

# **Design of Electrical Apparatuses for Hazardous Areas**

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## **7.1 Classification of Hazardous Areas**

### **7.1.1 The Overall Objective of Area Classification**

The overall objective of area classification is to minimize the probability of accidental ignition of explosive atmospheres in e.g. the process industries. The area classification forms the traditional basis for design of electrical apparatus. The basic philosophy is that more strict requirements have to be enforced to the design of electrical apparatuses to be used in areas where the probability of occurrence of explosive atmospheres is high, than to equipment to be used in areas where this probability is low. The prime objective of area classification is to assign different “zone” classes to the various parts of the industrial plant of concern according to the likelihood that explosive atmospheres may occur.

The area classification philosophy focuses on minimizing the probability of ignition. This is not the same as to minimize the explosion risk. The difference is that the explosion risk concept considers not only the probability of ignition, but also the consequence of an ignition. Explosion risk may then be defined as the product of the probability of ignition and the expected consequence of an ignition. In other words, a minute ignition probability combined with a catastrophic explosion resulting from an ignition, can easily give rise to an unacceptably high explosion risk. A very brief outline of some aspects of comprehensive risk analysis is given in Chapter 8.

## 7.1.2 Gases and Vapors

### 7.1.2.1 Definition of Area Classification

The area classification approach has traditionally been used as a basis for specifying requirements for electrical equipment for use in potentially explosive atmospheres. According to The Institute of Petroleum (2002) area classification is the assessed division of a facility into hazardous areas and non-hazardous areas, and the subdivision of the hazardous areas into zones. A hazardous area is defined as a three-dimensional space in which a flammable atmosphere may be expected to be present at such frequencies as to require special precautions for the control of potential ignition sources including fixed electrical equipment. All other areas are non-hazardous in this context, though they may, in part or whole, form part of a wider restricted area within the facility in which all work is carried out under special controls. Examples include petroleum distribution installations and offshore production installations.

The International Electrotechnical Commission (IEC) defines a hazardous area as an area within which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of (electrical) apparatus. Area classification is the effort to divide a process area into so-called “zones” characterized by different probability of occurrence of explosive atmospheres. This sub-division is to be documented in maps in all three elevations, showing the extent of the various zones. The zone definitions for gases and vapors are given in Section 7.1.2.7 below.

### 7.1.2.2 Purpose of Area Classification

The purpose of area classification is to avoid ignition of releases, intentional as well accidental, that may occur in the operation of facilities handling flammable gases, liquids, and vapors. The approach is to reduce to an acceptable minimum level the probability of coincidence of a flammable atmosphere and a source of ignition.

It is not the aim of area classification to guard against the ignition of major catastrophic releases of flammable gases or vapors, e.g. due to rupture of a pressure vessel or a pipeline. The philosophy is that in properly run facilities, such events have a very low probability of occurrence, and

that the likelihood of their occurrence must be kept below acceptable limits by correct design, construction, maintenance, and operation of facilities.

### 7.1.2.3 Limitations of Area Classification

As mentioned above, the traditional area classification system was developed at a time when more comprehensive risk analysis methods were not available, and does neither address catastrophic failure, nor the consequences of explosions. It is now realized that conventional area classification is not a sufficiently powerful tool to serve as a basis for estimating explosion risks. The absence of acceptance criteria, in terms of maximum acceptable risk (frequency • consequence), is a major problem in applying conventional area classification as the sole criterion for selection of proper equipment. In comprehensive risk analyses, both the probabilities of occurrence of explosive atmospheres and the possible effects of explosion of such atmospheres are quantified

In future, conventional area classification procedures may be supplemented or even replaced by thorough risk assessment procedures, which also take into account the effects of explosions and fires and the resulting quantitative consequences. If the conclusion of this kind of analysis is that the explosion/fire risk is unacceptable, then appropriate measures for reduction of the risk must be taken. This may be accomplished by one or a combination of several of the measures indicated in Figure 2–59. Careful consideration must be given both to technical risks during normal operating conditions and periods of limited technical malfunction during normal operation and also to risks during maintenance and repair work. Possible human errors must also be accounted for. In the context of preventing the occurrence of effective ignition sources, risks associated with the use of tools in maintenance and repair work are of prime concern. In any case, the overall aim must be to ensure the required level of safety by means of cost-effective solutions.

### 7.1.2.4 Small Scale Operations

Certain locations handling only small quantities of flammable fluids can, in the context of area classification, be classified as “non-hazardous.” For example, this may apply to laboratories for testing small petroleum fluid samples. It is not possible to set a cut-off point, as this must be judged according to the circumstances. For instance, when draining gasoline from

a vehicle fuel tank in an enclosed garage or a below-ground inspection pit, due precautions must be taken to prevent ignition. Such areas must be classified as Zone 1, and only Zone 1 (or Zone 0) electrical equipment should be permitted (see section 2.1.2.7). In addition due precautions must be taken to prevent ignition from any other type of ignition source. In making such a judgment, the risk to people should be assessed.

Each vessel containing flammable fluids should be treated individually, by considering the nature of its surroundings and the extent to which people need to be present. As a rough guide, hazardous area classification may not be needed if the maximum amounts of material that could be released are below the quantities given in Table 7-1.

**Table 7-1 Capacity Thresholds of Process Equipment Located inside and outside Buildings Below which Area Classification May Not be Required From The Institute of Petroleum (2002)**

	Gas (Volume corrected to 1 bar(abs) pressure)	Liquefied Flammable Gas	Flammable liquid at a temperature above its flash point
Inside	50 litres	5 litres	25 litres
Outside	1000 litres	100 litres	200 litres

However, in certain circumstances, ignition of quite small quantities of flammable gas/vapor mixed with air can cause danger to persons in the immediate vicinity. Where this is the case, as in a relatively confined location from which rapid escape would be difficult, area classification may be needed down to quite small quantities of fluid.

