10

Hazardous Area Classification and the Selection of Equipment

10.1 HISTORICAL DEVELOPMENTS

Some of the earliest work on the subject of hazardous area classification was documented by the API, IP and BS institutions, and the chemical manufacturing company ICI. Their particular documents are given in Table 10.1.

Some of these documents have become obsolete or little used, e.g. BS229, BS1259, Electrical Installations in Flammable Atmospheres (from ICI) whilst others have been up-dated several times. New standards have also been introduced. A similar situation exists with the international standards pertaining to the selection of equipment for hazardous areas, many more references could be quoted.

In the period up to about 1980 it was common practice for senior electrical engineers to determine the various hazardous areas on a site. This was historically due to the fact that electrical power equipment was the easiest to identify as a possible cause of ignition. It would often be the first equipment to be investigated when an incident occurred.

The modern approach has changed for the better. It is now the more common practice that senior mechanical and senior process engineers manage this task in co-operation with electrical, instrumentation and safety personnel. The emphasis in this approach is the clear identification of possible sources of leaking gas or vapour. This is by nature more within the experience of mechanical and process engineers because they tend to be mainly responsible for the layout of the plant at the start of a project. Thereafter the electrical engineers select the type and design of manufactured equipment to suit the hazardous areas that have been identified on scaled drawings.

10.2 PRESENT SITUATION

For the classification of hazardous areas the notable standards that are most frequently used are IEC60079 Part 10 for UK and Europe, BS5345 Part 2 for UK only, API 500 A for USA. Although the territories of origin are given it is found in practice that an oil company operating in a particular country may adopt any one or a combination of standards to comply with the governing rules of the country e.g. European standards are adopted in Abu Dhabi and Qatar, whereas the standards of the USA are preferred in Saudi Arabia. A similar situation exists in the Far East for example.

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Table 10.1. Early publications pertaining to hazardous area classification

Institution	Document reference (See also Appendix B)
American Petroleum Institute	RP 500A. Recommended practice for classification of location for electrical installations of petroleum facilities classified as class 1 division 1 or division 2
Institution of Petroleum	Model Code of Practice in the Petroleum Industry
British Standards Institution	BS229, 1259, 5345
Imperial Chemicals Industry	Electrical Installations in Flammable Atmospheres
Electrical Engineers (UK) (IEE)	Third International Conference of Electrical Safety in Hazardous Areas (1982)

Table 10.2. Summary of the most frequently used parts of IEC60079

Part of IEC60079	Title of Part
0	General requirements, plus Amendments.
1	Construction and verification test of flameproof enclosures of electrical apparatus, plus Amendments. Note that the type of protection 'd' is incorporated into this part.
2	Electrical apparatus, type of protection 'p'.
7	Electrical apparatus, type of protection 'e' plus Amendments.
10	Classification of hazardous areas (similar to BS5345 Part 2).
11	Electrical apparatus type of protection 'i'.
13	Construction and use of rooms or buildings protected by pressurisation.
14	Electrical installations in hazardous areas (other than mines).
15	Electrical apparatus, type of protection 'n'.
18	Electrical apparatus, type of protection 'm'.

For the purposes of this book the European standards will be used as appropriate references for illustrating the principles involved and for designing installations. In practice the principles upon which all the standards are based are very similar. Some standards are more stringent and comprehensive than others. For the area classification IEC60079 Parts 0 and 10 are most relevant. For the selection and design requirements of equipment all the remaining parts, 1 to 20 should be applied, where necessary. The parts given in Table 10.2 would normally be referred to most frequently.

Reference 1 gives a very comprehensive discussion on most of the standards that exist in Europe and USA, and is recommended for further reading. The reference gives excellent comparisons of the standard identity numbers e.g. IEC, BS, CENELEC, BASEEFA, VDE and NEC.

Reference 2, Chapter 5, gives a full description of the American practices including a comprehensive part for conduit equipment and systems.

The concepts of hazardous area classification and the legislation that supports the subject are in a continuous state of revision and so the engineer should keep abreast of such developments.

10.3 ELEMENTS OF HAZARDOUS AREA CLASSIFICATION

The objective is to determine the zonal number for an area surrounding a definable source of hazard. These areas are identified as non-hazardous with no zonal number and hazardous of the types Zone 2, Zone 1 and Zone 0. This will be described in more detail later on in this chapter.

A hazardous area is one in which a flammable mixture of gases or vapours may exist. Upon ignition the flammable mixture will burn or explode, usually the latter. A similar situation can arise with combustible dust. The ignition can be caused by one of two methods. The usually attributed method is by a spark. The second is by a high surface temperature being attained, usually by operating equipment.

Sparks can occur by electrical or mechanical activity. Electrically the sparks are usually made by switching contacts, loose contacts in a circuit carrying current, poorly mating metallic faces that are carrying current and static discharges. In addition there is the source of sparks produced by maintenance operations such as welding and grinding. Mechanical sparks can be caused by the impacting of steel or iron components, especially if there is some surface rust. Oxidised aluminium alloys can also cause sparks on impact with themselves or other metals.

This sub-section will mainly be concerned with sparks caused by electrical methods and hot surfaces.

