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A study of the hazard of fire and explosion due to electric charge by Gas-Solids flow in pipeline

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Abstract

When fire and explosion accidents have occurred due to a leak of the flammable gas involving the LNG & LPG in an industrialized society, it is a very important problem. Accordingly, in this paper, we have compared and analyzed the occurrence transition and the electrostatic energy according to dust supplies and pressure variations for the electric charge due to the gas-solids of pipe flow. As the experimental results, if dust amounts and the initial pressure increased, electric charge in the pipe and the exit increased. The Specific charge of Fe_2O_3 increased proportionally if the initial pressure increased but if the quantity of dust increased, the specific charge decreased. Energy increased significantly as the dust amounts and the initial pressure increased. The possibility of fire and explosion exist in the measuring point(M 1) and the Faraday cage if natural gas and LPG were used.

Key words : Natural gas(LNG), LPG, electric charge, Specific charge

1. Introduction

When fire and explosion accidents have occurred due to a leak of the flammable gas involving the LNG & LPG in an industrialized society, it is a very important problem. We carried out an experiment into the possibility of fire and explosion due to dust in combustible gases including natural gas(LNG) and LPG.

The electrostatic occurred when liquid, gas and solid are spouted though an exhausted nozzle to the air because of friction between a jet and an exhausted nozzle.[1] It is also occurred by a mutual impact.[5]

When the LNG, in the pipeline, is spouting and moving, the electric charge is extremely low.[2,3]

However, the fluid in the pipeline can

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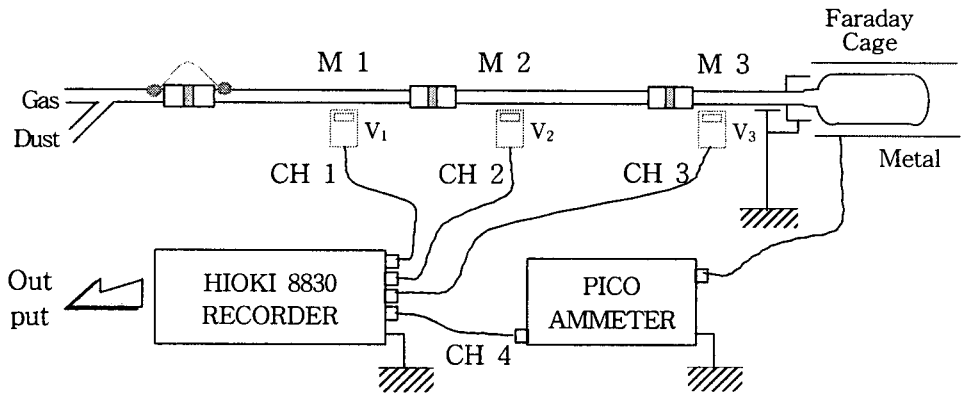


Fig. 1. The block diagram of experiment

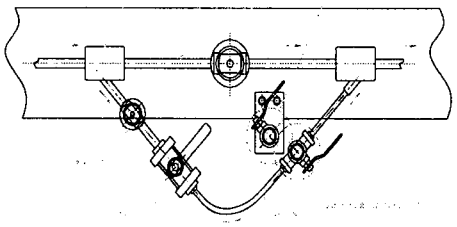


Fig. 2. Dust Supplies

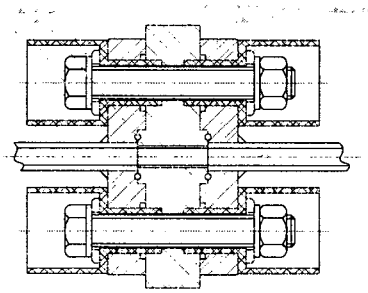


Fig. 3. prevent leakage of Flange

includes the dust such as Fe_2O_3, such fluid is exhausted with the natural gas. Therefore, the electric charge is extremely increase because of it.[3,4)]

Accordingly, in this paper, we have compared and analyzed the occurrence transition and the electrostatic energy according to dust supplies and pressure variations for the electric charge due to the gas-solids of pipe flow.

2. Apparatus and means for experiment

The apparatus is shown in the Fig.1.

