UDC 621. 313. 333-213.4+621.317.2-213.4

# NEW-SERIES FLAME-PROOF TYPE THREE-PHASE INDUCTION MOTORS AND EXPLOSION TESTING EQUIPMENT

*By* Tetsuji Ito

Takero Kito

Kunio Takahashi

Mie Factory

## I. INTRODUCTION

The chemical industry has progressed so much recently that demands for flame-proof type electric equipment have risen accordingly. Devices whose flame-proofing is effective against No. 3 type gases (hydrogen, water gas, acetylene, etc.) are particularly needed.

In the field of electric motors, the trend has been toward compact size and light weight because developments in materials and progress in production techniques have been considerable.

In terms of size, Class-E insulation motors which have standards specified by the IEC and are therefore internationally exchangeable have been developed in Japan, and standards for totally-enclosed and open-type three-phase cage-type induction motors were established in JEM 1180 in 1966. Fuji Electric has been systemizing these Class-E insulation motors from several years ago and has completed a new series of electric motors with IEC dimensions and flame-proofing against No. 2 and No. 3a type gases. Frame application numbers for these motors are as per JEM 1180, and installation dimensions are exactly the same as those of convenional totally-enclosed fan-cooled motors.

Since flame-proof electrical equipment is intended for uses in hazardous areas where combustible gases or vapors are expected, perfect safety must be assured. Fuji Electric has studied and tested this equipment in explosion testing facilities with enclosed-type explosion testing chambers, 2400 and 470 liters in volume. The 2400 liter enclosed-type explosion testing chamber is the largest of its kind in Japan; it is very convenient for tests on hydrogen, methane and other gases. The structure and components of the new-series Class-E flame-proof motors are now described.

## II. NEW-SERIES FLAME-PROOF TYPE THREE-PHASE INDUCTION MOTOR

Flame-proof type induction motors for normal industrial uses have been produced to withstand up to type 2 explosive gases as indicated in *Tables 1, 2,* and *3*. A pressurized chamber type structure is generally adopted for type 3 explosive gases, This is mainly because the extremely small flame-proof gap as required from the results of explosion tests has created special production difficulties in the form of extremely high dimensional accuracy. For this reason, flame-proof motors for type 3 gases have not generally been produced. Small size motors of the conventional pressurized chamber type have comparatively expensive auxiliary equipment and require complex handling procedures. Therefore, it would be very practical if flame-proof construction could be used with the motor.

Fuji Electric has completed a new series of flame-proof motors (d2G4 and d3aG1) with output ratings of 0.75 kw∼132 kw at 50 cps and 4 poles for shaft heights of 80 mm∼315 mm.

### 1. Features

1) The new series motors are flame-proof type against No. 3a hydrogen gas (d3aG1)

Although conventional standards require explosion type No. 2 and ignition type No. 4 (d2G4), this new series makes it possible to convert d2G4 into d3aG1 by partially changing the bearing.

*Table 1* Classification of Explosion Types

| Explosion Type | Gap value (in mm) which causes ignition propagation at 25 mm gap depth |
|---|---|
| 1 | Above 0.6 mm |
| 2 | Above 0.4 mm, below 0.6 mm |
| 3 | Below 0.4 mm |

*Table 2* Classification of Ignition Temperature Groups

| Ignition Group | Range of Ignition Temperature |
|---|---|
| G1 | Above 450°C |
| G2 | Above 300°C below 450°C |
| G3 | Above 200°C below 300°C |
| G4 | Above 135°C below 200°C |
| G5 | Above 100°C below 135°C |

*Table 3* **Classification of Typical Explosive Gases**

| Ignition Group / Explosion Type | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| 1 | Acetone<br>Ammonia<br>Carbon monoxide<br>Ethane<br>Acetic acid<br>Ethyl acetate<br>Toluene<br>Propane<br>Benzene<br>Methanol<br>Methane | Ethanol<br>Isoamyl acetate<br>N-butanol<br>Butane<br>Acetic anhydride | Gasoline<br>Hexane | Acetaldehyde<br>Ethyl ether | |
| 2 | Coal gas | Ethylene<br>Ethylene oxide | | | |
| 3 | Water gas<br>Hydrogen | Acetylene | | | Carbon bisulfide |

2) Compact and lightweight

In comparison with the conventional standards for flame-proof construction, these motors are extremely compact and light.

