SAFETY REQUIREMENTS AND SELECTION OF ELECTRICAL EQUIPMENT 
FOR PETROLEUM DRILLING RIGS


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ABSTRACT

The crude oil & gas when drilled and explored out of the earth are mixed with air and may form explosive atmosphere. The drilling rig is a giant structure where different kind of electrical equipment like motors, lighting fittings, control panels, etc. are installed for safe and smooth operation of oil mining. These equipment should be foolproof against any possible hazard of explosion. Such electrical equipment selected for drilling rigs should work safely in normal as well as abnormal condition of operation. The present paper describes the selection and safety requirements of Ex proof equipment for the petroleum drilling rigs.

KEYWORDS: Explosion, Flameproof, Increased safety, Gas Groups, Zones.

INTRODUCTION

Locations defined as hazardous and contains explosive environment, due to presence of explosive gases like hydrogen, acetylene, methane etc or due to presence of combustible dusts which can be ignited by electrical arc, spark, excessive surface temps. Static charges, or mechanical friction between dissimilar material/metals require special equipment designed to work safely without causing explosion.

The drilling of crude oil results in emission of hydrocarbons in the form of gases & vapors like ethylene, propane, etc. These gases coming out from the borehole mix with the air and form explosive zones. The explosive areas are classified in three zones – Zone 0, Zone 1 & Zone 2. Zone 0 is the area in which hazardous atmosphere is normally present continuously. Zone-1 is the area in which hazardous atmosphere is likely to occur under normal operating condition and Zone 2 is the area in which hazardous atmosphere is likely to occur only under abnormal operating conditions. Electrical motors, lighting fittings, control panels, junction boxes, starters, etc. are some equipment, which are installed in these zones to make drilling rig (Figure-1) operational. These all items are having a type of protection against explosion known as flameproof or explosionproof. The Flameproof apparatus is an apparatus designed to sustain explosion pressure developed inside it due to any possible cause of ignition and to prevent transmission of flame from inside to outside area by quenching it between joints, which could ignite surrounding explosive atmosphere. Sometimes, increased safety motors are also used in zone 2 area. These motors are designed to be safe against excessive temperature rise of winding as well as are having non-sparking features with respect to voltage by maintaining adequate creepage distance, clearance and air gap.

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A flameproof electrical apparatus is flameproof due to its mechanical structure. Material of construction, type of joint, length of joint, gap between two surfaces, size & shape of enclosure, nature of gas, etc., Strength of bolts, cementing materials for sealing boxes, cement for glass windows, sealing materials for interconnecting nipples are the parameters which make an apparatus flameproof.

(i) Flameproof Motor

Flameproof motor is one of the basic electrical equipment used on a drilling rig. The applications of these motors are for mud mixing, mud agitator, shale shaker, fuel pump and hole filling, etc. All motors are of different capacity as per application but all should be flameproof or increased safety type for gas atmosphere encountered therein. The gas atmosphere formed by the hydrocarbons emitted from crude oil are classified under gas group IIB.

A flameproof motor is stronger than a standard motor in terms of its pressure sustaining strength. The joints between end shield and the stator housing are normally spigotted joint maintaining min. 12.5mm flamepath and max. 0.15mm gap. All the bolts between end shield & stator housing are having min. 240 N/mm^2 yield strength. Similarly the shaft and inside or outside bearing cover (floating gland) form a flameproof joint. The floating gland & end shield also forms flameproof joint. The terminal studs are effectively fixed into terminal base plate and form metal to nonmetal joint. The terminal studs are effectively spaced from each other with adequate creepage distance & clearances, which make them non-sparking. The cover & terminal box body may either be having flange joint, spigot joint or threaded joint. In case of threaded joint the length of direct axial length should be min. 8mm and min. 5 full threads should be engaged. The cable termination into terminal box is either through double compression cable gland or through sealing box. In case of sealing box the box should be filled completely with cement or cold setting sealing compound. For proper sealing a sealing box normally consists two holes - one for filling compound & other for releasing air to avoid formation of air bubbles. Figure – 2 shows sketch diagram of a flameproof motor.

