

Petroleum, petrochemical and natural gas industries — Venting of atmospheric and low- pressure storage tanks

ICS 75.180.20

National foreword

This British Standard is the UK implementation of EN ISO 28300:2008. It is identical to ISO 28300:2008, incorporating corrigendum October 2009.

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Foreword

This document (EN ISO 28300:2008) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2008, and conflicting national standards shall be withdrawn at the latest by December 2008.

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Endorsement notice

The text of ISO 28300:2008 has been approved by CEN as a EN ISO 28300:2008 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 28300 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Introduction

This International Standard was developed from the 5th edition of API Std 2000 and EN 14015:2005, with the intent that the 6th edition of API Std 2000 be identical to this International Standard.

This International Standard has been developed from the accumulated knowledge and experience of qualified engineers of the oil, petroleum, petrochemical, chemical and general bulk liquid storage industry.

Engineering studies of a particular tank can indicate that the appropriate venting capacity for the tank is not the venting capacity estimated in accordance with this International 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.

In this International Standard, where practical, US Customary (USC) units are included in parentheses or in separate tables, for information.

Petroleum, petrochemical and natural gas industries — Venting of atmospheric and low-pressure storage tanks

1 Scope

AC1 This International Standard covers the normal and emergency vapour venting requirements for aboveground liquid-petroleum or petroleum-products storage tanks and aboveground and underground refrigerated storage tanks designed for operation at pressures from full vacuum through 103,4 kPa (ga) [15 psig]. **AC1** Discussed in this International Standard are the causes of overpressure and vacuum; determination of venting requirements; means of venting; selection, and installation of venting devices; and testing and marking of relief devices.

This International Standard is intended for tanks containing petroleum and petroleum products but it can also be applied to tanks containing other liquids; however, it is necessary to use sound engineering analysis and judgment whenever this International Standard is applied to other liquids.

This International Standard does not apply to external floating-roof tanks.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4126-4, *Safety devices for protection against excessive pressure — Part 4: Pilot operated safety valves*

ISO 16852, *Flame arresters — Performance requirements, test methods and limits for use*

ISO 23251, *Petroleum, petrochemical and natural gas industries — Pressure-relieving and depressuring systems*

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*

DIN 4119¹⁾ (all parts), *Above-ground cylindrical flat-bottom tank structures of metallic materials*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms apply.

3.1

accumulation

pressure increase over the maximum allowable working pressure or design pressure of the vessel allowed during discharge through the pressure-relief device

NOTE Accumulation is expressed in units of pressure or as a percentage of MAWP or design pressure. Maximum allowable accumulations are established by pressure-design codes for emergency operating and fire contingencies.

1) Deutsches Institut für Normung (DIN), Burggrafenstrasse 6, Berlin, Germany D-10787

3.2

adjusted set pressure

inlet static pressure at which a pressure-relief valve is adjusted to open on the test stand

See **set pressure** (3.19).

NOTE 1 Adjusted set pressure is equivalent to set pressure for direct-mounted end-of-line installations.

AC1 NOTE 2 The adjusted set pressure includes corrections for service conditions of superimposed back-pressure. **AC1**

3.3

British thermal unit

Btu

unit of heat that increases the temperature of one pound of water by one degree Fahrenheit

3.4

emergency venting

venting required when an abnormal condition, such as ruptured internal heating coils or an external fire, exists either inside or outside a tank

3.5

non-refrigerated tank

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

NOTE Generally, the storage temperature is close to, or higher than, ambient temperature.

3.6

normal cubic metres per hour

Nm³/h

SI unit for volumetric flow rate of air or gas at a temperature of 0 °C and pressure of 101,3 kPa, expressed in cubic metres per hour

3.7

normal venting

venting required because of operational requirements or atmospheric changes

3.8

overpressure

pressure increase at the PV valve inlet above the set pressure, when the PV valve is relieving

NOTE 1 Overpressure is expressed in pressure units or as a percentage of the set pressure.

NOTE 2 The value or magnitude of the overpressure is equal to the value or magnitude of the accumulation when the valve is set at the maximum allowable working pressure or design pressure and the inlet piping losses are zero.

3.9

petroleum

crude oil

3.10

petroleum products

hydrocarbon materials or other products derived from crude oil

3.11

PV valve

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

3.12

rated relieving capacity

flow capacity of a relief device expressed in terms of air flow at standard or normal conditions at a designated pressure or vacuum

NOTE Rated relieving capacity is expressed in SCFH or Nm³/h.

