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PERFORMANCE OF A TWO ELEMENT CRIMPED RIBBON FLAME ARRESTER

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SUMMARY

Tests with a single and a double element flame arrester have shown that the double element arrester offers similar performance in stopping moving flames as a single element arrester of the same thickness. The performance of a double element arrester in resisting flash-back of flame was inferior to the performance of a single element arrester.

Department of the Environment and Fire Offices' Committee
Joint Fire Research Organization

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INTRODUCTION

There are many kinds of flame arresters manufactured in the UK. Of these crimped ribbon arresters probably have the widest use, and there is a great deal of experience in their performance. In the UK crimped ribbon arresters are made from a straight and a crimped metal ribbon, with the crimp formed at right angles to the ribbon edges, wound round a central core and then cased within a suitable metal housing. All arresters have only one element, the desired levels of performance being achieved by varying the crimp height and the width of ribbon.

The UK methods of construction and the design differ from current practice in the Federal German Republic, where it is customary to use two or more 1 cm thick arrester elements, with a universal crimp height of 0.7 mm. The crimp is formed at 22^{o} to the ribbon edge. The reason for multi-element construction is not known but may represent an attempt to improve the performance of an arrester. In Germany compliance with certain tests is mandatory before arresters can be approved for industrial use. One such approved specimen of arrester was examined at the Fire Research Station to evaluate two aspects of its performance:

a) ability to extinguish moving flames
b) resistance to flash-back with a stationary premixed, flame burning on the surface of the arrester and the degree of heating and possibility of eddying through the arrester matrix with diffusion flames.

APPARATUS AND MATERIALS

The arrester assembly

Figure 1 is a photograph of the arrester assembly. The two arrester elements are housed in a cast steel body, which has one end flanged. The crimped ribbon arrester elements are enclosed in a separate cast steel capsule, which can be detached from the housing and then dismantled for withdrawal of the arrester elements. The crimped ribbon elements are identical. They are assembled with a space of 3 mm between the elements which have opposing crimp angles, herring bone fashion, giving apertures at an angle of 136^{o} to each other. The housing has a

100 mm nominal bore, expanding to 140 mm, the effective diameter of the arrester capsule. A hood is attached to the assembly to provide weather protection.

Explosion pipe

a) Tests with moving flame fronts

Steel pipes of 153 mm internal diameter were used for these tests. The length of the assembly was varied by bolting together an appropriate number of pipes of lengths 7.3, 5.5 and 3.7 m. A 460 mm long tapered adaptor was bolted to one end of the pipe assembly, in order to fit the arrester, the other end being closed with a blank flange. The flammable gas was introduced close to the closed end, Fig 2. A 1 m long polyethylene sleeve was attached to the arrester assembly.

(i) The explosion pressure and the flame speed measuring apparatus

The maximum explosion pressure was monitored with an inertia compensated piezo-gauge, and the progress of the flame front was monitored by several ionisation probes. Both the explosion pressure and the signals delivered by the ionisation probes were recorded by photographing the screen of the oscilloscope. Each photograph provided a time-pressure trace and indicated the speed of the flame front as it moved along the pipe.

(ii) Flammable gas and igniting source

A 6.5 per cent ethylene/air mixture was used in all tests. This was produced by metering appropriate volumes of air and ethylene into a mixing chamber and thence into the pipe assembly. The flammable gas was ignited near the closed end of the pipe using a 30 mJ inductive spark.

b) Pipe assembly for flash-back tests

For these tests the arrester assembly was mounted at the upper end of a vertical steel tube, 0.9 m long and 153 mm internal diameter, Fig 3. After metering, the flammable gas was fed to the tube at the bottom. A 0.5 mm diameter sheathed thermocouple was inserted into the matrix of the upper arrester element, with the junction located 25 mm from the centre point of the arrester and 5 mm below the upper surface.

(i) Flammable gas and igniting source

The flammable gas used was neat propane for diffusion flames and a 4.3 per cent propane/air mixture for premixed flames. The igniting source was a bunsen burner.