(ii) Flameproof Lighting fitting:

The drilling rig operates round the clock to extract crude oil from the earth. There is no night for drilling rig and to maintain day light in the area lighting fittings like well glass fitting, tube light luminaries, flood light fittings are installed at all parts. These lighting fittings are flameproof and consist of toughened quality heat and impact resistant glass part. The glass is hold in a glass retaining ring and fixed with cement or epoxy potting compound having min. 10mm length covering three sides. The glass is always supported with a backing plate or ring from inside of the fitting. The flamepaths & gaps or threaded path are always maintained between joints. The glass enclosure and the terminal enclosure are having interconnecting wire nipples or bushings to pass wires and are sealed with epoxy. Wire guard is provided to protect glass part from any mechanical impact. The max. meh size of wire guard permitted is 50 squares mm.
(iii) Flameproof Control Panel/Junction Box:

To operate different electrical equipment control panels and junction boxes are placed at different places. The main purpose of a panel is to regularize the power supply to motors, lighting fittings, pumps, etc. The junction box is used to distribute the power supply from one terminal to another terminal. The control panel or control gear boxes are having the provision to start/stop power supply, indicate the ON/OFF status and to measure electrical parameters like voltage & current by providing voltmeter, ammeter. For flameproof construction the operating rods passing through the press fit bushes into cover maintain cylindrical joint and diametrical clearance as per the gas group of application. The glass inspection windows are provided to read the voltmeter, ammeter readings placed inside the panel.

RESULTS & DISCUSSION

Flameproof apparatus is basically considered as an enclosure where strength of enclosure, gaps & length of joint should be adequate as per gas group of explosive mixture. The flameproof enclosure should pass a sequence of tests to be categorized as Flameproof. These tests are reference explosion pressure test, overpressure test & non-transmission of an internal ignition test. Also impact test, thermal shock test, maximum surface temperature (MST) classification, are the general requirement for all apparatus. Frictional non-incendivity of the material is also checked if the material of construction is light aluminium alloy.

(i) Ref. Pressure Tests:

The tests consist of igniting an explosive mixture inside the flameproof apparatus and measure the pressure developed due to explosion. The enclosure is tested with all the internal components. The development of pressure during the explosion and the pressure rise time are measured and recorded during each test. The highest of the maximum smoothened pressure obtained in these tests shall be taken as reference pressure. The test is repeated five times by changing the position of pressure gauge & spark plug & filling the fresh gas mixture. Figure – 3 shows the maximum explosion pressure recorded (6.3bar at 9.8ms) for a Junction Box for gas group IIB. As a result, no deformation or damage should be observed on walls or cover of enclosure. Motors should be tested both in the running condition without load and in the stationery condition. The pressure should also be measured in the terminal box, where this does not constitute a separate enclosure. The enclosure shall be tested with all the internal apparatus. The hydrocarbons like ethylene, propane comes under gas group IIB. For this test the mixture of the test gas (8±0.5)% Ethylene or (24±1)% (H\textsubscript{2}:CH\textsubscript{4}::85:15) in air.

(ii) Overpressure Test:

The maximum explosion pressure is called reference pressure because taking this into account the empty enclosure is tested at a overpressure hydraulically. This overpressure test is 1.5 times of reference pressure or 3.5bar/cm\textsuperscript{2}, whichever is maximum for at least one minute. No swelling, deformation or damage or leakage should be observed through the wall or cover of the enclosure.
(iii) Non-transmission of an internal ignition:

Each joint of the flameproof apparatus should have minimum length and maximum gap as required in the standard based on the volume and gas group. This minimum length of joint is called flamepath through which the flames will release its heat to the surface or body of the apparatus such as its temperature is less than the ignition temperature of the gas atmosphere. To check this feature, flameproof apparatus is placed in an explosion chamber or enclosed in a polythene bag. The test is made with the same flammable mixture inside the enclosure and in the explosion chamber. The mixture inside the enclosure is ignited by a low energy spark plug. The test is considered to be satisfactory, if the gas mixture present in the surrounding explosion chamber is not ignited. After the test, the mixture in the chamber is deliberately ignited to confirm that outside atmosphere of the equipment is hazardous. At least five tests are made. The mixture in the enclosure and if necessary, in the explosion chamber, being renewed for each test. The percentage of gas mixture used for this test is as follows: (37±0.5)% Hydrogen in air.

(iv) Impact Test:

The weakest parts of the apparatus like glass parts, cable entry bosses, Indicating Lamps, Switches etc., are subjected to mechanical impact tests by freely dropping a mass of 1kg from appropriate height to create impact of 7Joule for metal parts and 2Joule for glass parts provided with guard and 4Joules incase of glass parts provided without guard. This test is satisfactory if it does not violate type of protection of the apparatus.