#### 7.1.2.5 Good Standards of Design and Operation

The area classification technique described here assumes that the facilities to which it is applied are designed, constructed, maintained and operated in accordance with good industry practice so as to reduce releases to a minimum. Equipment and piping should be designed to international standards or national equivalents. The recommendations of the IP Model Codes (see The Institute of Petroleum, 2002) or their equivalents, regarding good operational and maintenance practice, should also be followed in accordance with good industry practice so as to reduce releases

to a minimum. Equipment and piping should be designed to international standards or national equivalents.

#### 7.1.2.6 Management of Area Classification

As a rule area classification should be carried out before the design and layout of equipment are finalized. At this stage, it may be possible to make considerable improvements at little cost. The area classification should always be reviewed and drawings modified, if necessary, on completion of design and before any change is made to existing plants handling flammable fluids.

Area classification should be incorporated into the company's Health, Safety, and Environmental Management System. The person responsible for the coordination of the area classification should be identified and be competent in this field. The work, which requires an interdisciplinary approach, should be carried out by persons who have full knowledge of the process systems and equipment, in consultation with safety, loss prevention, and electrical engineering personnel, as appropriate. Agreements reached on the area classification should be formally recorded and continually reviewed and updated. Records, such as drawings and/or tabulated data sheets, should include details as to the type of protection selected to meet the zone requirements and the apparatus sub-group and temperature class.

In principle, the classification of an area entails consideration of all the actual and potential sources of release of flammable fluid present. In practice, the procedure can be simplified by adopting a standardized area classification diagram. In other cases, a procedure of considering individual point sources will be required. A detailed procedure for this is given by The Institute of Petroleum (2002).

#### 7.1.2.7 Definition of Zones

Areas are subdivided into zones based on the likelihood of occurrence and duration of a flammable atmosphere, as follows:

- Zone 0

That part of a hazardous area in which a flammable atmosphere is continuously present or present for long periods.

- **Zone 1**

That part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation.

- **Zone 2**

That part of a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short period.

- **Non-hazardous areas**

Areas that do not fall into any of the above zones are non-hazardous. A Zone 1 area will often be surrounded by a larger Zone 2 area, but there is no specific requirement for this. However, whenever a Zone 1 area is not part of a larger Zone 2 then the possibility of any large but infrequent release, which would require a larger Zone 2 area, should be considered.

### 7.1.2.8 Sources and Grades of Release

For the purpose of area classification a point source of release is defined as a point from which a flammable gas, vapor or liquid may be released into the atmosphere. The following three grades of release are defined in terms of their likely frequency and duration.

#### 7.1.2.8.1 Continuous Grade Release

A release that is continuous or nearly so, or that occurs frequently for short periods.

- **Primary Grade Release**

A release that is likely to occur periodically or occasionally in normal operation i.e. a release which, in operating procedures, is anticipated to occur.

- **Secondary Grade Release**

A release that is unlikely to occur in normal operation and, in any event, will occur only infrequently and for short periods i.e. a release which, in operating procedures, is not anticipated to occur.

The grade of release is dependent solely on the frequency and duration of the release. It is completely independent of the rate and quantity of the

release, the degree of ventilation, or the characteristics of the fluid, although these factors determine the extent of gas/vapor travel and in consequence the dimensional limits of the hazardous zone.

To assist understanding of the boundaries of the definitions of the different grades of release, the following quantities are suggested. A release should be regarded as continuous grade if it is likely to be present for more than 1,000 hours per year and primary grade if it is likely to be present for between 10 and 1,000 hours per year. A release likely to be present for less than 10 hours per year and for short periods only should be regarded as secondary grade. This assessment should take account of any likelihood of leaks remaining undetected. Where releases are likely to be present for less than 10 hours per year but are anticipated in normal operation (e.g. routine sampling points), they should be regarded as primary grade releases.

The allocation of the grade of release should be reviewed in the course of the design stages to determine if practicable and economical design or engineering improvements can be made to reduce the number of continuous and primary grade releases. Assessment of the grade of release is not always obvious and will require experienced engineering and operational judgment. Releases that occur regularly but with short duration should generally be classified as primary grade sources giving rise to a Zone 1 area.

#### 7.1.2.9 Relationship Between Grade of Release and Class of Zone

Under unrestricted 'open air' conditions there is, in most cases, a direct relationship between the grade of release and the type of zone to which it gives rise; i.e.

- continuous grade normally leads to Zone 0
- primary grade normally leads to Zone 1
- secondary grade normally leads to Zone 2

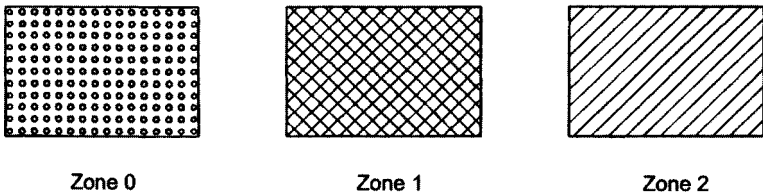
However, this may not always be true. For example, poor ventilation may result in a more stringent zone while, with generous ventilation, the opposite will be true. Also some sources may be considered to have a dual grade of release with a small continuous or primary grade and a larger secondary grade. Examples include vents with dual-purpose process requirement, and pump seals.

