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FLAME ARRESTERS AS BARRIERS AGAINST HOT METAL PARTICLES PART II

by

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SUMMARY

Particles produced by fusing of copper wires with a current up to 1200 A 250 v. D.C. penetrated the apertures of crimped ribbon arresters and remained incendive in atmospheres of ethylene and diethyl ether in air. Penetration could be prevented by containing such particles within strong insulating sleeves around the wires.

KEY WORDS: Flame arrester, particle incendive.

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INTRODUCTION

Results obtained in a previous investigation[1] indicated that crimped ribbon flame arresters when exposed to arc discharges obtained by fusing copper wires with an electric current, stopped propane-air mixtures from being ignited by molten particles of copper penetrating the arresters. This paper is an extension of the work and it evaluates the capability of the arresters to function in a similar manner in atmospheres of ethylene-air and ethyl ether-air. This work was carried out as a part of a programme aiming at the development of a new method of protection of equipment by the use of flame arresters.

APPARATUS AND MATERIALS

Explosion vessel

A 9 l mild steel cubical vessel was used for the experiments. This had detachable aluminium alloy (H.S. HP 30) covers, with a central venting hole, for mounting a flame arrester of 11 cm diameter. Several bosses were provided for introducing the power supply and the insertion of pressure measuring gauges. This vessel rested within a 440 l cubical enclosure, one side of which was provided with a relief vent sealed with 0.0038 cm thick polyethylene film.

Flame arresters

The flame arresters were of nickel chromium alloy and nickel. They were made from alternate lengths of straight and crimped ribbon packed together. The layers of the alloy ribbon were joined by welds on both sides of the arrester, outside the working area. The nickel ribbon pack was cased in sheet metal. Both types of arrester were mounted in an appropriate vessel cover with a central vent of 11 cm diameter for the arrester. The arresters had a crimp height of 0.051 cm and length of aperture 2.5 cm. In some tests an obstacle was inserted in front of the arrester. This was a metal plate 16 cm diameter held in position 5 cm away from the arrester outside the vessel.

Power source and power regulating unit

Twenty lead-acid accumulators were used as a power source at 250 v. D.C. With these it would be possible to obtain for a short time a maximum current of 1700 A with no external resistance. Fig. 1 shows a diagram of the circuit used.

Resistance A could be adjusted to obtain the desired prospective current. The prospective current is that which would flow in the circuit if the fuse wire were replaced by a resistance of negligible value, and which did not fuse. Contactor B was actuated by a relay to make the circuit. A double beam oscilloscope measured the voltage across the fuse wire C and the current across the shunt D. The traces of both current and voltage were obtained for all the wires with prospective currents of 330 and 1200 A.

Fig. 2 shows a photograph of the power supply and the control gear. E indicates accumulators, and A is a variable resistance; B is the contactor with an actuating solenoid through an intermediate relay, and is introduced to reduce interference on the cathode ray oscilloscope.

Wires

10 cm lengths of tinned copper wires of 0.025 and 0.071 cm diameter (33 and 22 S.W.G.) were used. These were mounted in such a way that a 5 cm length of wire was 1.3 cm away and parallel with the arrester.

Preparation of the flammable mixtures

A 6.5 per cent ethylene-air flammable mixture was prepared by metering and mixing of appropriate flows of air and ethylene.

A 3.4 per cent ethyl ether-air mixture was prepared by continuously evaporating a metered volume of ether in a glass condenser heated by water; the vapour was carried away by the metered stream of air sweeping the evaporating tube. The explosion vessel was filled by displacement.

Procedure

The explosion vessel fitted with the appropriate arrester and fuse wire was placed inside the 440 1 enclosure fitted with the polyethylene diaphragm. Both vessels were then charged with an appropriate flammable mixture; the volume of gas mixture passed was equal to ten volumes of the large enclosure. The fusing circuit was then made and if an ignition occurred in the outer enclosure it vented by rupturing the polyethylene diaphragm. If there was no ignition the mixture was disposed of by igniting it subsequently with an electric spark.

Results

Characteristics of current and voltage during fusing of copper wires.