3.13

refrigerated tank

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

3.14

relief device

device used to relieve excess pressure and/or vacuum that has developed in a tank

3.15

relieving pressure

pressure at the inlet of a relief device when the fluid is flowing at the required relieving capacity

3.16

required flow capacity

flow through a relief device required to prevent excessive pressure or vacuum in a tank under the most severe operating or emergency conditions

3.17

rollover

uncontrolled mass movement of stored liquid, correcting an unstable state of stratified liquids of different densities and resulting in a significant evolution of product vapour

3.18

standard cubic feet per hour

SCFH

USC unit for volumetric flow rate of air or gas (same as free air or free gas) at a temperature of 15,6 °C (60 °F) and an absolute pressure of 101,3 kPa (14,7 psi), expressed in cubic feet per hour

3.19

set pressure

gauge pressure at the device inlet at which the relief device is set to start opening under service conditions

3.20

thermal inbreathing

movement of air or blanketing gas into a tank when vapours in the tank contract or condense as a result of weather changes (e.g. a decrease in atmospheric temperature)

3.21

thermal out-breathing

movement of vapours out of a tank when vapours in the tank expand and liquid in the tank vaporizes as a result of weather changes (e.g. an increase in atmospheric temperature)

3.22

wetted area

surface area of a tank exposed to liquid on the interior and heat from a fire on the exterior

4 Non-refrigerated aboveground tanks

4.1 General

Clause 4 covers the causes of overpressure or vacuum; determination of venting requirements; means of venting; selection and installation of venting devices.

4.2 Causes of overpressure or vacuum

4.2.1 General

When determining the possible causes of overpressure or vacuum in a tank, consider the following:

- 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.

There can be additional circumstances that should be considered but are not included in this International Standard.

4.2.2 Liquid movement into or out of a tank

Liquid can enter or leave a tank by pumping, by gravity flow or by process pressure.

Vacuum can result from the outflow of liquid from a tank. Overpressure can result from the inflow of liquid into a tank and from the vapourization, including flashing of the feed liquid, that occurs 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. See 4.3 for calculation methods.

4.2.3 Weather changes

Vacuum can result from the contraction or condensation of vapours that is caused by a decrease in atmospheric temperature or other weather changes, such as wind changes, precipitation, etc. Overpressure can result from the expansion and vapourization that is caused by an increase in atmospheric temperature or weather changes. See 4.3 for calculation methods.

4.2.4 Fire exposure

Overpressure results from the expansion of the vapours and vapourization of the liquid that occur when a tank absorbs heat from an external fire. See 4.3.3 for calculation methods.

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 shall be considered and evaluated. Calculation methods for these other circumstances are not provided in this International Standard.

4.2.5.2 Pressure transfer vapour breakthrough

Liquid transfer from other vessels, tank trucks and tank cars can be aided or accomplished entirely by pressurization of the supply vessel with a gas, but the receiving tank can encounter a flow surge at the end of the transfer due to vapour breakthrough. Depending on the pre-existing pressure and free head space in the receiving tank, the additional gas volume can 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.

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 non-flammable atmospheres in the tanks and reduce the extent of the flammable envelope of the vapours vented 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 operating range. Failure of the supply regulator can result in unrestricted gas flow into the tank and subsequent tank overpressure, reduced gas flow, or complete loss of the gas flow. Failure closed of the back-pressure regulator can result in a blocked outlet and overpressure. If the back-pressure regulator is connected to a vapour-recovery system, its failure open can result in vacuum.

4.2.5.4 Abnormal heat transfer

Steam, tempered water and hot oil are common heating media for tanks whose contents it is necessary to maintain at elevated temperatures. Failure of a tank's supply control valve, temperature-sensing element or control system can cause an increase of heat input to the tank. Vapourization of the liquid stored in the tank can result in tank overpressure.

Heated tanks that have two liquid phases present the possibility of a rapid vapourization if the lower phase is heated to the point where its density becomes lower than the density of the liquid above it. It is recommended to specify design and operating practices to avoid these conditions.

If a tank maintained at elevated temperatures is empty, excessive feed vapourization can result when the tank is filled. If the temperature control system of the tank is active with the sensing element exposed to vapour, the tank's heating medium can be circulating at maximum rate with the tank wall at maximum temperature. Filling under such conditions can result in excessive feed vapourization. The excessive feed vapourization stops as soon as the walls have cooled and the fluid level covers the sensing element.

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

4.2.5.5 Internal failure of 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 is into the tank when the device fails. Chemical compatibility of the tank contents and the heat-transfer medium shall be considered. Relief of the heat-transfer medium (e.g. steam) can be necessary.