3) Adaptation to IEC dimensions

Since many countries have recently been adopting IEC standards, the dimensions recommended by IEC which allow for use with a wide range of machines and load equipment are adopted as standard for these motors.

4) Bearing mechanism

For bearings with more than 200 mm shaft height, a bearing cover with an automatic shaft-regulating mechanism is used to eliminate undesirable effects caused by contact between rotating shafts and bearing covers due to distorted rotating shafts and other factors.

5) Exchangeability between longitudinal and transverse construction types

Since legs are installed separately from the main body, alternation between longitudinal use and transverse use is easy.

6) Special applications

Corrosion-resistance and weather-proofing can be achieved by slight alterations in construction and treatment.

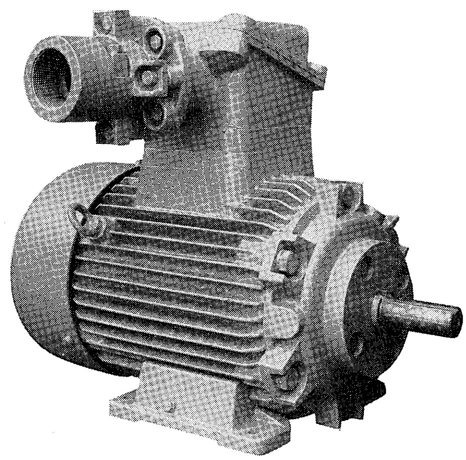

*Fig. 1* Outer view of flame-proof induction motor

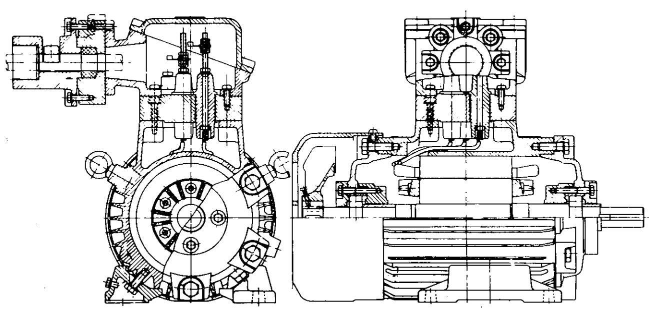

*Fig. 2* Construction of flame-proof type induction motor

## 2. Construction

*Fig. 1* shows an external view of the motor and *Fig. 2* indicates the construction of the motor. This electric motor is of the totally-enclosed fan-cooled type, internal heat is radiated from the surface of ribs, and air is moved from the non-operating side to the operating side. There are two types of internal fans: one is cast directly to the end of the rotor and the other is constructed independently of steel plate. These differences are classiffed by the use of frame numbers. With these internal fans, the heat produced at the stator coil end and rotor conductors is transferred to the interior frame surface and the inside of the shield so that it will radiate from the external ribs.

1) External construction

Strong cast iron is used for the frame and shield which are designed to withstand pressures from explosions as indicated in *Table 4*. Since the legs and frame are not cast in a unit, the leg can be used with longitudinal type electric motors. Better cooling is possible since air is able to circulate through the whole perimeter of the frame. Separate leg installation has made it possible to match dimensions of conventional electric motors and the legs comparatively easily. The terminal box is located on top of the frame for motors with a shaft height up to 132 mm, and the terminal box is positioned at the top in a 45° angle with the vertical line of motors

*Table 4* **Internal Pressure**

| Internal Volume | Less than 2 cm³ | More than 2 cm³ less than 100 cm³ | More than 100 cm³ |
|---|---|---|---|
| Explosion Type 1 | Strength required for production | More than 8 kg/cm² | More than 10 kg/cm² |
| Explosion Type 2 | | | |
| Explosion Type 3 | | More than 1.5 times explosion pressure measured by explosion test; minimum value is above 8 kg/cm² | above 10 kg/cm² |

having a shaft height of more than 132 mm. Optimum values for shape and number of ribs are selected at the exterior perimeter of the frame considering cooling efficiency and casting techniques. High dimensional accuracy of each frame and bracket part is achieved in consideration of the flame-proofing against hydrogen.

