Fire Research Note No 974

EXPLOSION PROTECTION OF EQUIPMENT WITH FLAME ARRESTERS - SPECIFICATION OF METHODS OF TEST AND CONSTRUCTION

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DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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FOREWORD

This specification is based principally on the results of investigations carried out at the Department of the Environment and Fire Offices' Committee Joint Fire Research Organisation, Borehamwood.

It refers to the protection of equipment by means of flame arresters mounted in the casing, when such equipment is used in areas where flammable gases or vapours may occur. In the event of gas or vapour passing into the equipment, and becoming ignited, the usual design is for the pressure developed to be relieved to atmosphere through the flame arresters, which should be so designed that the flame does not pass through them to the exterior. The explosion is thereby vented from the equipment, without causing ignition outside it, and so reducing the pressure.

Because this use of flame arresters was not traditional, there were no specific procedures for the testing of equipment protected with flame arresters in this way.

The present specification has been drawn up for testing purposes. It also contains recommendations as to the methods of construction of equipment protected with flame arresters.

SCOPE

This specification relates to equipment, whether electrical or not, protected with flame arresters and where flammable gas or vapour that may enter the casing can become ignited. The source of ignition may be present in normal working, or may be due to some malfunction. Safety is obtained by preventing the emission of flame from within the casing, and by reducing explosion pressures and so avoid disruption of the casing.

The specification is drawn up for equipment used in surface industries.

REQUIREMENTS AND TESTS

Conditions of acceptance for tests

The manufacturer of the equipment shall submit all required documentation including a complete set of drawings.

The manufacturer shall be responsible for providing any special fittings etc to the equipment, requested by the testing laboratory for testing purposes.

Modifications to equipment

The equipment to be tested, as supplied by the manufacturer, shall be provided with fittings for the entry of the flammable gas/air mixture, for a spark electrode, and for a pressure measuring device, agreed with the testing laboratory.

The flammable gas inlet shall be in a position remote from the arrester to ensure complete displacement of air when charging with the flammable mixture. The mixture supply line shall be provided with a non-return valve as close to the equipment casing as possible. There shall also be a manually operated valve on this line, see Fig.1. With complex designs, more than one gas inlet may be required.

The spark electrode shall be fitted in such a way as to permit ignition in positions remote from the arrester as well as the approximate centre of the equipment.

Test chamber

The equipment shall be tested inside a chamber which is at least ten times greater in volume, with one whole wall consisting of a light explosion relief panel with a bursting pressure of less than 7 kN/m^2 (1 lbf/in^2). A suitable panel material is polyethylene film.

The test chamber shall be provided with the following:

(a) a spark electrode near the explosion relief panel;

(b) a gas inlet, with valve, to convey the flammable gas/air mixture direct to the equipment inside the chamber;

(c) a gas outlet, with valve, to convey waste gas away during charging;

(d) fittings for the required cables, wires, and other services to the equipment under test;

(e) a small electric fan with blades approximately 100 mm diameter, which should be incapable of igniting the flammable gas/air mixture during normal running.

A sketch of the suggested test chamber, containing equipment for test, is shown in Fig.1.

The spark electrode in the equipment under test shall be positioned so as to permit, if required, ignition remote from the arrester as well as in the centre of the equipment (A, B and C Fig.1). The spark electrode in the test chamber (D, Fig.1) shall be mounted in the wall of the chamber. One test shall be carried out with ignition in the centre of the vessel and one in a most remote position from the arrester. The ignition position which gave the higher pressure shall be adopted in the subsequent main series of tests.

All electrodes shall have a spark gap of 1 mm, and be actuated by a 12 V induction coil to give a spark energy of approximately 30 millijoules.

Flammable gas/air mixture

The flammable gas/air mixture normally used in the test shall be as follows:

Propane/air 4.2 per cent by volume; acceptable limits for concentration 4.1 to 4.3 per cent

Ethylene/air 6.5 per cent by volume; acceptable limits of concentration 6.4 to 6.6 per cent

Other gas or vapour mixtures may be used, at the discretion of the testing laboratory.

Pressure measurements

A suitable pressure recording device shall be fitted to the equipment under test in order to record the maximum explosion pressure obtained during test. The number of pressure measurements made during a series of tests shall be at the discretion of the testing laboratory.