4.2.5.6 Vent treatment systems

If vapour from a tank is collected for treatment or disposal by a vent treatment system, the vent collection system can fail. This failure shall 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 venting or 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, may be used if appropriate.

4.2.5.7 Utility failure

Local and plant-wide power and utility failures shall be considered as possible causes of overpressure or vacuum. Loss of electrical power directly affects any motorized valves or controllers and can also shut down the instrument air supply. Also, cooling and heating fluids can 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, can cause overpressure in the tank. A lower-temperature inlet stream can result in vapour condensation and contraction, which can cause vacuum.

4.2.5.9 Chemical reactions

The contents of some tanks can be subject to chemical reactions that generate heat and/or vapours. Some examples of chemical reactions include inadvertently adding water to acid or spent acid tanks, thereby generating steam and/or vapourizing light hydrocarbons; runaway reactions in tanks containing cumene hydroperoxide; etc. In some cases, the material can foam, causing two-phase relief.

Technology available from the Design Institute for Emergency Relief Systems (DIERS) Users Group of the American Institute of Chemical Engineers (AIChE) or from the DIERS group in Europe may be used to evaluate these cases.

4.2.5.10 Liquid overfill protection

For information on liquid overfill protection, see API Std 2510, API RP 2350 and EN 13616. Prevent liquid overfill by providing instrument safeguards and/or effective operator intervention actions.

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. This should be considered for refrigerated storage tanks (see 5.2.1.2).

4.2.5.12 Control valve failure

The effect of a control valve failing open or failing closed shall be considered to determine the potential for pressure or vacuum due to mass and/or energy imbalances. For example, failure of a control valve on the liquid line to a tank shall be considered because such a failure can overload heat-exchange equipment resulting in the admission of high-temperature material into the tank. A control-valve failure can also cause the liquid level in a pressurized vessel feeding liquid to a tank to drop below the vessel outlet nozzle, allowing high-pressure vapour to enter the tank (see 4.2.5.2).

4.2.5.13 Steam out

If an uninsulated tank is filled with steam, the condensing rate due to ambient cooling can exceed the venting rates specified in this International Standard. Procedures, such as the use of large vents (open manways), controlling the tank cooling rate or adding a non-condensable gas such as air or nitrogen, are often necessary to prevent excessive internal vacuum.

4.2.5.14 Uninsulated hot tanks

Uninsulated tanks with exceptionally hot vapour spaces can exceed the thermal inbreathing requirements in this International Standard during a rainstorm. Vapour contraction can cause excessive vacuum. An engineered review of heated, uninsulated tanks with vapour-space temperatures above 48,9 °C (120 °F) is recommended.

4.2.5.15 Internal explosion/deflagration

Tank contents can ignite, producing an internal deflagration with overpressures that develop more rapidly than some venting devices can handle. For explosion venting, see NFPA 68 and EN 13237. For inerting, see Annex F.

4.2.5.16 Mixing of products of different composition

Introduction of materials that are more volatile than those normally stored can be possible due to upsets in upstream processing or human error. This can result in overpressure.

4.3 Determination of venting requirements

4.3.1 General

It is necessary to quantify the venting requirements for any applicable cause of excessive pressure or vacuum as identified based on guidance provided in 4.2 to establish the design basis for the sizing of relief devices or any other means of appropriate protection. To assist in this quantification, this International Standard provides guidance for the detailed calculation related to the following commonly encountered conditions:

- a) normal inbreathing resulting from a maximum outflow of liquid from the tank (liquid-transfer effects);
- b) normal inbreathing resulting from contraction or condensation of vapours caused by a maximum decrease in vapour-space temperature (thermal effects);
- c) normal out-breathing resulting from a maximum inflow of liquid into the tank and maximum vapourization caused by such inflow (liquid-transfer effects);
- d) normal out-breathing resulting from expansion and vapourization that results from a maximum increase in vapour-space temperature (thermal effects);
- e) emergency venting resulting from fire exposure.

When determining the venting requirements, the largest single contingency requirement or any reasonable and probable combination of contingencies shall be considered as the design basis. At a minimum, the combination of the liquid-transfer effects and thermal effects for normal venting shall be considered when determining the total normal inbreathing or out-breathing.

With the exception of refrigerated storage tanks, common practice is to consider only the total normal inbreathing for determining the venting requirements. That is, inbreathing loads from other circumstances described in 4.2.5 are generally not considered coincident with the normal inbreathing. This is considered a reasonable approach because the thermal inbreathing is a severe and short-lived condition.

For the total out-breathing, consider the scenarios described in 4.2.5 and determine whether these should be coincident with normal out-breathing flows.