10.3.1 Mixtures of Gases, Vapours and Air

Ignition can only lead to fire or explosion if three necessary components occur simultaneously, these are:

a) A flammable gas or vapour is present in sufficient quantity.

   This occurs due to leakage or accidental discharge from an enclosed vessel, pump, compressor, value, flange or the like.

b) Sufficient air is present.

   It can be assumed that there will always be sufficient air in the area. The oxygen in the air is required for the combustion.

c) A source of ignition occurs.

   This will be a spark having sufficient energy, or a hot surface that will cause spontaneous or autoignition e.g. a hot exhaust manifold and piping of a diesel engine.

10.3.1.1 Gases and vapours

When gases and vapours are present in air the resulting mixture may be flammable. Not all gases and vapours produce flammable mixtures. Imagine a flammable gas or vapour slowly leaking into a confined volume of air that is not replenished. Initially the concentration of the gas or vapour in the mixture will be too low to support combustion. As the concentration increases a critical point will be reached when combustion will be possible. This is called the Lower Explosive Limit (LEL). If the concentration is increased beyond this point by a significant amount then a second critical point will be reached. At this point the mixture will not contain sufficient oxygen to enable combustion to occur. This is called the Upper Explosive Limit (UEL), above which no combustion or explosion is possible. In terms of hazardous area analysis the UEL is not normally of practical significance. Various institutions have determined the LEL for most of the regularly encountered gases and vapours. Both the LEL and UEL are expressed in percentage of volume. Reference 1 Appendix 8 and Reference 2 Article 500 Table 2.1 give comprehensive listings of LEL, UEL and other important data.

When it is necessary to identify the hazardous gas or vapour the designer will also need to know whether or not the gas or vapour is heavier or lighter than air. It is normally assumed that the hazard appears and persists in 'still air' conditions. The effect of wind or forced air ventilation is not considered for this purpose, because 'still air' conditions can always arise in practice and so this becomes the 'worst case' condition. Heavier than air gases and vapours have a relative vapour density greater than air, air has a value of unity. Likewise lighter than air gases and vapours have a density less than unity. This aspect is important when the boundaries of the hazardous area are being determined, especially in elevated parts of a plant, where open flooring is used and where open drains exist.

10.3.1.2 Temperature class

In order to classify a gas or vapour by its ability to be ignited by a hot surface, the definition Temperature Class is used. Ignition by this classification is spontaneous or automatic. The classification is simple to apply and consists of a two-digit code, the first digit is the letter 'T' and second a number between 1 and 6. The lower the number the higher the maximum allowable surface temperature. Hence a T6 gas or vapour is relatively more hazardous than one with a T1 code, see Table 10.3.

The above table complies with the same classification used in the USA, except that the NEC sub-divides the classes in some cases to further A, B and C classes.

10.3.1.3 Grouping of gases and vapours

In order to classify a gas or vapour by its ability to be ignited by a spark, the definition Gas Group is used. Again the classification is simple to apply. It consists of a three-digit code. The first and second digits are I or II [The IEC may add Group III in future for dust hazards.] The third digit is letter A, B or C.

For the oil industry the Group I is of little concern because it pertains only to underground mining. Hence Group IIA, IIB and IIC are of concern in this sub-section. A Group IIA gas or vapour is the hardest of the three sub-groups to ignite by a spark. Conversely a Group IIC gas or vapour is the easiest to ignite.

Table 10.3. Temperature class for gases and vapours

'T' classification by IEC60079 Part 0	Maximum surface temperature, °C
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

The definitions in the USA differ slightly by the use of 'Class' rather than 'Group'.

The grouping code influences the design of jointed and mating surfaces and shaft seals, because the gases in different groups have different explosive and burning characteristics e.g. speed of flame propagation, rate of rise of explosive pressure. Hence the grouping codes influence the physical design of enclosures. The gases hydrogen and acetylene for example are notably difficult gases to cater for in designs. Hydrogen is often encountered in the oil industry, and acetylene in the chemical industry.

10.4 HAZARDOUS AREA ZONES

In the European and UK standards the term Zone is used for hazardous areas, whereas the term Division is used in the USA. In practice the end result of selecting appropriate equipment for a Zone or Division is usually very similar. There are a few subtle differences, especially when selecting electric motors. The zonal definitions vary in wording from one document to another but the essential elements are as follows.

10.4.1 Non-hazardous Area

In the earlier period the term Safe Area tended to be used to mean an area that was deemed to be completely free of potential hazards. As with many technologies their terms and definitions take on slight changes as time passes, usually because of the feedback effect of experience. In this way the term Non-hazardous Area seems to have superseded Safe Area. (Curiously the zonal numbering is in opposite sense to the severity of hazard, zero is the worst and 2 is the least, as discussed below.)

10.4.2 Zone 2 Hazardous Area

The lowest non-zero risk of hazard is to be found in a Zone 2 area. In a properly designed and maintained plant the occurrence of leakage of flammable gas, vapour or volatile liquid from within the vessels, tanks, piping, valves, seals, pumps, compressors and the like is accepted as being unlikely but possible. The possibility is deemed to exist when a fault develops in the equipment e.g. a flange gasket fails, a pipe fractures. These occurrences come under the category of 'wear and tear'. It is possible that a leakage may result from some mal-operation e.g. a heavy object is accidentally dropped onto equipment that contains a hazardous fluid e.g. a pipe, which either pierces the metal or loosens a joint. These occurrences may be categorised as 'accidental' causes, and can be considered as being statistically low, hence the risk of explosion is also low. They may be considered unlikely to occur over a long period of time (months, years) or if they do then the time period will be short (up to 10 hours per year, see Reference 1).

