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HAZARDOUS AREA CLASSIFICATION FOR IN FLAMMABLE LIQUID STORAGE TANKS

Levente Tugyi
PhD student, University of Miskolc, Institute of Energy engineering and Chemical Machinery, Department of Chemical Machinery
3515 Miskolc-Egyetemváros, e-mail: levente.tugyi@uni-miskolc.hu

Zoltán Siménfalvi
professor, University of Miskolc, Institute of Energy engineering and Chemical Machinery, Department of Chemical Machinery
3515 Miskolc-Egyetemváros, e-mail: zoltan.simenfalvi@uni-miskolc.hu

Gábor L. Szepesi
associate professor, University of Miskolc, Institute of Energy engineering and Chemical Machinery, Department of Chemical Machinery
3515 Miskolc-Egyetemváros, e-mail: gabor.szepesi@uni-miskolc.hu

Zoltán Kerekes
postgraduate student, University of Miskolc, Institute of Energy engineering and Chemical Machinery, Department of Chemical Machinery
3515 Miskolc-Egyetemváros, e-mail: kerekes.zoltan@rbesz.hu

Abstract

Many chemical plants use flammable liquids as raw materials or produce them. In both cases, the flammable medium is most likely need to be stored. One option is to use storage tanks. Currently, in Hungary, the fire and explosion protection requirements for upright cylindrical steeltanks are laid down in MSZ 9910-2:1993 standard and for horizontal cylindrical steeltanks in MSZ 9909-3:1998, supplemented by the MSZ 15633 series of standards. These standards have not changed in the last 30 years and have not followed the innovations in the field, unlike NFPA 497:2021; NFPA 59A:2023; API RP 505:2018; Area Classification Code for Installations Handling Flammable Fluids Part 15:2005 (IP 15); Health and Safety Executive (HSE) HSG 176 Storage of flammable liquid in tanks, 2nd edition:2015 and EIC 60079-10-1:2008 standard. The aim of this study is to compare the conclusions of these standards and to propose a new standard that could be applied in Hungary.

Keywords: *hazardous area classification, explosive atmosphere, ATEX, storage tanks*

1. Introduction

A storage tank is probably one of the simplest pieces of chemical equipment. It has a properly sized cylindrical body with a breather valve to prevent the vapours of the stored liquid from collapsing under vacuum and bursting under overpressure (Griffin, 2000). Tanks can be insulated to avoid these heat transfer problems, but uninsulated tanks are also used for cost reduction or technological. Finally, they can be installed in a containment or protection wall/ring design to contain any release of the stored medium. Storage tanks may be subject to i.g. corrosion, stress corrosion, which requires attention (Spisák & Szávai, 2019; Zagórski et al., 2004).

As relatively simple a piece of equipment as it is to talk about, different nations have, in the past and even today, treated their explosion protection and the identification of explosion hazard areas differently. Cox et al. in their book summarised the extent of explosive atmospheres in some countries in the 1990s for peripheral equipment, pumps or even tanks (Cox et al., 1990). Figure 1 is an informative example in the book of how explosive areas of storage tanks have been defined in the United States of America, Australia or even Sweden.

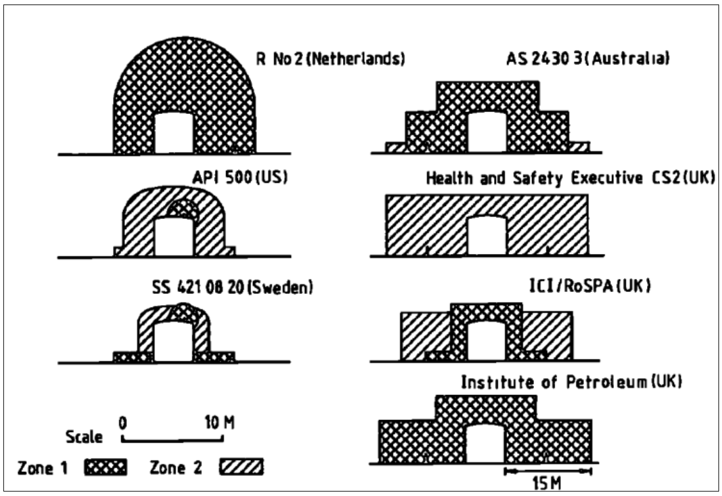

Figure 1. *Hazardous areas classification for storage tanks in different countries around 1990s* (Cox et al., 1990)

It is interesting that Zone 0 does not mention explosive atmosphere in relation to the interior of the containers, which is almost self-evident on the basis of today's approaches.

The reason why there were such large differences between the zones shown in *Figure 1*, is more than likely due to national economic interests and the conservative treatment of the presence of explosive regions.

It is also an interesting fact that the temperature in the United Kingdom was certainly lower at the time, and the number of sunny hours was also much lower than in Australia. Even so, zones of almost the same size were classified for the storage tanks as of both place.

More recent, but shorter summary of explosive atmospheres in storage tanks can be found in Lees' Loss Prevention in the Process Industries – 4th Edition (Lees', 2012). The literature mentions applicable standards in the US, such as API RP 500:2002; as well as other Anglo-Saxon standards, which are the Area Classification Code for Installations Handling Flammable Fluids Part 15:2005 (IP 15), the 2015 HS(G) 176) and British Standard BS EN 60079-10-1:2009. The latter is a harmonised, withdrawn standard that gave guidance on explosive atmospheres in tanks, but this has been cut from later editions.

2. Hazardous area classification of potentially explosive atmospheres different countries for storage tanks

In Hungary, for the storage of combustible materials, it is necessary to classify the stored media in accordance with the MSZ 9790:1985 standard (Hungarian Strandards Institute, 1985). Four types of fire-hazard classes have been defined, for which the corresponding criteria are summarised in *Table 1*.

Table 1

Fire hazard classification according to MSZ 9790:1985

Fire-hazard class I	**Fire-hazard class II**	**Fire-hazard class III**	**Fire-hazard class IV**
Flammable liquids having open-cup flash point below 21 °C.	Flammable liquids having a flash point of 21 °C or more in the close-cup but not more than 55 °C in the open-cup.	Flammable liquids having an open-cup flash point between 55 °C and 150 °C.	Flammable liquids having an open-cup flash point higher than 150 °C.
$T_{ccfp} < 21$ °C	$T_{ocfp} < 55$ °C	$T_{ocfp} \leq 150$ °C	$T_{ocfp} > 150$ °C
–	$T_{ccfp} > 21$ °C	$T_{ocfp} > 55$ °C	–
–	–	Gasoil with an open-cup flash point of 50 °C or fuel oils or petroleum used for lighting.	–
*Flammable liquids having an operating temperature above the open-cup flash point.	*Flammable liquids having an operating temperature below open-cup flash point but greater than the open-cup flash point minus 20 °C.	*Flammable liquids having an operating temperature below open-cup flash point with at least 20 °C but less than or equal to 50 °C.	*The operating temperature remains at least 50 °C below the open-cup flash point.
*$T_o > T_{ocfp}$	*$T_{ocfp} - 20$ °C $< T_o < T_{ocfp}$	*$T_{ocfp} - 50$ °C $< T_o < T_{ocfp} - 20$ °C	*$T_o < T_{ocfp} - 50$ °C

The MSZ 9790:1985 standard does not foresee the formation of explosive atmospheres, for this purpose in Hungary the standard MSZ 15633-1:1992 (Hungarian Strandards Institute, 1992) is applicable. According to the standard MSZ 15633-1:1992, the formation of an explosive medium is expected for flammable liquids of fire-hazard class I and II. Not for III and IV under normal operating conditions, but the designer or operator may deviate at any time in the direction of safety.