TABLE 1

SUMMARY OF TESTS WITH TWO-ELEMENT FLAME ARRESTER AT THE END OF A 7.3 M LONG PIPE

FLAMMABLE GAS 6.5 PER CENT ETHYLENE/AIR

Test No	Pressure kN/m^2		Performance	Flame speed near arrester m/s
	Maximum	When flame at arrester		
1	166	147	Flame arrested	153
2	151	114	Flame arrested	114
3	167	112	Flame arrested	114
4	166	108	Flame arrested	153
5	176	124	Failed	153
6*	155	141	Flame arrested	153
7*	ND	157	Failed	153
8*	ND	127	Flame arrested	153
9	ND	ND	Failed	153
10	ND	ND	Flame arrested	153
11	142	120	Failed	153

Note ND = Not determined

* = Indicates the presence of obstacle within the pipe

Failed = Ignition of gas in polyethylene sleeve

PROCEDURE

a) Tests with moving flame front

The pipe and arrester assembly were charged with the flammable mixture by displacement. After an amount of gas equivalent to ten volumes of the apparatus had been passed, the gas supply was stopped and the mixture in the pipe was ignited. The polyethylene sleeve also contained the gas mixture. If the arrester transmitted the explosion this volume exploded with very obvious audible and visual signals.

b) Test for flash-back

An appropriate gas mixture was admitted at the base of the pipe after metering and a bunsen burner was placed near the surface of the arrester. Timing of the test commenced as soon as the emerging gas was ignited by the bunsen flame. Flash-back created an obvious explosion within the pipe. All tests had a duration of 30 min unless flash-back occurred first.

RESULTS

a) Tests with moving flame front

Table 1 shows the results of tests with the two element arrester. The third column lists the maximum explosion pressures; the fourth the pressures at the time when the flame front entered the arrester assembly; the fifth the performance, and the sixth the average flame speed over the 46 cm length of tapered pipe adjacent to the assembly. In the tests Nos 6, 7, 8, a small obstacle was inserted within the pipe, which probably elevated the explosion pressure at the time when the flame front was entering the arrester assembly.

The maximum flame speed was 153 m/s in nine of the tests carried out. In four of these tests the arrester failed to stop the flame front. In the remaining two tests, where the flame speed was 114 m/s the arrester stopped the flame front.

TABLE 2

SUMMARY OF TESTS WITH SINGLE ELEMENT FLAME ARRESTER
AT THE END OF 7.3, 5.5 and 3.7 M LONG PIPES
USING 6.5 PER CENT ETHYLENE/AIR

Test No	Pipe length	Pressure kN/m^2		Performance	Flame speed near arrester m/s
		Maximum	When flame at arrester		
1	7.3	ND	104	Failed	153
2	7.3	ND	ND	Failed	153
3	7.3	131	101	Failed	153
4	5.5	118	89	Failed	147
5	5.5	120	81	Failed	147
6	5.5	94	73	Failed	114
7	3.7	54	43	Failed	92
8	3.7	56	48	Failed	76
9	3.7	63	52	Failed	92

Note ND = Not determined
Failed = Ignition of gas in polyethylene sleeve

Table 2 summarises the tests with the arrester assembly holding one crimped ribbon element only. In these series of tests the pipe length and consequently the flame speed was progressively reduced over the range 153 - 76 m/s. Although as the pipe length was reduced the maximum explosion pressure became lower, the arrester failed to stop the flame front in any test.