2) Construction of shaft feed-through portion

Gap and gap depth must be maintained at extremely accurate and limited values. To achieve these limited values, not only frame, bracket, bearing cover, shaft, and bearing dimensional accuracies but also out-of-round deviation and surface accuracies must be maintained precisely in order to keep the combined errors low. The direct gap with the rotating shaft is maintained by the bearing cover. *Fig. 3* shows the structure of bearings (d2G4 and d3aG1) with shaft heights up to 200 mm; *Fig. 4* indicates bearings (d3aG1) having shaft heights from 200 mm to 315 mm and is almost the same as d2G4 in *Fig. 2*.

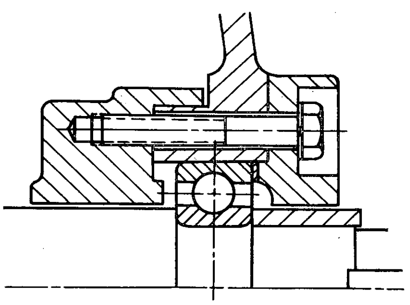

*Fig. 3* Construction of bearing part (d2G4)

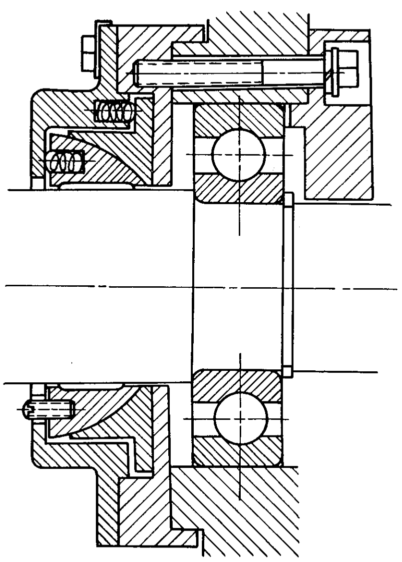

*Fig. 4* Construction of bearing part (d3G4)

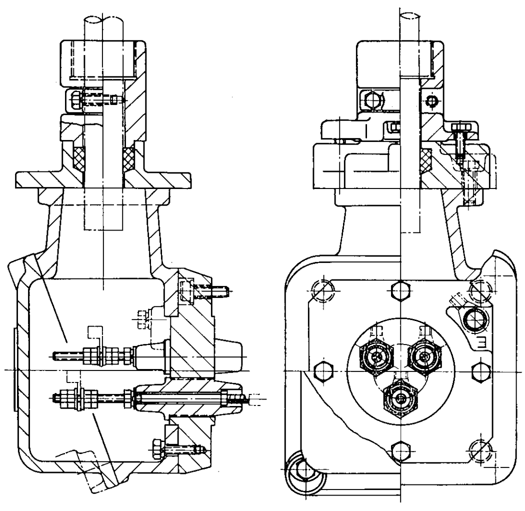

*Fig. 5* Construction of terminal box

Bearings indicated in *Fig. 4* are constructed so that they can conform to shaft deflection caused by the bending moment applied to it during motor operation. This is achieved by using a spherical sleeve with an automatically adjustable center.

3) Bearings

Since the gap in the portion which the shaft passes through is extremely small, single line deep-slot type radial ball bearings are used at both the non-operating and operating sides.

4) Shaft

The gap in the portion which the shaft passes through will be reduced by shaft deflection due to loads in the radial direction during pulley operation and also due to magnetic attractive force caused by unbalanced gap and weight of the rotor. Therefore, extra precautions are taken in determining shaft strength and machining the shaft.