NFPA 497:2021 standard (National Fire Protection Association, 2021) defines several classes of flammable liquids, summarized in *Table 2*, depending on the flash point and/or boiling point. The classes in the table are all applicable to the storage and process use of flammable liquids.

Table 2

Flammable and combustible liquids according to NFPA 497:2021

Flammable liquids			**Combustible liquids**		
Class IA	Class IB	Class IC	Class II	Class IIIA	Class IIIB
$T_{ccfp} < 22{,}8$ °C; $T_{boil} < 38{,}8$ °C	$T_{ccfp} < 22{,}8$ °C; $T_{boil} \geq 38{,}8$ °C	$22{,}8$ °C $\leq T_{ccfp} <$ $37{,}8$ °C	$37{,}8$ °C $\leq T_{ccfp} <$ 60 °C	60 °C $\leq T_{ccfp} <$ 93 °C	93 °C $\leq T_{ccfp}$

The standard requires vapours of any Class I liquid to be capable of forming an explosive atmosphere at ambient temperature. Vapours of Class II liquids are not expected to form an explosive atmosphere at ambient temperatures unless they are handled or stored above their flash point. It also states that any vapours cannot spread far because they cool and condense in contact with ambient air. Therefore, the only way to handle these materials for explosion protection purposes is to heat them above their flash point. Class IIIA liquids do not form flammable mixtures with air at ambient temperature unless heated above their flash point. Class IIIB liquids rarely evolve sufficient vapour to form flammable mixtures, even when heated. Therefore, Class III substances do not present an explosion hazard at ambient temperatures.

The Area Classification Code for Installations Handling Flammable Fluids Part 15:2005 (IP 15) (Energy Institute, 2005) is also presented in the study, regardless of whether it is applicable only to petroleum facilities. This is also a specific approach to classify the substances from which explosive atmospheres are generated. The classification of flammable substances is given in Table 3 (flash point means close-cup flash point). In Annex A of the document, specific examples of what might be relevant explosive substances in petroleum facilities are listed.

Table 3

The handling of petroleum materials classes according to IP 15:2005

Class 0	Liquefied petroleum gases (LPG).
Class I	Liquids that have flash point below 21 °C.
Class II(1)	Liquids that have flash points from 21 °C up to and including 55 °C, handled below flash point.
Class II(2)	Liquids that have flash points from 21 °C up to and including 55 °C, handled at or above flash point.
Class III(1)	Liquids that have flash points above 55 °C up to and including 100 °C, handled below flash point.
Class III(2)	Liquids that have flash points above 55 °C up to and including 100 °C, handled at or above flash point.
Unclassified	Liquids that have flash points above 100 °C.

According to IP 15:2015, if storage tanks are used for the storage of liquids of Class II(2) and III(2), an explosive atmosphere is likely to occur. Liquids stored in Class II(1) or III(1) conditions do not normally require an external hazardous area classification as described in IP 15:2005.

The HSG 176 Storage of flammable liquids in tanks, 2nd edition (2015) (Health and Safety Executice, 2015) is a more recent edition than the one Lee's refers. It does not explicitly define fire-hazard classes or other classes, but merely describes the limits of applicability. For clarity and ease of understanding, a summary of these applicability limits is given in *Table 4*.

Table 4

HSG 176 Storage of flammable liquid in tanks, 2nd edition, 2015

Applicable	Not applicable
Flashpoint of 55 °C or below. This includes all highly flammable liquids and all petroleum spirit and petroleum mixtures. It includes all liquids that are classified as flammable, highly flammable or extremely flammable for supply according to CHIP.	Liquids with flash points between 21 °C and 55 °C, but which do not support combustion/explosion when tested at 55 °C.
For liquids with a flash point above 55 °C which are stored at temperatures above their flash point.	Flammable liquids which present special hazards requiring specific storage conditions, such as ethylene oxide, peroxides, and other liquids which entail a risk of rapid decomposition, polymerisation or spontaneous combustion.

Applicable	Not applicable
For certain measures, for liquids which 32 °C–55 °C and are stored at ambient temperature are not subject to mandatory measures. (Explosion protection is always required for substances with a flash point of 32 °C.)	Liquefied petroleum gas and other substances which are gases at ambient temperature and pressure flammable liquids stored under pressure (flammable liquids stored under pressure also) but are stored as liquids under pressure orrefrigeration.

Some measures may include, for example liquids with flash points between 32 °C and 55 °C do not normally form flammable atmospheres unless they are stored at a temperature above their flash point.

2.1. Explosive atmospheres for cylindrical steeltank – based on MSZ 9910-2:1993 standard

According to the MSZ 9910-2:1993 standard (Hungarian Strandards Institute, 1993), a value *R (radius)* must be determined, which is the result of the close-cup flash point of the combustible liquid and the flow rate of the given tank filling pump, as shown in *Table 5*. The correspondence to the flash point is understandable, but the filling pump flow rate is not consistent. When compared to the fact that during filling the vapour pressure inside the tank can increase with the increase of the liquid level, it is still partially acceptable, which depends on the volume of the tank. However, this condition is only present during filling, and apart from this condition, it is not reasonable to take the volume of the filling to the basis, but rather the lower explosive limit of the combustible medium would be the relevant variable.

Table 5

Close-cup flash point and maximum volumetric flow rate of the filling pump MSZ 9910-2:1993

Maximum flow rate of the particular tank filling pump [m^3/h]	Close-cup flash point [°C]	R [m]
≤ 60	≤ 0	2
	0–21	1
	21–35	0.5
	35–55	0.5
60–180	≤ 0	3
	0–21	1.5
	21–35	1
	35–55	0.5
180–450	≤ 0	5
	0–21	2.5
	21–35	1.5
	35–55	1
450–900	≤ 0	7
	0–21	3.5
	21–35	2
	35–55	1
900–1350	≤ 0	8.5
	0–21	4.5
	21–35	2.5
	35–55	1.5

Maximum flow rate of the particular tank filling pump [m³/h]	**Close-cup flash point [°C]**	**R [m]**
1350–1800	≤ 0	10
	0–21	5
	21–35	2.5
	35–55	1.5
1800–2400	≤ 0	12
	0–21	6
	21–35	3
	35–55	2
2400–3000	≤ 0	14
	0–21	7
	21–35	3.5
	35–55	2

The figures for the *R* values given in the standard are mostly the result of scientific work, although a mathematical rationale can also be partially deduced from them.

