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Design construction and testing of high voltage (HV) flameproof electric motors for hydrogen explosive atmosphere (IIC) case studies

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Explosion proof motors play vital role in safe operation of industries associated with explosive gas dusts and chemicals of all categories and hence deserve special attention. Flameproof (Ex 'd') electric motors are used in hazardous areas like refineries, petrochemical, underground coalmines and oil mines installed in Zone I and II. Hydrogen is being used as a process gas in various refineries, thereby increasing the demand of Ex 'd' motors for Gas Group IIC area. High Voltage (HV) Ex 'd' IIC motors are being manufactured for the first time in India. Earlier such motors were imported. These motors are tested in CMRI for explosion proof. Case studies were made on three different HV motors and the data presented. The paper shows that it is not difficult for other manufactures to come out with such design, which may be found to be suitable for Gas Group IIC atmosphere. CMRI leads in testing of these motors. HV motors play an important role in the economy of India and are also being exported to different countries.

Keywords: Flameproof electric motors, Hydrogen, Gas group IIC atmosphere

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Introduction

In flameproof enclosure, explosion may occur inside the enclosure, but the enclosure is sufficiently strong to withstand the occurrence of any internal explosion of the flammable gas or vapour and Flame passing from inside to the outside is cooled to such an extent that it is incapable of igniting the surrounding flammable atmosphere. Flameproofness generally depends upon the length of the flame path and diametral clearances between joints and aperture where the shaft is coming out of motor enclosure and cable/ conduit entry box.

The length of flame paths, width of gaps and diametral clearances depend on the internal volume of enclosure and different gas groups of flammable gases. All flameproof electrical equipments are designed and constructed in accordance with IS 2148-1981 (equivalent to IEC 60079-1) and IS 13346-1992 (equivalent to IEC-60079-0) for use in hazardous areas.

The surface temperature rise of motor enclosure is below auto-ignition temperature of surround flammable gas. Pressures piling in motor (rotating electrical machine) from inflammation of pre-compressed gases in one side may abnormally raise the pressure inside the enclosure, which may bring serious situation. Thus, construction and testing of HV motors are important.

Laboratory Testing and Certification of Flameproof Motor Enclosure

Four different types of checks and tests were conducted on flameproof motor enclosure: i) Physical examination of drawing and documents; ii) External ignition test; iii) Determination of explosion pressure test; and iv) Over pressure test.

Physical Examination

It involves measurement of flamepath, diametral clearance and volume of all the enclosures, and verification of the rating of the motor as per design, drawing and rating plate.

Case Studies

Three different HV motors for gas group IIC were investigated (Tables 1 & 2). Results of physical examination are shown in Table 3. Flame path between motor shaft and floating gland is shown in Fig. 1. Code requirement for volume less than 6.0 l is flame path width 25.0mm and diametral clearance 0.10 mm (max). For volume greater than 6.0 l, code requirement has been left on desecration of testing lab.

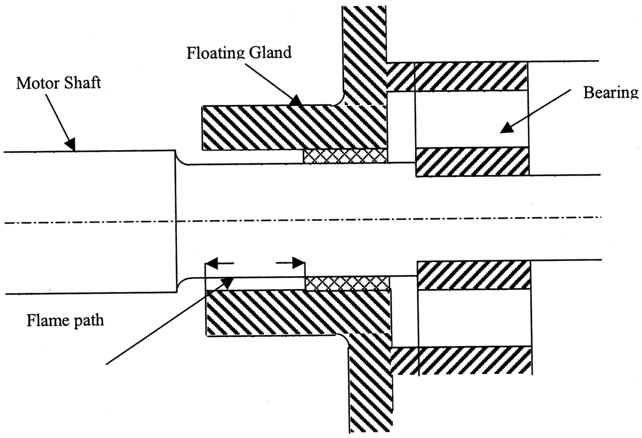

Fig.1 — Flame path between motor shaft and floating gland

External Ignition Test

External ignition ensures that flame is not transmitted from inside enclosure to outside explosive atmosphere and also confirms that the enclosure resists internal explosion effectively.

