hydrocarbons, runaway reactions of phenol tanks, etc. In some cases, the material may foam, causing two phase relief. Technology developed by the Design Institute for Emergency Relief (DIERS) may be used to evaluate these cases.

5.2.5.10 Heat Inleak

Heat inleak to a refrigerated tank can cause overpressure in the tank.

5.2.5.11 Liquid Overfill Protection

For information on liquid overfill protection, see API Standards 620, 2510, and API Recommended Practice 2350. Liquid overfill shall be prevented by providing positive design and operation steps, such as two reliable and repairable level instruments and an independent high-level alarm that independently stop the filling operation by closing the filling valves.

5.2.5.12 Atmospheric Pressure Changes

A rise or drop in barometric pressure is a possible cause of vacuum or overpressure in a tank.

5.2.5.13 Control Valve Failure

Failure of a control valve on the liquid line to a tank must be considered because a control valve failure may adversely affect the flow of material to a tank. A control valve failure may cause the liquid flow rate to a tank to increase, and an increased liquid flow rate may overload a cooler, causing higher temperature material to be admitted to the tank. A control valve failure may also cause the liquid level in a pressurized vessel feeding liquid to a tank to drop below the outlet nozzle, allowing vapor from the vessel to be pressured into the tank.

5.2.5.14 Steam Out

If an uninsulated portion of a refrigerated tank is filled with steam, the condensing rate due to ambient cooling will exceed the venting rates specified in this standard. Other steps including large vents (open manways) and slowly cooling the tank are necessary to prevent excessive internal vacuum.

5.2.5.15 Pump Recycle

Vapors generated during the operation of a pump on recycle or during recirculation can cause tank overpressure.

5.3 DETERMINATION OF VENTING REQUIREMENTS

5.3.1 General

Although design guidelines are not presented in this standard for other circumstances discussed in Section 5.2.5, they should be considered.

Venting requirements are given for the following conditions:

a. Inbreathing resulting from maximum outflow of liquid from the tank.
b. Outbreathing resulting from maximum inflow of liquid into the tank and maximum vaporization caused by such inflow.
c. Outbreathing resulting from fire exposure.

5.3.2 Requirements for Normal Venting Capacity

5.3.2.1 The pressure relief devices shall be suitable to relieve the flow capacity determined for but not limited by the largest single contingency or any reasonable and probable combination of contingencies, assuming that all of the outlets from a tank are closed.

5.3.2.2 The vacuum relief devices shall be suitable to relieve the flow capacity determined for but not limited by the largest single contingency or any reasonable and probable combination of contingencies. It is permissible to reduce the requirement for vacuum relief capacity by the rate of vaporization that results from minimum normal heat gain to the contents. A gas-repressuring line with a suitable control and source of gas may be provided to avoid drawing air into the tank. If a gas-repressuring system is used, it shall be used in addition to the vacuum relief devices, and no capacity credit shall be allowed.

5.3.2.3 The requirement for venting capacity for maximum liquid movement out of a tank should be equivalent to 5.6 SCFH of air for each 42 US gallon barrel (0.94 Nm^3/h per cubic meter) per hour of maximum emptying rate for liquids of any flash point.

5.3.2.4 The requirement for venting capacity for maximum liquid movement into a tank and the resulting vaporization should be equivalent to 12 SCFH of air for each 42 US gallon barrel (2.02 Nm^3/h per cubic meter) per hour of maximum filling rate (see Appendix A for the basis of this requirement).

A tank into which liquid is fed at or near the boiling point at the tank pressure may require an outbreathing capacity that is higher than the capacity indicated above. The values presented above are based on vaporization of 0.5 percent of the feed liquid; significantly higher vaporization rates can occur if the feed is above the boiling point. For instance, with hexane, 0.4 percent of the feed can vaporize for every 1°F (0.56°C) above the boiling point at tank pressure.

Note: Protection against liquid overfilling is not covered in this standard, but it is covered in API Standard 620 and in API Recommended Practice 2350.

5.3.3 Requirements for Emergency Venting Capacity for Tanks Subject to Fire Exposure

When storage tanks are exposed to fire, the venting rate may exceed the rate resulting from other conditions. The procedures in Sections 5.3.3.1 and 5.3.3.2 shall be used to evaluate the required venting capacity for tanks subject to fire exposure.

5.3.3.1 Emergency Venting for Fire Exposure for Single-Wall Refrigerated Storage Tanks

The capacity of the pressure relief valves for fire exposure for single-wall refrigerated storage tanks shall be determined in accordance with the procedures specified in Sections 5.3.3.1.1 through 5.3.3.1.6 and based on the factors contained in Tables 5 and 6.

5.3.3.1.1 For tanks subject to fire exposure, the required venting capacity shall be determined by Equations 5A or 5B.

A. English Units

$$SCFH = 3.091 \times \frac{QF}{L} \times \left(\frac{T}{M}\right)^{0.5} \quad (5A)$$

where

$SCFH$ = venting requirements in standard cubic feet per hour or air,

Q = heat input from fire exposure, in BTU per hour. Heat input is provided in Figure B-1 of Appendix B or the following summary:

Wetted Surface Area (square feet)	Design Pressure (psig)	Heat Input (Btu/hr)
<200	≤15	$Q = 20{,}000A$
≥200 and <1000	≤15	$Q = 199{,}300A^{0.566}$
≥1000 and <2800	≤15	$Q = 963{,}400A^{0.338}$
≥2800	≤15	$Q = 21{,}000A^{0.82}$

A = wetted surface area of the tank, in square feet (see the footnotes for Table 5A),

F = environmental factor from Table 6A. Credit may be taken for only one environmental factor,

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature, in BTU per pound,

T = temperature of the relieving vapor, in degrees Rankine. It is normally assumed that the temperature of the relieving vapor corresponds to the boiling point of the stored fluid at the relieving pressure,

M = molecular weight of the vapor being relieved.

B. Metric Units

$$Nm^3/h = 881.55 \times \frac{QF}{L} \times \left(\frac{T}{M}\right)^{0.5} \quad (5B)$$

where

Nm^3/h = venting requirement, in normal cubic meters per hour of air,

Q = heat input from fire exposure, in watts. Heat input is provided in Figure B-1 of Appendix B or the following summary:

Wetted Surface Area (square mm)	Design Pressure (barg)	Heat Input (Watts)
<18.6	≤1.034	$Q = 63{,}150A$
≥18.6 and <93	≤1.034	$Q = 224{,}200A^{0.566}$
≥93 and <260	≤1.034	$Q = 630{,}400A^{0.338}$
≥260	≤1.034	$Q = 43{,}200A^{0.82}$

A = wetted surface area of the tank, in square meters (see Footnotes for Table 5B),

F = environmental factor from Table 6B. Credit may be taken for only one environmental factor,

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature, in kJ/kg,

T = temperature of the relieving vapor, in degrees Kelvin. It is normally assumed that the temperature of the relieving vapor corresponds to the boiling point of the stored fluid at the relieving pressure,

M = molecular weight of the vapor being relieved.

5.3.3.1.2 Where a lesser degree of accuracy can be tolerated, the required venting capacity can be determined from Table 5 or Equation 5, as indicated in the following summary:

For English Units:

Wetted Surface Area (square feet)	Design Pressure (psig)	Required Venting Capacity (SCFH)
<2800	≤15	Table 5A and 5.3.3.1.3
≥2800	≤15	Equation 5A

$$SCFH = 1107FA^{0.82} \qquad (6A)$$

where

$SCFH$ = venting requirement, in standard cubic feet per hour of air,

F = environmental factor from Table 6A. Credit may be taken for only one environmental factor,

A = wetted surface area, in square feet (see Table 5A, Footnote a).

Note: Equation 6A is based on

$$Q = 21{,}000A^{0.82}$$

or

For Metric Units:

Wetted Surface Area (square feet)	Design Pressure (barg)	Required Venting Capacity (Nm³/h)
<260	≤1.034 barg	Table 5B and 5.3.3.1.3
≥260	≤0.07 barg	Equation 5B

$$Nm^3 / h = 208.2FA^{0.82} \qquad (6B)$$

where

Nm^3/h = venting requirement, in normal cubic meters per hour of air,

F = environmental factor from Table 6B. Credit may be taken for only one environmental factor,

A = wetted surface area, in square meters (see Table 5B, Footnote a).

Note: Equation 6B is based on

$$Q = 43{,}200A^{0.82}$$

The total heat absorbed, Q, is in BTU per hour for Equation 2A and in Watts for Equation 2B, Table 5 and the constants 1107 and 208.2 in Equations 5A and 5B, respectively, were derived from Equation 4 and Figure B-1 by using the latent heat of vaporization of hexane (144 BTU per pound 335,000 J/kg) at atmospheric pressure and the molecular weight of hexane (86.17) and assuming a vapor temperature of 60°F (15.6°C). This method will provide results within an acceptable degree of accuracy for many fluids having similar properties (see Appendix B).