Test procedure

1. The equipment under test shall be installed in the test chamber in its normal orientation and the appropriate connections made.
2. With the inlet and outlet valves to the test chamber opened, and the fan running, the flammable gas/air mixture shall be passed through the equipment and test chamber until ten complete changes of atmosphere within the chamber have been achieved.
3. Both valves shall then be tightly closed, and the fan turned off.
4. The flammable gas/air mixture inside the equipment small be ignited at the appropriate position and the maximum explosion pressure recorded.
5. If the explosion is not transmitted to the flammable gas/air mixture in the test chamber, the flammability of the mixture in the test chamber shall be demonstrated by igniting it with the spark electrode at position D. (Fig.1) If the mixture cannot be ignited, the test shall be regarded as void.
6. A new gas mixture shall be prepared for each test.
7. A total of ten tests shall be carried out for each arrangement of the equipment under test. Further tests shall be at the discretion of the testing laboratory.
8. When the equipment under test contains moving parts, the test shall be repeated with these parts moving at normal working speeds unless agreed otherwise with the testing laboratory.

9. Where a gasket is used to obtain a seal between the interior and exterior of the equipment under test, two complete series of tests shall be carried out, with and without the gasket in position, respectively.

10. Examination shall be made of any covers, guards, or other protection of the flame arresters.

11. Safety margins may be established by repeating certain tests with part of the area of explosion relief through the flame arresters blocked off, or with selected holding bolts or screws loosened, or by employing a more vigorous flammable gas/air mixture.

Test report

The results obtained during testing shall be recorded in a test report.

CONSTRUCTION OF EQUIPMENT

Materials

The casing of the equipment, if constructed from welded steel, shall be of thickness not less than 2 mm (14 SWG). Suitable castings, or other materials, may be used subject to the agreement of the testing laboratory.

Joints

All joints, and other inlets on the equipment casing, through which flame might be transmitted from the interior to the exterior of the casing shall be given special consideration. The maximum tolerances, or thicknesses, of any gaps shall not be exceeded, and shall be related to the length of the gap.

Values for maximum clearances, for different gases, are shown in Fig.2.

Windows

When windows are required in the equipment casing, these may be of glass or other material. The testing laboratory shall, however, be satisfied that their strength is adequate and that they could not be hazardous due to their flammability. Exposed panes shall be protected by suitable guards.

Isolation

As a safety measure, suitable pressure or other switches can be installed so that the power supply to the casing is disconnected internally when the lid of the casing is open.

Operating rods and spindles

The maximum diametrical clearances for a given length of aperture shall not be exceeded. Values are given in Fig.2.

Shafts and bearings for motors

The maximum diametrical clearances for a given length of aperture shall not be exceeded. Values are given in Fig.2.

Bolts, screws, studs and nuts

Removable bolts, screws, etc. shall be used in such a way that their removal would not leave an opening to allow the passage of flame from the interior to the exterior of the equipment casing.

Connections to external electrical circuits

Connections from the interior casing to the external circuit, through the wall of the casing, shall be by means of flameproof glands or equivalent protection.

Flame arresters

Crimped metal ribbon flame arresters are convenient, but other types may be used. A crimped ribbon flame arrester is shown in Fig.3. When light and easily shaped arrester material is required, metal foam offers advantages. Figure 4 shows a photograph of the metal foam.

When crimped ribbon arresters are used the width of the ribbon must not be less than 1.8 cm (0.75 in). The crimp height, the height of an individual three-sided cell excluding the metal thickness, must not exceed 0.1 cm (0.040 in) for Group IIA and must not exceed 0.05 cm (0.020 in) for Group IIB gases. The ribbon thickness shall not be less than 0.008 cm (0.003 in). Suitable metals for the ribbon are nickel and stainless steel; other metals may be used at the discretion of the testing laboratory. Aluminium shall not be used.

When metal foam is used, this must be not less than 13 cm ($\frac{1}{2}$ in) thick. It shall be made from corrosion resistant alloys. The pore size of metal foam shall be such that its performance is equivalent to that of an acceptable crimped ribbon arrester.

The arresters may be mounted on the equipment casing as a replaceable unit, or they can be an integral part of the casing. No clearances around the arrester body shall exceed the values shown in Fig.2.