4.3.2 Calculation of maximum flow rates for normal out-breathing and normal inbreathing

4.3.2.1 General

The method in 4.3.2.1 is based on engineering calculations. See Annex E for the assumptions on which this calculated method is based. For a more detailed understanding of this model, see References [21] and [22].

An alternative method of calculating normal out-breathing and normal inbreathing flows is given in Annex A. This alternative method may be used for tank/services that meet the boundary conditions specified in Annex A.

The method of calculation utilized shall be documented.

The inbreathing and out-breathing requirements in this International Standard are for air at normal or standard conditions. The user shall correct the inbreathing and out-breathing requirements to normal or standard conditions for tanks that are heated (insulated) or pressurized to greater than 6,9 kPa (1 psi).

4.3.2.2 Liquid filling and discharge capacities

4.3.2.2.1 Out-breathing

The out-breathing shall be determined as follows.

- a) The out-breathing volumetric flow rate, $\dot{V}_{op}$, expressed in SI units of cubic metres per hour of air, for products stored below 40 °C or with a vapour pressure less than 5,0 kPa, shall be as given by Equation (1):

$$\dot{V}_{op} = \dot{V}_{pf} \quad (1)$$

where $\dot{V}_{pf}$ is the maximum volumetric filling rate, expressed in cubic metres per hour.

The out-breathing volumetric flow rate, $\dot{V}_{op}$, expressed in USC units of cubic feet per hour of air, for products stored below 104 °F or with a vapour pressure less than 0,73 psi, shall be as given by Equation (2):

$$\dot{V}_{op} = 8,02 \cdot \dot{V}_{pf} \quad (2)$$

where $\dot{V}_{pf}$ is the maximum volumetric filling rate, expressed in US gallons per minute.

- b) For products containing more volatile components or dissolved gases (e.g. oil spiked with methane), perform a flash calculation and increase the out-breathing venting requirements accordingly.
- c) For products stored above 40 °C (104 °F) or with a vapour pressure greater than 5,0 kPa (0,73 psi), increase the out-breathing by the evaporation rate.

4.3.2.2.2 Inbreathing

The inbreathing venting requirement, $\dot{V}_{ip}$, expressed in SI units of cubic metres per hour of air, shall be the maximum specified liquid discharging capacity for the tank as given by Equation (3).

$$\dot{V}_{ip} = \dot{V}_{pe} \quad (3)$$

where $\dot{V}_{pe}$ is the maximum rate of liquid discharging, expressed in cubic metres per hour.

Calculate the inbreathing venting requirement, $\dot{V}_{ip}$, expressed in USC units of cubic feet per hour of air, in accordance with Equation (4):

$$\dot{V}_{ip} = 8,02 \cdot \dot{V}_{pe} \quad (4)$$

where $\dot{V}_{pe}$ is the maximum rate of liquid discharging, expressed in US gallons per minute.

4.3.2.3 Thermal out-breathing and inbreathing

4.3.2.3.1 General

Consider thermal out-breathing and inbreathing due to atmospheric heating or cooling of the external surfaces of the tank shell and roof.

4.3.2.3.2 Thermal out-breathing

Calculate the thermal out-breathing (i.e. the maximum thermal flow rate for heating up), $\dot{V}_{OT}$, expressed in SI units of normal cubic metres per hour of air, in accordance with Equation (5):

$$\dot{V}_{OT} = Y \cdot V_{tk}^{0,9} \cdot R_i \quad (5)$$

where

Y is a factor for the latitude (see Table 1);

V_{tk} is the tank volume, expressed in cubic metres;

R_i is the reduction factor for insulation [$R_i = 1$ if no insulation is used; $R_i = R_{inp}$ for partially insulated tanks [see Equation (10)]; $R_i = R_{in}$ for fully insulated tanks [see Equation (9)]].

Calculate the thermal out-breathing (i.e. the maximum thermal flow rate for heating up), $\dot{V}_{OT}$, expressed in USC units as standard cubic feet per hour of air, in accordance with Equation (6):

$$\dot{V}_{OT} = 1,51 \cdot Y \cdot V_{tk}^{0,9} \cdot R_i \quad (6)$$

where

Y is a factor for the latitude (see Table 1);

V_{tk} is the tank volume, expressed in cubic feet;

R_i is the reduction factor for insulation [$R_i = 1$ if no insulation is used; $R_i = R_{inp}$ for partially insulated tanks [see Equation (10)]; $R_i = R_{in}$ for fully insulated tanks [see Equation (9)]].