5.3.3.1.3 The total rate of venting determined from Table 5 may be multiplied by an appropriate environmental factor, F, selected from Table 6. Credit may be taken for only one environmental factor.

5.3.3.1.4 Full credit may be taken for the venting capacity provided for normal venting, since the normal thermal effect can be disregarded during a fire. Also, it can be assumed that there will be no liquid movement into the tank.

5.3.3.1.5 If normal venting devices are inadequate, additional emergency venting devices of the type described in Section 5.4.2 shall be provided so that the total venting capacity is at least equivalent to that required by Table 5 or Equation 4 or 5.

5.3.3.1.6 The total venting capacity shall be based on the pressure indicated in Section 5.5.1.1.

5.3.3.2 Emergency Venting for Fire Exposure for Double-Wall Refrigerated Storage Tanks

The heat input from a fire initially causes the vapors in the space between the walls of a double-wall refrigerated storage tank to expand, and the heat input also causes the vapors in the roof space of a double-wall tank with suspended-deck insulation to expand; however, it may be several hours before the increased heat input to the stored liquid causes a significantly increased vaporization rate. The venting requirements for handling the increased vaporization may be small compared to the requirements for handling the initial volumetric expansion of the vapors.

Because emergency venting for a double-wall refrigerated storage tank is complex, no calculation method is presented here. A thorough analysis of the fire relief for a double-wall refrigerated storage tank, including a review of the structural integrity of unwetted portions of the outer wall, should be conducted.

5.4 MEANS OF VENTING

5.4.1 Normal Venting

Normal venting shall be accomplished by a relief device (see API Standard 620).

5.4.1.1 Any relief device shall be designed so that it will protect the tank in the event of failure of any essential part.

5.4.1.2 A tank that may be damaged by internal vacuum shall be provided with at least one vacuum relief device set and sized to open at a vacuum that is sufficient to protect the tank from damage.

Table 5A—Emergency Venting Required for Fire Exposure Versus Wetted Surface Area
A. English Units

Wetted Area[a] (square feet)	Venting Requirement (SCFH)	Wetted Area[a] (square feet)	Venting Requirement (SCFH)
20	21,100	350	288,000
30	31,600	400	312,000
40	42,100	500	354,000
50	52,700	600	392,000
60	63,200	700	428,000
70	73,700	800	462,000
80	84,200	900	493,000
90	94,800	1,000	524,000
100	105,000	1,200	557,000
120	126,000	1,400	587,000
140	147,000	1,600	614,000
160	168,000	1,800	639,000
180	190,000	2,000	662,000
200	211,000	2,400	704,000
250	239,000	2,800	742,000
300	265,000	>2,800[b]	—

Table 5B—Emergency Venting Required for Fire Exposure Versus Wetted Surface Area
B. Metric Units

Wetted Area[a] (square meters)	Venting Requirement (Nm^3/h)	Wetted Area[a] (square meters)	Venting Requirement (Nm^3/h)
2	608	35	8,086
3	913	40	8,721
4	1,217	45	9,322
5	1,521	50	9,895
6	1,825	60	10,971
7	2,130	70	11,971
8	2,434	80	12,911
9	2,738	90	13,801
11	3,347	110	15,461
13	3,955	130	15,751
15	4,563	150	16,532
17	5,172	175	17,416
19	5,780	200	18,220
22	6,217	230	19,102
25	6,684	260	19,910
30	7,411	>260[b]	—

[a]The wetted area of a tank or storage vessel shall be calculated as follows:

Sphere and Spheroids—The wetted area is equal to 55 percent of the total surface area or the surface area to a height of 30 feet (9.14 meters) above grade, whichever is greater.

Horizontal Tanks—The wetted area is equal to 75 percent of the total surface area or the surface area to a height of 30 feet (9.14 meters) above grade, whichever is greater.

Vertical Tanks—The wetted area is equal to the total surface area of the vertical shell to a height of 30 feet (9.14 meters) above grade. For a vertical tank setting on the ground, the area of the ground plates is not to be included as wetted area. For a vertical tank supported above grade, a portion of the area of the bottom is to be included as additional wetted surface. The portion of the bottom area exposed to a fire depends on the diameter and elevation of the tank above grade. Engineering judgment is to be used in evaluating the portion of the area exposed to fire.

[b]For wetted surfaces larger than 2,800 square feet (260 square meters), see Section 5.3.3.1.3.

Note:

Table 5 and the constants 1107 and 208.2 in Equations 6A and 6B respectively were derived from Equation 5 and Figure B-1 by using the latent heat of vaporization (144 BTU per pound or 334900 J/kg) at atmospheric pressure and the molecular weight of hexane (86.17) and assuming a vapor temperature of 60°F (15.6°C). This method will provide results within an acceptable degree of accuracy for many fluids having similar properties (see Appendix B).

Table 6A—Environment Factors for Refrigerated Aboveground and Partially Belowground Tanks
A. English Units

Tank Design/Configuration	Insulation Conductance (BTU/hr ft^2 °F)	Insulation Thickness (in)	*F* Factor
Bare metal tank	—	0	1.0
Insulated tank[a]	4.0	1	0.3[b]
" "	2.0	2	0.15[b]
" "	1.0	4	0.075[b]
" "	0.67	6	0.05[b]
" "	0.5	8	0.0375[b]
" "	0.4	10	0.03[b]
" "	0.33	12	0.025[b]
Concrete tank or fireproofing	—	—	(see note c)
Water-application facilities[d]	—	—	1.0
Depressuring and emptying facilities[e]	—	—	1.0
Underground storage	—	—	0
Earth-covered storage above grade	—	—	0.03
Impoundment away from tank[f]	—	—	0.5

Notes:

[a]The insulation shall resist dislodgment by fire-fighting equipment, shall be noncombustible, and shall not decompose at temperatures up to 1000°F (537.8°C). The user is responsible to determine if the insulation will resist dislodgment by the available fire-fighting equipment. If the insulation does not meet these criteria, no credit for insulation shall be taken. The conductance values are based on insulation with a thermal conductivity of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness). The user is responsible for determining the actual conductance value of the insulation used. The conservative value of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness) for the thermal conductivity is used.

[b]These *F* factors are based on the thermal conductance values shown and a temperature differential of 1600°F (888.9°C) when using a heat input value of 21,000 BTU per hour per square foot (66,200 Watts per square meter) in accordance with the conditions assumed in API Recommended Practice 521. When these conditions do not exist, engineering judgment should be used to select a different *F* factor or to provide other means for protecting the tank from fire exposure.

[c]Use the *F* factor for an equivalent conductance value of insulation.

[d]Under ideal conditions, water films covering the metal surfaces can absorb most incident radiation. The reliability of water application depends on many factors. Freezing weather, high winds, clogged systems, undependable water supply, and tank surface conditions can prevent uniform water coverage. Because of these uncertainties, no reduction in environmental factors is recommended; however, as stated previously, properly applied water can be very effective.

[e]Depressuring devices may be used, but no credit shall be allowed in sizing the venting device for fire exposure.

[f]The following conditions must be met: A slope of not less than 1 percent away from the tank shall be provided for at least 50 feet (15 meters) toward the impounding area; the impounding area shall have a capacity that is not less than the capacity of the largest tank that can drain into it; the drainage system routes from other tanks to their impounding areas shall not seriously expose the tank; and the impounding area for the tank as well as the impounding areas for the other tanks (whether remote or with dikes around the other tanks) shall be located so that when the area is filled to capacity, its liquid level is no closer than 50 feet (15 meters) to the tank.

Table 6B—Environment Factors for Refrigerated Aboveground and Partially Belowground Tanks
B. Metric Units

Tank Design/Configuration	Insulation Conductance (Watts/m^2 °K)	Insulation Thickness (cm)	*F* Factor
Bare metal tank	—	0	1.0
Insulated tank[a]	22.7	2.5	0.3[b]
" "	11.4	5	0.15[b]
" "	5.7	10	0.075[b]
" "	3.8	15	0.05[b]
" "	2.8	20	0.0375[b]
" "	2.3	25	0.03[b]
" "	1.9	30	0.025[b]
Concrete tank or fireproofing	—	—	(see note c)
Water-application facilities[d]	—	—	1.0
Depressuring and emptying facilities[e]	—	—	1.0
Underground storage	—	—	0
Earth-covered storage above grade	—	—	0.03
Impoundment away from tank[f]	—	—	0.5

Notes:

[a]The insulation shall resist dislodgment by fire-fighting equipment, shall be noncombustible, and shall not decompose at temperatures up to 1000°F (537.8°C). The user is responsible to determine if the insulation will resist dislodgment by the available fire-fighting equipment. If the insulation does not meet these criteria, no credit for insulation shall be taken. The conductance values are based on insulation with a thermal conductivity of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness). The user is responsible for determining the actual conductance value of the insulation used. The conservative value of 4 BTU per hour per square foot per °F per inch of thickness (9 Watts per square meter per °C per centimeter of thickness) for the thermal conductivity is used.