Procedure

The motor enclosure is to be placed in an artificial chamber, which is constructed around the enclosure by thick polythene sheet (Fig. 2). The test is made with flammable mixture inside the enclosure and in the explosion chamber. The mixture inside the enclosure is ignited by sparking plug. The test is considered satisfactory, if the mixture present in the explosion chamber is not ignited by transmission of flame from the enclosure. It proves that explosion within the apparatus does not propagate the flame outside. The motor

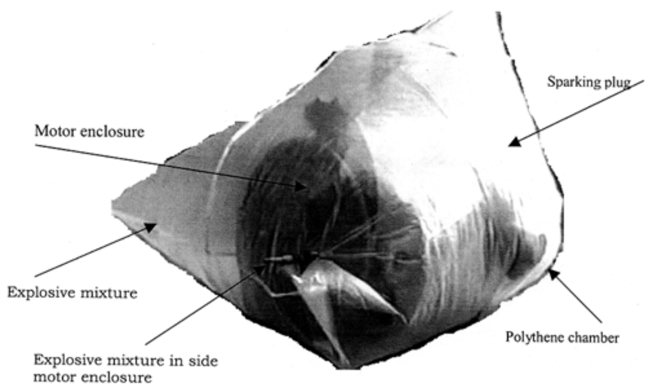

Fig.2 — Motor enclosure inside artificial chamber

Table 1 — Specification of the different motors

S No	kW	Voltage/rpm
Motor (1)	470	6.6 kV/987
Motor (2)	600	11 kV/1496
Motor (3)	300	11 kV/1488

Table 2 — Gross and net volumes of the motors under test

Enclosure	Gross volume l	Net volume l
Motor enclosure (1)	1310	710
Motor enclosure (2)	642	304
Motor enclosure (3)	320	119
Terminal box (1)	52	50
Terminal box (2) and (3)	33	32

Table 3 — Physical examination of motors in respect of length of flame path, gaps, diametral clearance

S No	Locations	Motor enclosure (1)		Motor enclosure (2)		Motor enclosure (3)	
		Min flame path mm	Max gap/ diametral clearance mm	Min flame path mm	Max gap/ diametral clearance mm	Min flame path mm	Max gap/ diametral clearance mm
1	Flame path between DE/NDE end shield and stator case (Yoke)	30	0.13	30	0.10	30	0.10
2	Flame path between DE/NDE floating gland and motor shaft	88.0	0.30	54.0	0.30	47.0	0.30
		Terminal box (1)		Terminal box (2)		Terminal box (3)	
3	Flame path between main terminal box and terminal cover	65.0	0.10	35.0	0.10	35.0	0.10
4	Flame path between main terminal box and lower terminal plate	58.0	0.10	30.0	0.10	30.0	0.10

Nature of flameproof joint: Spigot joint enclosure is considered to be not suitable if surrounding flammable atmosphere is ignited by the flame transmitted from inside to outside enclosure. The test is conducted for the enclosure of the motor with IIC representative gas mixture of 28 per cent hydrogen in air (IS: 2148-1981). The gas mixture inside being ignited by means of a low energy source of ignition the concentration of gas chosen is most easily ignited mixture.

Explosion Pressure (Reference Pressure) Test

Explosion pressure is determined to ensure the design of the equipment as per standard and measure the maximum explosion pressure developed inside the enclosure.

Procedure

The test consists of igniting an explosive mixture inside the enclosure and computer records developed pressure through "Piezo electric transducer and charge amplifier". The peak pressure obtained during test is taken as reference pressure. The rotating electrical machine is tested in running condition without load (motor run by pony motor) and static condition. The explosion pressure plays a vital role for design and development of flameproof motor enclosure (Figs 3-7). Explosion mixture used in test is 31percent H_2 in air as per IS 2148-1981.

On the basis of above data of explosion pressure, it was concluded that: i) Maximum explosion pressure developed by a gas explosion is independent of enclosure size and shape (volume); and ii) The rate of pressure rise increases as the size of enclosure increases (Table 4) that shows the abnormal behavior due to pressure piling in the motor enclosure.

Over Pressure Test (Excess Pressure Test)

The test aims to check the mechanical integrity of enclosure. The over pressure plays important role in flameproof enclosure because explosion pressure is very high for millisecond but hydraulic pressure is continuous for at least 10 sec but not exceeding 1 min.