A metal pipe(SGP, 4.5m, φ6mm) was used for the experiment. We arranged the pipe horizontally to feed the dusty gas into the Faraday cage(Copper 99.9%, L:290mm, H:0.2mm, φ130mm, Filter:cotton100%). A pressure regulator was used for changing the pressure of the gas.

Fig.2 shows the equipment for supplying dust. Dust was supplied due to the pressure difference between main pipe and sub pipe.

An insulator was used to prevent leakage of static electrical charge. Fig.3 shows the insulator used at each position, M 1, M 2 and M 3.

Fe_2O_3(color : red, Resistivity : $6.4\times10^8\Omega\cdot m\sim3.5\times10^8\Omega\cdot m$) was used as the dust for the experiment.

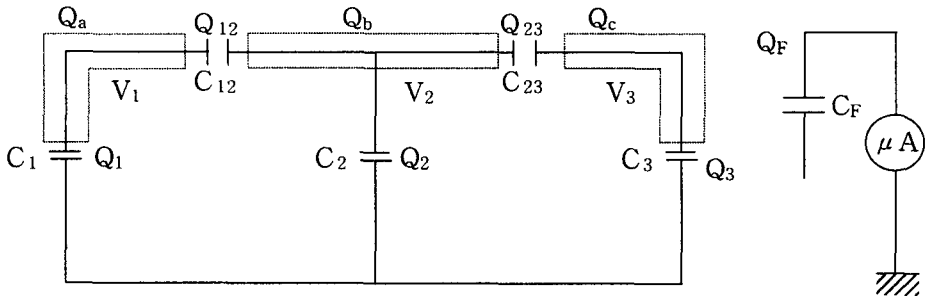


Fig. 4. A equipment circuit of measurement equipment

We used a mesh(KS-A5101) in order to ensure a uniform dust. The mean diameter of dust(Micro Color Camera : CS5330, Surface Finish Microscope) was 48 μm.

The Experimental conditions were 23±3℃, 45±5%RH. After compressed air and dust(0.1g, 0.2g, 0.3g, 0.4g, 0.5g) were simultaneously supplied for 10 seconds, the electric charge in the pipe and at the exit was analyzed.

Fig.4 is the circuit for measurement of electric charge.(Fig. 1) Capacitances were calculated with the equivalent circuit. (C_1 = 65pF, C_2 = 33pF, C_3 = 11pF, C_{12} = 20pF, C_{23} = 20pF, C_F = 15pF)

Each condenser was charged with Q_1, Q_2, Q_3, Q_{12}, and Q_{23}. Electric charge in the pipe was calculated using the expressions below

$$Q_a = C_1V_1+C_{12}(V_1-V_2)$$
$$= (C_1+C_{12})V_1-C_{12}V_2 \quad (1)$$

$$Q_b = C_{23}(V_2-V_3)+C_2V_2-C_{12}(V_1-V_2)$$
$$= (C_{12}+C_{23}+C_2)V_2-C_{23}V_3-C_{12}V_1 \quad (2)$$

$$Q_c = C_3V_3-C_{23}(V_2-V_3)$$
$$= (C_{23}+C_3)V_3-C_{23}V_2 \quad (3)$$

$$Q_F = Q_a+Q_b+Q_c \quad (4)$$

Where,

Q_a, Q_b, Q_c : electric charge in the each pipe,

Q_F : electric charge in the faraday cage

C_1 : a space to pipeline a and ground of capacitances

C_2 : a space to pipeline b and ground of capacitances

C_3 : a space to pipeline c and ground of capacitances

C_{12} : a space to pipeline a and b of capacitances

C_{23} : a space to pipeline b and c of capacitances

3. Results

3.1. Electric charge

Experimental conditions were maintained the same throughout the experiment(3kg/㎠, 0.1 g~0.5g) Fig.5 shows the electric charge at each condenser.(CH 1, CH 2, CH 3)

3.1.1 Occurrence place of static electricity

Because the resistivity of Fe_2O_3 is lower than the usual plastic dust, we expected that if Fe_2O_3 collided with the metal pipe a low charge would be generated. On the contrary, a high electric charge developed due to the supply and pressure of dust.(Fig.5)

The place where the highest electric charge was developed was CH1 because the pipe was straight but the flow of air in the pipe was turbulent.