The use of *R* value applied to the extent of explosive atmospheres around breathers and outside the containment, according to the standard, if it contains a flammable liquid where an explosive atmosphere is present. In case of breathers, explosive atmospheres shall always be established from 3.0 m from the opening to the top of the storage tank or to ground level. This explosive atmosphere shall be Zone 1 with radius *R* and Zone 2 with radius *2R* beyond this radius.

If Zone 1 overhangs the edge of the tank top, Zone 1 is considered to be an explosive atmosphere for a radius of up to 1.5 m around the shroud. Otherwise (not overhanging), it is defined as Zone 2 explosive atmosphere with an extent of 1.0 m.

It should be noted that there is an inaccuracy in the standard which states that if Zone 1 extends beyond the top of the tank, the damage to the inner top edge of the rescuers up to 0.8 m above the height of Zone 1 is considered a hazardous area. If there isn't Zone 1 explosive hazardous area is hanging over the breathing Zone 1, it is not required to establish an explosive hazardous area in the containment. It is already a Zone 2 outside the containment up to 0.8 meters above the ground level and *3R* wide.

In addition, it states that if the breathing Zone 2 explosive hazardous area extends beyond the top of the tank, it is considered to be a Zone 2 explosive hazardous area beyond the cylindrical space at radius *2R*, which may extend up to a maximum height of 3.0 m above the top of the tank and up to a maximum distance of 5.0 m horizontally, if this section is not Zone 1. Thus, this definition can override the 1.0 meter Zone 2 extent around the tank slab described previously.

The inside of the tanks are classified as Zone-0 hazardous area according to MSZ 15633-1:1992, but if the inside of the tank is inerted with nitrogen, MSZ 15633-1:1992 and MSZ 9910-2:1993 do not specify hazardous areas. However, according to section 2.6.2.4 of the said MSZ 15633-1:1992, it requires the use of electrical and non-electrical products meeting the technical requirements of the Zone 2 hazardous area, even if inert. For shafts within the damage containment, MSZ 15633-1 also can be applied, which states that their internal space is Zone 1. From 2.0 metres horizontally from the edge to 0.8 metres high, Zone 2 is considered an explosive atmosphere, which in effect falls within the Zone 1 area of the damage containment.

A generalised explosive atmosphere for a tank is shown in *Figure 2*, where the explosive atmosphere of the breather doesn't to the beyond the tank top. However, explosive atmospheres have been identified inside and outside the containment.

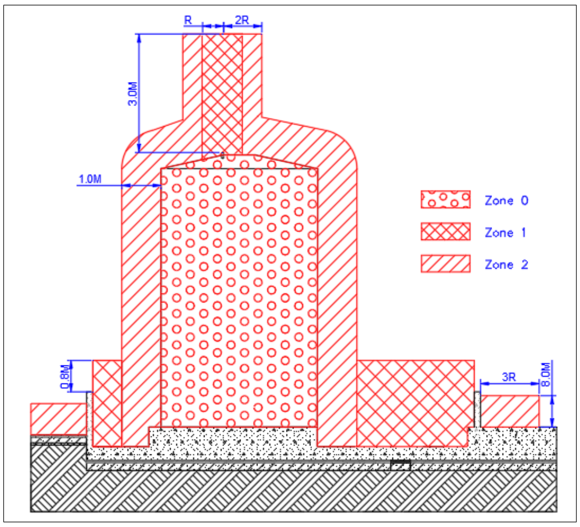

Figure 2. *One of explosive atmospheres of cylindrical steeltank according to MSZ 9910-2:1993*

In case of tanks with a containment ring, no textual description is given in the standard, but only the diagrams and logical professional reasoning can be used to conclude that the findings for the damage limiter, as shown in *Figure 3*.

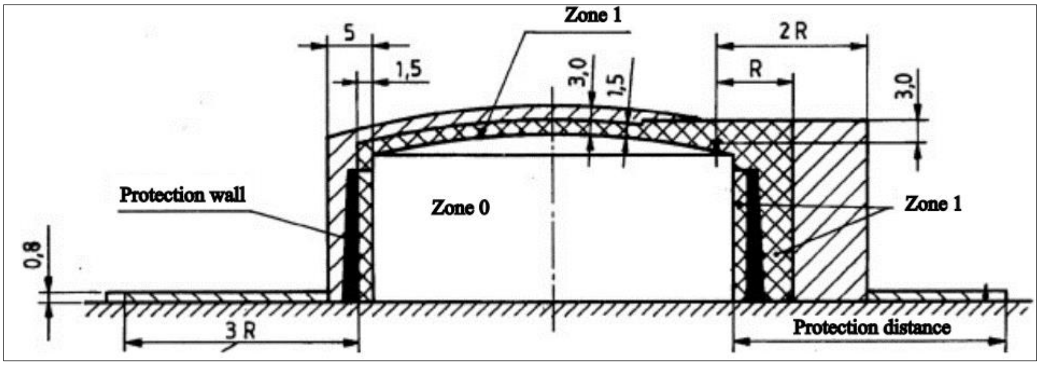

Figure 3. *One of hazardous areas for steeltank with containment rings according to MSZ 9910-2:1993*

It should be noted that the inner space of the containment ring is not defined, but only the explosive area around the enclosure is defined and illustrated. They can basically be seen as damage savers.

Overall, the standard does not deal well with the concepts of primary and secondary emission sources. It therefore defines unreasonably large and restrictive zones for the container, which is also true for the interior and exterior of the containment, where flammable liquid is unlikely to occur under normal operating conditions. If it does, it is more likely to be a catastrophic condition, against which it is almost impossible to protect adequately.

2.2. Explosive atmospheres for horizontal cylindrical steeltanks – based on MSZ 9909-3:1998 standard

Although MSZ 9909-3:1998 (Hungarian Strandards Institute, 1998) Hungarian standard has been withdrawn, the MSZ 15633 series of standards refers to it, making it applicable even for horizontal cylindrical tanks. For this standard, it is also useful to determine the *R* value, which can be determined from close-cup flash point of the flammable liquid and the flow rate of the particular tank filling pump, as shown in Table 6.

Table 6

Close-cup flash point and maximum volumetric flow rate of the filling pump MSZ 9909-3:1998

Maximum flow rate of the particular tank filling pump [m^3/h]	Close-cup flash point [°C]	R [m]
≤ 60	≤ 0	2
	0–21	1
	21–35	0.5
	35–55	0.5
60–180	≤ 0	3
	0–21	1.5
	21–35	1
	35–55	0.5

The standard notes here that if the filling flow rate of the pump exceeds 180 m^3/h, then the standard MSZ 9910-2:1993 should be used as an additional standard.