### 7.1.2.10 Area Classification Drawings

Area classification records can comprise detailed drawings with notes and/or can be in the form of tabulations. The area classification drawings should be in sufficient scale to show all the main items of equipment and all the buildings in both plan and elevation. The positions of all openings such as doors, windows and ventilation inlets and outlets, and utility entries if not scaled gas/vapor-tight should be included as the careful positioning of these openings can affect the sizing of related external hazard zones.

Area classification drawings should be marked up to show the boundaries of all hazardous areas and zones present using the shading convention adopted internationally and shown in Figure 7–1. It is acceptable to indicate any requirement for small local zones/areas, e.g. around pumps and control valves, in a note on the drawing.

The final area classification should include a record of all additional supporting details. It is necessary to clearly distinguish regions on the drawing where different gas properties prevail, e.g. hydrogen with a Gas Group IIC on part of a drawing where mainly hydrocarbons are present. This may be illustrated using half-width hatching for the “hydrogen” region.



**Figure 7–1 Shading convention for area classification drawings of areas where explosive clouds of gases and vapors can occur. From The Institute of Petroleum (2002).**

### 7.1.2.11 Combustible-Fluid Properties and Area Classification

#### 7.1.2.11.1 Class I Fluids

For definitions of fluid classes, see Section 2.1.3.3 in Chapter 2. Class I fluids have very low flash points, and will always produce a vapor in the



flammable range in air even at temperatures far below ambient. Facilities handling Class I fluids must always be area classified.

#### 7.1.2.11.2 Class II and Class III Petroleum and the Distinction between Subdivisions (1) and (2)

Materials with flash points according to in Class II or III (see definitions in 2.1.3.3) will often be stored or handled at temperatures below their flash points, i.e. at temperatures where the vapor pressure is too low to give explosive fuel/air mixtures. In such cases, and where the possibility of releases in the form of a flammable mist or spray can also be excluded, the surrounding area does not have to be classified. However, where a material is held under pressure and there is a possibility of mist or spray formation on release, that material may produce a flammable atmosphere regardless of the storage conditions and flash point. In such circumstances, therefore, those materials classified as Class II(1) or III(1) (i.e. non-hazardous) should be classified as II(2) or III(2) respectively. In such cases it must be confirmed that the liquid temperature cannot be raised by any means in the event of release, e.g. by contact with a hot surface or proximity to an adjacent non-electrical source of ignition. As a typical example, within the UK mainland a maximum ambient temperature of 30 °C can be assumed, while typically offshore in the North Sea a maximum would be 24 °C. Aviation fuels of the kerosene type (flash point > 38 °C) may therefore, under these conditions, be classed as non-hazardous when stored away from processing areas and hot lines and vessels. Because of the greater variability in temperature in typical process areas Class II liquids should, however, be regarded as hazardous, i.e. Class II(2), in such areas. Special assessment may be required in climate regions of high normal ambient temperatures. When petroleum materials are to be stored or handled that are in the Class II(2) or III(2) condition, or are likely to be exposed to conditions of temperature above the flash point, the facilities should be classified as laid down for Class I.

#### 7.1.2.11.3 Unclassified

Petroleum materials having a flash point above 100 °C can be given the subdivision accorded to Class III petroleum and should be regarded as Class III(2) when handled at or above their flash points. A distinction, however, should be made between distillates in this unclassified range

and products such as bitumens. When such materials are stored in heated fixed roof tankage (wherein the ullage space is essentially unventilated), the flash point as sampled or recorded will not be indicative of the presence or absence of a flammable atmosphere that may have accumulated in the ullage space. In common with the ullage space of fixed roof tanks or road or rail tank vehicles containing all classes of petroleum, the ullage space should be classified as Zone 0, with a 1,5 m Zone 1 surrounding vents and other roof openings. It should also be recognised in respect of heated petroleum of high flash point that although flash point and ignition temperature are different characteristics, at very high temperatures the effects can converge, i.e. the high temperatures, for example, of a hot surface can create a flammable condition locally which may be ignited by auto-ignition by that hot surface, as well as by an alternative ignition source.

#### 7.1.2.11.4 Fluid Categories

In some situations and processes flammable fluids may have quite extreme and varied temperatures and pressures. In order to facilitate area classification by the point source method developed by The Institute of Petroleum (2002) in such cases, the concept of fluid categories has been introduced. This categorizes the fluids according to their potential for rapid production of flammable vapor when released to the atmosphere. The fluid categories used are defined in Table 7-2.

**Table 7-2 Fluid Categories. From The Institute of Petroleum (2002)**

Fluid Category	Description
A	A flammable liquid that, on release, would vapourize rapidly and substantially. This includes: (a) Any liquefied petroleum gas or lighter flammable liquid. (b) Any flammable liquid at a temperature sufficient to produce, on release, more than about 40% vol. vapourization with no heat input other than from the surroundings.
B	A flammable liquid, not of Category A, but at a temperature sufficient for boiling to occur on release.
C	A flammable liquid, not of Categories A or B, but which can, on release, be at a temperature above its flash point, or form a flammable mist or spray.
G(i)	A typical methane-rich natural gas.
G(U)	Refinery hydrogen.

### 7.1.2.11.5 Simple Relationship Between Petroleum Class and Fluid Category

For simple situations Table 7-3 may be used to convert petroleum classification to fluid category. It will be noted that the degree of vaporization that will occur on release to the atmosphere reduces in going from Category A to Category C, i.e. Category C is the least volatile.