[b]These *F* factors are based on the thermal conductance values shown and a temperature differential of 1600°F (888.9°C) when using a heat input value of 21,000 BTU per hour per square foot (66,200 Watts per square meter) in accordance with the conditions assumed in API Recommended Practice 521. When these conditions do not exist, engineering judgment should be used to select a different *F* factor or to provide other means for protecting the tank from fire exposure.

[c]Use the *F* factor for an equivalent conductance value of insulation.

[d]Under ideal conditions, water films covering the metal surfaces can absorb most incident radiation. The reliability of water application depends on many factors. Freezing weather, high winds, clogged systems, undependable water supply, and tank surface conditions can prevent uniform water coverage. Because of these uncertainties, no reduction in environmental factors is recommended; however, as stated previously, properly applied water can be very effective.

[e]Depressuring devices may be used, but no credit shall be allowed in sizing the venting device for fire exposure.

[f]The following conditions must be met: A slope of not less than 1 percent away from the tank shall be provided for at least 50 feet (15 meters) toward the impounding area; the impounding area shall have a capacity that is not less than the capacity of the largest tank that can drain into it; the drainage system routes from other tanks to their impounding areas shall not seriously expose the tank; and the impounding area for the tank as well as the impounding areas for the other tanks (whether remote or with dikes around the other tanks) shall be located so that when the area is filled to capacity, its liquid level is no closer than 50 feet (15 meters) to the tank.

5.4.1.3 A discussion of the types and operating characteristics of venting devices can be found in Appendix C.

5.4.2 Emergency Venting

Emergency venting may be accomplished by the use of the following:

a. Larger or additional relief devices.

b. A gauge hatch that permits the cover to lift under abnormal internal pressure.

c. A manhole cover that lifts when exposed to abnormal internal pressure.

5.5 SELECTION, INSTALLATION, AND MAINTENANCE OF VENTING DEVICES

5.5.1 Total Venting Requirements

5.5.1.1 Pressure

5.5.1.1.1 The pressure relief device or emergency venting device shall be suitable to relieve the flow capacity determined for but not limited by the largest single contingency or any reasonable and probable combination of contingencies.

5.5.1.1.2 Consultation between the tank designer, the person specifying the venting devices, and the venting device manufacturer is strongly recommended to ensure that the venting devices are compatible with the tank design. The set or start-to-open pressure often must be lower than the design pressure of a tank to allow for adequate flow capacity of the devices. The operating pressure should be lower than the set pressure to allow for normal variations in pressure caused by changes in temperature and by other factors that affect pressure in the tank vapor space. The set pressure and relieving pressure must be consistent with the requirements of the standard according to which the tank was designed and fabricated. Some standards present specific requirements, but others may not.

5.5.1.1.3 Requirements for pressure-relieving devices for tanks that are designed and fabricated in accordance with API Standard 620 are given in API Standard 620. The pressure setting of a pressure-relieving device shall not exceed the maximum pressure that can exist at the level where the device is located when the pressure at the top of the tank equals the nominal pressure rating for the tank and the liquid contained in the tank is at the maximum design level.

Under normal conditions, pressure-relieving devices must have sufficient flow capacity to prevent the pressure from rising more than 10 percent above the maximum allowable working pressure. Under fire emergency conditions, the devices shall be capable of preventing the pressure from rising more than 20 percent above the maximum allowable working pressure.

5.5.1.2 Vacuum

A vacuum relief device shall be installed to permit the entry of air, or another gas or vapor, to avoid excessive vacuum that may result. The vacuum relief device shall be suitable to relieve the flow capacity required for the largest single contingency or any reasonable and probable combination of contingencies. A gas-repressuring line with a suitable control and source of gas may be provided to avoid drawing air into the tank. The design of a gas-repressuring system to eliminate the requirement for vacuum relief valves is beyond the scope of this standard and should be considered only when the induction of air represents a hazard equal to or greater than failure of the tank.

In general, the set and relieving pressures for vacuum relief are established to prevent damage to a tank and must limit vacuum to a level no greater than that for which a tank has been designed. The vacuum-relieving devices of a tank shall be set to open at a pressure or vacuum that will ensure that the vacuum in the tank will not exceed the vacuum for which the tank has been designed when the inflow of air through the devices is at its maximum specified rate.

5.5.2 Installation of Pressure and Vacuum Relief Devices

Pressure and vacuum relief devices shall be installed to:

a. Provide direct communication with the vapor space and not be sealed off by the liquid contents of the tank.

b. Prevent plugging of the inlet by insulation during relieving conditions.

c. Protect the tank from the closure of a block valve or valves installed between the tank and the pressure or vacuum relief device or between the pressure or vacuum relief device and the discharge outlet. This may be done by locking or sealing the block valves open without installing excess relief capacity or by providing excess pressure or vacuum relief capacity with multiple-way valves, interlocked valves, or sealed block valves arranged so that isolating one pressure or vacuum relief device will not reduce the remaining relief capacity below the required relief capacity.

d. Ensure that the inlet and outlet assemblies, including any block valves, will permit the relief device to provide the required flow capacity.

e. Keep cold vapor from producing a thermal gradient in the roof of the tank or reducing the temperature in the roof of the tank. For a tank with the suspended-deck-type roof insulation system, the inlet piping to the relief valve must penetrate the suspended deck to prevent cold vapor from entering the warm space between the outer roof and the suspended deck. The influence of this piping must be considered in the relief valve capacity calculations. Relief valves should be sized for the pressure available across the valve. Consideration should be given to the inlet pressure losses and the back pressure developed on the outlet flange.

5.5.3 Discharge Piping

5.5.3.1 Discharge piping from the relief devices or common discharge headers shall be installed to:

a. Lead to a safe location.

b. Be protected against mechanical damage.

c. Exclude or remove atmospheric moisture and condensate from the relief devices and associated piping. This may be done by the use of loose-fitting rain caps or drains, but an accounting must be made of the pressure loss effects of these items. Drains, if provided, shall be installed to prevent possible flame impingement on the tanks, piping, equipment, and structures.

d. Discharge in areas that (1) will prevent flame impingement on personnel, tanks, piping, equipment, and structures, and (2) will prevent vapor entry into enclosed spaces.

e. Prevent air from recirculating into the valve body during relief conditions to prevent ice from forming when the relief temperature is below 32°F (0°C).

f. Prevent vapor from the tank from freezing.

5.5.3.2 When a tank is located inside a building, the tank venting devices shall discharge to the outside of the building.

5.5.3.3 Relief device discharge lines from one or more tanks may be connected to a common discharge header, provided the header complies with the other provisions of this paragraph. Liquid traps that can introduce sufficient back pressure to prevent relief devices from functioning properly shall be avoided. Other vents, drains, bleeders, and relief devices shall not be tied into the common discharge header if back pressures can be developed that prevent the relief devices on the tank from functioning properly. Back pressures developed during relief conditions must be taken into account when sizing the discharge header, sizing the relief devices, and compensating the set pressure of unbalanced relief devices (see API Recommended Practices 520 and 521).

5.5.3.4 Relief valves shall be arranged to discharge to open air unobstructed so that any impingement of escaping cold gas upon the container and any roof mounted items is prevented.

5.5.3.5 A venting device discharge stack or vent shall be designed and installed to prevent water, ice, snow, or other foreign matter from accumulating and obstructing the flow. The discharge shall be directed upwards when relieving to the atmosphere. Independent support of the vertical stack should be considered. Provisions shall be made to reduce the thermal effects on the container and any roof mounted items caused by the ignition of vapor from the relief valve discharge stack.

5.5.4 Set Pressure Verification

The set pressure of all pressure and vacuum relief devices should be verified by testing before the devices are placed in operation.

5.5.5 Materials of Construction

Materials for a relief device and its associated discharge piping shall be selected for the stored-product service temperature and pressure at which the device and its piping are intended to operate. Also, the materials should be compatible with the product stored in the tank and with any products formed in the vicinity of the relief device (in case there is a discharge).

5.5.6 Maintenance

For recommended maintenance and inspection procedures, see API Bulletin 2521 and API Recommended Practice 576.

