कर्नाटक केन्द्रीय विश्वविद्यालय ಕರ್ನಾಟಕ ಕೇಂದ್ರೀಯ ವಿಶ್ವವಿದ್ಯಾಲಯ
Central University of Karnataka
(Established by an Act of the Parliament in 2009)

Electrical Equipments in Hazardous Industries

Madhumita Sanjay Patil III year B Tech Dec 2021

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Abstract

Many fire accidents have happened in the hazardous industries in the past and many have lost their lives in such incidents. In some hazardous industries it has led to catastrophic disasters. If we go through the investigation of such incidents the electrical spark is one of the root causes for such incidents.

In my project I have tried to study on the precautions to be taken in electrical installations in the hazardous industries, the applicable electrical standards and equipment selection as per hazard classifications

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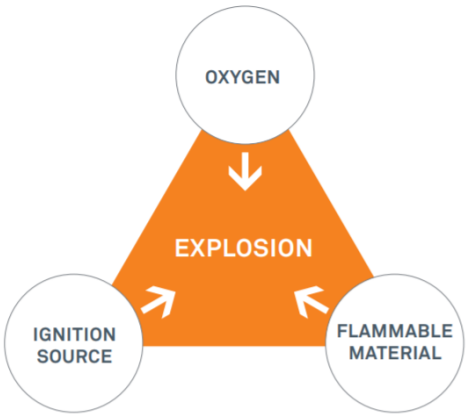
Introduction & Problem Definition

For heating we need to generate fire for industrial as well as domestic use. Many of us use the fire on a regular basis in our daily life. But uncontrolled fire or incidental fire can lead to disaster. Fire or explosion can happen when the fire triangle is complete.

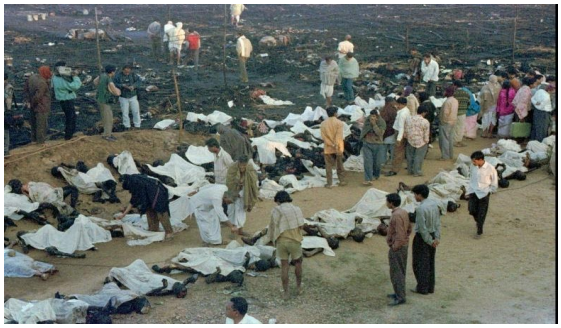


As a rule, for explosions to happen in atmospheric air, three factors have to be present at the same time
(see Figure)

- flammable material
- oxygen (air)
- source of ignition

Oxygen is available in air, many industries like Oil and Gas, Paint industry, Chemical industries substantial amount of flammable material is available, so it becomes vital to prevent source of ignition for fire incidents not to happen. As electrical power equipment is required to carry out different functions in the industry it becomes highly important the electrical equipment should be designed or selected in such a way it will not become a source of ignition in the hazardous Industry.

To understand the importance of it, let us see some unfortunate incident that happened in India which could have been avoided if proper equipment would have been used.

	The Jaipur oil depot fire broke out on 29 October 2009 at 7:30 PM at the Indian Oil Corporation oil depot's giant tank holding 8,000 kilolitres of petrol, in Sitapura Industrial Area on the outskirts of Jaipur, Rajasthan, **killing 12 people and injuring over 300.**
	Date: 23 December 1995. Venue: Rajiv Marriage Palace, Mandi Dabwali. Location: Mandi, District Sirsa, Haryana, Type: Building Fire. Cause: Short Circuit. Deaths: **500 including 258 children.**
	A fire broke out at state-run Bharat Petroleum Corporation's Mahul refinery in Mumbai, injuring about **40 people**. The accident took place around 2:45 pm on 08-Aug-2018
	On 24 May 2019, a fire occurred at a commercial complex in Surat in the Gujarat state of India. **Twenty-two students died** and others were injured in an academic coaching centre located on the building'

Solution methodology

Hazardous Area:

It is defined as the area in which the atmosphere contains, or may contain in sufficient quantities, flammable or explosive gases, dust or vapours. In such an atmosphere a fire or explosion is possible when three basic condition are met

Explosive atmosphere:

An explosive atmosphere is a mixture of air and combustible material in form of gases, vapours, mist or dust, in which – due to an ignition by sufficient energy combustion spread to the entire unburned mixture.

Prevention of explosion: To eliminate the risk of explosion, one of the three elements of the fire triangle must be removed. Two possibilities exist to prevent explosion.