Procedure

The hydraulic pressure applied should be at least equal to 1.5 times the reference pressure or 10 kg/cm^2, whichever is maximum (i.e. the peak pressure obtained in the test). However, if the pressure rise time obtained in the test is less than 5 millisecond, the test pressure shall be raised to 3 times the reference pressure. In the above motors, hydraulic pressure applied is 20 kg/cm^2 for 1 min. The motor enclosure withstood the over pressure without any visual evidence of distress. Over pressure tests were conducted on motor shell after

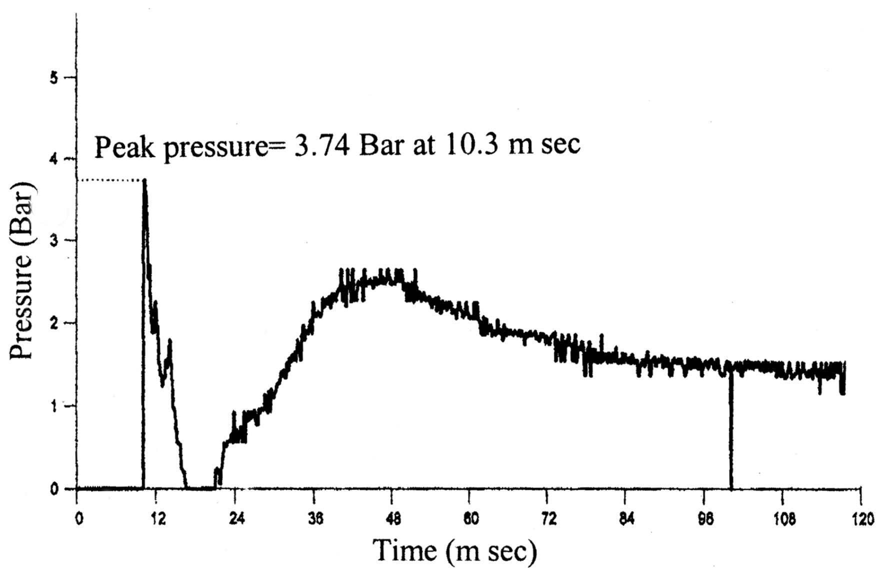

Fig.3 — Reference pressure of motor (1) recorded by a piezo electric sensor

blocking the aperture through which the shaft comes out.

Conclusions

During testing of these motors, it was observed that reference pressure does not vary significantly by increase of motor enclosure volume but it is a known fact that this pressure depends on so many parameters like ignition source, the orientation, the air gap and turbulence inside the motor. The rate of pressure rise

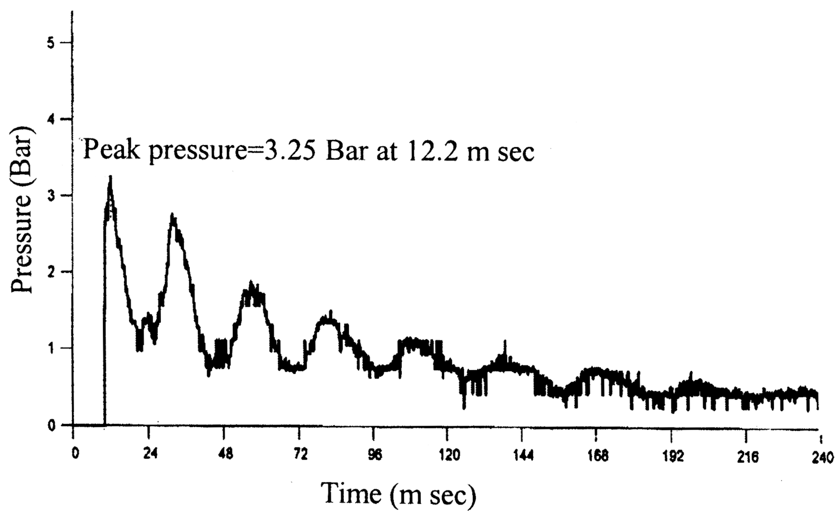

Fig.4—Reference pressure of Motor (1)

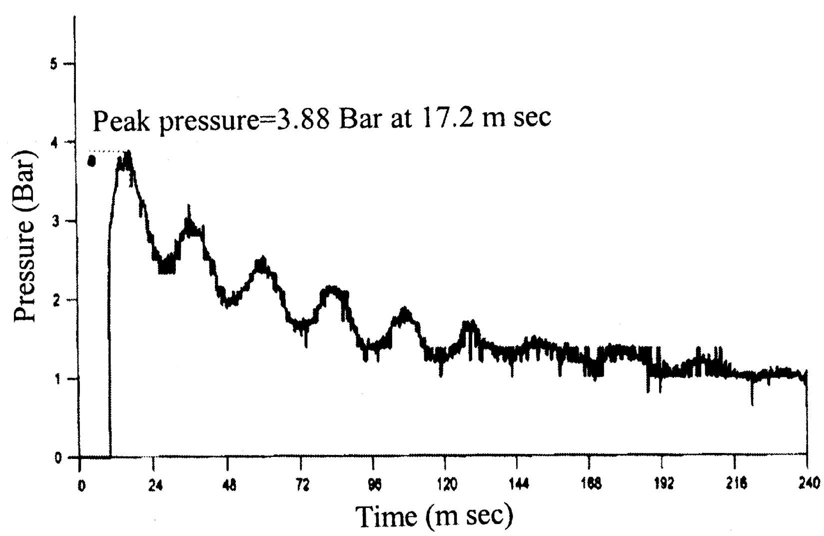

Fig.5—Reference pressure of motor (1)