5.6 TESTING AND MARKING OF VENTING DEVICES

The procedures for the testing and marking of venting devices for refrigerated aboveground and belowground tanks are the same as the procedures for nonrefrigerated aboveground tanks (see Section 4.6).

APPENDIX A—BASIS OF THE NORMAL VENTING FOR TABLES 1 AND 2

For liquids with a flash point below 100°F (37.8°C), this standard recommends a venting capacity of 12 SCFH of air for each barrel (2.02 Nm^3/h per cubic meter) per hour of filling rate. Of this quantity, one half, or 6 SCFH (1.01 Nm^3/h per cubic meter) of air, represents the vapor displacement caused by liquid movement. The additional 6 SCFH (1.01 Nm^3/h per cubic meter) of air was established on the basis of an evaporation rate of approximately 0.5 percent and to account for the conversion of dense vapors being vented to an air equivalent.

The evaporation rate of approximately 0.5 percent was selected on the basis of gasoline being pumped into an essentially empty tank. During this period, heat pickup is the greatest. Also, any vapor flashing as a result of hot line products (for example, the pipeline being exposed to the sun) is the most critical at this time, since there is no large heat sink such as exists in a full tank. In addition, vaporization is increased since there is essentially no tank pressure to suppress vaporization. For conversion of hydrocarbon vapor to air, a specific gravity of 1.5, compared with 1 for air, was arbitrarily selected.

In addition to the venting capacity for product movement indicated above, a thermal evaporation rate based on tank size (see Table 2) was established. This is additive to the venting for liquid movement.

It was established that in the southwestern United States, tanks could be cooled rapidly, as happens when a sudden rainstorm occurs on a hot, sunny day. For vacuum conditions, it was found that roof plates could be cooled as much as 60°F (33°C) and that shell plates could be cooled about 30°F (17°C). This can be converted to a heat loss from the tank vapor space of about 20 BTU per hour per square foot (63 Watts per square meter) of shell and roof surface. From this, vacuum (inbreathing) requirements were set. Since records were not available on how fast tank vapor spaces can be heated (outbreathing), a figure of 60 percent of the inbreathing requirements was arbitrarily selected as the basis for thermal outbreathing.

In establishing the basis above, it was recognized that the requirements for outbreathing are somewhat conservative; however, some conservatism was believed to be desirable to take into account both unusual climatic conditions and products that might generate more vapor than gasoline generates. Also, the cost involved for a larger venting device is very small, considering the overall cost of a tank. This conservatism also provides some margin of safety should pumping rates be increased slightly above design rates.

APPENDIX B—BASIS OF EMERGENCY VENTING FOR TABLES 3 AND 5

The emergency venting requirements contained in the first edition of API Recommended Practice 2000, *Guide for Venting Atmospheric and Low-Pressure Storage Tanks*, were based on the assumption that a tank subjected to fire exposure will absorb heat at an average rate of 6000 BTU per hour per square foot (18,900 Watts per square meter) of wetted surface. The minimum emergency relief capacity, given in approximate diameter of a free circular opening, was computed from the results of a detailed analysis of the distillation characteristics of a typical straight-run gasoline from Mid-continent crude oil, using a conventional orifice formula, an orifice coefficient of 0.7, and a vapor specific gravity of 2.5. An emergency venting capacity of 648,000 cubic feet (17,400 cubic meters) per hour was the maximum required for any tank, regardless of size. This maximum emergency venting capacity was based on the following: tanks with a capacity of more than 17,500 barrels (2,780 cubic meters), when heated, require such a long period of time to elapse before their contents reach a temperature at which rapid boiling starts that it is extremely unlikely that this point would ever be reached, and even if it should be, there would be ample time to take the necessary precautions to safeguard life and property.

This basis for emergency venting was adopted by the National Fire Protection Association (NFPA)[2] and was successfully used for many years. As far as can be determined, except for some containers of unusually small capacities, no case has been recorded in which a tank failed from overpressure because of insufficient emergency venting capacity when vented in accordance with this basis.

A few catastrophic tank ruptures did, however, occur in cases in which the emergency venting was not in accordance with this basis. These tank ruptures focused attention on emergency venting requirements. Many small-scale fire tests demonstrated that heat inputs of more than 6,000 BTU per hour per square foot (18,900 Watts per square meter) of surface could be obtained under ideal conditions; however, large-scale test data were lacking. In June 1961, during fire demonstrations in Tulsa, Oklahoma, a horizontal tank measuring 8 feet x 26 feet 10 inches (2.44 meters x 8.18 meters) was equipped with an emergency venting device sized to limit the internal pressure of the tank to approximately 3 inches of water column (7.5 mbarg). Measurements indicated that under exposure to fire, the pressure rose to approximately 1.6 pounds per square inch gauge (110 mbarg). Based on these tests, it was agreed that emergency venting requirements should be reexamined. As a result of this study, the current basis for heat input under exposure to fire was developed.[2]

[2]National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, Massachusetts 02269-9101.

Tables 3 and 5 are based on a composite curve that is composed of three straight lines when plotted on log graph paper. The curve may be defined in the following manner: The first straight line is drawn between 400,000 BTU per hour (117,240 Watts) at 20 square feet (1.86 square meters) of wetted surface area and 4,000,000 BTU per hour (1,172,400 Watts) at 200 square feet (18.6 square meters) of wetted surface area. The equation for this portion of the curve is

$$Q = 20{,}000A \text{ (English Units)} \qquad \text{(B-1)}$$
$$Q = 63{,}150A \text{ (Metric Units)}$$

The second straight line is drawn between 4,000,000 BTU per hour (1,172,400 Watts) at 200 square feet (18.6 square meters) of wetted surface area and 9,950,000 BTU per hour (2,916,000 Watts) at 1,000 square feet (93 square meters) of wetted surface area. The equation used for this portion of the curve is

$$Q = 199{,}300A^{0.566} \text{ (English Units)} \qquad \text{(B-2)}$$
$$Q = 224{,}200A^{0.566} \text{ (Metric Units)}$$

The third straight line is drawn between 9,950,000 BTU per hour (2,916,000 Watts) at 1,000 square feet (93 square meters) of wetted surface area and 14,090,000 BTU per hour (4,129,700 Watts) at 2,800 square feet (260 square meters) of wetted surface area. The equation used for this portion of the curve is

$$Q = 963{,}400A^{0.338} \text{ (English Units)} \qquad \text{(B-3)}$$
$$Q = 630{,}400A^{0.338} \text{ (Metric Units)}$$

Figure B-1 shows the composite curve for English Units.

For nonrefrigerated tanks designed for pressures of 1 pound per square inch gauge (69 mbarg) and below, with wetted surfaces larger than 2,800 square feet (260 square meters), it has been concluded that complete fire involvement is unlikely and loss of metal strength from overheating will cause failure in the vapor space before development of the maximum possible rate of vapor evolution. Therefore, additional venting capacity beyond the vapor equivalent of 14,090,000 BTU per hour (4,129,700 Watts) will not be effective.

For all refrigerated tanks, regardless of design pressure, and for all nonrefrigerated tanks and storage vessels designed for pressures over 1 pound per square inch gauge (69 mbarg), additional venting for exposed surfaces larger than 2,800 square feet (260 square meters) is believed to be desirable because, under these storage conditions, liquids often are stored at temperatures close to their boiling points. Therefore, the time required to bring these liquids to the boiling point may not be significant. For these situations, a heat input value should be determined on the basis of

$$Q = 21{,}000A^{0.82} \text{ (English Units)} \qquad \text{(B-4)}$$
$$Q = 43{,}200A^{0.82} \text{ (Metric Units)}$$

The total emergency venting requirements, in SCFH of air, are based on the heat input values described in the preceding paragraphs. These heat input values, in BTU per hour (Watts), are converted to SCFH (Nm^3/h) of air on the assumption that the stored liquids will have the characteristics of hexane and the venting will occur at 60°F (15.6°C), using the following formula:

A. English Units

$$SCFH = \frac{70.5Q}{LM^{0.5}} \qquad \text{(B-5)}$$

where

$SCFH$ = venting requirement, in standard cubic feet of air per hour,

70.5 = factor for converting pounds of vapor to standard cubic feet of air,

Q = total heat input, in BTU per hour (determined from Figure B-1 using the calculated wetted surface, A),

L = latent heat of vaporization at relieving conditions, in BTU per pound,

M = molecular weight of the vapor being relieved.

In the equation:

$$SCFH = 1107A^{0.82} \qquad \text{(B-6)}$$

the constant 1107 is derived from the previous equation, substituting 21,000 BTU per hour for Q, and the latent heat of vaporization, L, and the molecular weight M, for hexane (144 BTU per pound and 86.17, respectively).