**Table 7-3 Relationship between Petroleum Classification and Fluid Category. From The Institute of Petroleum (2002)**

Classification of petroleum by the based (except for LPG) on closed cup flash points			Fluid Category		
Class	Description	Handled above flash point	Handled above boiling point	Can be released as mist	Handled below boiling point and cannot be released as mist
Class 0	Liquefied petroleum gases (LPG)	Yes	A	A	A <sup>2</sup>
Class I	Flash point less than 21 °C	Yes	B	C	C
Class II (1)	Flash point 21-55 °C	No	N/A <sup>1</sup>	C	N/A <sup>1</sup>
Class II (2)	Flash point 21-55 °C	Yes	B	C	C
Class III (1)	Flash point 55- 100 °C	No	N/A <sup>1</sup>	C	N/A <sup>1</sup>
Class III (2)	Flash point 55- 100 °C	Yes	B	C	C
Unclassified (1)	Flash point greater than 100 °C	No	N/A <sup>1</sup>	C	N/A <sup>1</sup>
Unclassified (2)	Flash point greater than 100 °C	Yes	B	C	C

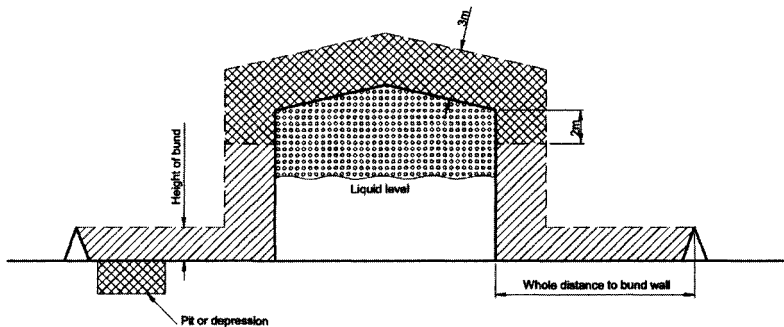
Note 1: Not applicable (N/A) because liquids are not handled above their flash point cannot be above their boiling point.  
 Note 2: Cryogenic fluids need special consideration.

From the definitions it is clear that for the same flammable fluid, at various stages of its processing or handling, there can be different fluid categories depending upon temperature and pressure at the specific points of release. Each situation at a point of release should be separately evaluated.

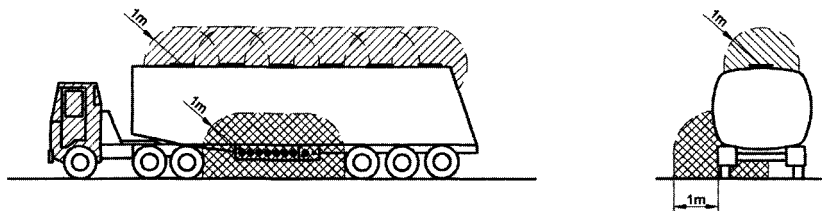
### 7.1.2.12 Area Classification by Direct Examples

The Institute of Petroleum (2002) has produced a set of examples of area classification of simple industry operations in the open. Often the specific case requiring classification is very close to one of the examples provided, and this may justify area classification by just copying this specific example, either without any changes or by appropriate adjustment to suit the case to be addressed. The publication advises on modifications that may be made.

Figure 7-2, Figure 7-3, and Figure 7-4 constitute a small selection of the comprehensive collection of examples provided by IP.



**Figure 7-2** Area classification of a bunded tank with cone or dome roof. From The Institute of Petroleum (2002).



**Figure 7-3** Area classification of a fuel tank vehicle during filling. From The Institute of Petroleum (2002).

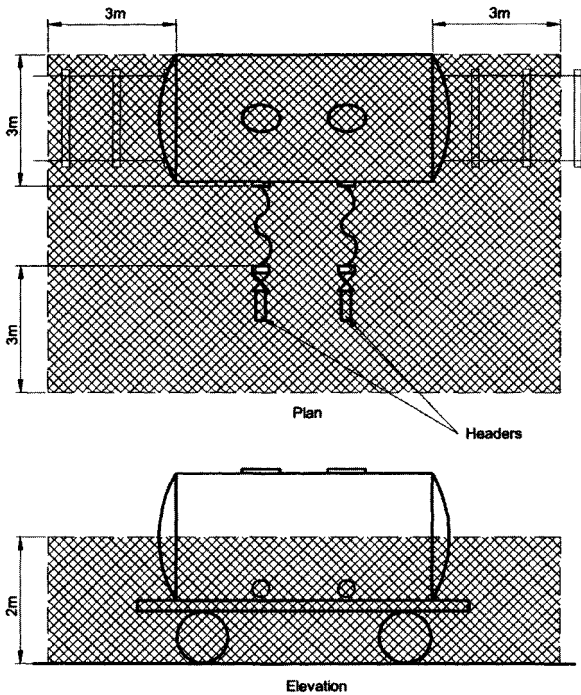
#### 7.1.2.13 Area Classification by Point Source Method Developed by the Institute of Petroleum (2002)

Generally, process plant will constitute a Zone 2 area inside plant boundaries, within which there may be local Zone 1 and, more rarely, Zone 0 areas.

Some release sources are true point sources, e.g. vents, drains and sample points. Other equipment, such as pump units, constitute assemblies of several individual point sources. Determination of hazard radii using the point source methodology entails consideration of each identifiable potential release point in such assemblies.

The point source method comprises the following steps:

- (1) identify point sources
- (2) determine grades of release



**Figure 7-4** Area classification of a rail car discharge of Class I, II and III fuels via hose connection. From The Institute of Petroleum (2002).