1) Primary explosion protection

2) Secondary explosion protection

Primary explosion protection

Primary explosion protection is based on the concept of preventing the formation of a potentially explosive atmosphere.

These might include:

1. Using a substitute for flammable material.
2. Substituting the oxygen with inert gases.
3. Using gas detectors
4. Preventing formation of an explosive atmosphere in hazardous area

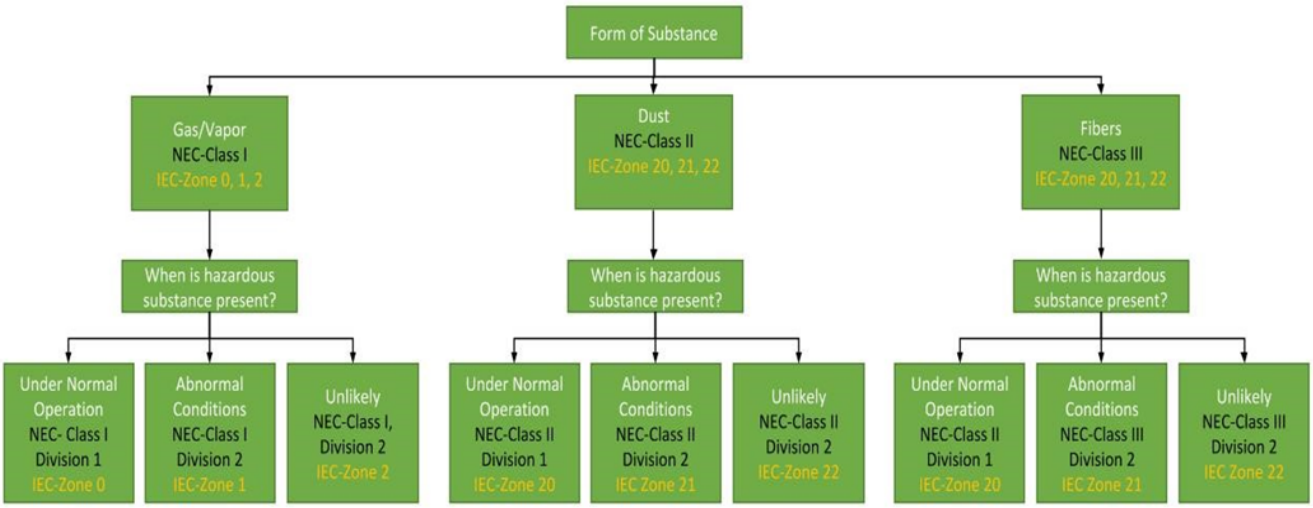
Secondary explosion protection

Secondary explosion protection is related to preventing the ignition of potentially explosive atmospheres. This means avoiding sparks, flames, hot gas or hot surfaces, as well as eliminating other possible ignition sources such as electromagnetic, ultrasonic etc.

Code and standards

- IS 5571: Guide for Selection of Electrical Equipment for Hazardous Area
- IS 5572: Classification of Hazardous Areas (other than mines) having Flammable Gases & vapours for Electrical Installations
- IS 9570: Classification of Flammable Gases or Vapours with Air according to their Maximum Experiment Safe Gaps and Minimum Igniting Current
- IS 13408: Code of Practice for the Selection, Installation and Maintenance of Electrical Apparatus for Use in Potentially Explosive Atmospheres
- IS 13346: General Requirements for Electrical
- The Petroleum Rules 1976
- NFPA 497A Recommended Practice for
- Classification of Class I Hazardous (Classified) Location for Electrical Installations in Chemical Process Areas
- API RP 500 Classification of locations for Electrical Installations in Petroleum Refineries
- SP-30 (BIS) National Electric Code
- Oil Mines Regulations
- NFPA 30 Flammable and Combustible Liquids Code
- NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals
- OISD 113: Classification of areas for Electrical Installations at Hydrocarbon Processing and handling facilities

Hazardous area classification



Class/Division System

Hazardous locations per the Class/Division system are classified according to the Class, Division, and Group.

1) Class— The Class defines the general nature (or properties) of the hazardous material in the surrounding atmosphere which may or may not be in sufficient quantities.
    a) Class I —Locations in which flammable gases or vapours may or may not be in sufficient quantities to produce explosive or ignitable mixtures.
    b) Class II—Locations in which combustible dusts (either in suspension, intermittently, or periodically) may or may not be in sufficient quantities to produce explosive or ignitable mixtures.
    c) Class III—Locations in which ignitable fibres may or may not be in sufficient quantities to produce explosive or ignitable mixtures.