The Y -factor for the latitude in Equations (5) and (6) can be taken from Table 1.

Table 1 — Y -factor for various latitudes

Latitude	Y -factor
Below 42°	0,32
Between 42° and 58°	0,25
Above 58°	0,2

4.3.2.3.3 Thermal inbreathing

Calculate the maximum thermal flow rate during cooling down, $\dot{V}_{IT}$, expressed in SI units of normal cubic metres per hour of air, in accordance with Equation (7):

$$\dot{V}_{IT} = C \cdot V_{tk}^{0,7} \cdot R_i \quad (7)$$

where

C is a factor that depends on vapour pressure, average storage temperature and latitude (see Table 2);

V_{tk} is the tank volume, expressed in cubic metres;

R_i is the same as for Equation (5).

Calculate the maximum thermal flow rate during cooling down, $\dot{V}_{\text{IT}}$, expressed in USC units of standard cubic feet per hour of air, in accordance with Equation (8):

$$\dot{V}_{\text{IT}} = 3,08 \cdot C \cdot V_{\text{tk}}^{0,7} \cdot R_i \quad (8)$$

where

C is a factor that depends on vapour pressure, average storage temperature and latitude (see Table 2);

V_{tk} is the tank volume, expressed in cubic feet;

R_i is the same as for Equation (5).

Table 2 — C-factors

Latitude	C-factor for various conditions			
	Vapour pressure			
	Hexane or similar		Higher than hexane, or unknown	
	Average storage temperature °C			
	< 25	≥ 25	< 25	≥ 25
Below 42°	4	6,5	6,5	6,5
Between 42° and 58°	3	5	5	5
Above 58°	2,5	4	4	4

4.3.2.4 Reduction factor for tanks with insulation

The thermal flow rate for heating up (thermal out-breathing) or cooling down (thermal inbreathing) is reduced by insulation and depends upon the properties and thickness of the insulation.

Calculate the reduction factor, R_{in} , for a fully insulated tank as given by Equation (9).

$$R_{\text{in}} = \frac{1}{1 + \frac{h \cdot l_{\text{in}}}{\lambda_{\text{in}}}} \quad (9)$$

where

h is the inside heat-transfer coefficient, expressed in watts per square metre-kelvin;

NOTE An inside heat-transfer coefficient of 4 W/(m²·K) [0,7 Btu/(h·ft²·°F)] is commonly assumed for typical tanks.

l_{in} is the wall thickness of the insulation, expressed in metres;

λ_{in} is the thermal conductivity of the insulation, expressed in watts per metre-kelvin.

EXAMPLE For an insulation thickness, L_{in} , equal to 0,1 m, a thermal conductivity of the insulation, λ_{in} , equal to 0,05 W/(m·K), and a heat-transfer coefficient, h , equal to 4 W/(m²·K), the reduction factor, R_{in} , is equal to 0,11. Thus, the out-breathing of the insulated tank is 0,11 times that of the uninsulated tank.

Calculate the reduction factor, R_{inp} , for a partially insulated tank as given by Equation (10):

$$R_{inp} = \frac{A_{inp}}{A_{TTS}} \cdot R_{in} + \left(1 - \frac{A_{inp}}{A_{TTS}}\right) \quad (10)$$

where

A_{TTS} is the total tank surface area (shell and roof), expressed in square metres (square feet);

A_{inp} is the insulated surface area of the tank, expressed in square metres (square feet).

4.3.3 Requirements for emergency venting capacity for tanks subject to fire exposure

4.3.3.1 General

When storage tanks are exposed to fire, the venting rate can exceed the rate resulting from normal out-breathing.

4.3.3.2 Tanks with weak roof-to-shell attachment

On a fixed-roof tank with a weak (frangible) roof-to-shell attachment, such as that described in API Std 650, the roof-to-shell connection will fail prior to other tank welds, allowing relief of the excess pressure if the normal venting capacity proves inadequate. For a tank built to these specifications, it is not necessary to consider additional requirements for emergency venting; however, additional emergency vents may be used to avoid failure of the frangible joint. Care should be taken to ensure that the current requirements for a frangible roof-to-shell attachment are met, particularly for tanks smaller than 15 m (50 ft) in diameter.

4.3.3.3 Fire relief requirements

4.3.3.3.1 When a tank is not provided with a weak roof-to-shell attachment as described in 4.3.3.2, the procedure given in 4.3.3.3.2 through 4.3.3.3.7 shall govern in evaluating the required venting capacity for fire exposure.