The definitions in the standard are relatively short but complex. It defines the interior of the tank and its piping as Zone 0.

Around the breathers, it makes a similar statement as the Hungarian standard described above. Starting 3.0 m above the opening of the breathers, which extends to the contour of the tank and to ground level, Zone 1 defines an explosive atmosphere. In the lateral direction, its extent is *R*, thus forming a cylinder. Where the container surface is in contact with this Zone 1, the space around it is also Zone 1 up to a distance *R*, but not more than 1.5 metres.

The inner space of the rescuers and up to a height of 0.8 metres above them is a Zone 1 explosion hazard area. A possible example is illustrated in *Figure 4*.

However, if the breather is diverted from the rescuer or the breather zone does into to the rescuer at all, then the tank surroundings and rescuer are not Zone 1.

It also defines a Zone 2 area extending beyond the Zone 1 explosive area of the breathing zone, within a *2R* radius, 3.0 m above the exit opening the container office and/or ground level. If the mentioned Zone 2 is in contact with the tank surface, the tank surroundings are also Zone 2 *2R* up to a distance of 3.0 m (maximum) from the top edge of the tank. The tank's surroundings may also be Zone 2 up to a height of 0.8 m and a distance of *3R*, but not more than 5.0 m, which is also established and extends beyond the area of the Zone 1 damage zone *(Figure 3)*.

If the tank's breathing apparatus is routed away from the containment and the Zone 1 hazardous area is not in contact with the tank surface, then the 1.0 m area around the tank is Zone 2.

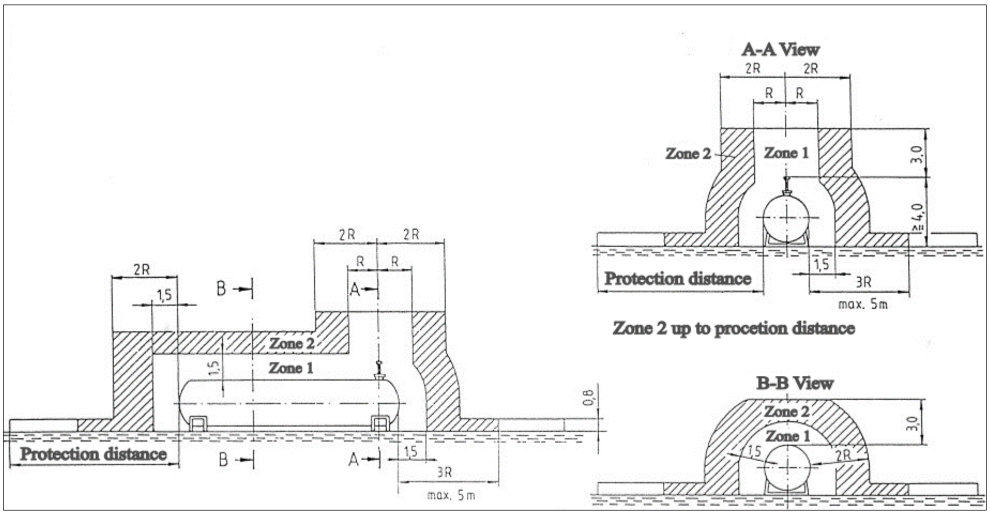

Figure 4. *One of hazardous areas for horizontal cylindrical steeltank according to MSZ 9909-3:1998*

The standard also specifies explosive atmospheres for underground, horizontal, cylindrical tanks. In fact, the text only mentions the breather as a potential source of release, but the example diagram in the standard, shown in *Figure 5*, also zones the dome stack.

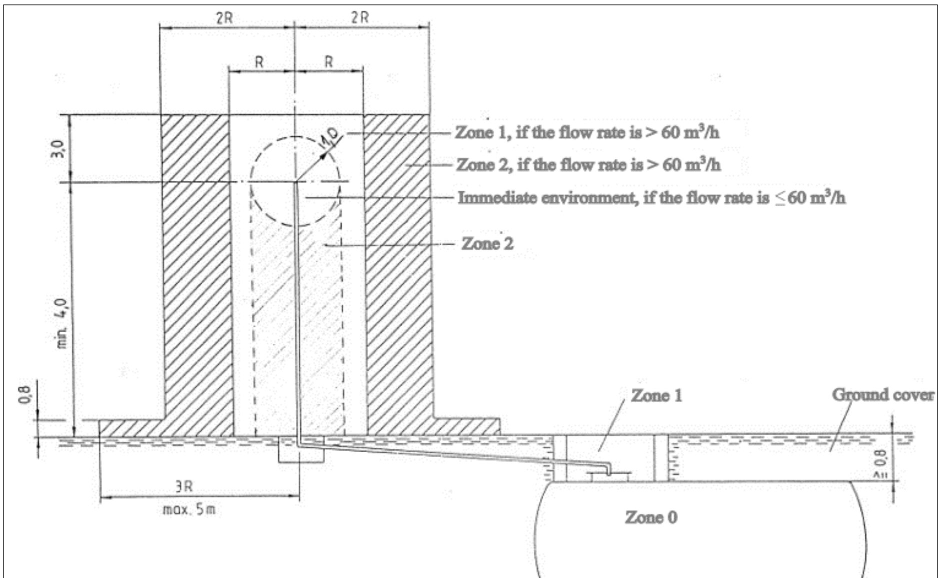

Figure 5. *One of hazardous areas for underground horizontal cylindrical steeltank according to MSZ 9909-3:1998*

The interior of the dome is a Zone 1 hazardous area, which is generally referred to in the MSZ 15633 series of standards, but the specific point, and only one sentence of it, has not been transposed into the standard. Regardless, the approach is correct, although the 15633-1 series of standards defines the Zone 2 explosive atmosphere for the external space of dome shafts as extending to a radius of 0.5 m, which is missing from the diagram in the standard MSZ 9909-3:1998.

If the underground tank is covered by at least 0.8 m of ground cover (frost limit accepted in Hungary), the flow rate is below 60 m^3/h and the breather is discharged to a height of at least 4.0 m, the explosion hazard area for the exit opening can be reduced. Only the sphere of 1.0 m radius around the exit point Zone 1, with the same radius below ground level Zone 2 is considered a hazardous area. The 4.0 m height criterion is acceptable, the dilution rate is effective there assuming a free, unobstructed airflow *(Figure 5)*.

In Sweden, at the same time as described chapter of the Hungarian standard was published, the Swedish petrol station standard SÄIFS 1997:8 (Swedish Institute for Standards, 1997.) contains explosion protection requirements for underground tanks. The Swedish approach contains some similarities with the Hungarian standard, its shown in *Figure 6* and it presents more technical practical sound findings. For example, if there is already a breather outlet 6.0 m above the ground, the zone does to ground level or the approach to the dome shaft is clear.