2) Division—The Division defines the probability of the hazardous material being able to produce an explosive or ignitable mixture based upon its presence.
    a) Division 1 indicates that the hazardous material has a high probability of producing an explosive or ignitable mixture due to it being present continuously, intermittently, or periodically or from the equipment itself under normal operating conditions.
    b) Division 2 indicates that the hazardous material has a low probability of producing an explosive or ignitable mixture and is present only during abnormal conditions for a short period of time.
3) Group— The Group defines the type of hazardous material in the surrounding atmosphere. Groups A, B, C, and D are for gasses (Class I only) while groups E, F, and G are for dust (Class II or III).
    a) Group A—Atmospheres containing acetylene.
    b) Group B—Atmospheres containing a flammable gas, flammable liquid-produced vapour, or combustible liquid-produced vapour whose MESG is less than 0.45 mm or MIC ratio is less than 0.40. Hazardous Area Classifications D103222X012 Product Bulletin 9.2:001 September 2019 Hazardous Area Classifications D103222X012 Product Bulletin 9.2:001 September 2019 2 typical gases include hydrogen, butadiene, ethylene oxide, propylene oxide, and acrolein.
    c) Group C—Atmospheres containing a flammable gas, flammable liquid-produced vapour, or combustible liquid-produced vapour whose MESG is greater than 0.45 mm but less than or equal to 0.75 mm or MIC ratio is greater than 0.40 but less than or equal to 0.80. Typical gases include ethyl, ethylene, acetaldehyde, and cyclopropane.
    d) Group D—Atmospheres containing a flammable gas, flammable liquid-produced vapour, or combustible liquid-produced vapour whose MESG is greater than 0.75 mm or MIC ratio is greater than 0.80. Typical gases include acetone, ammonia, benzene, butane, ethanol, gasoline, methane, natural gas, naphtha, and propane.
    e) Group E—Atmospheres containing combustible metal dusts such as aluminium, magnesium, and their commercial alloys.

f) Group F—Atmospheres containing combustible carbonaceous dusts with 8% or more trapped volatiles such as carbon black, coal, or coke dust.
g) Group G—Atmospheres containing combustible dusts not included in Group E or Group F. Typical dusts include flour, starch, grain, wood, plastic, and chemicals.

Zone System

locations per the Zone system are classified according to its Zone which can be gas or dust. For gas atmospheres electrical equipment is further divided into Groups and Subgroups.

Zone—The Zone defines the probability of the hazardous material, gas or dust, being present in sufficient quantities to produce explosive or ignitable mixtures.

1) Gas
    a) Zone 0—Ignitable concentrations of flammable gases or vapours which are present continuously or for long periods of time.
    b) Zone 1—Ignitable concentrations of flammable gases or vapours which are likely to occur under normal operating conditions.
    c) Zone 2—Ignitable concentrations of flammable gases or vapours which are not likely to occur under normal operating conditions and do so only for a short period of time.
2) Dust
    a) Zone 20— An area where combustible dusts or ignitable fibres are present continuously or for long periods of time.
    b) Zone 21— An area where combustible dusts or ignitable fibres are likely to occur under normal operating conditions.

c) Zone 22—An area where combustible dusts or ignitable fibres are not likely to occur under normal operating conditions and do so only for a short period of time.

Groups

Electrical equipment is divided into three groups.

1) Group I—Equipment intended for use in mines susceptible to firedamp (flammable mixture of gases naturally occurring in a mine).
2) Group II—Equipment intended for use in places with an explosive gas atmosphere other than mines susceptible to firedamp. Group II equipment is subdivided into three subgroups.
    i) Group IIA—Atmospheres containing propane, or gases and vapours of equivalent hazard.
    ii) Group IIB—Atmospheres containing ethylene, or gases and vapours of equivalent hazard.
    iii) Group IIC—Atmospheres containing acetylene or hydrogen, or gases and vapours of equivalent hazard.
3) Group III—Equipment intended for use in places with an explosive dust atmosphere. Group III equipment is subdivided into three subgroups.
    i) Group IIIA—Atmospheres containing combustible dust.
    ii) Group IIIB—Atmospheres containing non-conductive dust.
    iii) Group IIIC—Atmospheres containing conductive dust