Fig. 3 shows a record of voltage and current while fusing a wire. All tests were carried out with a prospective current of 1200A. Soon after making the circuit the current rose to a peak value A and then slightly declined to B. During this period the voltage across the wire rose steadily to C. Both traces during this period are represented by solid lines. At point B the current commenced to decline rapidly until it reached zero, at the same time the voltage rose and with some wires exceeded for a short time the open circuit value. The traces during this period were represented by a broken line and this was accepted as the arcing period. With thicker wires the maximum current attained the value of the prospective current; with thinner wires, however, this value was never reached.

Performance of arresters

Table 1 shows the results of tests with nickel chromium alloy ribbon and nickel ribbon arresters with and without the obstacle. Evidently with the thicker wires in one out of ten experiments transmission of an explosion occurred. Results indicate that neither the different ribbon metal nor the presence of obstacle had any obvious effect on the performance.

Table 2 shows the repeat of these experiments using nickel chromium alloy ribbon arrester in 3.4 per cent ethyl ether-air flammable mixture. The performance of the arrester was similar to that with ethylene-air mixture; with thicker wires arc energies were, however, considerably lower, this being probably caused by the deterioration of the accumulators.

Table 3 shows the attempts to contain the incandescent particles within various insulating sleeves. Both in ethylene and ether flammable mixtures, only woven glass fibre covered with PVC gave satisfactory performance. Some of the results show low arc energies, again this being probably caused by the deterioration of the accumulators.

Discussion

The mechanism of ignition of gaseous mixtures by fuxing similar wires in atmospheres of propane-air was investigated in (1). That work showed that hot particles of metal produced by arc discharges, penetrated the arrester and that aluminium particles were capable of causing ignition of propane-air mixtures. Photographs indicated that these particles were reacting vigorously with surrounding oxygen throughout their flight after emergence from the arrester. Copper wire produced less bright particles and there was evidence that their temperature dropped soon after the emergence from the arrester. The latter condition obtained in the present experiments, but both ethylene and ethyl ether-air mixtures were ignited by hot particles of copper with little or no chemical activity while they were airborne. There has been relatively little work done in the past on the mechanism of such ignitions[2,3,4], and it was concerned with the minimum ignition temperatures of various hydrocarbons by hot spherical projectiles. The authors reported that : the ignition temperature increased substantially with the decrease in size of the particle, town gas and hydrogen-air flammable mixtures were ignited at lower temperatures than pentane-air mixtures. Particles made of material having good thermal conductivity ignited a given gas at a lower temperature than the same sized particle made of low conductivity material. The experimental results were subjected to tentative theoretical analyses; at the same time the authors indicated the great complexity of the problem.

Results described in this paper indicate that flammable mixtures of group III gases (B.S. 229) in air may be ignited if protecting arresters are exposed to powerful arc discharges caused by short circuits involving copper. It would also be desirable to establish how arcs produced by separating copper electrodes compare in the degree of incendivity with arcs generated as in the present work. It has been shown that the hot particles could be contained safely within strong insulating sleeves. Although some of the arc energies in the tests are low because of the deterioration of accumulations, the tests do show that a strong insulating sleeve will contain substantial arcs. In order not to transmit the explosion, the sleeve must remain undamaged by heat and the pressure created by the discharge.

Acknowledgement

Mr. P. Field assisted in experimental work.

References

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4. PATERSON, S. Ignition of flammable gases by hot moving particles. Phil. Mag. 1940. Series 7 30 437.

TABLE 1

Performance of arresters in 6.5 per cent ethylene-air flammable mixture

Nickel chromium alloy ribbon arrester

Diameter of wire cm (S.W.G.)	Mean arc energy J	Explosion contained No. of tests	Explosion transmitted No. of tests	
0.071 (22)	152	10	1	Test with no obstacle
0.025 (33)	23	10	0	
0.071 (22)	114	8	2	Tests with obstacle

Nickel arrester

Diameter of wire cm (S.W.G.)	Mean arc energy J	Explosion contained No. of tests	Explosion transmitted No. of tests	
0.071 (22)	110	10	1	Tests with no obstacle
0.025 (33)	13	10	0	
0.071 (22)	119	10	0	Tests with obstacle