10.4.3 Zone 1 Hazardous Area

A higher risk of hazard than that applicable to a Zone 2 area, is found in a Zone 1 area. Again it can be considered that the plant is properly designed and maintained. However, some parts of the plant are more prone to leakage than others, some types of seals used in rotating shafts of pumps and compressors, discharges from safety valves, some methods of venting gases and vapours, some types of open drains for volatile liquids. Hence leakage may be considered likely to occur some time during a long period (tens of hours or longer in a year, see Reference 1). The risk of an explosion in a given period of time is therefore higher than with a Zone 2 area.

10.4.4 Zone 0 Hazardous Area

The highest risk of hazard is to be found in a Zone 0 area. These areas are usually the gaseous volume immediately above a volatile liquid contained in a vessel or tank. In some situations the contents of a vessel or tank will normally be at atmospheric pressure e.g. crude oil storage tanks in an exporting tank form, refinery feed stock tanks, temporary storage of liquid products in a chemical plant. Some designs of vessels and tanks need a means of venting to prevent an increase in surface pressure as the liquid rises, or a reduction in pressure as the same liquid falls. In a large tank these small changes in surface pressure, and hence the enclosed vapour pressure, can cause serious damage to the tank walls and roof if some form of two-way venting is not allowed. The surroundings close to the atmospheric vent aperture would therefore be a Zone 0 area.

10.4.5 Adjacent Hazardous Zones

In many locations where a hazardous area is identified and numbered as 0, 1 or 2 the immediate surroundings are given the next higher number, except for an original Zone 2 area, which automatically is surrounded by a non-hazardous area. A Zone 0 area is surrounded by a Zone 1 area, which in turn is, surrounded by a Zone 2 area. A Zone 2 area stands alone.

During the preparation of drawings that show the extent and shapes of the areas surrounding a source, it is usually found that overlapping areas create complicated geometrical shapes, e.g. two adjacent circular boundaries almost touching each other. In these situations the shapes should be simplified by using tangent lines. Local pockets within the geometry should be absorbed into a more uniform shape, especially non-hazardous pockets in Zone 2 geometry. Experience shows that equipment located in a non-hazardous area that is 'near' to a Zone 2 area will usually be of the same specification as that which is to be installed in the Zone 2 area. The same approach is sometimes used for Zone 2 areas near to a Zone 1 area if the equipment are small items e.g. junction boxes, lighting fittings, instrument casings, and local control stations.

10.5 TYPES OF PROTECTION FOR HAZARDOUS AREAS

Most electrical equipment consists of live or active static parts, and in some cases such as motors, solenoid valves and relays moving mechanical parts, encased in an enclosure. The electrically live conductors are kept out of touch to prevent electric shock hazards. The detrimental effects of the atmosphere e.g. rain, sprayed water, fine dust and particles are kept out of contact with the conductors, insulation, bearings and the like. For equipment that is to be used in hazardous areas there is the additional requirement that gases and vapours should be restricted from entering into the enclosure. There are various basic methods that attempt to ensure that this requirement is achieved at a more or less degree, which generally is dependent upon the Zone of the intended area of installation.

The design of the enclosure with regard to hazardous area applications is defined by several lower case letter codes, mostly single digits for electrical power equipment but occasionally two

Table 10.4. Enclosure codes for hazardous area equipment

Ex or EEx code	Brief description
d	Flameproof enclosure
e	Increased safety
i	Intrinsic safety. There are two types ia and ib
m	Encapsulated enclosure
n	Basically a UK concept that is similar to type 'e', but only for use in Zone 2 areas
o	Oil-immersed enclosure
p	Pressurisation and continuous dilution by non-hazardous air or inert gas such as nitrogen
q	Sand-filled enclosure
s	Special designs of enclosure or system of components

digits for very low energy electronic equipment. The most frequently encountered codes are d, e, n, p and i. The lesser used codes are o, m, s and q. Table 10.4 gives a brief description of each code. The codes are usually embraced with double or single quotation marks, or less often single round brackets ( ). The code is prefixed with the letters Ex or EEx. Occasionally two letters are combined for special designs of equipment e.g. Ex 'de' for some types of motors.

Reference 3 gives a useful Table 1 therein, that relates various international standards to the different types of protection 'd' to 's'.

10.5.1 Type of Protection 'd'

This type of protection is also referred to as 'flameproof' in some literature. An enclosure that is designed as type 'd' will be able to withstand an internal explosion of the gas-air mixture without being damaged beyond repair. Furthermore the mating surfaces of joints e.g. terminal boxes, bearing seals on shafts, will be so designed that the flame inside the enclosure will not pass to the outside with sufficient energy to ignite the environmental gas-air mixture. In effect the design of the surfaces is such as to act as a very slow pressure relief system for the internal explosion. (Care should be exercised when dismantling such an enclosure after an internal explosion has occurred, because there may be some residual pressure internally.)