Vent areas

Information is available on the area of vent required to keep explosion pressures down to acceptable values, in vessels of various sizes, with different flammable gas/air mixtures. Figure 5 shows the relationship between the maximum explosion pressure and the vent area for cubical vessels with crimped ribbon flame arresters mounted on one side. The data applies to the vessels containing

insufficient solid contents, stationary or moving, to interfere markedly with the development of the explosion. The data applies to vessels of volume not exceeding 0.085 m^3 (3 ft^3) and of length/diameter ratio not more than three.

If this volume or this ratio are exceeded, the resulting maximum explosion pressures may be higher than those quoted. Also the presence of solid contents occupying a substantial fraction of the interior of the vessel or of moving parts, may raise the maximum explosion pressure.

In general, the maximum explosion pressure should not exceed 100 kN/m^2 (15 lbf/in^2).

The vent area, protected with flame arresters, may be sub-divided and distributed over more than one side of the casing. This sub-division tends to reduce the maximum explosion pressures obtained. A particularly beneficial effect may be obtained by distributing the vent area along the longest wall of the casing, and further enhancement may be obtained by distribution along two opposite walls.

Protection of arresters against accidental damage

All arresters which are exposed should be protected against accidental damage or against paint, by substantial shields. These should provide an open peripheral area of not less than twice the arrester area. Alternativelt, self-closing covers may be used. These may be spring-loaded gravity or magnetically operated devices. They all may cause some increase in the maximum explosion pressure. All such devices shall be tested.

SAFETY MARGINS

Arresters

No arrester shall show any structural damage after completion of all tests.

Safety margins for the flame arresters are based on use of arresters which have apertures adequate for quenching flames much faster than those that may be produced by an explosion within the container.

A flame may pass through an arrester if its velocity of approach is sufficiently high. The critical flame velocity for failure of crimped ribbon arresters due to flame passing through it is given by[1]

$$V = 0.5\ ay/d^2$$

where V is the flame speed (ft/s)

a is the free area: i.e. the proportion of arrester surface area not blocked by ribbon

y is the thickness of the arrester (in)

d is the diameter of the aperture (in)

With crimped ribbon arresters the apertures are often triangular, and the equivalent hydraulic diameter $\left(\frac{= 4 \times \text{area}}{\text{perimeter}}\right)$ should be used.

Photography of explosions in cubical containers of appropriate size without solid contents has shown that the maximum flame speeds did not exceed 30 m/s (100 ft/s) with a 6.5 per cent ethylene/air flammable mixture. Equation 1 indicates that a 2.5 cm (1 in) thick arrester, crimp height 0.05 cm (0.020 in), will quench flames moving with speeds up to 440 m/s (1440 ft/s).

It is not difficult to match the crimped ribbon arrester performance, with an appropriate metal foam of similar flow resistance.

Maximum permissible gaps

Values shown in Fig.2 represent maximum experimental safe gaps divided by a factor of 2. These gaps were obtained at the Joint Fire Research Organisation using an 8 l ($\frac{1}{5}$ ft^3) stainless steel cylinder.

Equipment casing

Safety margins for equipment casings shall be established by tests. A recommended method is that a quarter of the arrester area shall be blocked, by placing a suitably shaped metal plate on the internal surface of the arresters and ten tests shall be carried out using an appropriate flammable mixture, following procedure described previously.

These tests shall be carried out with and without protective covers if these are fitted and at the end of the tests there shall be no structural damage to the casing.

REFERENCE

1. Guide to the use of flame arresters and explosion reliefs. Ministry of Labour. Safety Health and Welfare New Series No 34. H M Stationery Office, London, 1965.