Fig 4 shows the plot of average flame speeds along the pipe for all tests of double and single arresters using the 7.3 m long pipe. All the curves, with the exception of the one for results obtained in a pipe with the obstacle, have similar shapes. Curves for shorter pipes are not shown but these had very similar shapes to the curves shown for the pipe with no obstacle.

b) Performance when resisting flash-back

No flash-back occurred with neat propane metered at 5 or 10 l/min with either a single or double-element arrester, nor did the arrester ribbon glow. Thus no eddying or other disturbance of gas flow, causing flame to penetrate, took place. A propane diffusion flame, burning at the surface of the double element arrester is shown in Fig 5. However, when the single element arrester was tested with 4.3 per cent propane/air mixture the upper surface of the crimpled ribbon element became red hot, although the arrester held the flame without flash-back occurring, Fig 6. In a similar test with the double crimped ribbon element arrester flash-back took place after 15 min 5 s. Five minutes before flash-back the flame entered the exposed arrester matrix; there was no flame above the upper surface of the exposed arrester at this time, but the upper surface of the ribbon, however, was glowing.

Fig 7 shows the time-temperature curves recorded in these tests. Where there was no flash-back the temperatures reached equilibrium before the test was terminated. In the test where the flash-back took place, there was sudden increase in the rate of temperature rise 5 min before the flash-back. The thermocouple indicated 1075°C when the flash-back took place.

DISCUSSION

Previous investigations on the performance of crimped ribbon arresters, correlated the minimum flame spread (m/s) required for the transmission of explosions with the dimensional characteristic of the arrester[1].

All experimental data in this investigation were obtained with arresters having diameters equal to the internal diameter of the pipe, for which, subject to certain conditions, the following equation has been shown by experiment to be in reasonable agreement:

$$v = 0.95 \ ny \ \frac{P_o}{P}$$

where v is the minimum flame spread required for transmission of explosions (m/s)

n is the number of apertures in 1 cm^2 area of arrester surface

p is the atmospheric pressure (kN/m^2)

p_o is the explosion pressure (absolute) when the flame reaches the arrester

y is the thickness, of the arrester (cm)

Similar work carried out subsequently using metal foam arresters Ref 2 also shows a broad agreement between the experimental values, and values predicted from the equation.

Table 3 presents the calculated and experimental values obtained in this investigation for an arrester having two crimped ribbon elements. The correction for angle of crimp is approximately 1.06. Evidently the calculated values under-estimate the minimum flame spread required for transmission of an explosion. Such an under-estimate may be due to the shape of the apertures which were equilateral triangles in the crimped ribbon arresters used in Ref 1, while the apertures in the arresters used in this investigation were triangles 0.7 mm high and 2 mm long base. Thus for a given crimp height the German arrester had approximately half the number of apertures of arresters described in Ref 1. The term n in the equation thus appears to depend on the shape of apertures. As all the arresters investigated in Ref 1 had a minimum length of aperture of 2 cm there is no direct comparison with the 1 cm long single element arrester tested here. The limited number of tests carried out with this arrester, show that relatively slow flame fronts < 76 m/s will penetrate the matrix. These results are however of little practical importance in the UK as no crimped ribbon arresters having such a short length of aperture are used in practice, and the velocity of flame front at which it would arrest the flame is probably too low to be acceptable.

The flash-back performance of crimped ribbon and metal foam arresters has been investigated[3]. This investigation indicated that crimped ribbon arresters will flash-back when a premixed flammable/air flame is allowed to burn on the arrester surface. The flash-back is preceded by the intense heating of the upper surface of the arrester, until the matrix reaches a temperature, which equals or exceeds that for the relevant quenching distance. Once this has taken place the rate of heat transfer to the arrester matrix increases, the whole body of the arrester is heated rapidly, and the flame front penetrates the arrester. However, flash-back occurred only with the 6.5 per cent ethylene/air mixtures, and arresters resisted the flame in all tests with the 4.2 per cent propane/air mixture. The mechanism of the flash-back was very similar in the present series of tests. The time-temperature curves, Fig 7, indicate the sudden increase in the rate of temperature rise. This occurred 5 min before flash-back and coincided with the entrance of the flame front into the arrester. When flash-back took place the thermocouple indicated the temperature of 1075°C. The flame front took 5 min to penetrate both arrester elements. It is not clear why the single element gave a better performance than double element arrester, and further evidence is required before any conclusions can be drawn. The superior performance of the single element arrester, however, is more consistent with the behaviour of other single element flame arresters[3].