TABLE 2

Performance of arresters in 3.4 per cent ether-air mixture

Nickel chromium alloy ribbon arrester   No obstacle

Diameter of wire cm (S.W.G.)	Mean arc energy J	Explosion contained No. of tests	Explosion transmitted No. of tests
0.071 (22)	96	9	1
0.025 (33)	30	10	0

TABLE 3

Performance of arrester with wires protected by various insulating sleeves

6.5 per cent ethylene-air

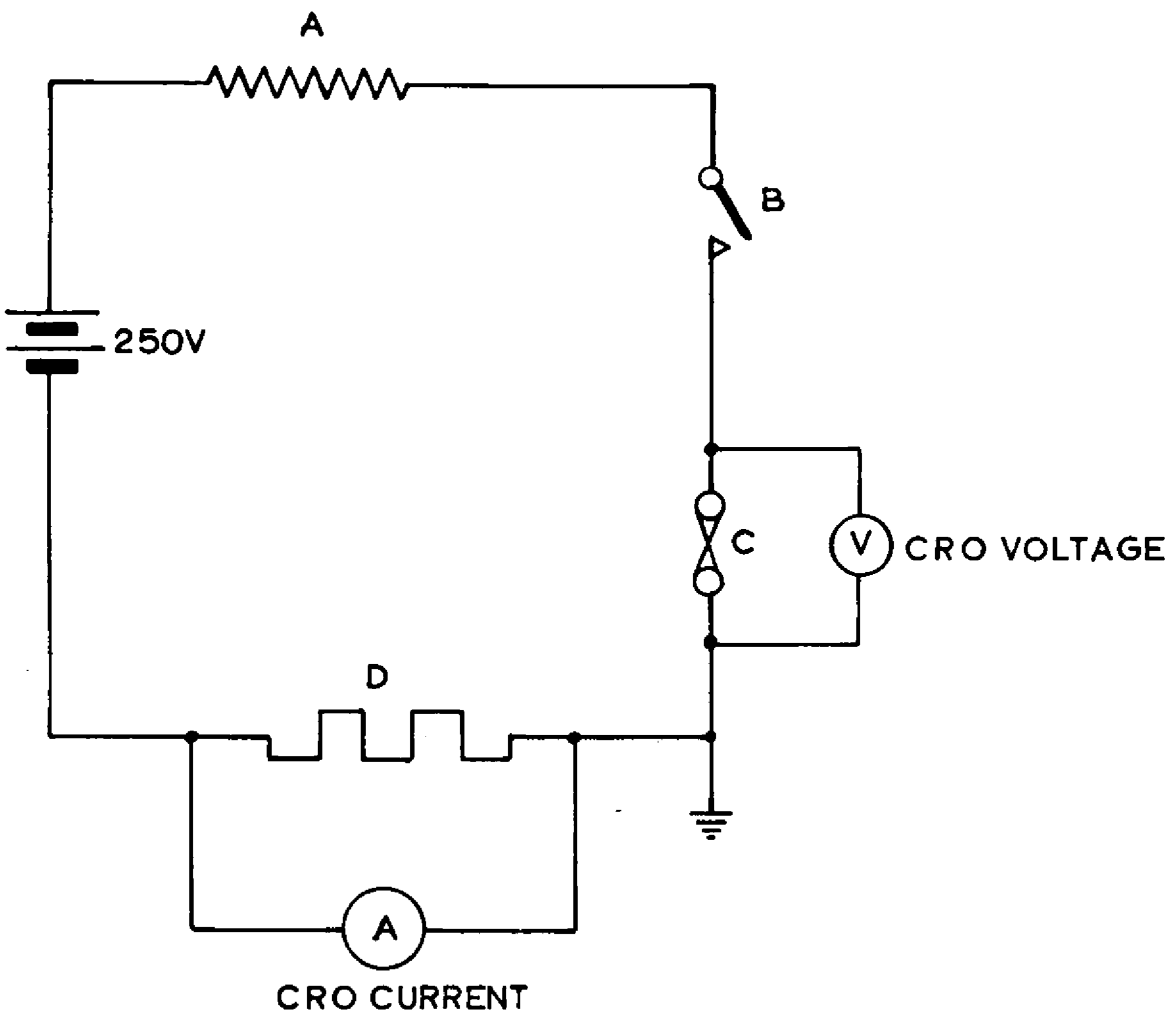
wire 0.07 cm diameter 22 S.W.G.