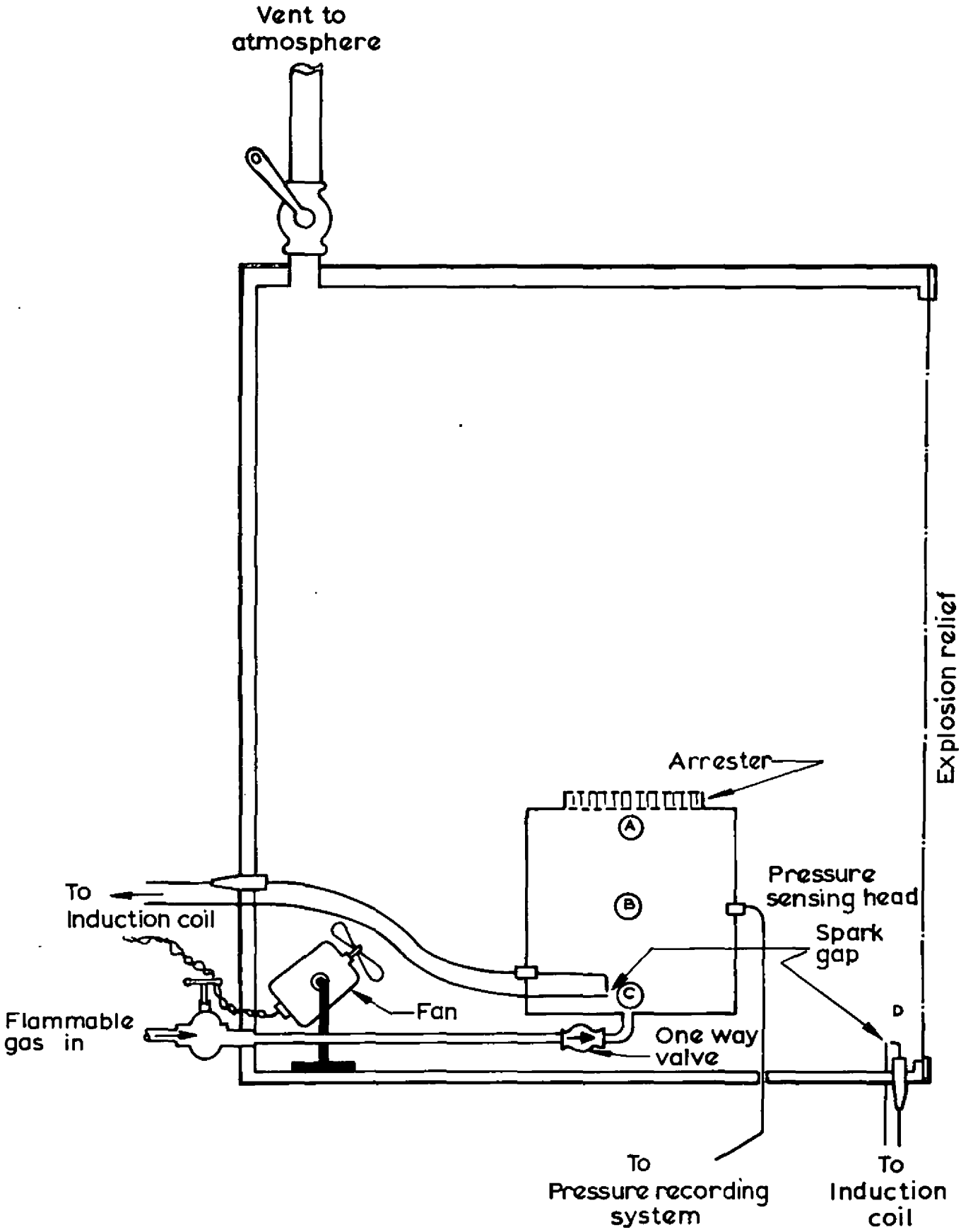


FIG. 1. SUGGESTED TEST CHAMBER WITH EQUIPMENT IN POSITION FOR TESTING

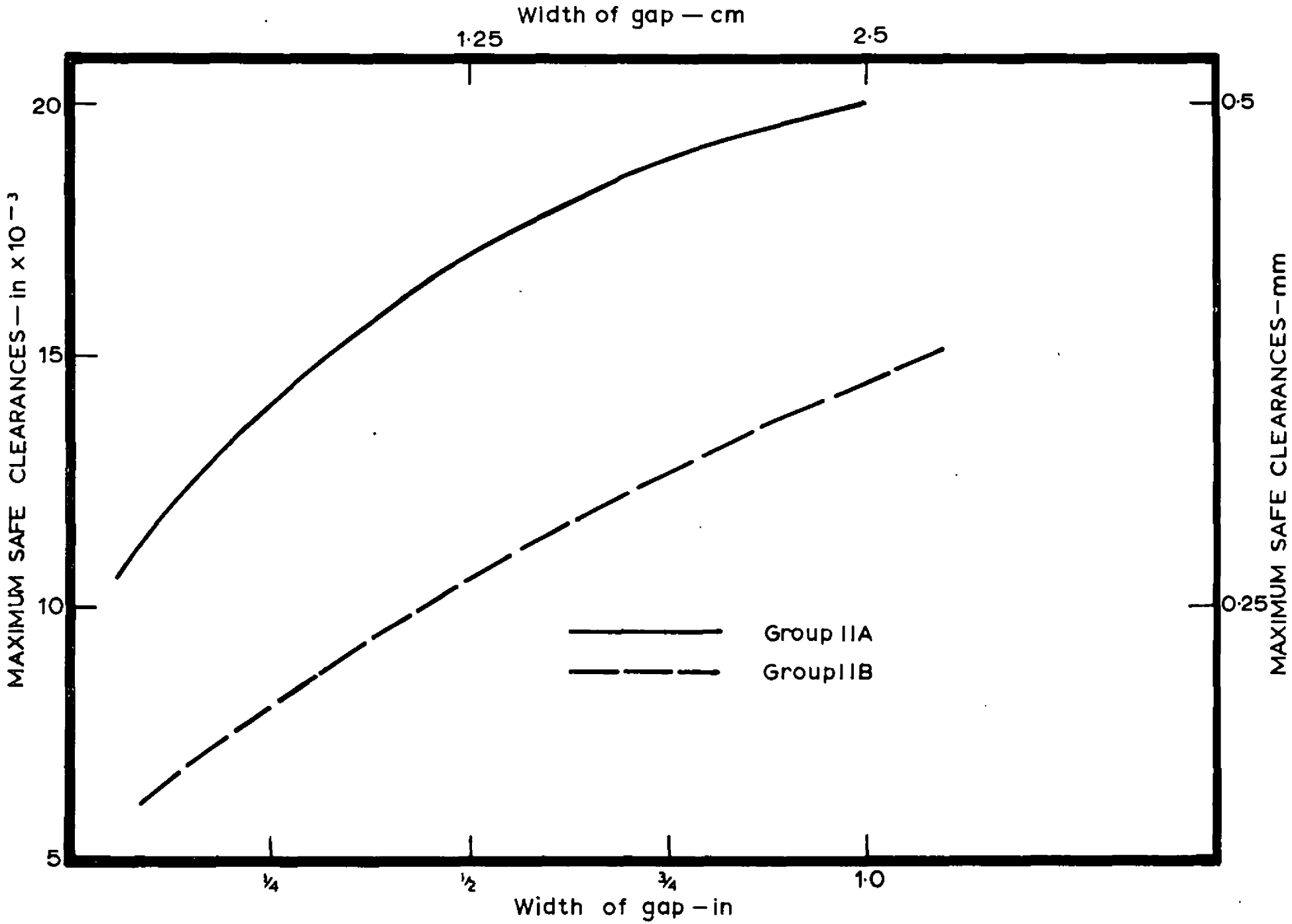