B. Metric Units

$$Nm^3/h = \frac{14982Q}{LM^{0.5}}$$

where

Nm^3/h = venting requirement, in normal cubic meters of air per hour,

14982 = conversion factor,

Q = total heat input, in Watts (determined from Figure B-1 using the calculated wetted surface, A),

L = latent heat of vaporization at relieving conditions, in J/kg,

M = molecular weight of the vapor being relieved.

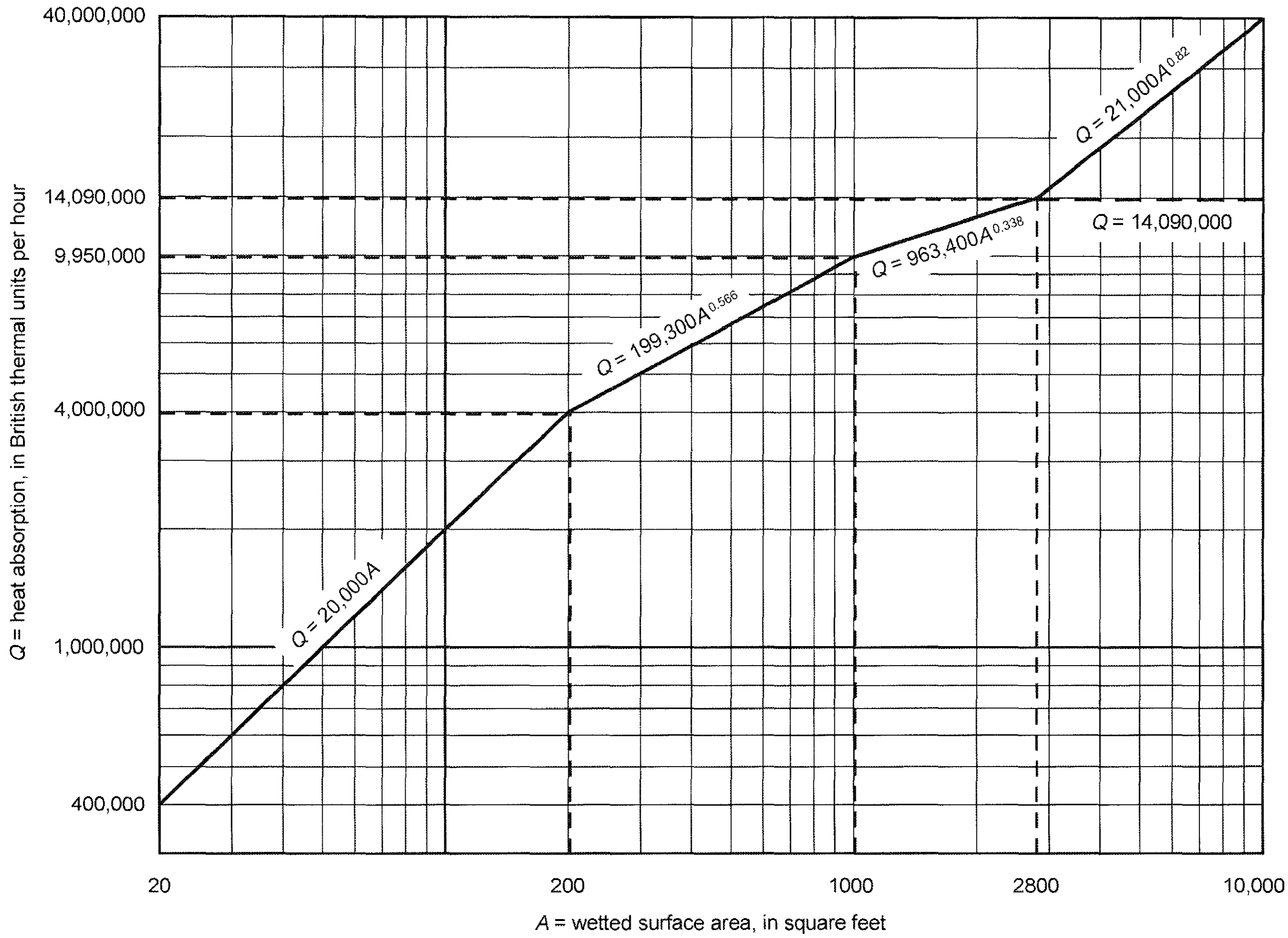
In the equation:

$$Nm^3/h = 208.2A^{0.82} \qquad \text{(B-7)}$$

the constant 208.2 is derived from the previous equation, substituting 43,200 W for Q, and the latent heat of vaporization, L, and the molecular weight M, for hexane (334,900 J/kg and 86.17, respectively).

No consideration has been given to possible expansion from heating the vapor above the boiling point of the liquid, the specific heat of the vapor, or the difference in density between the discharge temperature and 60°F (15.6°C) because some of these changes are compensating.

Because of some concerns expressed about the differences in various methods for determining fire case venting requirements, and a desire to standardize on one method, the subcommittee surveyed approximately 100 companies from 1993 to 1996. This survey indicated that there was no detectable difference in the level of safety provided by using the fire sizing methods found in this document, API RP 520, API RP 521, NFPA documents, or other commonly used fire case venting calculation methods. The subcommittee abandoned efforts to standardize the industry on one method for determining fire case venting requirements in 1996.



Note: Above 2,800 square feet of wetted surface area, the total heat absorption is considered to remain constant for nonrefrigerated tanks below 1 pound per square inch gauge. For nonrefrigerated tanks above 1 pound per square inch gauge and for all refrigerated tanks, the total heat absorption continues to increase with wetted surface area. This is the reason why the curve splits above 2,800 square feet.

Figure B-1—Curve for Determining Requirements for Emergency Venting During Fire Exposure

APPENDIX C—TYPES AND OPERATING CHARACTERISTICS OF VENTING DEVICES

C.1 Introduction

Two basic types of pressure or vacuum vents, direct-acting vent valves and pilot-operated vent valves, are available to provide overpressure or vacuum protection for low-pressure storage tanks. Direct-acting vent valves may be weight loaded or spring loaded. Springs are generally used for set pressures above 1 pound per square inch gauge (69 mbarg) or vacuum below –1 pound per square inch gauge (–69 mbarg). These venting devices not only provide overpressure protection but also conserve product. Direct-acting vent valves are sometimes referred to as conservation vents.

Another type of venting device, an open vent, is available to provide overpressure or vacuum protection for storage tanks designed to operate at atmospheric pressure. An open vent is always open. It allows a tank designed to operate at atmospheric pressure to inbreathe and outbreathe at any pressure differential. An open vent is usually provided with some type of weather hood or shape that prevents rain or snow from entering the tank (see Figure C-1).

A summary of operating characteristics is provided in Table C-1.

C.2 Direct-Acting Vent Valves

C.2.1 DESCRIPTION

Direct-acting vent valves are available to provide pressure relief, vacuum relief, or a combination of pressure and vacuum relief. Combination vent valves may be of a side-by-side configuration (see Figure C-2). Side-by-side vent valves or pressure relief vent valves are available with flanged outlets for pressure discharge when pressure relief vapors must be piped away.

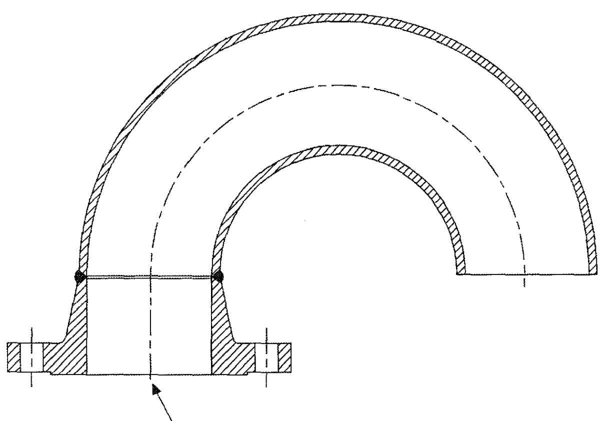


Figure C-1—Open Vent

Larger direct-acting vent valves are available to provide emergency relief and can provide access to a tank's interior for inspection or maintenance. They are typically available in sizes from 16 inches (400 mm) to 24 inches (600 mm) (see Figure C-3). Figure C-4 shows other types and configurations of direct-acting vent valves.

C.2.2 PRINCIPLE OF OPERATION

The principle of operation of a direct-acting vent valve is based on the weight of the pallet or the spring force acting on the pallet to keep the device closed. When tank pressure or vacuum acting on the seat sealing area equals the opposing force acting on the pallet, the venting device is on the threshold of opening. Any further increase in pressure or vacuum causes the pallet to begin to lift off the seat.