5) Terminal box

*Fig. 5* shows construction of the terminal box. A pressure-resistant packing method is used for leading

*Table 5* **Output of Flame-Proof Type Induction Motors**

| DORK Type | IEC Frame No. | Output (kw) 50 cps | | | | |
|---|---|---|---|---|---|---|
| | | 2 poles | 4 poles | 6 poles | 8 poles | 10 poles |
| 81L | 80 | 0.75 | 0.75 | 0.4 | 0.2 | |
| 91L | 90L | 1.5 | 1.5 | 1.1 | 0.4 | |
| 112 | 100L | 2.2 | 2.2 | 1.5 | 0.75 | |
| 312 | 112M | 3.7 | 3.7 | 2.2 | 1.5 | |
| 411 | 132S | 5.5 | 5.5 | 3.7 | 2.2 | |
| 412 | 132M | 7.5 | 7.5 | 5.5 | 3.7 | |
| 611 | 160M | 11 | 11 | 7.5 | 5.5 | |
| 612 | 160L | 15 | 15 | 11 | 7.5 | |
| 811 | 180M | 19 | 19 | 13 | 9 | |
| 812 | 180L | 22 | 22 | 15 | 11 | |
| 1012 | 200L | 30 | 30 | 22 | 15 | |
| 1211 | 225S | 37 | 37 | 26 | 19 | 15 |
| 1212 | 225M | 45 | 45 | 30 | 22 | 19 |
| 1312 | 250M | 55 | 55 | 37 | 30 | 22 |
| 1512 | 280M | 75 | 75 | 45 | 37 | 30 |
| 1512 | 280M | 90 | 90 | 55 | 45 | 37 |
| 1712 | 315M | 110 | 110 | 75 | 55 | 45 |
| 1712 | 315M | 132 | 132 | 90 | 75 | 55 |

external conductors into the terminal box, and a pressure resistant stud method is used for taking the conductors to the terminal box.

The inner volume of the terminal box is extra large in accordance with " Guide for flame-proof industrial electrical facilities (flame-proofing for gases and vapors—1965) ".

6) Winding

Since both 200 v and 400 v are standard voltages, the motor can be adapted for either 200 v or 400 v

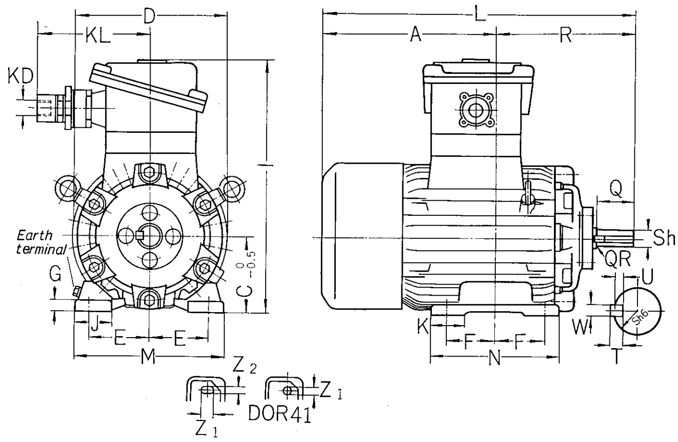


**Table 6 Dimensions of Flame-Proof Type Induction Motors**

No. of poles: 2P~

| Frame | Frame No. | Motor | | | | | | | | | | | | | | | | | Shaft End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | C | D | E | F | G | I | J | K | KD | KL | L | M | N | R | Z1 | Z2 | Q | QR | S | T | U | W |
| 80 | 81L | 210 | 80 | 162 | 62.5 | 50 | 10 | 308 | 45 | 38 | PS1¼ | 208 | 350 | 155 | 135 | 140 | 12 | 9.5 | 40 | — | 19 | 5 | 3 | 5 |
| 90L | 91L | 221.5 | 90 | 182 | 70.0 | 62.5 | 13 | 323 | 50 | 40 | PS1¼ | 208 | 390 | 180 | 160 | 168.5 | 12 | 9.5 | 50 | — | 24 | 7 | 4 | 7 |
| 100L | 112 | 233 | 100 | 200 | 80.0 | 70 | 14 | 338 | 50 | 45 | PS1¼ | 208 | 416 | 200 | 170 | 183 | 13 | 11 | 50 | — | 24 | 7 | 4 | 7 |
| 112M | 312 | 271 | 112 | 222 | 95.0 | 70 | 15 | 362 | 60 | 50 | PS1¼ | 208 | 471 | 230 | 175 | 200 | 13 | 11 | 60 | 0.5 | 28 | 7 | 4 | 7 |
| 132S | 411 | 277 | 132 | 262 | 108 | 70 | 17 | 432 | 64 | 54 | PS2 | 259 | 516 | 256 | 180 | 239 | 11 | — | 80 | 1.5 | 32 | 8 | 4.5 | 10 |
| 132M | 412 | 296 | 132 | 262 | 108 | 89 | 17 | 432 | 64 | 54 | PS2 | 259 | 554 | 256 | 218 | 258 | 11 | — | 80 | 1.5 | 32 | 8 | 4.5 | 10 |