FIG. 2. MAXIMUM SAFE CLEARANCES

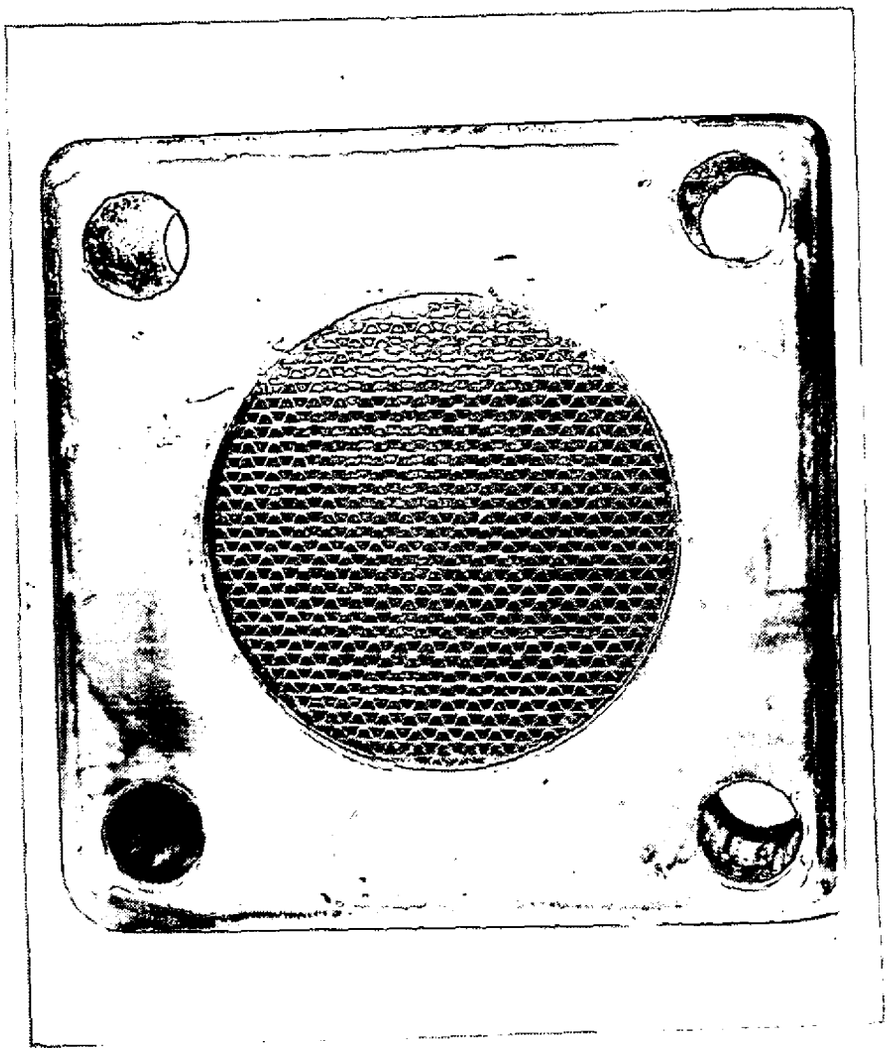


FIG 3. CRIMPED RIBBON FLAME ARRESTER

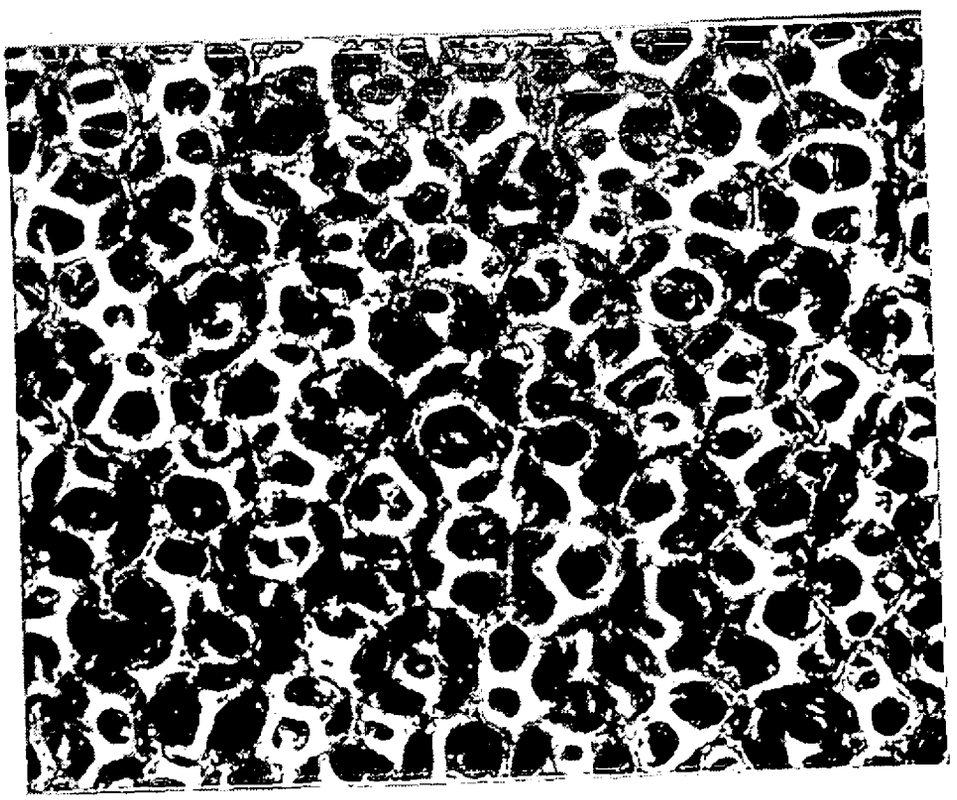