All in all, this Hungarian standard also takes way more conservative approach to the extent of explosive hazard areas, which may have had a domestic economic interest or simply a higher explosive hazard area. The latter may be simpler and safer, but a revision of the latter in relation to the up-to-date technical material presented in the current and following chapters may be warranted.

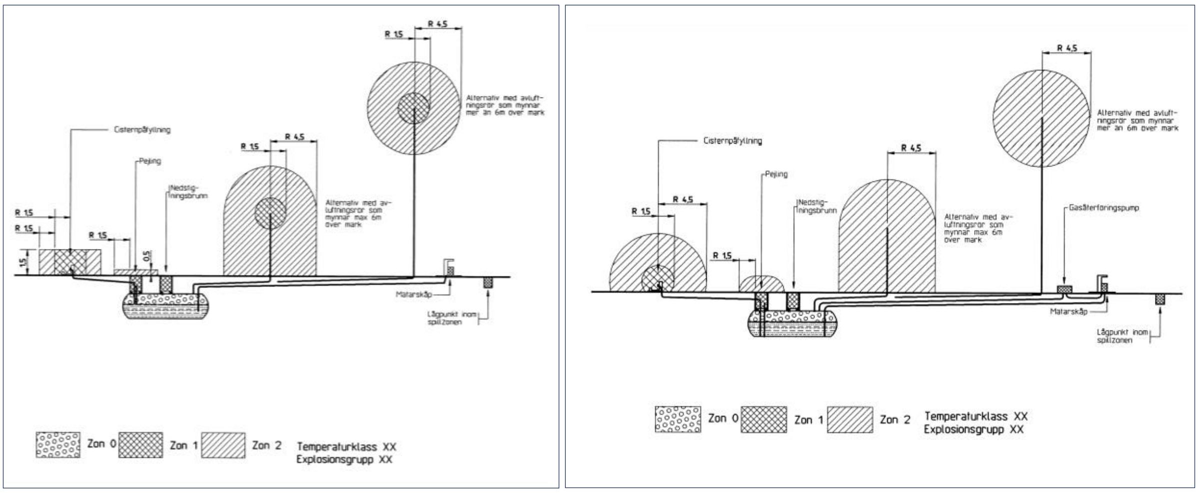

Figure 6. *Explosive areas of petrol stations without vapour recovery (left), explosive areas of petrol stations vapour recovery (right) in SÄIFS 1997:8*

2.3. Explosive atmospheres for storage tanks – based on NFPA 497:2021 standard

In the case of the NFPA 497:2021 US standard, the first step is to qualify the device as to which category it belongs to. The categories are size, pressure and flow rate, with “small/low”, “moderate” or “large/high” volume values defined in Table 7, summarised in Imperial and metric units.

Table 7

Equipment classification according to NFPA 497:2021

Process Equipment	Units		Small (Low)		Moderate		Large (High)	
Size	gal	m^3	<5000	<18.92	5000–25 000	18.92–94.63	>25 000	>94.63
Pressure	psi	kPa	<100	<689.47	100–500	689.47–3447.37	>500	>3447.37
Flow rate	gpm	m^3/h	<100	<22.71	100–500	22.71–113.56	>500	>113.56

The standard makes virtually no distinction between the categories. For a possible equipment type that is an emission source, it uses all three categories as a basis for assessing whether it fits in, and makes a recommendation as to whether the standard says it fits into a “small/low”, “moderate” or “large/high” application. In many cases, more than one ration is indicated (matrix), in which case, if it falls into a higher category. It should be used as a basis, as the zones in the example figures are defined accordingly. Surprisingly, no specific calculation is added, but the zones must be defined according to the examples shown in the diagrams. The ranges shown in the figures are for combustible materials with a low lower explosive limit (LEL) and for combustible materials with a relatively higher LEL, a reduction in explosion atmospheres range may be considered. However, it is not clear what the lower bound of this lower explosion limit is. There is no benchmark against which the zone can be reduced. It would have been worthwhile to have named specific ranges, to which simply multiplying by the given maximum extent of the zone by assigning factors gives a reduced value.

For tanks, the classification and the extent of the explosion hazard zones are shown in *Figure 7*.

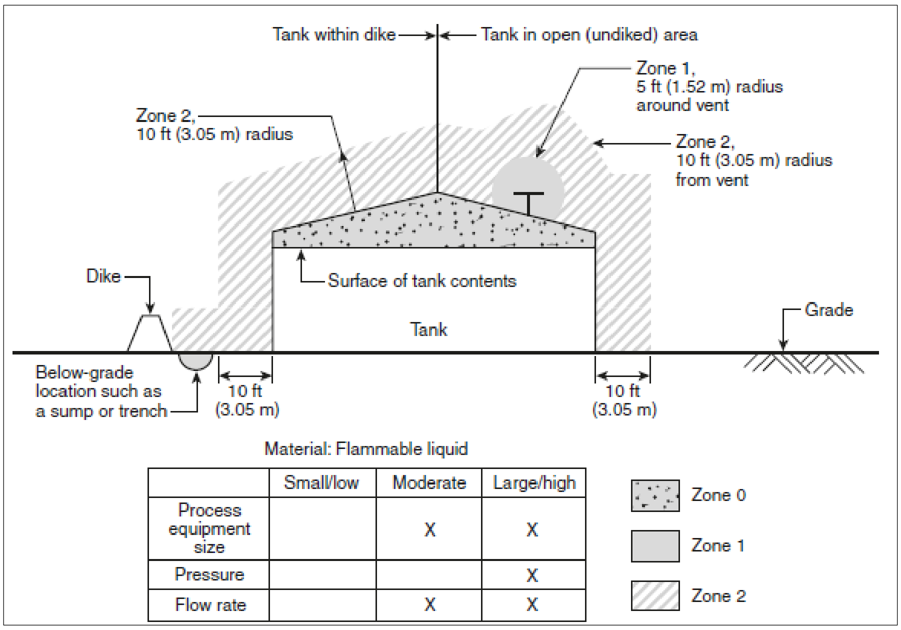

Figure 7. *Storage tank explosive atmospheres according to NFPA 497:2021*

It offers all three possible options for classifying the tank, with the size classification being the most relevant. Pressures higher than 689.47 kPa are unthinkable for atmospheric liquid storage tanks, but can occur for gases or liquefied gases. The precise approach to these pressure values, whether absolute or gauge pressure is meant, is clearly not given in NFPA 497:2021, but is assumed to be in gauge pressure. The flow rate is rarely used for circulation, it is a different type of equipment, and it is not the point of the standard that is relevant here. Furthermore, there is no difference between a stationary and horizontal cylindrical tank, the standard simply mentiones storage tank.