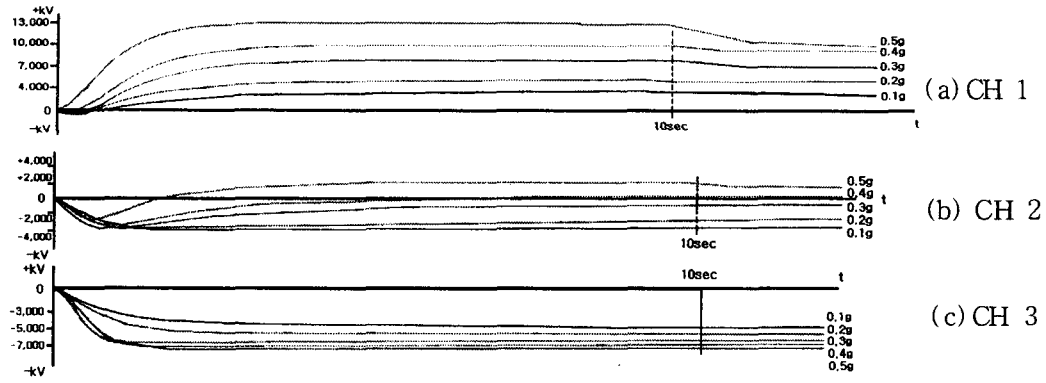
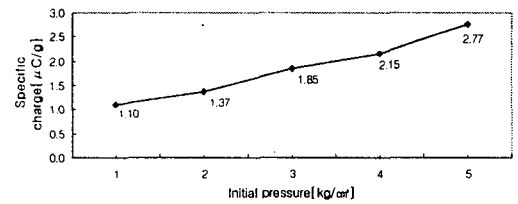


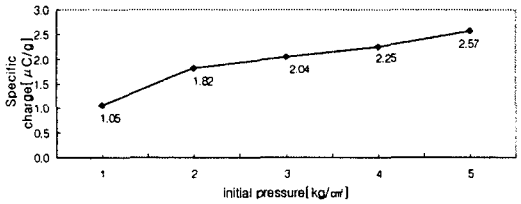
Fig. 5. Electric charge of according to dust transition

3.1.2 Effects of the initial pressure

The initial pressure in the pipe was the regulator's pressure for making an air stream in the pipe. Usually the faster the flow velocity, the higher the electric charge generated. The electric charge in the pipe was found to increase as the initial pressure increased.(Fig.6)



(a) Pipeline(Q_a, Dust 0.3g)



(b) Faraday Cage(Q_F, Dust 0.3g)

Fig. 6. Non electric charge of according to initial pressure transition

3.1.3 Effect of the amount of dust

Fig.7 shows the electric charge on the Fe_2O_3.(0.1~0.5g, pressure: 3kg/㎠)

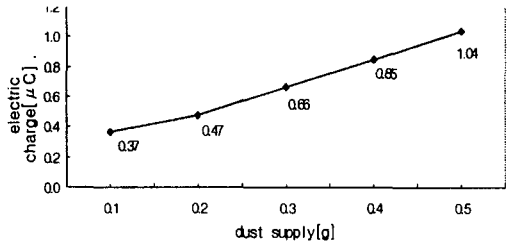
If the amount of dust was constant and the initial pressure increased, the specific charge increased proportionally.

If the initial pressure was constant and the amount of dust increased, the specific charge decreased as shown in Fig.7(c) but it became the definite value at once.

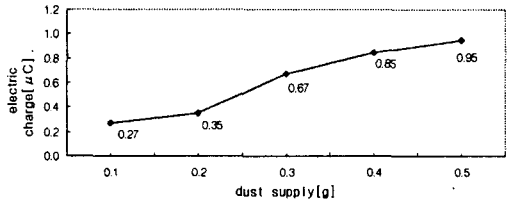
3.1.4. Electric potential at each measuring point

The measurement showed that the electric potential was positive in the measuring point(M 1) and negative in M 2, and M 3. The Dust coming out of the pipe was negative so M 1 charged positively because of electrostatic induction.