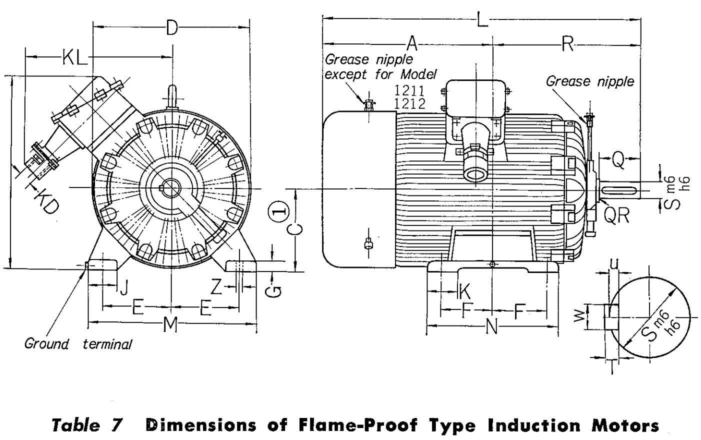


**Table 7 Dimensions of Flame-Proof Type Induction Motors**

| Frame | Frame No. | No. of Poles | Motor | | | | | | | | | | | | | | | Shaft End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | C | D | E | F | G | I | J | K | KD | KL | L | M | N | R | Z | Q | QR | S | T | U | W |
| 160M | 611 | 4~ | 428 | 160 | 310 | 127 | 105 | 20 | 430 | 70 | 65 | PS2 | 395 | 751 | 306 | 256 | 323 | 15 | 110 | 1 | 42 | 8 | 4.5 | 12 |
| 160L | 612 | 4~ | 450 | 160 | 310 | 127 | 127 | 20 | 430 | 70 | 65 | PS2 | 395 | 795 | 306 | 300 | 345 | 15 | 110 | 1 | 42 | 8 | 4.5 | 12 |
| 180M | 811 | 4~ | 455.5 | 180 | 350 | 139.5 | 120.5 | 22 | 505 | 80 | 83 | PS2½ | 480 | 807 | 350 | 292 | 351.5 | 15 | 110 | 1.6 | 48 | 8 | 4.5 | 12 |
| 180L | 812 | 4~ | 474.5 | 180 | 350 | 139.5 | 139.5 | 22 | 505 | 80 | 83 | PS2½ | 480 | 845 | 350 | 330 | 370.5 | 15 | 110 | 1.6 | 48 | 8 | 4.5 | 12 |
| 200L | 1012 | 4~ | 510.5 | 200 | 385 | 159 | 152.5 | 25 | 535 | 80 | 85 | PS2½ | 490 | 906 | 390 | 360 | 395.5 | 19 | 110 | 2 | 55 | 10 | 5 | 15 |
| 225S | 1211 | 4~ | 555 | 225 | 440 | 178 | 143 | 34 | 585 | 80 | 95 | | 520 | 985 | 436 | 366 | 432 | 19 | 140 | 2 | 60 | 10 | 5 | 15 |
| 225M | 1212 | 4~ | 570 | 225 | 440 | 178 | 155.5 | 34 | 585 | 80 | 95 | | 520 | 1010.5 | 436 | 391 | 444.5 | 19 | 140 | 2 | 60 | 10 | 5 | 15 |
| 250M | 1312 | 4~ | 590 | 250 | 480 | 203 | 174.5 | 42 | 655 | 100 | 120 | | 535 | 1072.5 | 506 | 449 | 482.5 | 24 | 140 | 2 | 65 | 12 | 6 | 18 |
| 280M | 1512 | 4~ | 650 | 280 | 540 | 228.5 | 209.5 | 42 | 726 | 100 | 120 | | 570 | 1179.5 | 557 | 519 | 539.5 | 24 | 140 | 2 | 75 | 13 | 7 | 20 |
| 315M | 1712 | 4~ | 720 | 315 | 600 | 254 | 228.5 | 52 | 795 | 120 | 145 | | 595 | 1334.5 | 628 | 577 | 614.5 | 28 | 170 | 2 | 80 | 13 | 7 | 20 |

by altering the coil-end connections (except for 0.75 kw). Class E insulation used for stator windings provides excellent insulation which is both moisture-proof and chemical-proof.