4.3.3.3.2 Calculate the required venting capacity, q , expressed in SI units of normal cubic metres per hour of air, for tanks subject to fire exposure as given by Equation (11):

$$q = 906,6 \cdot \frac{Q \cdot F}{L} \cdot \left(\frac{T}{M}\right)^{0,5} \quad (11)$$

where

Q is the heat input from fire exposure as given by Table 3, expressed in watts;

F is the environmental factor from Table 9 (credit may be taken for only one environmental factor);

L is the latent heat of vapourization of the stored liquid at the relieving pressure and temperature, expressed in joules per kilogram;

T is the absolute temperature of the relieving vapour, expressed in kelvins;

NOTE It is normally assumed that the temperature of the relieving vapour corresponds to the boiling point of the stored fluid at the relieving pressure.

M is the relative molecular mass of the vapour.

Calculated the required venting capacity, q , expressed in USC units of standard cubic feet per hour of air, for tanks subject to fire exposure as given by Equation (12).

$$q = 3,091 \cdot \frac{Q \cdot F}{L} \cdot \left(\frac{T}{M} \right)^{0,5} \quad (12)$$

where

Q is the heat input from fire exposure as given by Table 4, expressed in British thermal units per hour;

F is the environmental factor from Table 9 (credit may be taken for only one environmental factor);

L is the latent heat of vapourization of the stored liquid at the relieving pressure and temperature, expressed in British thermal units per pound

T is the absolute temperature of the relieving vapour, expressed in degrees Rankine;

NOTE It is normally assumed that the temperature of the relieving vapour corresponds to the boiling point of the stored fluid at the relieving conditions in the tank.

M is the relative molecular mass of the vapour.

Table 3 — Heat input, Q
(expressed in SI units)

Wetted surface area A_{TWS} m ²	Design pressure kPa (gauge)	Heat input Q W
< 18,6	≤ 103,4	63 150 A_{TWS}
≥ 18,6 and < 93	≤ 103,4	224 200 × (A_{TWS}) ^{0,566}
≥ 93 and < 260	≤ 103,4	630 400 × (A_{TWS}) ^{0,338}
≥ 260	> 7 and ≤ 103,4	43 200 × (A_{TWS}) ^{0,82}
≥ 260	≤ 7	4 129 700

Table 4 — Heat input, Q
(expressed in USC units)

Wetted surface area A_{TWS} ft ²	Design pressure psig	Heat input Q Btu/h
< 200	≤ 15	20 000 A_{TWS}
≥ 200 and < 1 000	≤ 15	199 300 × (A_{TWS}) ^{0,566}
≥ 1 000 and < 2 800	≤ 15	963 400 × (A_{TWS}) ^{0,338}
≥ 2 800	> 1 and ≤ 15	21 000 × (A_{TWS}) ^{0,82}
≥ 2 800	≤ 1	14 090 000

4.3.3.3.3 Where the fluid properties are similar to those of hexane, the required venting capacity can be determined from Table 5 or Table 6.

Table 5 — Venting capacity
(expressed in SI units)

Wetted surface area A_{TWS}^a m ²	Design pressure kPa (gauge)	Required venting capacity Nm ³ /h of air
< 260	≤ 103,4	See Table 7 and 4.3.3.3.4.
≥ 260	≤ 7	19 910 (see 4.3.3.3.4)
≥ 260	> 7 and ≤ 103,4	Use Equation (13) ^b .

^a The wetted area of a tank or storage vessel shall be calculated as follows.

- For spheres and spheroids, the wetted area is equal to 55 % of the total surface area or the surface area to a height of 9,14 m above grade, whichever is greater.
- For horizontal tanks, the wetted area is equal to 75 % of the total surface area or the surface area to a height of 9,14 m above grade, whichever is greater.
- For vertical tanks, the wetted area is equal to the total surface area of the vertical shell to a height of 9,14 m above grade. For a vertical tank setting on the ground, the area of the ground plates is not included as wetted area. For a vertical tank supported above grade, it is necessary to include a portion of the area of the bottom 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. It is necessary to use engineering judgement in evaluating the portion of the area exposed to fire.

^b Calculate the venting requirement, q , expressed in normal cubic metres per hour of air as given in Equation (13), which is based on the total heat absorbed, Q , expressed in watts, equal to $43\,200 A_{TWS}^{0,82}$ [see Equation (B.7)]:

$$q = 208,2 F A_{TWS}^{0,82} \quad (13)$$

where

F is the environmental factor from Table 9 (credit may be taken for only one environmental factor);

A_{TWS} is the wetted surface area, expressed in square metres.