By the form of the design these enclosures are usually robust, 'heavy duty' and often made of thick cast iron, steel or bronze with many bolts to fasten the fabricated sections and lids. They are therefore the most expensive enclosures when compared with the 'e' or 'p' types. It becomes impractical to manufacture 'd' type enclosures for very large ratings of motors. The amount of metal and machining required would not be economical and so the 'p' type would be an alternative.

This type of protection is mainly intended for Zone 1 areas.

In addition the electrical components inside the enclosure may be of the sparking type e.g. commutators for DC motors, local control stations with push buttons, relay boxes.

When an internal explosion occurs or under normal running conditions, the outside surface of the enclosure must not exceed the gas-air autoignition temperature i.e. Temperature Class.

The maintenance procedures for working with Ex ‘d’ equipment need to be exercised with care so that the machined surfaces are not degraded or damaged. BS5345 was introduced in 1976 to address this and similar subjects. See Reference 4 for practical view of the problems involved with maintenance of hazardous area equipment.

10.5.2 Type of Protection ‘e’

Type ‘e’ is also called ‘increased safety’ and intended for apparatus that is to be installed in a Zone 1 area. Two of the allowable features of the type ‘d’ enclosures, namely permitting sparking components and no Temperature Class limit to the internal components, cannot be incorporated into the type ‘e’ designs. The practical aspect of this is the removal of a source of ignition i.e. a spark or a hot surface. In many types of equipment e.g. luminaries, terminal boxes, junction boxes, some designs of motor control stations, telephones and public address speakers, the elimination of these two sources of ignition is not a difficult problem.

For motors the removal of sparking components, such as a commutator is not too difficult, but the prevention of a hot internal surface is a problem for the designer. Clearly a DC motor cannot be designed as an ‘e’ type machine. The identification of hot-spots in the windings or core of a motor at the design stage is extremely difficult. This applies especially to the rotor cage of an induction motor. Consequently the design of an ‘e’ motor needs to be somewhat conservative. For example the temperature rise of the windings needs to be reduced. The power output of an ‘e’ type motor for a given frame size is generally found to be less than for type ‘d’ or ‘p’ motors. There are also restrictions on the allowable starting current and run-up time. Hence the motor characteristics will need to be more carefully matched to the driven machine. High inertia rotors in the driven machines should therefore be avoided. This conservativeness is also supported by the requirement that the protective relay equipment at the motor control centre shall have special characteristics. Hence the use of an ‘e’ type motor means that a ‘system’ of components or equipment must be used, not just the motor by itself. This adds an element of ‘unusualness’ to the circuits in a motor control centre, and for this reason the use of ‘e’ type motors in the oil industry is not common practice.

10.5.3 Type of Protection ‘i’

Intrinsically safe type ‘i’ protection is not applicable to electrical power equipment. It is mainly intended for electronic measuring and control circuits i.e. instrumentation and telemetry. The principle behind ‘i’ protections is that a circuit and its devices do not have sufficient operating energy or stored energy to cause a spark that will ignite the gas-air mixture. A spark can occur but it must be inherently too weak to ignite the mixture. There are two sub-divisions of type ‘i’, namely ‘i_a’ and ‘i_b’. The type ‘i_a’ has a more stringent specification than ‘i_b’ and is therefore allowed to be used in a Zone 0 area. Type ‘i_b’ equipment cannot be used in a Zone 0 area.

Like the type ‘e’ protection of motors a ‘system’ approach is required for type ‘i’ equipment. The system includes the source of power and its Zener Barrier, the interconnecting cables which by their nature have inductance and capacitance, and the connected apparatus or load. If the connected apparatus has inherent capacitance or inductance then extra attention must be paid to the design and certification of the system. Reference 1 Chapter 13 gives more information about certifying a system of components.

10.5.4 Type of Protection 'm'

Type 'm' enclosures are encapsulations, for example an electronic circuit encapsulated in solid epoxy resin or fire-resistance solid material. There are very few examples in electrical power equipment used in the oil industry.

10.5.5 Type of Protection 'N' and 'n'

This type of protection does not have any particular title description. It also has some mixed connotations with type of protection 'N' which is very similar but not identically the same.

The subject of type of protection 'N' attracted much debate in the 1980s and 1990s, as explained in Chapter 6 of Reference 1 and Reference 5, much of which centred around whether or not sparking equipment could be included in an enclosure.

The 'N' was originally developed in the UK and became covered by BS4683 Part 3. BS4683 has been superseded by BS6941, which has been updated in 1997. BS5000 part 16 covers non-sparking motors with the type of protection 'N'. The use of type of protection 'N' in zone 2 areas may not be universally assumed to be completely satisfactory, as described in Reference 5 which recommends that some action should be taken to reduce the hazardous situation when a release of gas occurs. Taking appropriate action manually may not be achievable on a highly reliable basis in practice. A form of automatic action will be needed such as a 'fire and gas detection' scheme, with alarms and tripping functions.

References 1 and 5 give good descriptions of the background to the development of the type 'N' concept.

Type 'n' was not covered by the early editions of IEC60079, it became included as Part 15 in 1987.