In the case of a storage tank, it is often the case that the flammable liquid is stored under a nitrogen cushion. However, the standard does not inform how inertisation reduces the formation of explosive atmospheres in the interior of the containers or equipment.

In contrast, the Venting Atmospheric and Low-pressure Storage Tanks standard (API STD 2000, 2014), which is applicable to low-pressure atmospheric storage tanks, provides guidance on the use of inert media in its Annex F. Since, in an inert cushion, there is some kind of opening pressure to breathing apparatus, nitrogen regulation is assumed to be associated with it. According to the API STD 2000, if the breather is open and proportionally takes in more air (oxygen) than inert media (F.2 – level 1), the interior of the tank is Zone 1. Conversely, if after the opening the process is reversed (F.2 – level 2), i.e. there is a higher replenishment of inert medium, then the internal space of the tank is Zone 2.

2.4. Explosive atmospheres for cryogenic and other cold liquefied flammable storage tanks – based on NFPA 59A:2023 standard

The storage of refrigerated flammable liquids, NFPA 59A:2023 (National Fire Protection Association, 2023) is available, which includes fire and explosion protection requirements. In fact, the findings for explosion protection are fully covered in NFPA 497:2021, except that it uses separate figures for Zone 1 and Zone 2, and this one use Division 1 and Division 2, which are UL certified (UL Certification, 2023). Division 1 means Zone 0 and Zone 1, and Division 2 means Zone 2.

Figure 8 shows an example of the explosion hazard areas of these storage indicated in the standard.

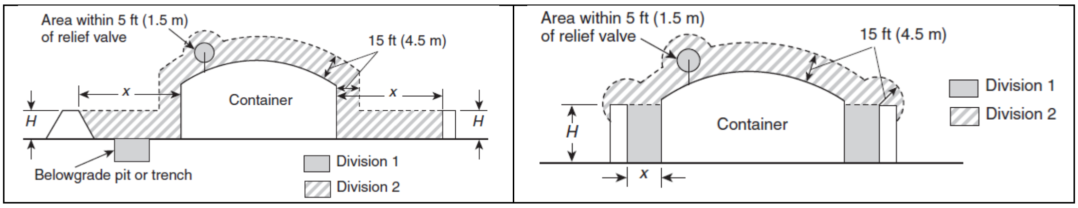

Figure 8. *Explosion hazard areas of a tank in a trench (left), explosion hazard areas of a containment ring tank (right) according to NFPA 59A:2023*

It can be seen that there is no radical difference compared to the tanks without cooling. What is worth to mention, the classification of the tanks mentions tanks with a protective ring.

In fact, only the interior of the tanks is not considered to be an explosive area, as the low temperature could not cause the temperature of the flammable liquid to rise above the flash point under normal operating conditions. Thus, only in the event of a material spillage in an external environment is an explosive atmosphere established.

2.5. Explosive atmospheres for equipments at Petroleum Facilities – based on API RP 505:2018 standard

The API RP 505:2018 standard refers several times in its title and in the document itself to its applicability to petroleum facilities, but its applicability to other chemical installations cannot be excluded. applicability (National Fire Protection Association, 2018).

Specifically, in the "Application" section, it states its applicability in general way, but refers to petroleum facilities by paragraph. Also, in the classification of flammable and combustible liquids, it does not list the typical substances that may be present in petroleum facilities, but refers to the classification in NFPA 497:2021, which is already known. Thus, by using the same approach as NFPA 497:2021, which is generally applicable to the classification of explosive atmospheres, one could, in effect, use this standard the starting point is the same.

In summary, this standard is presented because it may be legally applicable only the petroleum facilities, but describes professionally relevant findings. As will be seen in *Figure 9*, it also adopts similar approaches to the US standards presented so far, but has a very pertinent statement for storage tanks: *"The area surrounding the vents is classified to allow for the possibility that the surface of the liquid might be heated above its flash point by the ambient."* The limit value of 37.8 °C flash point is already a low value because climate change possibly makes ambient temperatures of 35–40 °C in summer and metal surfaces can heat up well above this level due to solar radiation. It does not mean that such a warming would occur for liquids, as it depends on the specific heat, the volume of the liquid and the insulating properties of the tank. However, the part of the volume in contact with the surface of the liquid will heat up much faster than the whole volume. This suggests the presence of an explosive vapour on its surface.

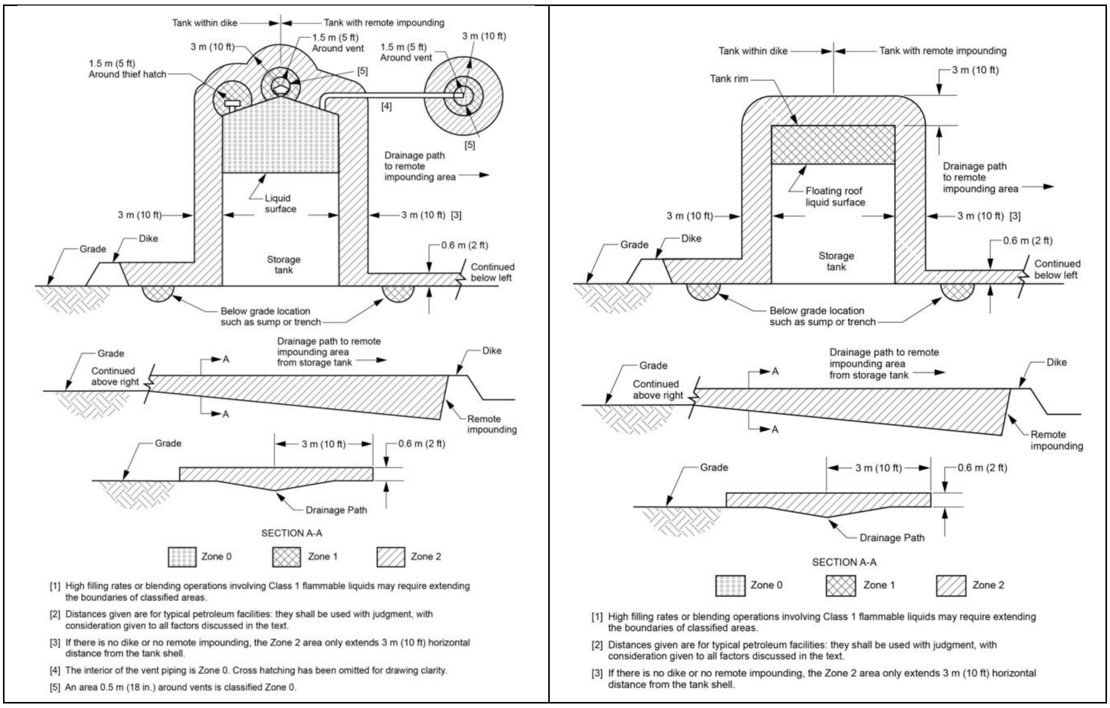

Figure 9. *Explosion hazard areas of a fixed-roof flammable liquid storage tank (left), explosion hazard areas of an open top floating roof flammable liquid (right) in accordance with API RP 505:2018*

Compared to the standards presented in the foreword, what is immediately striking is that Zone 0 defines an explosive atmosphere in the vicinity of the breather. This can be explained by the following:

- Zone 0 explosive atmosphere is the explosive medium present for more than 1000 hours in a year (Zone 1 between 10–1000 hours, Zone 2 less than 10 hours).
- According to the standard, based the ambient temperature relative to the heating of the liquid surface and the flash point of the flammable liquid at 37.8 °C, calculated on a 4-hour period per day, 250 days should meet this condition. This may be the case in many areas of the United States, such as California, Arizona, New Mexico, Texas, and Florida.
- If the flash point of the liquid is less than this, the risk is much higher and the professional approaches in the standard are more applicable.