The total heat absorbed, Q , is expressed in watts for Equation (13). Table 7 and the constant 208,2 in Equation (13) are derived from Equation (11) and Figure B.1 by using the latent heat of vapourization of hexane, equal to 334 900 J/kg at atmospheric pressure, and the relative molecular mass of hexane (86,17) and assuming a vapour temperature of 15,6 °C. This method provide results within an acceptable degree of accuracy for many fluids having similar properties (see Annex B).

Table 6 — Venting capacity
(expressed in USC units)

Wetted surface area A_{TWS}^a ft ²	Design pressure psig	Required venting capacity SCFH of air
< 2 800	≤ 15	See Table 8 and 4.3.3.3.4.
≥ 2 800	≤ 1	742 000 (see 4.3.3.3.4)
≥ 2 800	$[AC_1] > 1$ and $≤ 15 [AC_1]$	Use Equation (14) ^b .

a The wetted area of a tank or storage vessel shall be calculated as follows.

- For spheres and spheroids, the wetted area is equal to 55 % of the total surface area or the surface area to a height of 30 ft above grade, whichever is greater.
- For horizontal tanks, the wetted area is equal to 75 % of the total surface area or the surface area to a height of 30 ft above grade, whichever is greater.
- For vertical tanks, the wetted area is equal to the total surface area of the vertical shell to a height of 30 ft above grade. For a vertical tank setting on the ground, the area of the ground plates is not included as wetted area. For a vertical tank supported above grade, it is necessary to include a portion of the area of the bottom 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. It is necessary to use engineering judgement in evaluating the portion of the area exposed to fire.

b Calculate the venting requirement, q , expressed in $[AC_1]$ standard cubic feet per hour $[AC_1]$ of air as given in Equation (14), which is based on the total heat absorbed, Q , expressed in British thermal units per hour, equal to $21\,000 A_{TWS}^{0.82}$ [see Equation (B.8)]:

$$q = 1\,107 F A_{TWS}^{0.82} \quad (14)$$

where

F is the environmental factor from Table 9 (credit may be taken for only one environmental factor);

A_{TWS} is the wetted surface area, expressed in square feet.

The total heat absorbed, Q , is expressed in Btu per hour for Equation (14). Table 8 and the constant 1 107 in Equation (14) are derived from Equation (12) and Figure B.2 by using the latent heat of vapourization of hexane, equal to 144 Btu/lb at atmospheric pressure, and the relative molecular mass of hexane (86,17) and assuming a vapour temperature of 60 °F. This method provides results within an acceptable degree of accuracy for many fluids having similar properties (see Annex B).

Table 7 — Emergency venting required for fire exposure versus wetted surface area
(expressed in SI units)

Wetted area ^a m ²	Venting required Nm ³ /h		Wetted area ^a m ²	Venting required 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.
- For spheres and spheroids, the wetted area is equal to 55 % of the total surface area or the surface area to a height of 9,14 m above grade, whichever is greater.
 - For horizontal tanks, the wetted area is equal to 75 % of the total surface area or the surface area to a height of 9,14 m above grade, whichever is greater.
 - For vertical tanks, the wetted area is equal to the total surface area of the vertical shell to a height of 9,14 m above grade. For a vertical tank setting on the ground, the area of the ground plates is not included as wetted area. For a vertical tank supported above grade, it is necessary to include a portion of the area of the bottom 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. It is necessary to use engineering judgement in evaluating the portion of the area exposed to fire.

^b For wetted surfaces larger than 260 m², see Table 5

NOTE This table and the constant 208,2 in Equation (13) are derived from Equation (11) and Figure B.1 by using the latent heat of vapourization of hexane, equal to 334 900 J/kg at atmospheric pressure, and the relative molecular mass of hexane (86,17) and assuming a vapour temperature of 15,6 °C. This method provides results within an acceptable degree of accuracy for many fluids having similar properties (see Annex B).

Table 8 — Emergency venting required for fire exposure versus wetted surface area
(expressed in USC units)

Wetted area ^a ft ²	Venting required SCFH		Wetted area ^a ft ²	Venting required 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	—

^a The wetted area of a tank or storage vessel shall be calculated as follows.

- For spheres and spheroids, the wetted area is equal to 55 % of the total surface area or the surface area to a height of 30 ft above grade, whichever is greater.
- For horizontal tanks, the wetted area is equal to 75 % of the total surface area or the surface area to a height of 30 ft above grade, whichever is greater.
- For vertical tanks, the wetted area is equal to the total surface area of the vertical shell to a height of 30 ft above grade. For a vertical tank setting on the ground, the area of the ground plates is not included as wetted area. For a vertical tank supported above grade, it is necessary to include a portion of the area of the bottom 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. It is necessary to use engineering judgement in evaluating the portion of the area exposed to fire.