7) Corrosion-proof construction

Corrosion resistance is usually required in conjunction with flame resistance and can be provided by simple treatment.

8) External dimensions

IEC dimensions are used as installation dimensions for the electric motor. *Table 5* gives frame numbers in relation to motor output, and *Table 6* and *Table 7* give external dimensions.

## III. OUTLINE OF EXPLOSION TESTING EQUIPMENT FOR FLAME-PROOF ELECTRIC DEVICES

### 1. New Explosion Testing Equipment

According to the brochure prepared by the Industrial Safety Research Institute of the Labor Department, tests for flame-proof electrical equipment consist of construction checks, mechanical strength tests, explosion tests, ignition tests, temperature tests, and air tight tests. These are standard tests which must be conducted when checking explosion proof performance of newly designed and manufactured flame-proof electrical equipment. In recent years, many manufacturers have established private facilities for explosion testing to meet increased safety demands. There are two types of explosion test equipment, enclosed-type and open-type, depending upon construction of main explosion test equipment. Open-type testing equipment consists of a circulating fan for mixing and feeding gases and an explosion test tank with one side open (the open side is covered with a thin film such as polyethylene, and is secured with a metal ring to the tank). During the flash test, if an internal explosion in the device being tested causes an explosion in the external test tank, the thin polyethylene film will be broken, scattering exploded gas in the air. For this reason, the explosion strength test cannot be performed in this type of equipment. The enclosed-type testing equipment consists of a vacuum pump, air compressor, explosion-resistance high pressure gas mixing container, and totally-enclosed explosion testing tank made of thick steel plate which is able to withstand pressures produced by the explosion. Since both the explosion strength test and the flash test can be performed with this equipment, it is indispensable in meeting recent explosion-proof requirements.