Type of sleeve	Mean arc energy J	Explosion contained No. of tests	Explosion transmitted No. of tests
Woven glass fibre	150	4	6
Woven glass fibre covered with PVC	69	10	0
Varnished woven terylene	50	7	3

3.4 per cent ethyl ether

wire 0.07 cm diameter 22 S.W.G.

Type of sleeve	Mean arc energy J	Explosion contained No. of tests	Explosion transmitted No. of tests
Woven glass fibre	144	10	-
Woven glass fibre covered with PVC	37	10	-
Varnished woven terylene	52	10	-



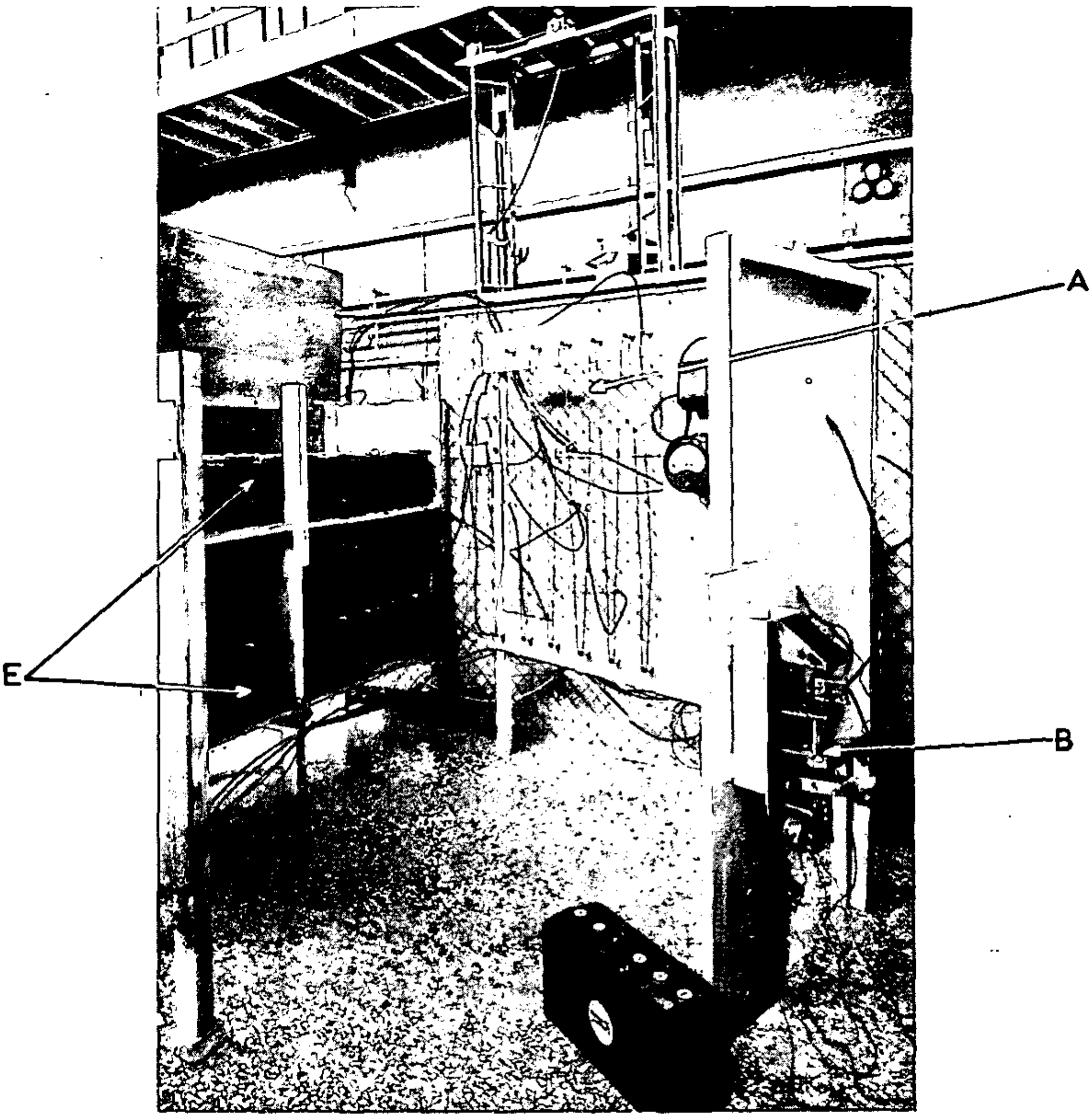
A Variable resistance

B Contactor

C Fuse wire

D Shunt

FIG.1 DIAGRAM OF THE CIRCUIT USED FOR FUSING THE WIRES



A VARIABLE RESISTANCE
B CONTACTOR
E ACCUMULATORS

FIG.2. POWER SUPPLY AND CONTROL GEAR

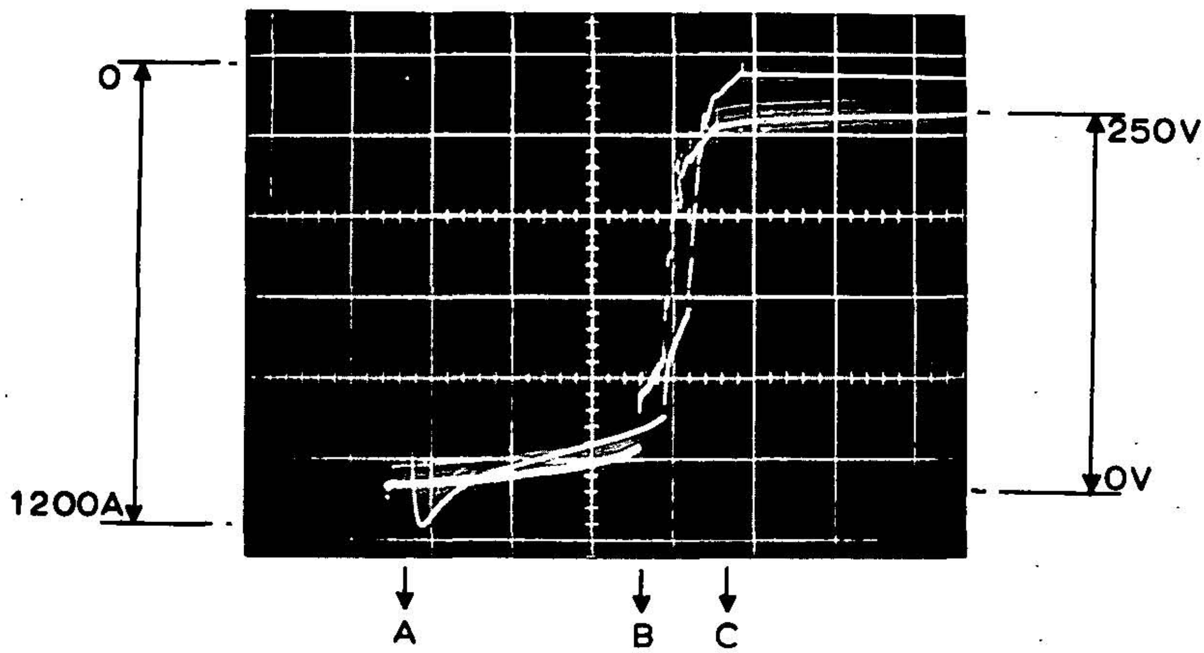


FIG. 3. OSCILLOSCOPE RECORD OF VOLTAGE AND CURRENT WHILE FUSING 0·07cm DIAMETER (22 S.W.G.) COPPER WIRE AT A PROSPECTIVE CURRENT OF 1200 A