The standard also mentions the following:

- High filling rates or blending operations involving class 1 flammable liquids my require extending the boundaries of classified areas.
- Distances given for typical petroleum facilities: they shall be used with judgment, with consideration given to all factors discussed in the text.

In practice, it highlights risk factors such as displacement due to filling or heating of the stored fluid.

In addition, what is also noteworthy in API RP 505:2018 is that, in a departure from the approach of NFPA 497:2021, it also defines hazardous areas for the storage of flammable liquids, which is shown in *Figure 10*.

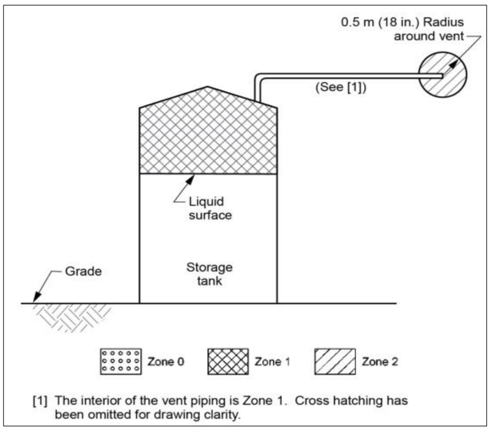

Figure 10. *Explosion hazard areas of a combustible liquid storage tank according to API RP 505:2018*

However, in both cases, it does not mention the possibility of intermixing, so in this case, the API STD 2000 standard could be used if this possibility exists.

Overall, this standard sets out professionally acceptable approaches for explosive atmospheres. The diagrams are clear, illustrating possible examples of tanks with breathers, or are routed away from the breather, or the containment is not completely horizontal.

2.6. Explosive atmospheres for storage tanks – based on Area Classification Code for Installations Handling Flammable Fluids Part 15:2005 (IP 15) standard

The IP 15:2005 states a relatively simple approach for stationary cylindrical tanks, as shown in *Figures 11* and *12*.

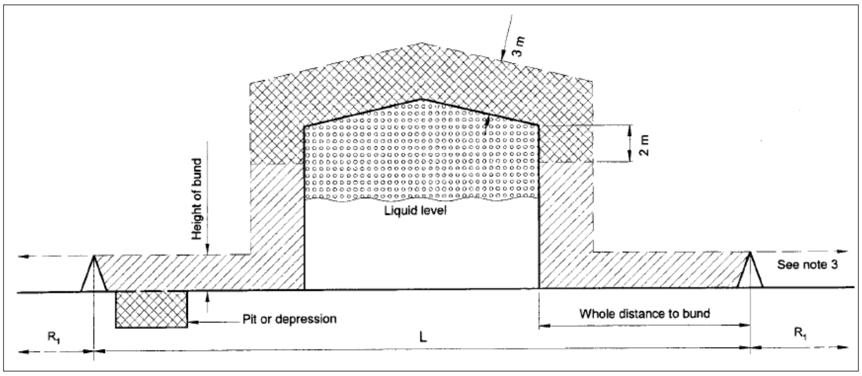

Figure 11. *Explosion hazard areas of a fixed roof storage tank according to IP 15:2005*

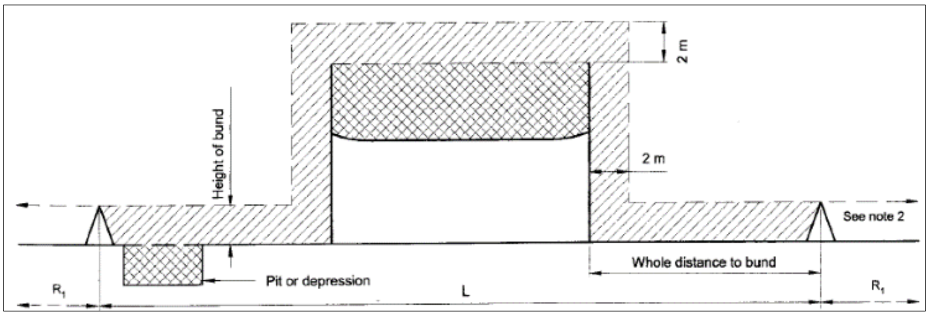

Figure 12. *Explosion hazard areas of a floating roof storage tank according to IP 15:2005*

If the container has a protective ring design, *Figure 13* shows the explosion hazard areas applicable to it.

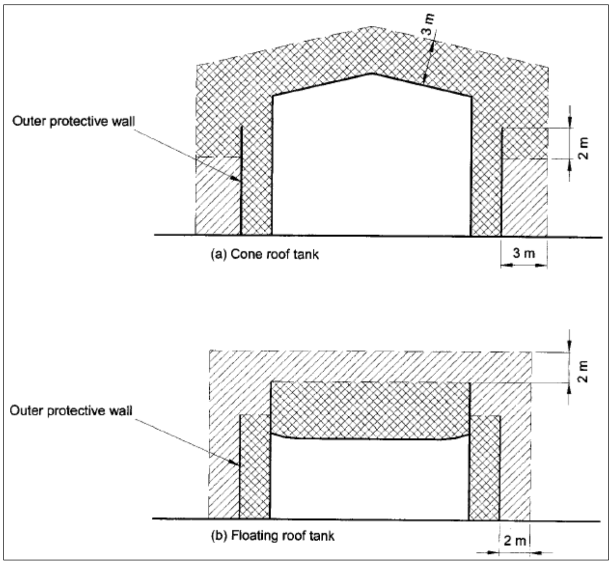

Figure 13. *Explosion hazard areas of tanks with outer protective wall according to IP 15:2005*

In Zone 1 and Zone 2 region changes at the edge of the tank in *Figures 11* and *13*, cannot be explained by factual arguments. Contradictions are raised because what if the tank does not contain as much or even more fluid than shown in the figures.

In case of a closed container with a protective wall, the Zone 0 region is missing from the inside. Also, no reference to the concept of inertization is mentioned.

The standard does not really contain findings on breathers. It essentially treats only vent systems with or without vapour collection, which is illustrated in *Figure 14*.