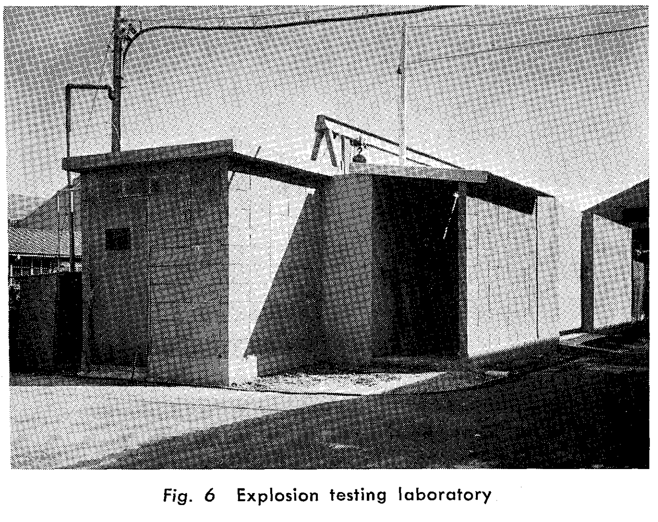

*Fig. 6* Explosion testing laboratory

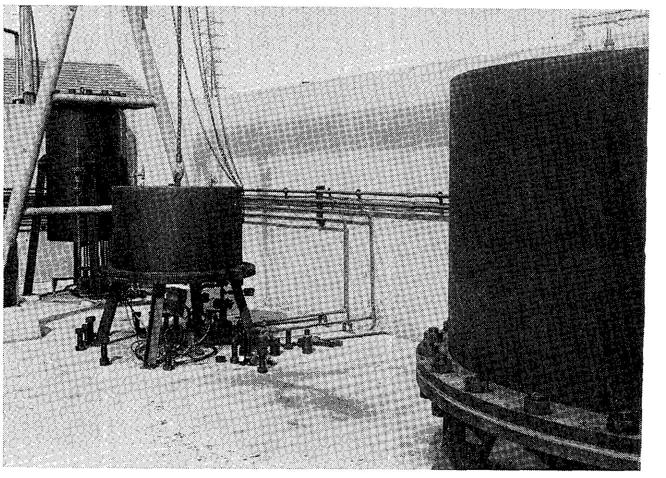

*Fig. 7* Enclosed-type explosion testing room

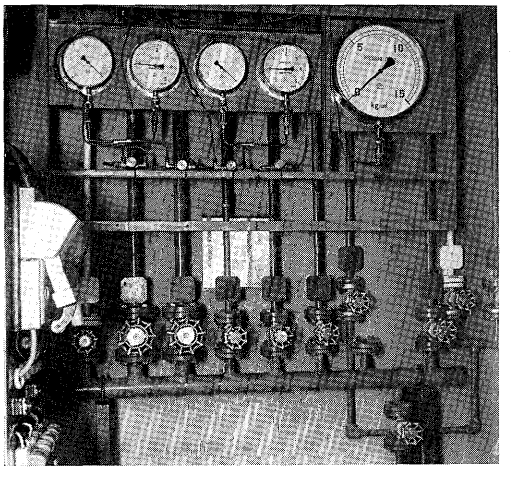

*Fig. 8* Observation room

### 2. Explosion Testing Facilities of Fuji Electric

*Fig. 6* shows an overall view of the explosion testing laboratory.

Building: Reinforced concrete structure

Building area: 77 $m^2$

Following rooms are provided:

1) Enclosed-type explosion testing room (*Fig. 7*)

2400 liters and 470 liters enclosed type explosion testing tanks and respective high-pressure gas-mixing containers.

2-ton hoist.

2) Observation room (*Fig. 8*)

Explosion pressure measuring instruments, operating switch control panel, and valve operation control panel

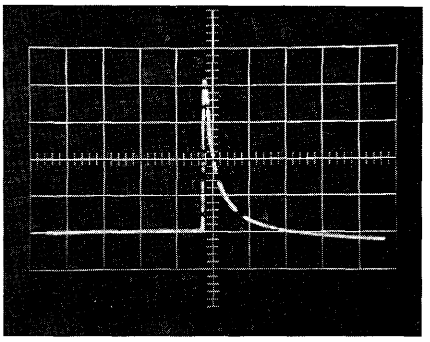

*Fig. 9 (a)* Oscillogram of explosion strength test

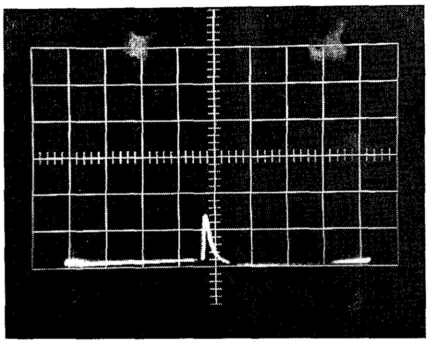

*Fig. 9 (b)* Oscillogram of explosion ignition test

for enclosed-type explosion equipment.

3) Machine room

Vacuum pump, compressor.

4) High pressure gas container room

Compressed air and various other gas cylinders

This laboratory is designed to withstand the impacts produced by gas explosions and strikes by portions of the broken equipment being tested.

## IV. RESULTS OF EXPLOSION TESTS

*Fig. 9* shows an oscillogram of an explosion strength test and flame test for 30%-hydrogen gas. In this case, a motor with a frame number 90L, 4 poles and 1.5 kw is used which has passed 15 flame tests. *Fig. 9* (*a*) shows an explosion strength test in which initial internal pressure in the motor tested is 1.5 $kg/cm^2$, and maximum explosion pressure is 10.5$kg/cm^2$. *Fig. 9* (*b*) shows a flame test in which explosion pressure at flash time is 2.8 $kg/cm^2$.

## V. CONCLUSION

As described above, a new series (4 poles, 0.75 kw ∼132 kw) of flame-proof electric motors using Class-E insulation and IEC standard dimensions has been developed. These motors are produced with d2G4 as a standard, but they can be also manufactured using d3aG1. Details of explosion test results and explosion testing facilities will be reported in the near future.