Seventy percent to 100 percent overpressure is usually required to achieve full lift of a pallet (see Figure C-5). For an application in which full lift of the seat pallet is required for capacity reasons but cannot be obtained because of a pressure limit on the storage tank, a larger venting device or multiple venting devices must be used at reduced lift and capacity. Several large venting devices instead of many small venting devices are usually preferred to minimize the number of tank penetrations. As an alternative, a set pressure below the maximum allowable working pressure of the tank may be selected to allow full lift.

C.2.3 SEAT TIGHTNESS

A soft, nonstick material is typically used on the sealing surface of the pallet. This material produces a better seal between the pallet and the nozzle and prevents the pallet from sticking to the nozzle.

A direct-acting vent valve is tightest when tank pressures are 75 percent or less of set pressure. When tank pressures are 90 percent or more of set pressure, seat leakage is common. The closer a tank gets to the set pressure, the more the seats leak. For the same set pressure, larger vent valves are tighter than smaller vent valves. This is because the circumferential unit load at the pallet seating surface is directly proportional to the diameter of the seating area.

Seat leakage can cause vent valve seats to stick closed if the vapors from the storage tank product polymerize when exposed to atmospheric air or the vapors autorefrigerate, condense, and freeze atmospheric moisture. Purging the seat area with an inert gas, such as nitrogen, or using a steam-jacketed venting device may be necessary to prevent sticking.

Seat leakage can be caused by uneven bolt torque on flanged connections, particularly in large diameter devices such as weight-loaded emergency venting devices.

Table C-1—Operating Characteristics of Venting Devices

Characteristic	Type of Venting Device: Direct Acting	Pilot Operated
Seat Tightness	Leakage rate increases with increasing pressure. Leakage may begin at 75% of set.	Leakage rate decreases with increasing pressure. Typically, no leakage above 30% of set. A small amount of leakage at pilot may begin at 90% of set.
Capacity/Overpressure (Refer to Figure C-5)	Rated capacity normally obtained at 200% of set, for pressure or vacuum.	Rated capacity obtained at 110% of set for pressure or vacuum.
Set Pressure Range—Typical	Pressure—Weight Loaded $^1/_2$ oz/in^2 to 16 oz/in^2 (0.865" WC to 27.7" WC) (2 mbarg to 69 mbarg) Pressure—Spring Loaded 1.0 psig to 15.0 psig (69 mbarg to 1.034 barg) Vacuum—Weight Loaded $^1/_2$ oz/in^2 to –10 oz/in^2 –0.865" WC to –17.3" WC) (–2 mbarg to –43 mbarg) Vacuum—Spring Loaded –10 oz/in^2 to –7 psig (–43 mbarg to 0.48 barg)	Pressure— 2" WC to 15.0 psig (5 mbarg to 1.034 barg) Vacuum— –2" WC to –14.7 psig (–5 mbarg to –1.013 barg)
Typical Blowdown	0	0% to 7%

In areas with strict fugitive emissions regulations, open vents may not be acceptable and vent device selection must consider maximum leakage requirements during periods of normal tank operation.

C.2.4 VENTING DEVICE SIZES AND SET PRESSURES

Direct-acting vent valves are typically available in sizes from 2 inches (50 mm) to 12 inches (300 mm); however, vent valves in a stacked configuration (see Figure C-4) are available in sizes up to 24 inches (600 mm). The size of a vent valve is based on the venting device's tank connection.

Typical set pressure ranges for weight-loaded vent valves are up to 16 ounces per square inch pressure (69 mbarg) and up to 10 ounces per square inch vacuum (–43 mbarg). Spring-loaded vent valves must generally be used for pressure or vacuum settings that exceed these values because the supporting structure and space for the added weights is not available.

Verification of the set pressure of a venting device after it has been installed on a storage tank can be accomplished by increasing the tank pressure or vacuum. To change the set pressure, weights must be added or removed from the pallet, a new pallet must be used, or the spring must be adjusted (if a spring-loaded vent valve is being used).

C.3 Pilot-Operated Vent Valves

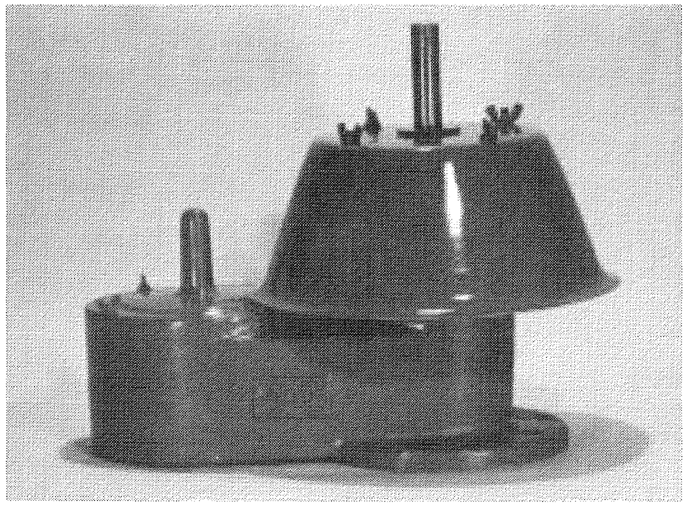
C.3.1 DESCRIPTION

Pilot-operated vent valves are available to provide pressure relief, vacuum relief, or a combination of pressure and vacuum relief. Some vent valves may be equipped with flanged outlets when pressure relief vapors must be piped away. Unlike side-by-side direct-acting vent valves, pilot-operated vent valves relieve pressure or vacuum through the same opening to atmosphere (see Figure C-6).

C.3.2 PRINCIPLE OF OPERATION

A pilot-operated vent valve for pressure relief uses tank pressure, not weights or a spring, to keep the vent valve seat closed. The main seat is held closed by tank pressure acting on a large area diaphragm. This tank pressure covers an area greater than the seat sealing area, so the net pressure force is always in a direction to keep the seat closed. The volume above the diaphragm is called the dome. Should the diaphragm fail, the dome pressure will decrease, and the vent valve will open.

The pilot is a small control valve that continuously senses tank pressure. When the tank pressure increases to set pressure, the pilot actuates to reduce the pressure in the dome volume, the force holding the seat closed is reduced, and the seat