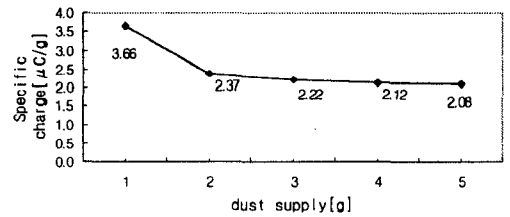
However if the initial pressure was high, M 2 was sometimes positive. This is believed to be because with high pressure the rate of charge generation in the second segment becomes higher than the rate of leakage.



(a) Pipeline(Q_a, Pressure 3kg/㎠)



(b) Faraday Cage(Q_F, Pressure 3kg/㎠)



(c) Specific electric charge of according to dust supply(Pressure 3kg/㎠)

Fig. 7. Electric charge of according to dust supply

CH 3 was (-). CH 3 was induced easily due to the faraday Cage and the leak of potential from dust to pipe increased.

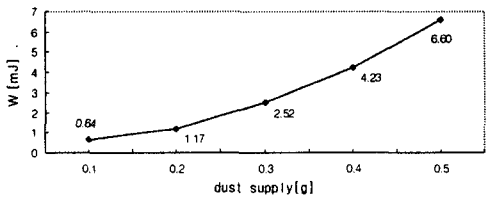


Fig. 8 Dust supply and electrostatic energy(W_a)

3.2. Consideration

3.2.1 CH 1

The relationship between the energy and the amount of dust(0.1~0.5g) and the pressure (1kg/㎠~5kg/㎠) are shown in Fig.8 and 9.

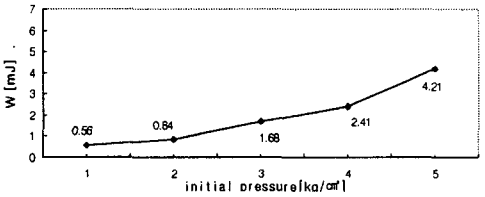


Fig. 9 Initial pressure transition and electrostatic energy(W_a)

3.2.2 Faraday Cage

Fig.10 showed the total energy of static electricity of dust at the faraday cage.

If the quantity of dust and the pressure increased, the energy increased also. In particular, the energy in the faraday cage is higher than in the pipe so we believe the region in the vicinity of faraday cage is more hazardous than in the pipe.

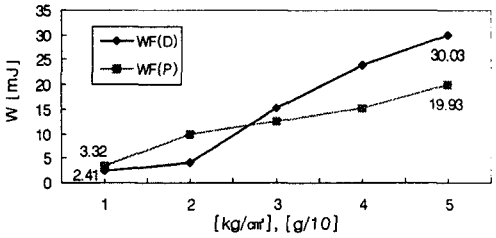


Fig. 10. Electrostatic energy transition of dust(Q_F)

The minimum ignition energy(MIE) of Natural gas, LPG was less than 0.3mJ[1] so we could there is the potential for a fire or explosions

4. Conclusion

1) If dust amounts and the initial pressure increased, electric charge in the pipe and the exit increased.
2) The Specific charge of Fe_2O_3 increased proportionally if the initial pressure increased but if the quantity of dust increased, the specific charge decreased.
3) Energy increased significantly as the dust amounts and the initial pressure increased. The possibility of fire and explosion exist in the CH 1 and the Faraday cage if natural gas and LPG were used.

5. Hereafter

1) We will analyze the change of polarity accurately in M 1, 2 and 3.
2) We will examine the effect of diameter and shape of pipe and the kind and the quantity of dusts.

Thanks to

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Reference

1) Joung jae hee etc, "Electricity Safety Engineering", Donghwa, 1998
2) Lee duck chul, Joung jae hee, "Prevention of the Accident and Barrier by Electrostatic", Sungandang, 1996
3) "最新 靜電氣 ハンドブック", 靜電氣學會, 1998
4) "管內固氣二相流における粒子靜電氣とその應用", 日本 靜電氣學會誌, Vol.23, No 2, 1999
5) "粉體の帶電現象と機構", 日本 靜電氣學會誌, Vol.23, No 2, 1999