- (3) determine fluid categories
- (4) determine zone categories surrounding each points source
- (5) determine hazard radii around each point source
- (6) determine global hazardous areas

#### 7.1.2.13.1 Identify Point Sources

The first stage in the area classification of a plant or facility is the identification of the possible point sources of release. Usually these are small, and the associated equipment typically includes valves, flanges, vents, sampling and drainage points, instrument connections, rotating machinery such as pumps and compressors, and any areas where spillage from these sources could collect. The Institute of Petroleum

(2002) provides the following list of equipment configurations that often give rise to leak point sources:

- pumps
- equipment drains and liquid sampling points
- compressors
- vents
- piping systems
- pig receivers and launchers
- liquid pools during spillage
- sumps, interceptors and separators
- pits and depressions
- surface water draining systems

#### 7.1.2.13.2 Determination of Grades of Release

In principle, the area classification procedure entails the consideration of all actual and potential sources of release of flammable gases or vapors. All continuous and primary grade sources of release should be identified and assessed to determine the extent of the resulting Zone 0 and Zone 1 hazardous areas for each source. For secondary grade sources of release, it is often sufficient to consider only the sources located towards the periphery of a plant, which will be the point sources defining the outer boundary of the overall Zone 2 area. The extent of vapor travel, and hence the hazard radius for each point of release to be assessed, will be a function of the fluid characteristics and vapor-forming conditions during release, including mass or mass rate and the rate of vaporization. In assessing the grade of a release, the following points are pertinent:

- (a) In the case of operationally controlled releases, e.g. sampling and draining points, vents, filter-cleaning and pig-receiving operations, no single grade of release is generally applicable. This is because the operational frequency chosen will determine whether the equipment release should be graded as primary, secondary or continuous.
- (b) For uncontrolled releases, e.g. from pump seals, glands and pipe flanges, the Institute of Petroleum (2002) has provided release hole

sizes assessed and compiled for various situations on the basis of experience. Alternatively the manufacturers of various equipment may have provided typical specific release rates, or actual failure rates have been determined through observation for specific release situations.

#### 7.1.2.13.3 Determination of Fluid Categories

The fluid category for each point as defined in Table 7–2 has to be determined, e.g. by using tables provided by the Institute of Petroleum (2002). It is important to consider that the fluid state under shutdown conditions may give rise to a different vapor producing potential than the state under normal operating conditions. An example would be the fluids in a fractionating column or receiver, which at shutdown might be less well separated from lighter fractions.

#### 7.1.2.13.4 Determination of Zone Category for each Point Source

The zone category around a point of release is a function of the grade of release and the type of ventilation in the area of the release.

#### 7.1.2.13.5 Determination of Hazard Radii for the Zones around Each Point Source

The methodology for determining the hazard radius is dependent on the grade of release (primary, continuous, or secondary). The Institute of Petroleum (2002) has produced a system of block diagrams and tables by which hazard radii may be estimated. However, if the case considered is not covered by the standard fluid categories and tabulated values, dispersion modeling using an adequate numerical code will have to be carried out.

#### 7.1.2.13.6 Determination of Global Hazardous Area Drawing

The global area classification drawing is obtained by constructing the envelopes of the various zone categories on the drawing containing all the individual hazardous zones for the point sources.

### 7.1.3 Clouds of Liquid Droplets (at Temperatures Below Flash Point of Liquid)

As pointed out by The Institute of Petroleum (2002), flammable atmospheres may also be formed where flammable fluids handled below their flash points are released in the form of a spray or mist. Such materials are normally regarded as non-hazardous from a flammability-of-liquids point of view. However, they should be treated as hazardous when being pumped or stored under pressure, because they may then be capable of producing a spray or mist due to the possibility of a release from a small hole or flange leak. They should be regarded as a Category C fluid generating a hazardous area as appropriate. There is little knowledge on the formation of flammable mists and the appropriate extents of associated hazardous areas. Some of the issues related to the formation and the hazard of flammable mists are discussed by Bowen and Shirvill (1994). Pressure differentials of a few bars are sufficient to atomise commonly encountered liquids. Generation of mists created by the impact of liquid streams on a surface close to the point of release also appears to be possible. However, Bowen and Shirvill do not make any recommendations for the assessment of the extent of flammable clouds of mists and sprays. They do suggest, however, that porous spray guards can be used around flanges and known potential leakage points, causing the material to coalesce back to a liquid below its flash point, rendering it non-hazardous. But this is only practicable in a few specialized applications, and requires rigorous control over maintenance activities to ensure that removed guards are reinstalled after work completion.

Until further research has clarified the situation more fully, The Institute for Petroleum (2002) suggests as follows: Where the fluid temperature is at least 5°C below the fluid's flash point, and the pressure is atmospheric or only a few m liquid head in non-pressurized storage tanks, the fluid can be treated as non-hazardous. However, if being pumped and/or stored under high overpressure, it should be regarded as a Category C fluid (see Table 7-2), generating a hazardous area because of the possibility of mist or spray being generated by leaks from a small hole or a flange.



## 7.1.4 Dust Clouds

### 7.1.4.1 Basic Similarities and Differences between Dusts and Gases/Vapors

As discussed in Chapter 2 and Chapter 5 explosive gas/vapor clouds and explosive dust clouds, once existing, exhibit very similar ignition and combustion properties, such as

- flammability/explosivity limits
- laminar burning velocities and quenching distances
- the response of the burning velocity to cloud turbulence
- detonation phenomena
- adiabatic constant-volume explosion pressures of similar magnitudes
- well-defined minimum ignition energies, and
- minimum ignition temperatures for given experimental conditions

Recognition of these similarities may have contributed to the development of a new gas/dust “alignment” concept that has been adopted in the European “Atex” philosophy. However, there are two fundamental ways in which dusts differ substantially from gases, and both should have a major impact on the ways that electrical apparatuses are constructed to prevent them from becoming potential initiators of dust explosions and fires.

