TECHNICAL REPORT

ISO/TR 16732-3

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Fire safety engineering — Fire risk assessment —

Part 3: Example of an industrial property

Ingénierie de la sécurité incendie — Évaluation du risque d'incendie —

Partie 3: Exemple d'un complexe industriel

Reference number
ISO/TR 16732-3:2013(E)

Contents

Page

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.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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/TR 16732-3 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

ISO 16732 consists of the following parts, under the general title *Fire safety engineering — Fire risk assessment*:

— *Part 1: General*

— *Part 2: Example of an office building* [Technical Report]

— *Part 3: Example of an industrial property* [Technical Report]

Introduction

This part of ISO/TR 16732 presents an example of the application of ISO 16732-1, prepared in the format of ISO 16732-1. It includes only those sections of ISO 16732-1 that describe steps in the fire risk assessment procedure. It preserves the numbering of sections in ISO 16732-1 and so omits numbered sections for which there is no text or information for this example.

This example is intended to illustrate the implementation of the steps of fire risk assessment, as defined in ISO 16732-1. Only steps that are considered as relevant in this example are well detailed in this annex.

Risk assessment is preceded by two steps – establishment of the context, including the fire safety objectives to be met, the subjects of the fire risk assessment to be performed and related facts or assumptions; and identification of the various hazards to be assessed. (A "hazard" is something with the potential to cause harm.)

Assumptions made in the present document have been chosen to illustrate, in a simple manner, how the fire risk assessment methodology proposed in ISO 16732-1 can be applied to an industrial facility. These assumptions must be regarded as examples only, and not be applied to other cases without verifying they are representative of the considered cases.

Fire safety engineering — Fire risk assessment —

Part 3: Example of an industrial property

1 Scope

This part of ISO/TR 16732 deals with a fictitious propane storage facility dedicated to the reception of propane transported by tank wagons, the storage of propane in a pressurized vessel and the bulk shipment of propane by tank trucks. The fire risk assessment developed in this part of ISO/TR 16732 is not intended to be exhaustive, but is given as an example to illustrate the application of ISO 16732-1 to an industrial facility.

The scope of this part of ISO/TR 16732 is further limited to design-phase strategies, including changes to the layout of the facility and selection of relevant fire safety strategies (implementation of risk reduction measures). Not included are strategies that operate during the operation phase, including process modifications.

This part of ISO/TR 16732 illustrates the value of fire risk assessment because multiple scenarios are analysed, and several design options are available, which may perform well or not depending on the considered scenario. Risk estimation is needed to determine the result of these different combinations, and overall measures of performance that can be compared between design options. If there were only one scenario of interest, or if the options all tended to perform the same way on all the scenarios, then a simpler type of engineering analysis would suffice.

2 Normative references

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

ISO 16732-1:2012, *Fire safety engineering — Fire risk assessment — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16732-1 and the following apply.

3.1
BLEVE
Boiling Liquid Expanding Vapour Explosion
phenomenon which occurs when a vessel containing a pressurized liquid substantially above its (atmospheric) boiling point is ruptured, releasing the contents explosively

Note 1 to entry: Taken from Reference [1].

Note 2 to entry: A more detailed description of phenomena involved during a BLEVE is given in 5.3.

3.2
flashing vaporization
rapid transformation into vapor that is released when a saturated liquid stream undergoes a reduction in pressure

3.3
LPG
Liquefied Petroleum Gas
flammable mixture of propane and butane mainly used as a fuel in heating appliances and vehicles

3.4
LOC
Loss of containment
release of product, such as a leak of product on a pipe, an instantaneous release of product due to a vessel rupture, etc.

3.5
end-cap
curved end part of a pressurized cylindrical vessel shell

3.6
ERS
Emergency Release System
special mechanical device designed to break when a locked loading arm is accidentally displaced, and which isolates the leak by the automatic closing of two valves on each side

4 Applicability of fire risk assessment

ISO 16732-1 lists some examples of circumstances where it is important to give due consideration to scenarios with low frequency but high consequence and hence, fire risk assessment is useful.

The example in this part of ISO/TR 16732 was conducted to support an analysis of different designs for a propane storage facility, where the main risk is a BLEVE of the pressurized storage vessel (which is a spherical storage tank). A BLEVE particularly fits well with the definition of a high consequences and low frequency event where fire risk assessment is useful.

5 Overview of fire risk management

5.1 General

This clause specifies the different design options to be assessed.

5.2 Overall description of the industrial facility

The facility chosen for this example is a propane storage facility, due to its simple process and generic character. The propane storage facility activities include

— reception of propane transported by tank wagons: a compressor sucks up the pressurized storage vessel gaseous atmosphere and compresses it into a tank wagon vapour space to push the liquid into the storage vessel,

— storage in a pressurized vessel,

— bulk shipment of propane by tank trucks: a pump sucks up the pressurized storage vessel liquid and injects it in a tank truck, for delivery to privates or companies.

The following main types of equipment are used: a pressurized storage vessel (with a diameter of 12.5 m for a volume of about 1 000 m^3), tank wagons and tank trucks, pumps, compressors and pipes.