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Classification of Hazardous Atmospheres

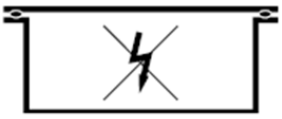
Class I, Division 1 & 2		Typical Atmosphere	Ignition Temp. (C)
GROUP	A	Acetylene	305
	B	Butadlene	420
		Ethylene Oxide	429
		Hydrogen	520
		-Mfg. gases containing more than 30% hydrogen (by volume)	
		Propylene Oxide	449
	C	Acetaldehyde	175
		Clyclopropane	503
		Diethyl Ether	160
		Ethylene	450
		- Unsymmetrical Dimethyl Hydrazine (UDMH)	249
	D	Acetone	465
		Acryonitrile	481
		Ammonia	498
		Benzene	498
		Butane	288
		1 - Butanol	343
		2 - Butanol	405
		N - Butyl Acetate	421
		Ethane	472
		Ethanol	363

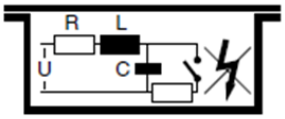
Class I, Division 1 & 2		Typical Atmosphere	Ignition Temp. (C)
GROUP	D	Ethyl Acetate	427
		Ethylene dichloride	413
		Gasoline	280,536
		Heptane	204
		Hexane	225
		Isoamyl Alcohol	350
		Isoprene	220
		Methane	630
		Methanol	385
		Methyl Ethyl Ketone	404
		Methyl Isobutyl Keytone	440
		2 - Methyl - 1 Propanol	416
		2 - Methyl - 2 Propanol	478
		Petroleum Naphtha	288
		Octane	206
		Pentane	243
		1 - Pentanol	300
		Propane	450
		1 - Propanol	413
		2 - Propanol	399
		Vinyl Acetate	402
		Vinyl Chloride	472
		Xylenes	464-529

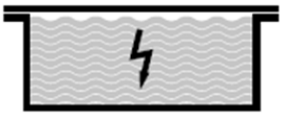
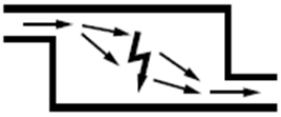
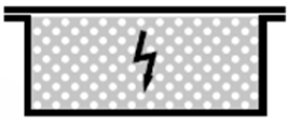
NEC ENCLOSURE CLASSIFICATIONS

1) Explosion-Proof Enclosure: An enclosure which can withstand the pressures resulting from an internal explosion of specified gases, and contain such an explosion sufficiently to prevent the ignition of the explosive atmosphere surrounding the enclosure (for Class I, II and III).
2) Oil Immersion: The electrical apparatus are arranged such that the arcing contacts, connections, etc., are immersed in oil. Arcing is confined under the oil such that it will not ignite an explosive mixture of specified gases above the oil or in the atmosphere surrounding the enclosure (for Class I, II and III).
3) Purged & Pressurised Enclosures: The accumulation of ignitable gases or vapours in the enclosure is prevented by maintaining, inside the enclosure, sufficient flow of clean air or inert gas (for Class I, II and III).
4) Intrinsically Safe Equipment: Wiring that is incapable of releasing sufficient electrical or thermal energy, under normal and abnormal conditions, to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentration (for Class I, II and III).
5) Dust Ignition-Proof: The enclosure prevents the entrance of dust, and external surfaces shall not reach temperatures capable of igniting or discoloration dust on the enclosure or igniting dust-air mixtures in the surrounding atmospheres (for Class II).

ATEX ENCLOSURE CLASSIFICATIONS

Explosion Protection Symbol	Hazardous Area Zones			Description	Drawing
	0	1	2		
"d"		♦	♦	Type of protection in which the parts which can ignite an explosive atmosphere are placed in an enclosure which can withstand the pressure developed during an internal explosion of an explosive mixture and which prevents the transmission of the explosion to the explosive atmospheres surrounding the enclosure.	
"e"		♦	♦	Type of protection in which measures are applied so as to prevent with a higher degree of safety the possibility of excessive temperatures and of the occurrence of arcs or sparks in the interior and on the external parts of electrical apparatus, which does not produce them in normal service.	