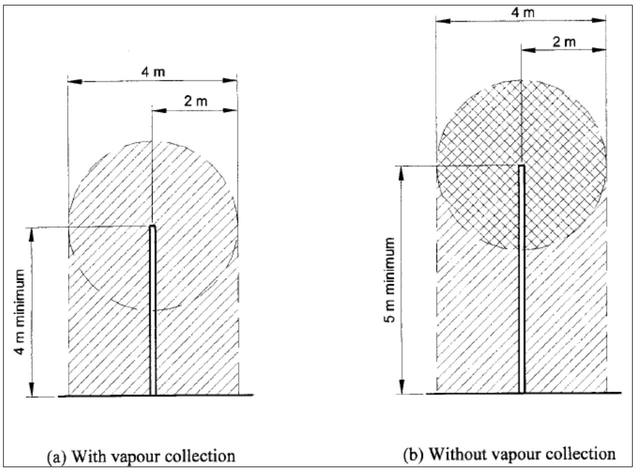

Figure 14. *Explosion hazard areas of vent system according to IP 15:2005*

Horizontal, cylindrical tanks are treated exclusively as gasoline storage tanks, an example of which can be seen in *Figure 15*.

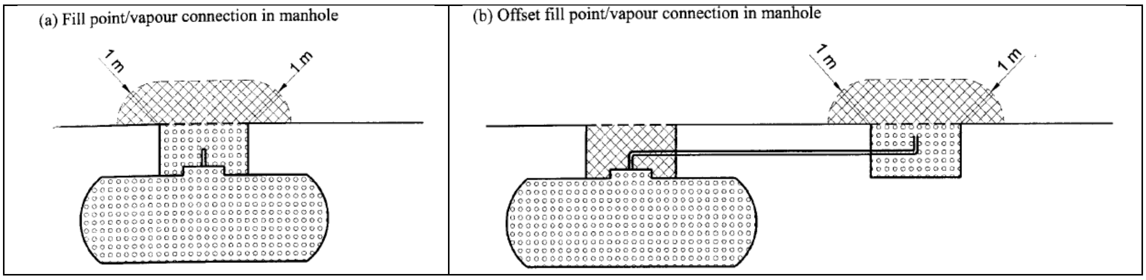

Figure 15. *Explosion hazard areas of gasoline storage tanks according to IP 15:2005*

2.7. Explosive atmospheres for storage tanks – HSG 176 Storage of flammable liquid in tanks, 2015 and IEC 60079-10-1:2008 standard

The HSG 176:2015 and IEC 60079-10-1:2008 (International Electrotechnical Commission, 2009.) provide the same approximation of the extent of hazardous areas for storage tanks. This is shown in *Figure 16*. Although IEC 600791-10-1:2008 has been withdrawn, as it is a harmonised EU standard, it could be applied in Hungary at the same time. Following its withdrawal, the UK implemented it in HSG 176 in 2015 in a separate document. What has been changed and thus made easier is that higher-flashpoint liquids at temperatures above their flashpoint, electrical equipment within 1.0 m of tank vents and other openings should be protected to Zone 2 standards.

There is also a lot of overlap in these approaches to define the hazardous areas of the tanks already described in this article, although the drainage of the breathers is missing. Also, they are only defined for the case of an ordinary flammable liquid, the lower explosion limit is not considered, which may increase or decrease the type and extent of the hazardous area.

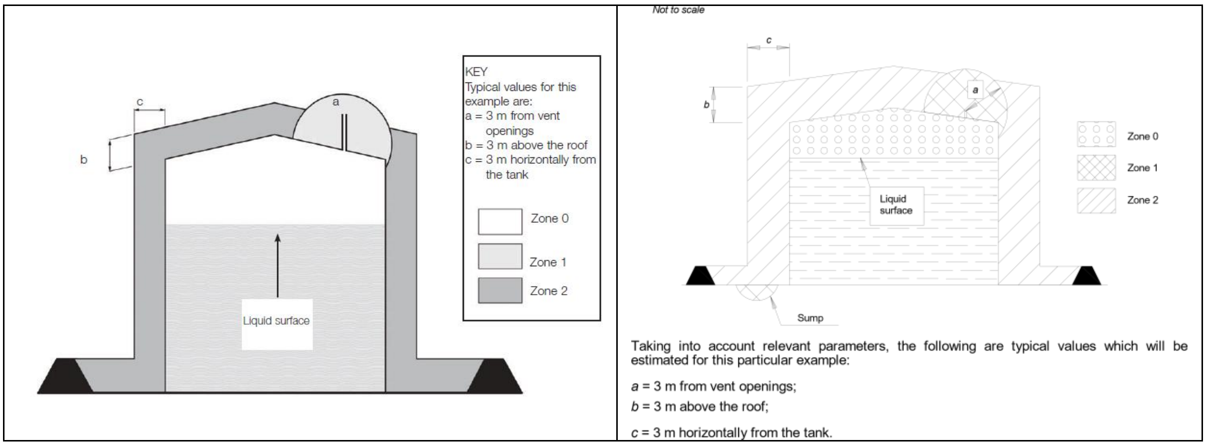

Figure 16. *Explosion hazard areas of storage tanks according to HSG 176:2015 (left) and EIC 60079-10-1:2008 (right)*

3. Summary and evaluation

The investigated standards known, it can be seen that the Hungarian standards provide the largest possible explosion hazard zones. Based on the investigated standards, Zone 1 is acceptable as the primary source of explosion hazard in the vicinity of the breathers, but Zone 1 is also unjustified in the external vicinity of the tank shell.

There is little difference between the basic design of a stationary and a horizontal cylindrical tank, so there would be no need for two separate standards.

In fact, they could be combined in one document. A clear and well-developed approach would be to define the extent of the explosive parts in relation to be corresponding ranges of flash point and lower explosive limit. For proper understanding, it is completed visually with figures illustrating the zones.

The API RP 505:2018 standard would be a good reference to renew the Hungarian standard, but reviewing the zones according to the climatic conditions in Hungary, and the findings in HSG 176:2015 and IEC 60079-10-1:2008 are also correct, but should be checked as described in the previous paragraph in addition, NFPA 59A:2023 is a standard, as the latter also shows the design of the protective ring. Furthermore, for underground tanks, the approaches in SÄIFS 1997:8 and even IP 15:2005 may not be discarded. In the case of IP 15:2005, with more review, one can reduce the extent and type of zones.

It would be highly recommended that the approach to interoperability described in API STD 2000 be transposed into a new national standard.

In its overall form, a new standard would certainly benefit both designers and operators. From the design side, a more accessible, understandable and all-encompassing standard would be easier to work with. From an operator's point of view, there would be lower costs for the selection of ATEX equipment in terms of instrumentation. In addition, another important area is the lightning protection of tanks, which could also be lower cost if the whole area above the tank is not zoned.

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