This example focuses on the influence of the truck loading area layout and risk reduction measures upon the pressurized storage vessel BLEVE frequency.

5.3 Phenomenology of a BLEVE

According to the Center for Chemical Process Safety, a BLEVE is defined as “a sudden loss of containment of a pressure-liquefied gas existing above its normal atmospheric boiling point at the moment of its failure, which results in rapidly expanding vapor and flashing liquid. The release of energy from these processes (expanding vapor and flashing liquid) creates a pressure wave”[2].

The overall phenomena involved in a BLEVE (see Figures 1 to 3) have been extensively described in Reference [3].

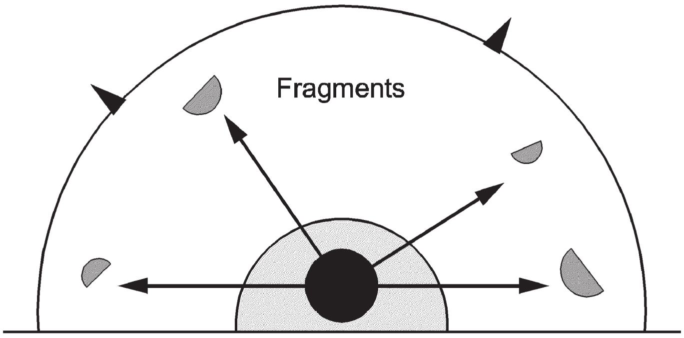

Figure 1 — Vessel failure (dark grey), fireball (light grey), ejection of fragments (black semicircles) and pressure wave (outer circular line)[3]

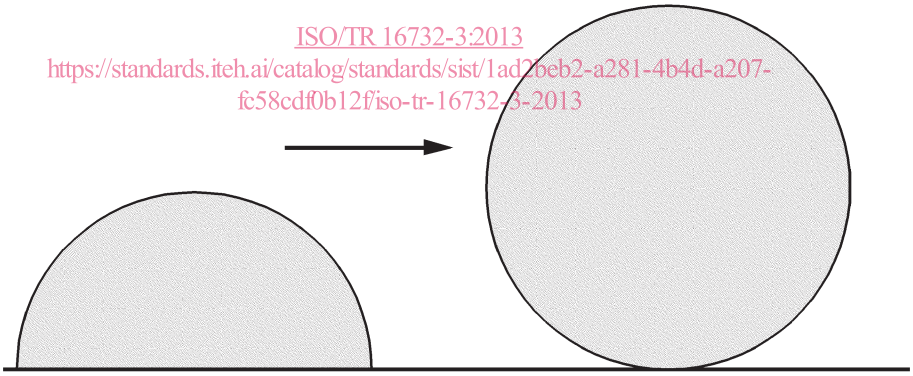

Figure 2 — Fireball lift-off[3]

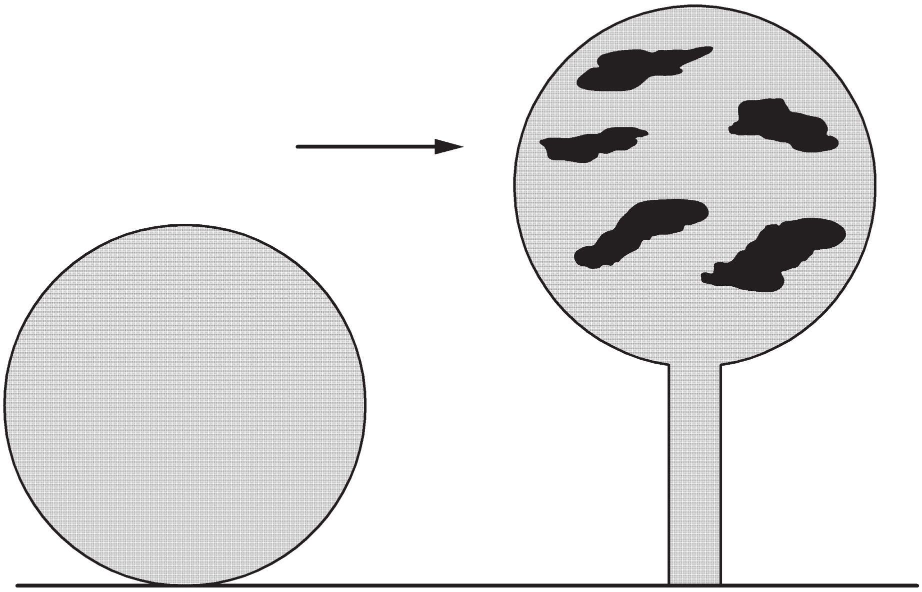

Figure 3 — Fireball apogee[3]

Numerous BLEVEs of stationary storage tanks, tank wagons and tank trucks occurred during the last decades, leading to large disasters and loss of hundreds of lives. Shalif[4] has listed 74 BLEVEs in the period 1926-1986, resulting in 1,427 fatalities and 635 injuries. The catastrophic failure of a pressurized vessel is a sine qua non condition for a BLEVE to occur: it can be provoked by either mechanical or thermal threats with a sufficiently high energy. Table 1 illustrates the different causes leading to a BLEVE.