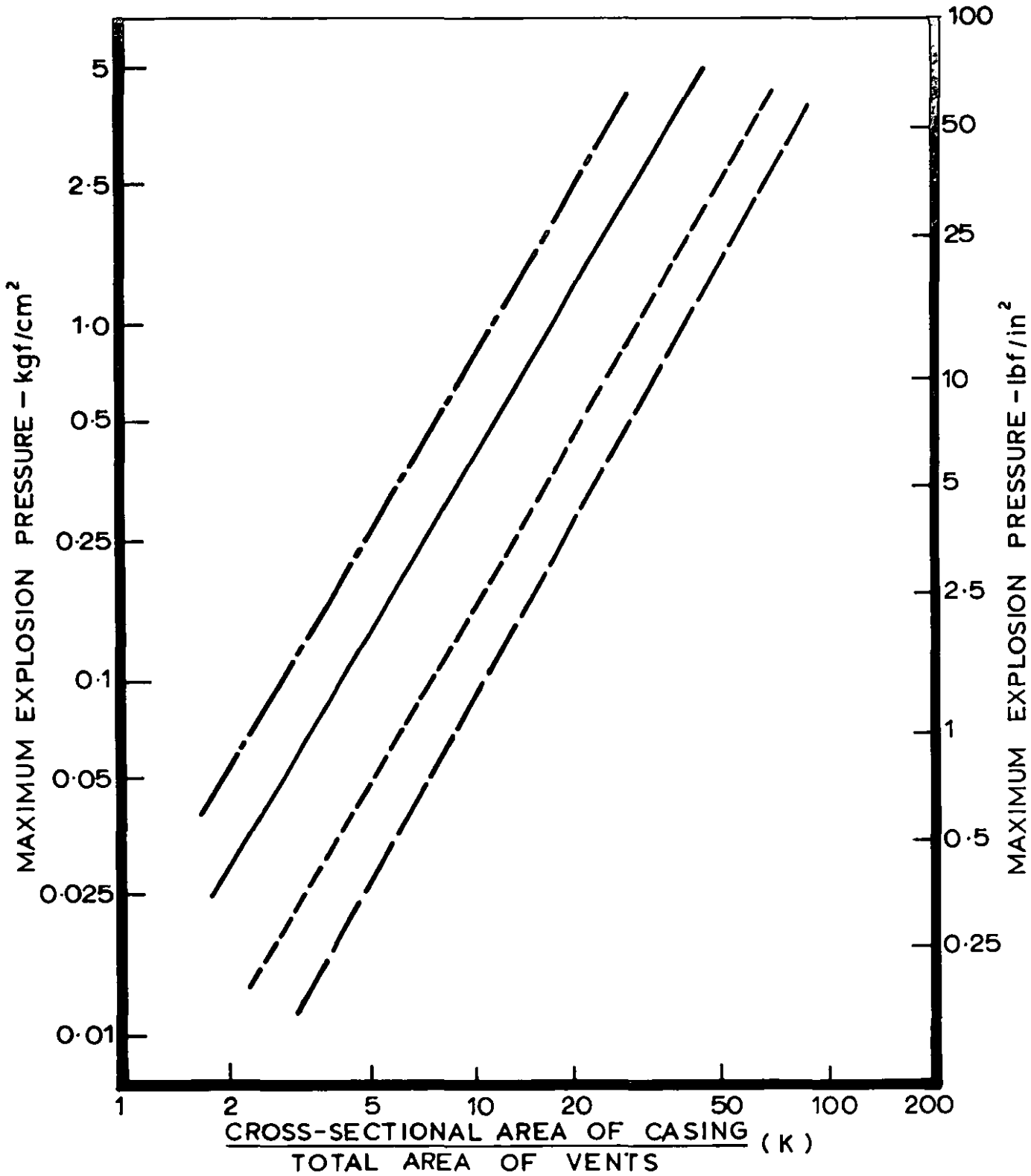


FIG. 4. METAL FOAM



	Flammable gas	Volume
———	Ethylene - air	up to 1ft³
—·—·—	Ethylene - air	1ft³ to 3ft³
— — —	Propane - air	up to 1ft³
- - - -	Propane - air	1ft³ to 3ft³

FIG. 5. RELATIONSHIP BETWEEN MAXIMUM EXPLOSION PRESSURE AND THE VENT AREA

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