"i"	"ia"	♦	♦	♦	Type of protection when no spark or any thermal effect in the circuit, produced in the test conditions prescribed in the standard (which include normal operation and specific fault conditions), is capable of causing ignition.	
	"ib"		♦	♦		
"m"			♦	♦	Type of protection in which the parts which can ignite an explosive atmosphere are enclosed in a resin sufficiently resistant to the environmental influences in such a way that this explosive atmosphere cannot be ignited by either sparking or heating which may occur within the encapsulation.	
"n"			♦	♦	Method of protection for electrical equipment designed so that it will not ignite the surrounding explosive atmosphere in normal operation and under certain fault conditions specified in the standard. There are 5 categories of equipment: nA (non-sparking), nC (hermetically sealed), nR (restricted breathing), nL (limited energy) and nP (simplified pressurisation).	

"o"		♦	♦	Type of protection in which the electrical apparatus is immersed in oil.	
"p"		♦	♦	Type of protection in which the protective inert gas inside the enclosure is maintained at a higher pressure than that of the surrounding atmosphere.	
"q"		♦	♦	Type of protection in which the enclosure is filled with a material in a finely granulated state.	

T- Codes classification

**NEC/CEC Designation T - Code	IEC Designation T - Code	Maximum Surface Temperature	
		°C	°F
T1	T1	450	842
T2	T2	300	572
T2A		280	536

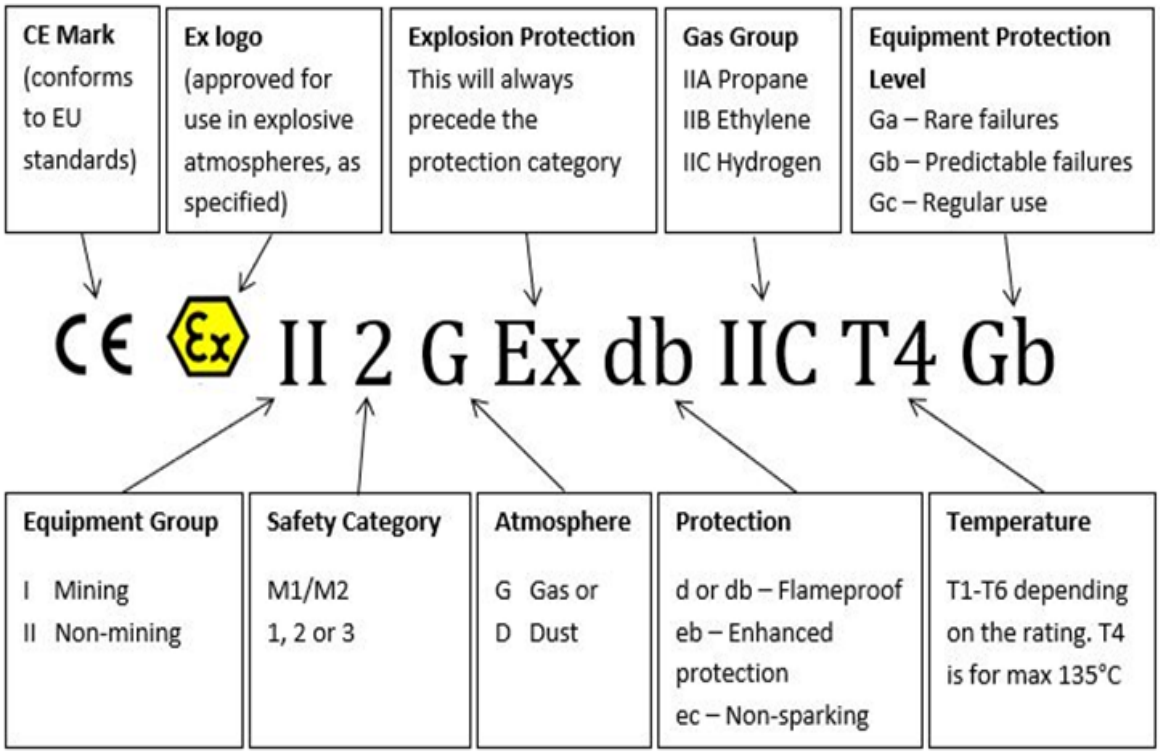
T2B		260	500
T2C		230	446
T2D		215	419
T3		200	392
T3A	T3	180	356
T3B		165	329
T3C		160	320
T4	T4	135	275
T4A		120	248
T5	T5	100	212
T6	T6	85	185