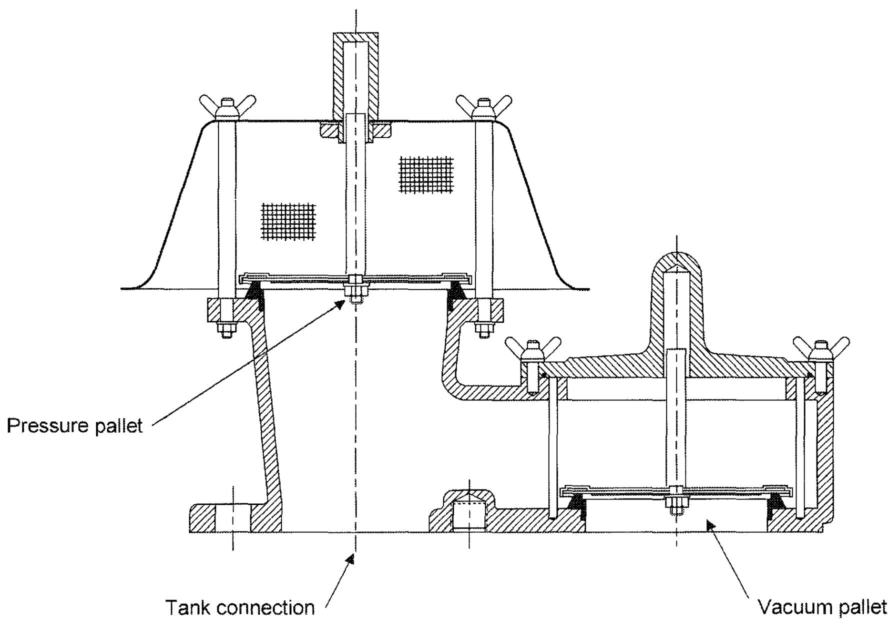


Figure C-2—Side-by-Side Pressure/Vacuum Vent

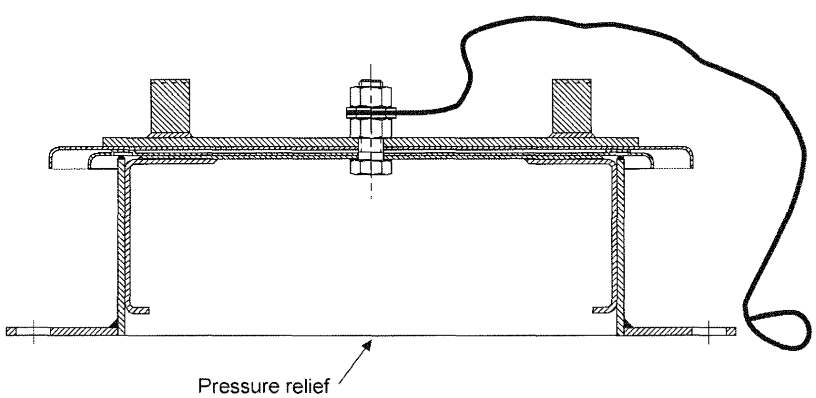
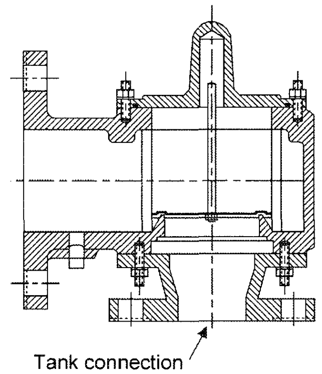
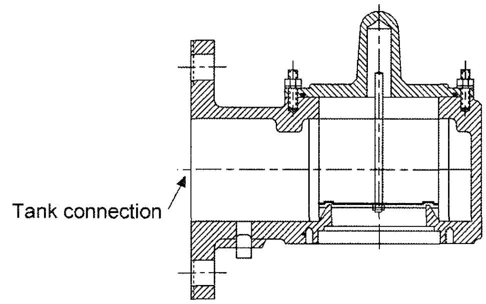


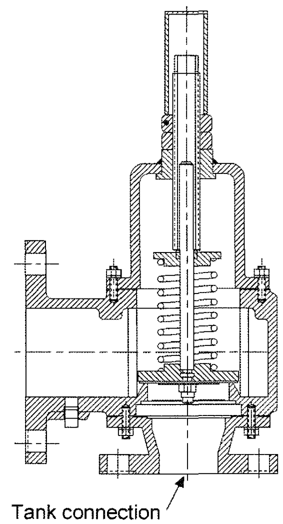
Figure C-3—Large Weight-Loaded Emergency Vent



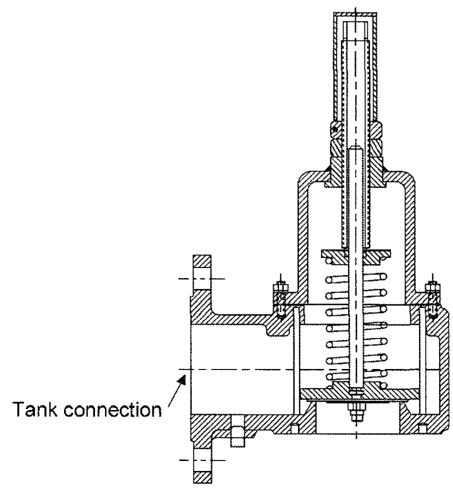
WEIGHTED PALLET PRESSURE VENT FLANGED OUTLET



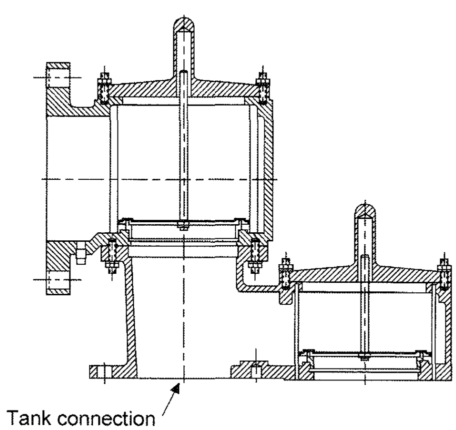
WEIGHTED PALLET VACUUM VENT



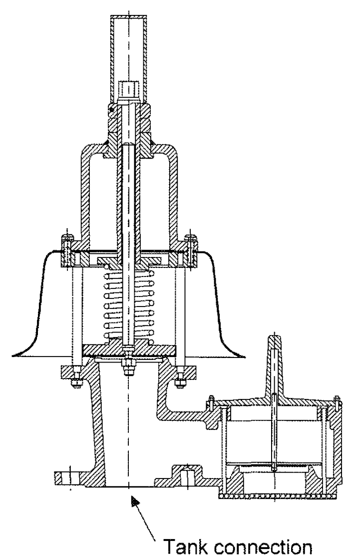
SPRING–LOADED PRESSURE VENT FLANGED OUTLET



SPRING–LOADED VACUUM VENT



SIDE–BY–SIDE WEIGHTED PRESSURE/VACUUM VENT FLANGED PRESSURE OUTLET



SIDE–BY–SIDE SPRING–LOADED PRESSURE WEIGHT–LOADED VACUUM VENT

Figure C-4—Direct-Acting Vents

lifts to permit tank pressure to discharge through the vent valve. When the tank pressure decreases, the pilot closes, the dome volume repressurizes, and the main seat closes.

Blowdown is defined as the difference between opening and closing pressure. This pressure difference is expressed as pressure or as a percent of the set pressure. Typical blowdowns are 0 percent to 7 percent. A vent valve with 0 percent blowdown is known as a throttling vent valve. A throttling vent valve is similar to a direct-acting vent valve because it begins to open and close at almost the same pressure; however, unlike in a direct-acting vent valve, full lift of the seat in a throttling vent valve is obtained at or below 10 percent overpressure (see Figure C-5). Where tank operating pressures are very close to the maximum allowable tank pressure, this lift characteristic permits overpressure protection to be accomplished with smaller or fewer venting devices.

A pilot-operated vent valve for vacuum relief uses atmospheric pressure to keep the seat closed. The force holding the seat closed is equal to the seat sealing area times the pressure differential across the seat. This pressure differential is equal to atmospheric pressure plus the tank vacuum. When the tank vacuum equals the pilot set, the pilot opens to apply tank vacuum to the large dome volume above the diaphragm. Atmospheric pressure acting on the downstream side of the diaphragm forces the diaphragm and seat up. Little or no increase in tank vacuum beyond the vent valve setting is required to obtain full lift of the seat. When the tank vacuum decreases, the pilot closes and atmospheric pressure enters the dome to close the main seat.

Should the diaphragm fail, atmospheric air will enter the dome and prevent tank vacuum from creating a force differential to lift the seat. Double diaphragm vent valves are available to prevent such a failure (see Figure C-7): One diaphragm is for pressure actuation, and one is for vacuum actuation. Each diaphragm is isolated and protected from the flow stream and fully supported to minimize stress. The vacuum diaphragm moves only to provide vacuum relief to extend its service life.

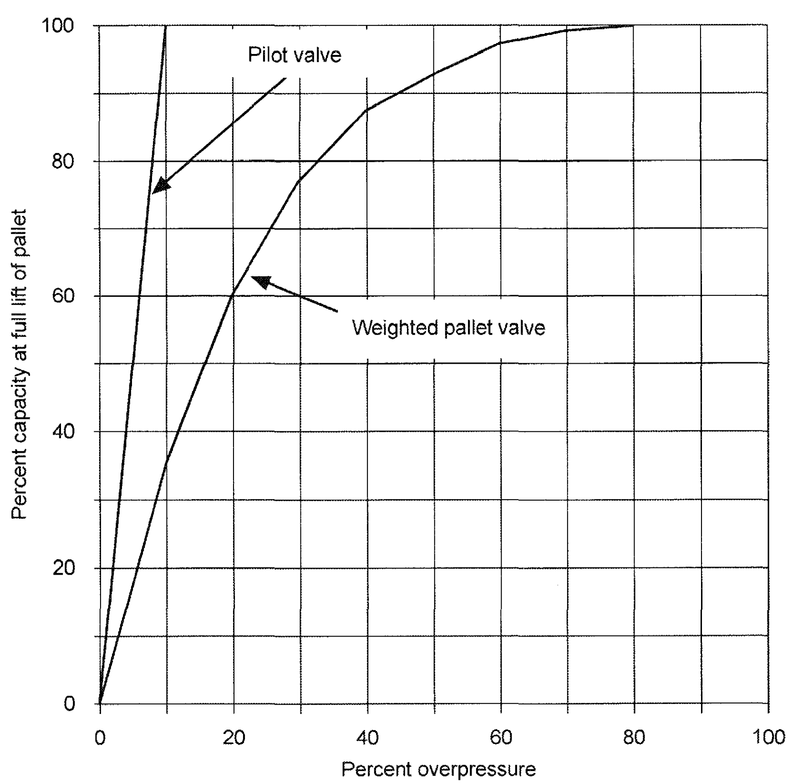


Figure C-5—Capacity/Overpressure Characteristic of Vent

C.3.3 SEAT TIGHTNESS

All low-pressure pilot vent valves are soft seated for premium tightness. Unlike in a direct-acting vent valve, the force holding the seat closed in a pilot vent valve increases with increasing pressure. This force is maximum just before the vent valve opens, so leakage will not occur when tank pressure increases or when tank pressure is kept near the set point of the venting device. The force available to open the seat at set pressure is also maximum, since the force holding the seat closed is removed when set pressure is reached. The opening force available is essentially equal to the seat area times the tank pressure.