^b For wetted surfaces larger than 2 800 ft², see Table 6.

NOTE This table, and the constant 1 107 in Equation (14), were derived from Equation (12) and Figure B.1 by using the latent heat of vapourization of hexane, equal to 144 Btu/lb at atmospheric pressure, and the relative molecular mass of hexane (86,17) and assuming a vapour temperature of 60 °F. This method provides results within an acceptable degree of accuracy for many fluids having similar properties (see Annex B).

Table 9 — Environmental factors for non-refrigerated aboveground tanks
(expressed in SI and USC units)

Tank design/ configuration	Insulation conductance		Insulation thickness		<i>F</i> -factor
	W/m ² ·K	Btu/(h·ft ² ·°F)	cm	in	
Bare metal tank	—	—	0	0	1,0
Insulated tank ^a	22,7	4,0	2,5	1	0,3 ^b
	11,4	2,0	5,1	2	0,15 ^b
	5,7	1,0	10,2	4	0,075 ^b
	3,8	0,67	15,2	6	0,05 ^b
	2,8	0,5	20,3	8	0,037 5 ^b
	2,3	0,4	25,4	10	0,03 ^b
	1,9	0,33	30,5	12	0,025 ^b
Concrete tank or fireproofing	—	—	—	—	^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

^a The insulation shall resist dislodgment by fire-fighting equipment, shall be non-combustible and shall not decompose at temperatures up to 537,8 °C (1 000 °F). The user is responsible for determining whether the insulation can 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 9 W/m²·K/cm (4 Btu/h·ft²·°F/in) of thickness. The user is responsible for determining the actual conductance value of the insulation used. The conservative value of 9 W/m²·K/cm (4 Btu/h·ft²·°F/in) 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 887,9 K (1 600 °F) when using a heat input value of 66 200 W/m² (21 000 Btu/h·ft²) in accordance with the conditions assumed in ISO 23251. 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.

NOTE For the purposes of this provision, API 521 is equivalent to ISO 23251.

^c Use the *F*-factor for an equivalent conductance value of insulation.

^d Under ideal conditions, water films covering 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 shall be met.

- A slope of not less than 1 % away from the tank shall be provided for at least 15 m (50 ft) 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.
- The impounding area for the tank, as well as the impounding areas for the other tanks (whether remote or with dykes around the other tanks), shall be located so that when the area is filled to capacity, its liquid level is no closer than 15 m (50 ft) to the tank.

4.3.3.3.4 The total rate of venting determined from Table 7 or Table 8 may be multiplied by an appropriate environmental factor, F , selected from Table 9; credit may be taken for only one environmental factor.

4.3.3.3.5 Credit may be taken for the venting capacity provided by the device installed for normal venting, since the normal thermal effect can be disregarded during a fire. Also, it can be assumed that there is no liquid movement into the tank during fire exposure.

4.3.3.3.6 If normal venting devices have inadequate capacity, additional emergency venting devices of the type described in 4.4.2 shall be provided so that the total venting capacity is at least equivalent to that required by Table 5 or Table 6 or by Equation (11) or Equation (12).

4.3.3.3.7 The total venting capacity shall be based on the pressure indicated in 4.6.2.

4.4 Means of venting

4.4.1 Normal venting

4.4.1.1 General

Normal venting for pressure and vacuum shall be accomplished by a PV valve with or without a flame-arresting device or by an open vent with or without a flame-arresting device.

Protect atmospheric storage tanks against flame transmission from outside the tank if

- the stored liquid has a low flash point, i.e. less than 60 °C (140 °F) or in accordance with the applicable regulations, whichever is higher, or
- the storage temperature can exceed the flash point, or
- the tank can otherwise contain a flammable vapour space.

See 4.5 for design considerations for tanks that have potentially flammable atmospheres. A discussion of the types and operating characteristics of venting devices can be found in Annex C.

Relief devices equipped with a lever and weight and non-reclosing relief devices are not recommended for normal venting.

4.4.1.2 Pressure/vacuum valves

To avoid product loss, PV valves are recommended for use on atmospheric storage tanks.

4.4.1.3 Open vents

If open vents are selected to provide venting capacity for tanks that can contain a flammable vapour space as defined in 4.4.1.1, a flame-arresting device should be used. Open vents without a flame-arresting device may be used for tanks that do not contain a flammable vapour space.

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 4.4.1.3; or heated vents that ensure that the vapour temperature stays above the dew point may be used.

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