The first difference is in the ranges of hazardous fuel concentrations in air. For mixtures of combustible gases/vapors and air, flame propagation is only possible when the fuel/air mixing ratios lie between the lower and the upper flammability limits. Dust flame propagation, however, is not limited only to the flammable dust concentration range of clouds. The state of settled layers/deposits constitutes an additional singular regime of flame propagation. This is because, contrary to combustible gases and liquids, settled powders/dusts in air will always have some air trapped in the voids between the particles, which facilitates sustained, although often very slow, combustion propagation throughout the deposit.

The second basic difference between dusts and gases is in the generation and sustainment of explosive clouds. The paramount question is whether there will be an explosive dust cloud in the first place. The physics of generation and sustainment of dust clouds and premixed gas/vapor clouds are so substantially different that explosive dust clouds are highly unlikely to

be generated in a variety situations where explosive gas/vapor clouds may form quite readily, e.g. by release from process equipment to the open atmosphere. The important consequence is that in practice the explosive dust clouds that give rise to primary dust explosions are always found inside process equipment, such as mills, mixers, ducts, buckets elevators, cyclones, filters, and silos. This, of course will also be reflected in area classification.

NFPA (1997) contains a paragraph that in an excellent way, using practical terms, clarifies the basic difference between gases and dusts with regard to their abilities to migrate through narrow passages. In a slightly modified form this paragraph says as follows:

Walls are much more important in separating hazardous and non-hazardous zones in the case of combustible dusts than in the case of combustible gases. Only completely non-perforated solid walls make satisfactory barriers in the case of gases, whereas closed doors, light-weight partitions, and even partial partitions could make satisfactory barriers between hazardous and non-hazardous zones in the case of dusts.

#### 7.1.4.2 Definition of Zones

Many countries including U.S.A., Germany, and Norway traditionally used a dust zone classification system based on two hazardous zones only. However, in many countries this system has gradually been replaced by a common three-zone concept. The Atex 118a Directive (1999) defines the three hazardous zone categories that have to be identified in areas containing combustible dusts, in the context of European standardization. These definitions, which have also been adopted by IEC (International Electrotechnical Commission), are:

- Zone 20

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods, or frequently.

- Zone 21

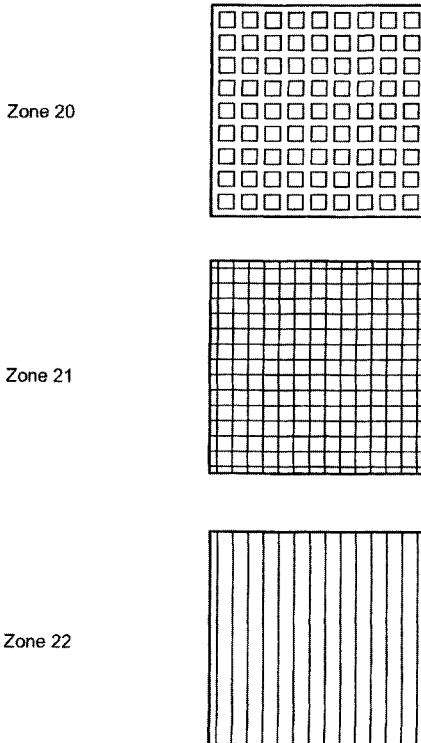
A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

- Zone 22

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

In the context of the philosophy of the Atex 118a Directive (1999), layers/deposits of combustible dusts are not considered as hazardous in themselves. They are only taken into account if they are considered to be possible sources of generation of explosive dust clouds, or if they can give rise to dust fires that can ignite dust clouds.

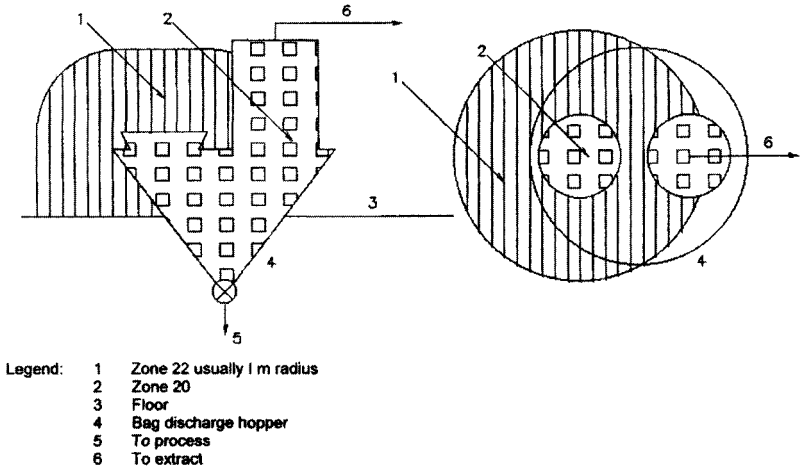
The symbols used for identifying the various zone categories are shown in Figure 7-5.