C.3.4 PILOT TYPES

Two types of pilot actions are available, modulating and snap action. For modulating action, the main vent valve opens gradually with increasing pressure and achieves rated relieving capacity at relieving pressure. Modulating valves reclose at set pressure. For snap action, the main valve opens rapidly at set pressure and achieves rated relieving capacity at relieving pressure. Blowdown is normally adjustable.

C.3.5 VENTING DEVICE SIZES AND SET PRESSURES

Low-pressure pilot-operated vent valves are typically available in sizes from 2 inches (50 mm) to 12 inches (300 mm). The size of a vent valve is based on the venting device's tank connection. Available set pressures range from 15 pounds per square inch gauge pressure (1.034 barg) to 14.7 pounds per square inch gauge vacuum (–1.013 barg). The minimum opening pressure is typically 2-inch water column pressure (5 mbarg) or 2-inch water column vacuum (–5 mbarg).

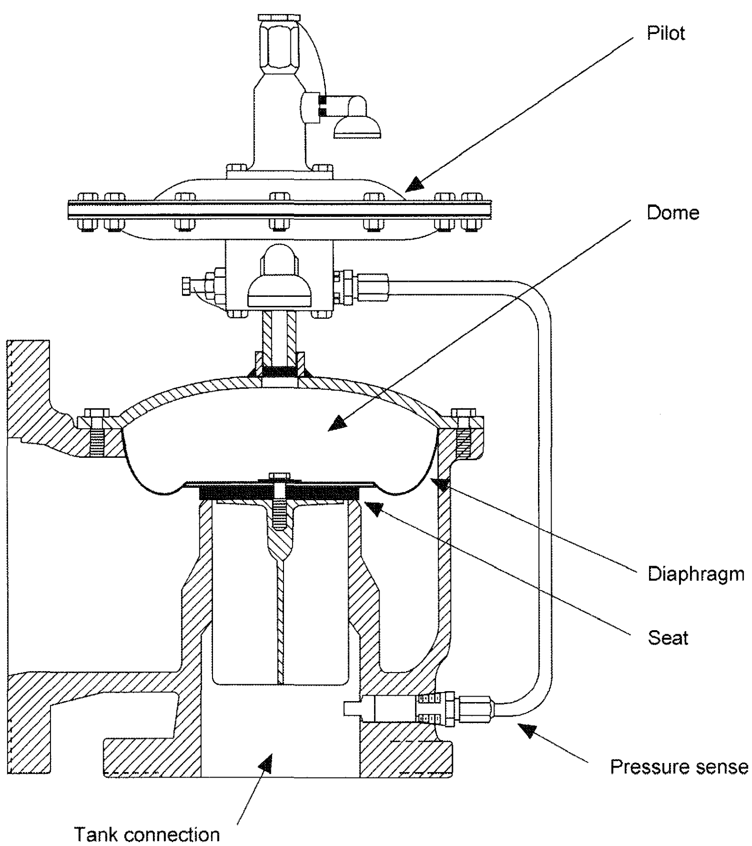


Figure C-6—Pilot-Operated Pressure Vent (Single Diaphragm)

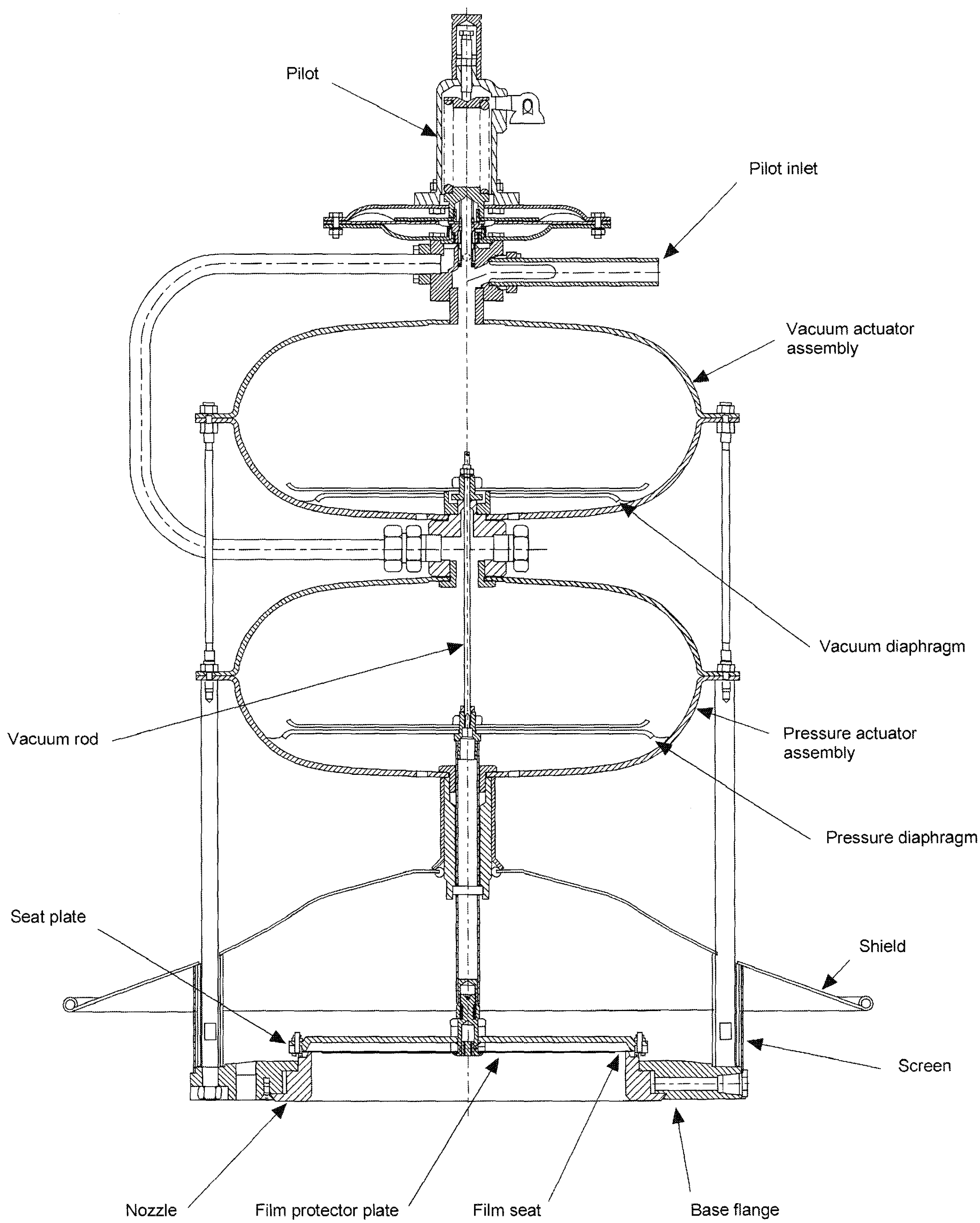


Figure C-7—Pilot-Operated Pressure/Vacuum (Double Diaphragm)

C.3.6 OPTIONAL FEATURES

Several options are available with a pilot-operated vent valve. For verifying set pressure, a field-test connection can be supplied that permits checking the set pressure with the vent valve installed and pressurized.

A valve to operate the vent valve as a blowdown device can be supplied if depressurizing the storage tank is required. This valve can be operated manually at the vent valve or remotely from a control room.

For installations where inlet piping pressure losses may cause the vent valve to rapid cycle, the pilot can be equipped to sense tank pressure at a location upstream of the inlet pipe to prevent the vent valve from rapid cycling. This option, known as remote sense, will prevent the vent valve from rapid cycling; however, the relieving capacity will be reduced because capacity is dependent upon the pressure at the vent valve inlet.

When particulates in the tank vapors may be a problem, an external, fine element filter can be supplied for the pilot pressure sense line. When polymerization of tank vapors in the pilot may be a problem, an inert gas purge at the pilot pressure sense line can be supplied to prevent the tank vapors from entering the pilot.

A pilot-operated vent valve can be equipped with a pilot lift lever and a position indicator. A lift lever permits manual operation of the pilot to make sure it is free to operate. Actuation of this lever will always open the main valve if the tank is pressurized. A position indicator is a differential pressure switch that can be used to signal a control room when the vent valve is open or closed.

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