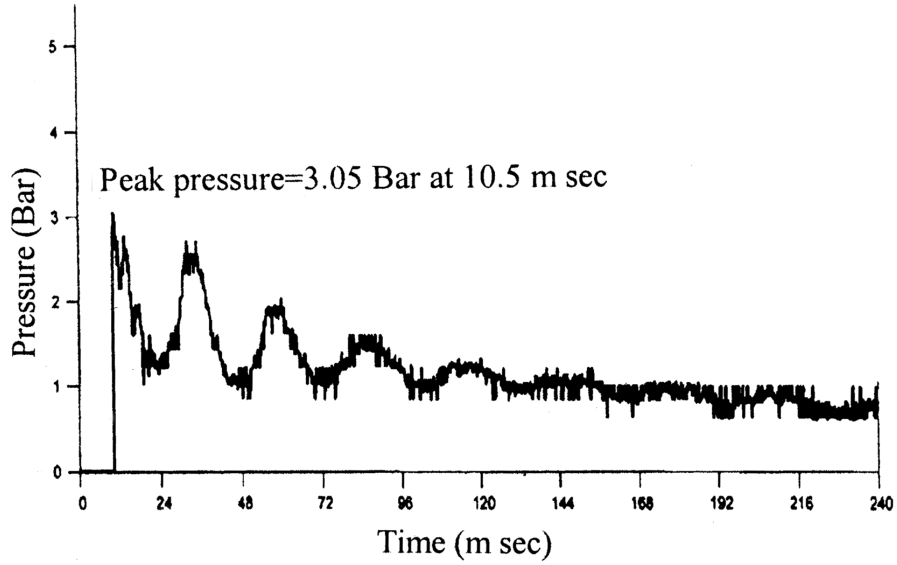

Fig.6—Reference pressure of motor (1)

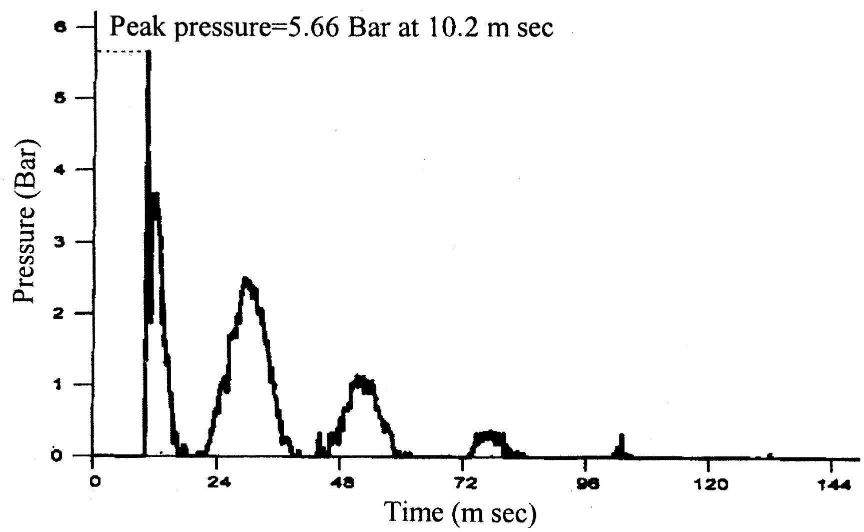

Fig.7—Reference pressure of terminal enclosure (3)

increases as the size of enclosure increases, it shows the abnormal behavior due to pressure piling in the motor enclosure. Explosion pressure inside enclosure increases as the size of enclosure increases, it shows the abnormal behavior due to pressure piling in the motor enclosure. Explosion pressure inside enclosure was maximum when ignition point and measuring position (meter gauge) were closed to each other, which was due to turbulence inside the motor. On the basis of this study, it is advisable that the enclosure having volume greater than 200 l may contain flame path and gap 40.0 mm (minimum) and 0.30 mm (maximum), respectively. It was found that reference pressure during test series varied much widely due to pressure pilling. In this case margin of safety of 1.5 times static pressure is not sufficient.

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