The height of fall for various impact energy requirement may be estimated from the relationship:  \[ h = \frac{E}{mg} \]

Where, \( h \) = height in m, \( E \) impact energy in Jule, \( m \) is mass in kg, and \( g = 10m/s^2 \).

(v) Temperature Class Test:

The flameproof apparatus is tested at full load and between 90% to 110% of rated voltage for determination of maximum surface temperature attained during the service. The junction boxes or terminal boxes with terminals are supplied with 110% of rated current. Other equipment like lighting fittings are supplied with 110% of rated voltage by fixing lamp of appropriate rating. The surface temperature is measured at each half an hour interval at different locations. When the difference between two consecutive readings is \( \pm 1^\circ\text{C/hr} \) w.r.t. ambient temperature, the test is stopped and the final reading is measured. The maximum of all readings from all locations is considered the maximum surface temperature and the temperature class is classified. The T-class and corresponding maximum temperature is listed in Table-1. In case of increased safety apparatus the maximum temperature of the internal component (winding temperature in case of motor or terminal temperature in case of terminal boxes) is considered for classification of T-class.

(vi) Thermal shock test:

During thermal shock test water of \( 10^6^\circ\text{C} \) is splashed by a nozzle of 1mm diameter on the glass part when the apparatus is at its maximum service temperature. As a result the glass should not crack.
(vii) Frictional Non incendivity test:

Due to its lightweight and non-corrosive properties light aluminium alloy (such as LM6, LM20) is a common material of construction for flameproof Junction Boxes, Control Panels, Light fitting enclosures, etc. But, the elements like Magnesium can cause frictional spark if strikes with rusty surfaces. This resulted in exothermic reaction due to oxidization of magnesium. To, ascertain the non-incendive characteristics of the material, sample is collected from the apparatus made of light alloy and dropped vertically along with a brass weight of 16 Kgs and from a height of 4 meters to the rusty steel plate into an explosion chamber. The explosion chamber contained 28% Hydrogen in air (for IIC) and 21% in case of IIB group. Tests were carried out in a special chamber containing rusty steel plate kept at an angle of 45° to the horizon. No ignition of the hydrogen and air mixture should be obtained due to the impact & friction between the sample and rusty steel plate in all cases.

CONCLUSION

Before selecting the electrical equipment for drilling rig, the area classification and distance of zone from bore hole is necessary. The flameproof equipment can be installed anywhere in zone 1 & zone 2. If the motors are increased safety they should only be installed in zone 2 area. All the cables should be terminated into the flameproof terminal boxes, junction boxes either through double compression cable glands or through sealing boxes completely filled with cement or epoxy. Unused cable entries should be plugged with stopping plugs. Earthing terminals should be provided both internal and external to the apparatus. The equipment should be cleaned routinely to avoid excessive temperature rise of the surface due to accumulation of dusts. The bolts and covers should be tightly fixed. All apparatus should be protected against ingress of dust and water. Minimum of IP65 for fittings, junction boxes, panels and minimum of IP55 for motors is necessary to avoid any short-circuiting due to ingress of water or dust.

If the equipments installed on a rig are very old they must be submitted to a National test house for checking its flameproof features. The rust may be one of the reasons that could damage flameproof properties of an apparatus. Remember! a flameproof apparatus is designed to sustain explosion pressure without any deformation or damage. This test is always non destructive. This test is only destructive if the apparatus was not at all flameproof and damaged during the test. Thank God! It saved your rig.

REFERENCES

Figure 1: Drilling rig

Figure 2: Sketch of a flameproof motor:
Figure 3: Explosion pressure vs time graph for a junction box for IIB area:

![Explosion Pressure vs Time Graph](image)

6.3bar, 9.8ms

Figure 3

Figure 4: Explosion pressure recording arrangement

![Explosion Pressure Recording Arrangement](image)

Apparatus       Sensor       Charge Ampl       PC
Spark plug    Gas mixture

Figure 4

Table 1: Temperature class and corresponding maximum temperature.

<table>
<thead>
<tr>
<th>T-class</th>
<th>Maximum surface temperature in °C</th>
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<tbody>
<tr>
<td>T6</td>
<td>85</td>
</tr>
<tr>
<td>T5</td>
<td>100</td>
</tr>
<tr>
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<tr>
<td>T3</td>
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<td>T2</td>
<td>300</td>
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<td>T1</td>
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Table-1