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

Industries du pétrole, de la pétrochimie et du gaz naturel — Ventilation des réservoirs de stockage à pression atmosphérique et à basse pression

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Foreword

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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

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 as atmospheric storage tanks or low-pressure storage tanks. 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 4119[1)] (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.

NOTE 2 The adjusted test pressure includes corrections for service conditions of superimposed back-pressure.

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
Nm^3/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 Nm^3/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 vapourizes 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):

$$\dot{V}_{op} = \dot{V}_{pf} \tag{1}$$

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):

$$\dot{V}_{op} = 8{,}02 \cdot \dot{V}_{pf} \tag{2}$$

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).

$$\dot{V}_{ip} = \dot{V}_{pe} \tag{3}$$

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):

$$\dot{V}_{ip} = 8{,}02 \cdot \dot{V}_{pe} \tag{4}$$

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):

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