The basic concept of type 'n' protection was to have an enclosure design that would be suitable for Zone 2 areas. The application to Zone 1 areas was deliberately excluded. Consequently it should be possible to design an enclosure which is 'better' than standard industrial designs of good quality and which has some similarity with type 'e' designs. The intent was to have non-sparking components inside a suitable enclosure, and to have a certifiable item of equipment for Zone 2 use. Inherent in the concept of a good quality industrial design for use in a Zone 2 area is the need for a robust water and dust resistant enclosure. Hence the IEC and BSI standards require a certain high level of 'ingress protection', see sub-section 10.6. In most cases the minimum ingress protection is IP54, but fully insulated conductors IP44 may be used e.g. motors.

As far as motors are concerned, the emphasis on hot surfaces, high starting currents and extended run-up times is not as great as with type 'e' for Zone 1 areas, due to the inherently lower risk of hazard in a Zone 2 area. Special protective relays are not required and a 'system' approach is not used. Similar design features in the mechanical part will be found e.g. clearances of fan blades, length of the air-gap between the rotor surface and the stator inner surface. Oil company specifications often call for non-sparking materials for the construction of the fans.

Other types of equipment than motors are often chosen with type 'n' enclosures, e.g. luminaries, junction boxes, terminal boxes, if the designer can be sure that they will be located in a Zone 2 or non-hazardous area.

Note: Until 1999 the practice in the USA did not recognise type 'n' or the certification of equipment for Zone 2 (Division 2) areas. In these areas good quality, standard industrial equipment may be installed. It is worth noting, however, that the NEC, Reference 2, was revised in 1999 and Article 500 now includes the IEC system of zones and the types of protection 'd', 'e', 'm', 'n', 'o', 'p' and 'q' in Article 505. Type of protection 'N' is not included.

10.5.6 Type of Protection 'o'

With this type of protection the active and sparking parts of the equipment are immersed in mineral oil. The concept is similar to that used in the manufacture of bulk oil immersed and small volume oil immersed switchgear (both of which are seldom encountered nowadays). Oil immersion finds application with electronic and telemetering equipment.

Type 'o' protection is only permitted in Zone 2 and non-hazardous areas. Oil immersed switchgear is not normally specified in the oil industry because there are far better insulating media available in modern designs e.g. SF6 and vacuum.

10.5.7 Type of Protection 'p'

This is also known as pressurisation or continuous dilution. It is mainly applied to large motors, control panels, display panels, and occasionally special purpose generators. Type 'p' protection is suitable for Zone 1 and Zone 2 areas.

Type 'p' protection allows well-designed standard industrial equipment to be used in hazardous areas, provided that the enclosure is suitable for pressurisation by air or an inert gas. The enclosure should be reasonably airtight so that the pressurisation can be maintained by a modest throughput of air or gas.

The pressurisation process is carried out in two parts, the first part when the equipment is ready to be energised and the second part to cater for the running and shutdown of the equipment.

The first part is called 'purging'. Air or inert gas is passed into and vented from the enclosure, to purge out any gas-air mixture that may be present. The equipment is prevented from being energised until the purging cycle is complete. The purging cycle will need to pass a prescribed volume of air or inert gas through the equipment. Measuring devices will be incorporated into the purging equipment to ensure that the necessary volume of air or gas has been passed. If the purging equipment fails then the enclosure cannot be energised. The purging equipment maintains a throughput of air or gas to balance the leakage to atmosphere from joints, bearing seals, gaskets and the like, and to maintain a prescribed pressure inside the enclosure.

The purging air must be drawn from a non-hazardous area source e.g. through suitable ducting or from a plant air compressor. If the enclosure is large, as in the case of high voltage motors, then the use of plant air may present problems of air consumption. The purging gas for a small enclosure may be taken from high-pressure storage cylinders, using a suitable pressure reduction regulator.

Wherever the purging medium is derived from, it should be filtered and dried so that the enclosure is not contaminated or dampened, and the insulation of the internal components degraded.

10.5.8 Type of Protection 'q'

This type of protection uses sand or similar dry powder to exclude the flammable gas-air mixture. It is mainly intended for electronic equipment as it has very little application in the oil industry.

10.5.9 Type of Protection 's'

Type 's' protection is also called 'special' protection and enables unusual designs to be designed, tested and certified. It is a little used method and the applications are mainly suited to electronic and low power equipment.

10.5.10 Type of Protection 'de'

The type of protection 'de' is a hybrid of the 'd' and 'e' types. It is mainly used for motors. The concept is that the motor is type 'd' whilst its terminal boxes are type 'e'. This hybrid concept evolved from the difficulties experienced with the use of 'direct' and 'indirect' entry of the cables at their terminal boxes. A direct entry requires a barrier gland, which is filled with a compound to displace all the air pockets inside the gland where the cable conductors are exposed. An indirect entry does not require a barrier gland. However, with both methods the cable gland must be of the type of protection 'd', with the correct threading to suit the terminal box.

The type 'e' terminal box contains the winding terminations, which are usually in the form of threaded studs mounted on a robust flameproof partition or interface. The studs are sealed into 'through-type' insulators, which are often made of epoxy resin compound. The arrangement ensures a strong hermetical seal between the internal volume of the motor and that of the terminal box. Since the components inside the terminal box are of the non-sparking type and their surface temperature is kept low by design, then the box can be certified as type 'e'. There must be a fully sealed barrier or interface between the type 'd' part and the type 'e' part.