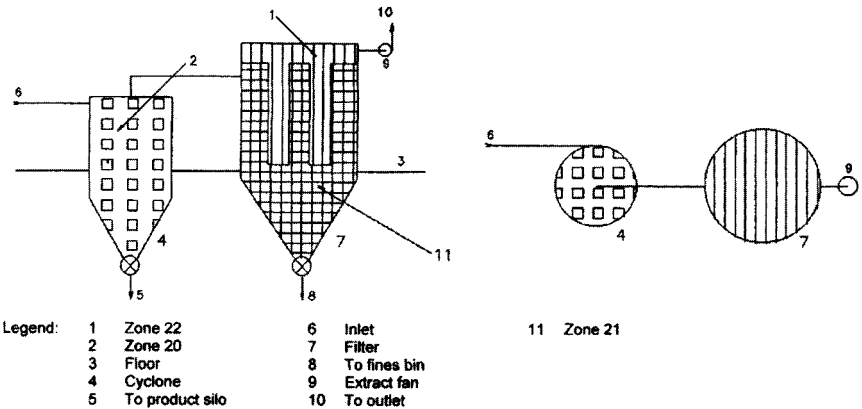
**Figure 7-5** Standardized system for marking zones 20, 21 and 22 on hazardous area classification maps of industrial plant. From GENELEC (2002).

7.1.4.3 Examples of Area Classification

Figure 7–6 and Figure 7–7 illustrate the application of area classification in two practical cases.



**Figure 7–6 Marking of zones 20 and 22 on a hazardous area classification map of a station for emptying bags containing combustible powder into a hopper equipped with dust extraction. From CENELEC (2002).**



**Figure 7–7 Marking of zones 20, 21, and 22 on hazardous area classification map of dust collection plant comprising a cyclone and a filter in series. From CENELEC (2002).**

The interior of the hopper in Figure 7–6 is classified as Zone 20 because explosive dust cloud will be generated there during the quite frequent emptying of bags into the hopper. Because of the dust extraction system, explosive dust clouds are not expected to extend outside the hopper in normal operation. However, abnormal situations may arise where this may occur, e.g. if a bag bursts during being emptied, or if the dust extraction system fails. Therefore a Zone 22 is assigned to a limited area just outside the hopper opening.

The interior of the cyclone in Figure 7–7 is classified as Zone 20 because of the presence of an explosive dust cloud frequently, or even continuously, for long periods. However, the dust concentration in the gas leaving the cyclone and entering the dusty side of the filter is normally below the minimum explosive concentration, except for short periods when the filter bags are blown or shaken to release accumulated dust. Hence, the dusty side of the filter is classified as Zone 21. Normally only negligible quantities of dust will exist on the clean side of the filter. However, filter bags may burst, or other abnormal situations may arise causing explosive dust clouds to be generated on the clean side of the filter, which is therefore classified as Zone 22.

## 7.1.5 Explosives, Pyrotechnics, and Propellants

### 7.1.5.1 Introduction

CENELEC (1997) defines explosive substances as solid, liquid, pasty or gelatinous substances and preparations which are liable to react exothermally and under rapid gas generation even without the participation of atmospheric oxygen, and which, under specified test conditions under partial confinement will detonate or deflagrate rapidly during heating. It is important to note that this definition not only comprise the genuine explosives, but also pyrotechnics and propellants.

### 7.1.5.2 Definitions of Hazardous Zones According to Cenelec

According to CENELEC (1997), hazardous zones in the context of explosives, pyrotechnics, and propellants are areas where, during manufacture, production, processing or storage of such substances, there may be a finite risk of ignition due to electrical equipment. CENELEC (1997) introduces the following zone definitions:

- Zone E1  
Areas where explosive substances
  - come in contact with electrical equipment as a function of design and/or process, or
  - may to a significant extent appear as dust, vapor, liquid, sublimate, or another state.
- Zone E2  
Areas where explosive substances
  - do not come in contact with electrical equipment as a function of design and/or process, but
  - may occasionally occur in the form of dust, vapor, liquid, sublimate, or another state.
- Zone E3  
Areas where explosive substances
  - do neither come into contact with electrical equipment as a function of design and/or process, nor
  - occur in the form of dust, vapor, liquid, sublimate or another state, neither as a function of design nor of process.

#### 7.1.5.3 Definitions of Hazardous Zones According to a Swedish Standard

The Swedish standard SS 421 08 24(1988) defines the various zones as follow:

- Zone E1  
Areas where
  - explosives are handled, and where
  - considerable quantities of dust, vapor, condensate and/or sublimate from explosive substances can normally occur.

All the interior of containers, vessels, piping etc. for explosive substances is normally classified as Zone E1, irrespective of whether there is a risk of dust generation.

- Zone E2

Areas where

- explosives are handled (not stored), and where
- considerable quantities of dust, vapor, condensate and/or sublimate from explosive substances occur only rarely, or where
- only non-dusting handling of explosive substances is taking place occasionally, but where specific requirements as to electrical apparatuses are nevertheless considered necessary.

- Zone E3

Areas where

- explosive substances are only stored in packed form so that spreading of the explosive substances in the area is effectively prevented.

#### 7.1.5.4 Temperature Classes

SS 421 08 24(1988) specifies the following temperature classes for apparatuses and equipment in contact with explosive substances:

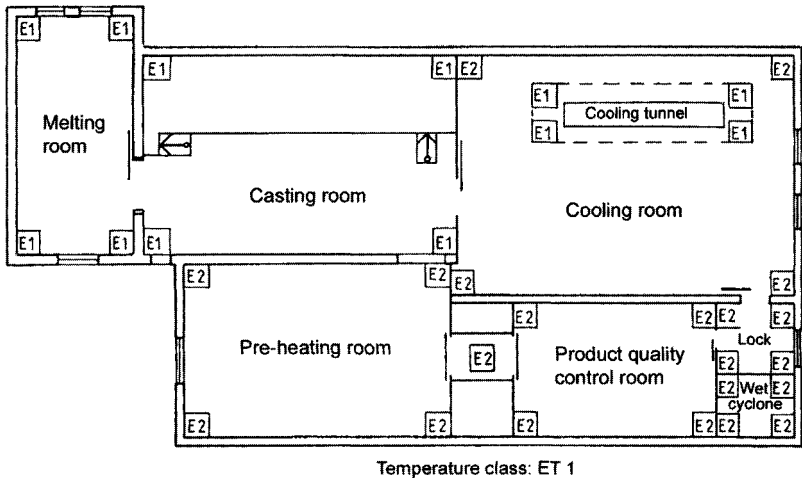
- ET 1: apparatuses and equipment suitable for substances having a minimum ignition temperature of at least 180°C
- ET 2: apparatuses and equipment substances having a minimum ignition temperature of < 180°C

SS 421 08 24(1988) gives minimum ignition temperatures for a range of explosive substances. For TNT the value is 290-310°C, i.e. the temperature class is ET 1.