Table 1 — Past accidents involving BLEVEs and corresponding causes[5]

Causes	BLEVEs
Fire	25
Impact	19
Vessel overfilling	11
Vessel over pressurization	3
Fatigue	2
Explosion	2
Corrosion	1
Earthquake	-
Flood	-
Lightning	-
Others (runaway, overheating, etc.)	25

This survey shows that fire and impact events are the most common causes leading to a BLEVE. Therefore, if the scope of the example is limited to effects of an adjacent fire, BLEVE or explosion, the scope will include roughly half of the circumstances leading to past BLEVE accidents.

According to Roberts et al.[6], "if a pressurised vessel is attacked by fire, its temperature rises and this reduces the strength of the vessel. This, combined with the pressure within the vessel, may lead to failure of the vessel with catastrophic consequences".

The global heat transfer mechanisms involved during thermal threat on a pressurized vessel are described in Figure 4. When a fire engulfs a vessel, the total incident flux (due to radiation and convection) is absorbed by the vessel, the liquid and the gas. It causes the evaporation of the liquid phase, and hence both a pressure increase as well as the decrease of the liquid level. Thus, absorption capacity is decreasing with time. Safety valves are commonly used to delay the occurrence of a BLEVE by discharging a part of the vessel content. The rapid rise of pressure inside the equipment due to boiling combined with the drop of material strength due to external heating of the envelope will lead to the catastrophic rupture of the vessel.

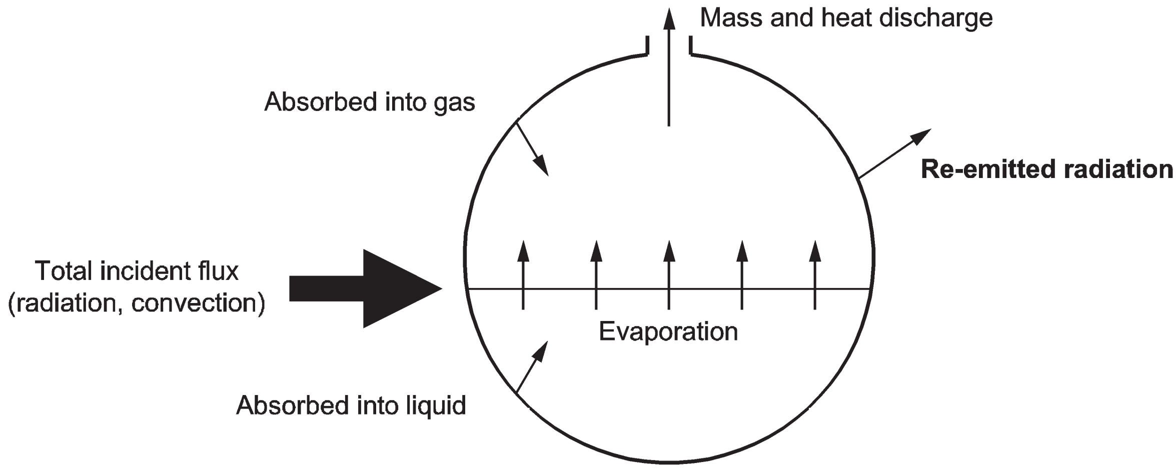

Figure 4 — Heat transfer mechanisms involved during thermal threat on a pressurized vessel[6]

5.4 Risk reduction measures

Table 2 lists risk reduction measures that can be used to prevent or delay a BLEVE, based on a review provided by Fulleringer.[7]

Table 2 — Examples of common risk reduction measures against BLEVEs

Risk reduction measures	Function
Layout (distance)	Increases separation distances to decrease accidental loads on the vessel
Layout (orientation)	Decreases the probability that a thermal/mechanical event threatens the vessel
Isolation of leak (emergency release system)	Isolates loading arm in case of tank truck displacement
Isolation of leak (automatic pump shutdown)	Shutdowns feeding pumps in case of pressure drop (i.e. a leak)
Containment/evacuation of the product (bund, slope)	Prevents liquid accumulation under the vessel/Increases separation distances to reduce thermal loads on the vessel
Safety valve	Discharges product outside the vessel and hence reduces the stress induced by increase of internal pressure
Passive fire protection (protective coating, thermal shielding)	Reduces heat transfer rate to vessel wall
Active fire protection (water deluge, water curtain)	Protects the vessel as it absorbs part of the heat produced by a fire/a jet fire[a]
Concrete wall around the vessel or mounding	Protects the vessel against thermal and mechanical loads

[a] Several tests and studies[8] have shown that a typical water deluge system on a LPG storage vessel cannot maintain a water film over the whole vessel surface if a jet fire impinges on the vessel. API 2510A[9] indicates that "...effective cooling of a vessel shell that is exposed to jet flames is difficult to achieve. The velocity of the jet stream may deflect a water spray pattern or fog pattern from a fire hose." So the current example assumes water deluge is only efficient for radiant jet fires, not impinging jet fires.

5.5 Presentation of design options

In the present example, several alternative designs are considered, differing in

— the separation distances between the pressurized storage vessel and the truck loading area,