Barrier glands are generally unpopular in the oil industry because of the practical difficulties associated with making and remaking the glands in difficult environments, for example during periods of routine maintenance.

The introduction of BS5345 in the mid-1970s focused attention on maintenance and installation of hazardous area equipment for the first time. It placed responsibility on the user of equipment in addition to that which already existed for the manufacturers.

Keeping the materials clean and dry whilst the glanding is being prepared is sometimes difficult e.g. outdoors offshore in bad weather, in dusty desert conditions.

Overall the type 'e' terminal box with a non-barrier type 'd' gland provides an economical as well as a very practical method of terminating cables.

The method has potential with equipment other than motors e.g. local control stations, switched socket outlets.

10.6 TYPES OF PROTECTION FOR INGRESS OF WATER AND SOLID PARTICLES

10.6.1 European Practice

Whether equipment is certified for hazardous area use or not, it needs to be suitable for the daily environment in which it will be installed. The description of the environment as 'daily' takes account of human interaction with the equipment. For example motors may be installed in a normally dry location either indoors or outdoors, but the plant personnel may regularly hose down the location with water. Equipment may be installed in a plant room that is protected against fire by water spray heads.

IEC60529 is the most commonly used standard for defining the 'degree of ingress protection' for both liquids and particles. (IEC60694, 1996 version, also describes the coding with particular emphasis on switchgear and controlgear, and IEC60034 part 5 to rotating electrical machines.) The most familiar form of the 'IP' code is described herein. The 1989 and later versions of the standard do have some additional refinements for special situations.

The basic code has six digits of the form, I P n m a s. The first two signify 'Ingress Protection' and do not change. The third digit n, refers to ingress by particles. The fourth digit, m, refers to ingress by liquids. The digits n and m range from 1 to 9, the higher the number the more protection is provided. Some combinations of n and m have a generally accepted connotation. The fifth digit a, is called an 'additional letter' and relates to the diameter and length of across probes that can gain access to parts that are a hazard in terms of electric shock. The sixth digit s, is called a 'supplementary letter', and relates to high voltage, rotating and stationary dangerous internal parts. It also relates to extra protection requirements for specified weather conditions. The fifth and sixth letters are often omitted.

Note: Large particles should be read as to include human hands, fingers, insects, tools and foreign bodies.

The familiar form is that which is well understood by manufacturers, suppliers and their customers.

The protection against particles is summarised in the Table 10.5:

Table 10.5. Ingress protection against particles

Third digit	Brief description of the protection provided against particles
0	No mechanical protection
1	Particles greater than 50 mm diameter e.g. human hands and several fingers, rods, screwdrivers
2	Particles greater than 12 mm diameter e.g. one finger, rods, screwdrivers
3	Particles greater than 2.5 mm diameter e.g. thin rods, thin screwdrivers
4	Particles greater than 1.0 mm diameter e.g. wire, course dust, sand
5	Small particles less than 1.0 mm diameter e.g. find dust, cement powder.
6	Complete protection

Table 10.6. Ingress protection against liquids

Forth digit	Brief description of the protection provided against liquids (typically water)
0	No mechanical protection
1	Water droplets falling vertically, i.e. condensation droplets, not heavy rainfall
2	As for 1, except that the enclosure can be inclined in angle up to 15° from its normal position
3	Rain water or sprayed water. Falling vertically or at angle up to 60° from the vertical (horizontal spray is excluded e.g. man with a hose pipe)
4	Water being splashed from any direction e.g. rain water hitting the ground, but not under pressure
5	Water applied by jets from any direction e.g. hose pipe with a nozzle
6	Conditions on the deck of a ship (or offshore platform), during stormy seas and high waves; this implies good water tightness at atmospheric pressure
7	Submersed in water at a given depth for a given time e.g. 1 m depth for 30 minutes; this prescribes a hydrostatic pressure greater than atmospheric pressure
8	Submersed in water at a given depth for an indefinite time; this implies that almost complete protection is provided

The protection against liquids is summarised in Table 10.6:

It can be seen in practice that the design of a jointed surface or an enclosure grill to protect against particles will, by its physical construction, satisfy to some extent the requirements for ingress of liquid. Table 10.7 shows an approximate relationship between the two requirements, and shows those codes which are generally available from manufacturers.

When hazardous area equipment is being specified, it will need to be given a minimum degree of ingress protection. The degree will depend upon whether the equipment is to be installed outdoors and exposed to the extremes of the weather, or indoors and exposed (or not) to dust or liquid ingress. The degree may also depend upon whether the equipment is located at ground level or, for example, attached to a ceiling in a plant room. If the location is outdoors, then the IP code will typically vary between IP54 and IP66. For indoor equipment in a hazardous area not exposed to particles or water, the minimum IP code would be typically IP44. The installation designer should consult the manufacturers of particular types of equipment e.g. motors, luminaries, in order to determine what minimum IP is normally available. It is often easy to overspecify equipment by being too cautious or conservative, and this results in severely restricting the manufacturers that are available in the market place or they will decline to offer equipment. This causes delay in a project and necessitates revising a specification and repeating the enquiry process.