#### 7.1.5.5 An Example of Area Classification According to the Swedish Standard

The example is the casting plant for TNT illustrated in Figure 7–8.

The process taking place in this example is as follows: At first the drums containing the TNT chips to be cast are pre-heated in the pre-heating room. No significant dust generation is expected, and the entire room is classified as E2.



**Figure 7-8 Area classification of plant for casting of TNT. From SS 421 08 24 (1988).**

The drums are then transferred to the melting room where the TNT chips are poured from the drums into a melting pot. This process creates considerable amounts of TNT dust. In spite of local dust extraction just above the pouring point, the dust cloud may at times extend across the entire room. The molten TNT is poured from the melting pot into intermediate containers. These are transported from the melting room to the casting room by an elevated transportation track running outside the building, from which the containers are hanging freely while being transported.

The entire melting room is classified as E1, whereas the transportation area outside the melting room to the casting room, including a 0.5 m wide zone on each side of, as well as above and below, the suspended containers, is classified as E2.

In the casting room the molten TNT is poured from the transportation container into the molding pot. Further TNT chips are added to the molten material while this is being stirred and shaken. Even during this process there will be some dust generation, most of which is removed by local dust extraction.

When the TNT has reached the desired slurry-like consistency, it is poured into high-explosives shells, mines etc. according to the production



plan. During this process there will be some generation of TNT vapor, which sublimates as soon as it makes contact with cold surfaces. Furthermore, some spill of molten TNT during casting is unavoidable. The floor in the casting room is kept wet by applying water, both in order to collect settling TNT dust and to prevent spilled TNT from the casting operations from becoming firmly stuck to the floor.

The conditions in the casting room are generally such that the entire room is to be classified as E1. The outdoor transportation track from the casting room to the cooling room is classified as E2 in the same way as the track from the melting room to the casting room.

In the cooling room the cast products are cooled down, normally in special cooling cupboards or cooling tunnels, which are usually equipped with local dust extraction. The interior of these tunnels and cupboards is to be classified as E1, whereas the cooling room in general is E2. However, often there is a need to remove excess TNT that has become attached to the outside of the mines, high-explosives shells etc. during the casting process. In such operations TNT dust is likely to be generated, and a local spherical E1 zone with a radius of 2 m around the point of such material removal has to be established.

The room for the wet cyclone that collects the dust from the various local dust extraction stations is classified as E2. Finally the quality of the cast products has to be controlled in a special product quality control room, which is normally classified as E2.

The temperature class for electrical and other equipment requiring consideration is ET 1, which means that the maximum permissible temperature of any hot surface in all classified areas is 180°C.

#### 7.1.5.6 Australian Interim Standard

An Australian interim standard (2004) defines an explosives hazardous area an area in which an explosives vapor atmosphere and/or an explosives dust atmosphere is present, or may be expected to be present in quantities such as to require special precautions for the construction, installation, and use of electrical equipment. For explosives vapor areas three zone categories 0E, 1E and 2E are defined in accordance with the definitions of zones 0, 1, and 2 in section 7.1.2.7. For explosives dust

cloud areas three zone categories 20E, 21E, and 22E are defined in accordance with the definitions in 7.1.4.2.

In addition, a zone category SE is defined as follows: an area in which very small quantities of explosives may be present, where its ignition could not cause the subsequent initiation of other hazardous materials, significant damage to equipment, or injury to personnel.

## 7.2 Basic Design Concepts for Electrical Apparatus

### 7.2.1 Gases and Vapors

A series of standardized basic design concepts for electrical apparatuses intended for use in explosive gas atmospheres have been available for a long time. The details are described in a corresponding series of international standards (IEC, CENELC etc.). The following summary is mainly based on BBC (1983). The figures are from Eckhoff (1996).

#### 7.2.1.1 Intrinsic Safety (Ex 'i')

This design concept can be used for apparatuses to be used in all three Zones (0, 1 and 2). An intrinsically safe circuit is a circuit in which no spark or any other thermal effect can be generated, which is capable of causing ignition of a given explosive atmosphere. The basic principles of intrinsically safe design are given in Figure 7–9.

In order to prevent hot-surface ignition of an explosive gas/vapor atmosphere by electrical apparatuses, the apparatuses must be designed so as to ensure that the temperatures of all surfaces that can make contact with the explosive atmosphere are below the minimum ignition temperature of the explosive atmosphere (see Section 2.2.4.4). For practical reasons it has been agreed internationally to standardize on a limited number of temperature classes for electrical apparatuses, and these are given in Table 7–4. Table 2–2 in Chapter 2 gives the minimum ignition temperatures and the corresponding temperature classes for a range of combustible gases and vapors in air.

The intrinsic safety concept originated in UK nearly 100 years ago through the pioneering work by Wheeler and others. British Standard