RESULT

HOW TO SELECT THE EQUIPMENT FOR HAZARDOUS AREA

For selection of any kind of equipment that to be installed in hazardous area following things to be kept in mind :

1. Equipment approved to be explosion proof
2. Atmosphere where equipment is to be installed
3. Gas group of the atmosphere
4. Temperature of the atmosphere
5. Explosion protection level that needed to be used for particular atmosphere
6. Equipment protection level that to be used
7. Safety category of the equipment



Selecting motor for hazardous area(example)

Selecting the right kind of motor that meets the requirements for use in hazardous environments is not an easy task. However, manufacturers of electric motors for use in hazardous locations have standard nameplates that contain the following information:

1. Type of Enclosure of Motor
2. Class of hazardous materials for which the motor is suitable
3. Group of the hazardous materials
4. T-code of the electric motor

Characteristics of Motors in Class I, Division 1 & 2 Hazardous Locations

To be able to apply an electric motor successfully in a hazardous environment, these motors must possess certain critical characteristics that make them suitable to operate in this environment without creating problems.

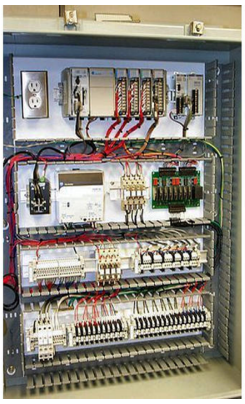
1. These motors must be built and labelled as explosion-proof
2. An explosion-proof motor must contain an internal explosion without rupturing
3. An explosion-proof motor must have flame paths for exhausting hazardous gases during an explosion and for cooling the hazardous material as they leave the motor to prevent further explosion.
4. The more severe the explosion hazards, the stronger the enclosures of the motor and the longer the flame paths. For example, motors for use in group A environments which have acetylene gas require the highest enclosure strength and longest flame paths compared with those used in group D environments with only propane gas.
5. Motors for use in hazardous environments are assigned a temperature code (T-Code), an identification number which describes the maximum temperature of surfaces subject to contact with hazardous materials. The temperature value defined by the T-code applies under all conditions of motor operation including burnt out, overload and locked rotor current.

6. The T-code for a given motor must be less than the AIT of the hazardous gas or mixture in the environment where the motor operates. This is to ensure that the hazardous materials do not spontaneously ignite when it contacts the motor surfaces and enclosure during operation.

Characteristics of Motors for use in Class II locations

1. As class II locations contain ignitable dust, electric motors operating in this kind of environment must be dust-ignition-proof.
2. The enclosures of dust-ignition-proof motors are designed to exclude hazardous materials from accessing the internals of the motors unlike explosion-proof motors.
3. The T-code of a dust-ignition-proof motor must correspond to a maximum surface temperature below the AIT of the hazardous dust materials.

Equipments at different areas

Electrical equipments	at hazardous area	at non - hazardous area
Electrical Panel		

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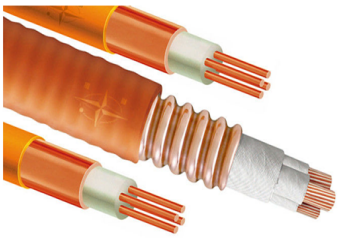
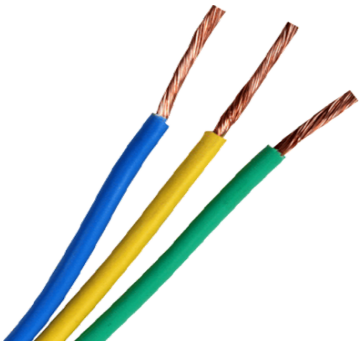
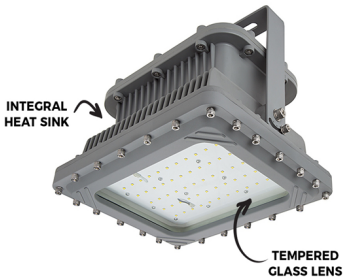
Circuit Breaker		
Junction Box		
Electrical Cables		

Soket		
Lights		
Cable Glands		
Plug		

Conclusion

While selecting the electrical equipment for the hazardous area we need to make sure that we select the standardised approved equipment for the particular area. For selecting correct equipment one should know the exact class, division , group, temperature and atmosphere where the equipment has to be installed. Selection must be done only after the proper study of all the guidelines and the standardised codes because one small mistake can lead to a big disaster.