10.6.2 American Practice

A similar approach to the IP code is used in the USA and is described in the ANSI/UL and ANSI/ISA standards but a 'Type Number' is used instead of the two or four digit code (n, m, a, s). The basic principles are very similar. Reference 2 Article 500-4 summarises the subject and quotes the appropriate codes and standards.

Table 10.7. Commonly used IP codes for protection of enclosures against particles and liquids

First number for particles	Second number for liquids								
	0	1	2	3	4	5	6	7	8
0		–	–	–	–	–	–	–	–
1		IP 11	IP# 12	–	–	–	–	–	–
2		IP# 21	IP# 22	IP# 23	–	–	–	–	–
3		IP 31*	IP 32	IP 33	IP 34	– –	– –	– –	– –
4		IP 41*	IP 42*	IP 43	IP# 44	–	–	–	–
5	–	–	–	–	IP# 54*	IP# 55*	–	–	–
6	–	–	–	–	–	IP 65*	IP 66*	IP 67	IP 68

Complete code = IP + first number + second number
These are the usually preferred combinations of the first and second numbers.
*Note: These are the codes most frequently used in general.
#Note: These are the codes most frequently used for motors.

In the USA the National Electrical Manufacturing Association (NEMA) places certain standards on electrical products. This organisation has established a 'NEMA' type coding system for enclosures. Each type, numbered from 1 to 13, describes a specific type of protection, see ANSI/NEMA standard 250.

The NEMA coding system specifically includes three categories for equipment that is to be installed in oil industry hazardous areas, namely Types 7, 8 and 9, but only for indoor locations.

In the interest of completeness all the NEMA 'types' are summarised below:

10.6.2.1 Type No. 1: General purpose

An enclosure intended for indoor use where there are normal atmospheres. The enclosure protects against accidental contact of personnel with the enclosed control.

10.6.2.2 Type No. 2: Drip-proof

An enclosure intended for indoor use to protect the enclosed control against falling non-corrosive liquids and falling particles. These enclosures must have provisions for drainage.

10.6.2.3 Type No. 3: Dust-tight, rain-tight and sleet (ice) resistant

An enclosure intended for outdoor use to protect the enclosed control against windblown dust and water. These enclosures must have provisions for watertight connectors, provisions for mounting external to the enclosure cavity and provisions for locking.

10.6.2.4 Type No. 3R: Rainproof and sleet (ice) resistant

An enclosure intended for outdoor use to protect the enclosed control against rain. These enclosures must have provisions for watertight connectors, for locking and for drainage.

10.6.2.5 Type No. 3S: Dust-tight, rain-tight and sleet- (ice) proof

An enclosure intended for outdoor use to protect the enclosed control against windblown dust and water and to provide for its operation when the enclosure is covered by external ice or sleet. These enclosures do not protect the enclosed equipment from malfunction due to internal icing. These enclosures must have provisions for watertight connectors, for mounting external to the enclosure cavity and for locking. In addition, these enclosures must have the ability to support the additional weight of ice and to withstand the removal of ice by a hand tool to permit access to the enclosure interior.

10.6.2.6 Type No. 4: Water-tight and dust-tight

An enclosure intended for indoor use to protect the enclosed control against splashing water, seepage of water, falling or hose-directed water and severe external condensation. These enclosures must have provision for watertight connectors and for mounting external to the enclosure cavity.

10.6.2.7 Type No. 4X: Water-tight, dust-tight and corrosion-resistant

Same as Type No. 4 with corrosion-resistant construction.

10.6.2.8 Type No. 5:

Superseded by Type No. 12

10.6.2.9 Type No. 6: Submersible, water-tight, dust-tight and sleet-(ice) resistant

An enclosure intended for use indoors or outdoors where occasional submersion is encountered. The enclosure protects the enclosed control against a static head of water of 6 feet for 30 minutes, dust, splashing or external condensation of non-corrosive liquids, falling or hose-directed water, lint and seepage. These enclosures must have provisions for watertight connectors and mounting external to the enclosure cavity.

10.6.2.10 Type No. 7: Class I, Group A, B, C or D indoor hazardous locations air-break equipment

An enclosure intended for indoor use in the atmospheres and locations defined as Class I, Group A, B, C or D in the National Electrical Code. The letters A, B, C or D, which indicate the gas or vapour atmospheres in the hazardous location must appear as a suffix to the designation Type 7, to give the complete NEMA designation.

Note: Type 7 enclosures are termed explosion proof as defined in NEMA and the National Electrical Code.

10.6.2.11 Type No. 8: Class I, Group A, B, C or D indoor hazardous locations oil immersed equipment

Same requirements as for Type 7 regarding locations, atmospheres, marking and use of suffix letters to designate NEMA type.

Note: Type 8 enclosures are used for oil immersed equipment and are 'not' considered explosion proof as defined in NEMA or National Electrical Code.

10.6.2.12 Type No. 9: Class II, Group E, F or G indoor hazardous locations air-break equipment

Type 9 enclosures are intended for use indoors in atmospheres defined as Class II and Group E, F or G in the National Electrical Code. The letters E, F or G, which indicate the dust atmospheres in the hazardous location, must appear as a suffix to the designation Type 9, to give the complete NEMA designation. These enclosures prevent the ingress of explosive amounts of hazardous dust. If gaskets are used, they must be mechanically attached and of a non-combustible, non-deteriorating, vermin-proof material.

Note: Type 9 enclosures are 'not' considered explosion proof as defined in NEMA or the National Electrical Code.

10.6.2.13 Type No. 10: Bureau of mines

Type 10 enclosures must meet the requirements of the US Bureau of Mines, which relate to atmospheres containing mixtures of methane and air, with or without coal dust present.

Note: Type 10 enclosures are termed explosion proof as defined in NEMA and National Electrical Code.

10.6.2.14 Type No. 11: Corrosion resistant and drip proof-oil immersed

An enclosure intended for indoor use to protect the enclosed control against dripping, seepage and external condensation of corrosive liquids. In addition, the enclosures protect against the corrosive effects of fumes and gases by providing for the immersion of the control in oil. These enclosures must have provisions for watertight connectors and for mounting external to the enclosure cavity.

10.6.2.15 Type No. 12: Industrial use dust-tight and drip-tight

An enclosure intended for indoor use to protect the enclosed controls against fibres, flyings, lint, dust, dirt and light splashing, seepage, dripping and external condensation of non-corrosive liquids. All accesses to the enclosure cavity must have oil-resistant gaskets and where necessary dust-tight or oil-tight mechanisms. These enclosures must have mounting means external to the enclosure cavity, captive closing hardware and provisions for locking.

10.6.2.16 Type No. 13: Oil-tight and dust-tight

An enclosure intended for indoor use primarily to house pilot devices such as limit switches, foot switches, push-buttons, selector switches, pilot switches etc., and to protect these devices against lint and dust, seepage, external condensation and spraying of water, oil or coolant. These enclosures must have oil-resistant gaskets and when intended for wall or machine mounting, must have mounting means external to the enclosure cavity. There are no conduit knockouts or unsealed openings providing access into the enclosure cavity. All conduit openings must have provisions for oil-tight conduit entry.

10.7 CERTIFICATION OF HAZARDOUS AREA EQUIPMENT

In general the installation designer and the user require confidence that manufactured equipment for use in a hazardous area carries an internationally recognised certificate. In addition the certificate should be the result of laboratory testing of a sample of the same equipment. The laboratory should be specialised in the type of testing required.

In the UK and Europe a certificate is required from the manufacturer for equipment that is to be used in Zone 1 and Zone 2 areas. In some situations a certificate will be obtained for a system of components, for example with intrinsically safe equipment.

In the USA the practice is slightly different. Only equipment that will be installed in a Division 1 area should require a certificate.

For manufacturers offering a range of products, the process of testing and obtaining a certificate is expensive and time consuming. Subsequent modification to a design can also be a long and expensive process for retesting and re-approval.

Over the last 15 years there has been a process called 'harmonisation' of the various national standards within the UK and Europe with the internationally accepted IEC standards. This has made the subject of certification rather complicated, but as time passes the results should be simpler to obtain both for the manufacturer and to the satisfaction of the user.

The harmonisation process has been managed by the Committee of Electrotechnical Standardisation (CENELEC) in Europe. The committee standardises many subjects of electrical and electronic engineering, not only those pertaining to hazardous area equipment and its installation. When equipment is certified in accordance with a CENELEC standard the symbol 'Ex' is modified to become 'EEx'. This serves to give the designer and the user extra confidence in the certification.

The certification process, like so many other manufacturing functions, is now being influenced by the generally accepted requirement for quality assurance, through the ISO9000, 9001 and 9002 standards.

There are several permutations for certification involving European harmonisation and countries inside or outside the EC (European Community). Equipment can be manufactured in any country. The manufacturer may choose to design his equipment to the national standards of his country, or he may wish to cover a wider market by using an international or even a CENELEC standard. Once the equipment is manufactured, samples of it will need to be tested. There may be a testing authority in the particular country, or for some reason the manufacturer may choose to have the testing carried out in another country e.g. the testing laboratory may have a wider scope of facilities. Eventually the manufacturer will obtain a certificate. The installation designer and the user may need to carefully scrutinise the whole sequence of events leading up to the issuance of a valid certificate. Reference 1 explains the European situation in detail, together with the various types of certificates that are obtainable from within Europe and from other continents. The subject is complex and requires careful study to ensure that the correct documentation is obtained.

10.8 MARKING OF EQUIPMENT NAMEPLATES

Hazardous area equipment that has been tested and approved by a recognised laboratory should have a marking plate attached to its surface, in a place easily seen by the user. This plate is usually the nameplate that shows the normal information such as the name of the manufacturer, voltage, rated power, full load current, frequency, model number, serial number, ambient temperature and date of manufacture. The additional information to be shown for the hazardous area application, should be at least the following:

- Applicable national or international standard e.g. BS5501 Part 5, IEC60079 Part 2.
- Name or abbreviation of the testing laboratory that issued the certificate, e.g. BASEEFA.
- Approved symbol for the certifying authority, and if appropriate the EEC hexagonal symbol.
- Type of protection e.g. EEx ‘d’, Ex ‘e’, Ex ‘n’.
- Gas Group e.g. IIA, IIB, IIC.
- Temperature Class e.g. T6.
- Certificate unique identification number.

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FURTHER READING

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