TABLE 3

COMPARISON OF MEASURED AND CALCULATED CRITICAL FLAME SPEEDS FOR A DOUBLE ELEMENT ARRESTER

Flame speed measured m/s	ny $\frac{P_o}{P}$	Performance
153	61	Flame arrested
114	71	Flame arrested
114	72	Flame arrested
153	73	Flame arrested
153	68	Failed
153	53	Failed
153	60	Failed
153	60	Failed
153	67	Flame arrested
153	69	Failed

Failed = Ignition of gas in polyethylene sleeve

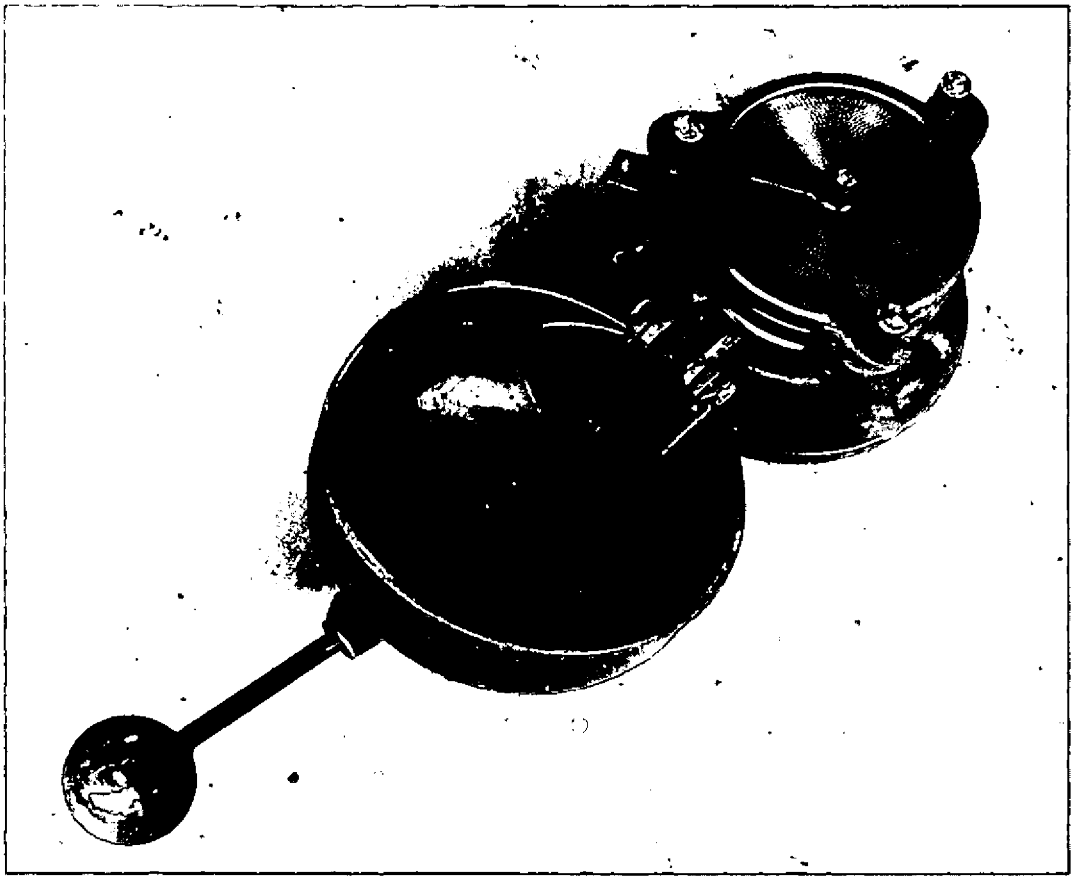

FIG 1. ARRESTER ASSEMBLY WITH THE PROTECTIVE HOOD IN OPEN POSITION.

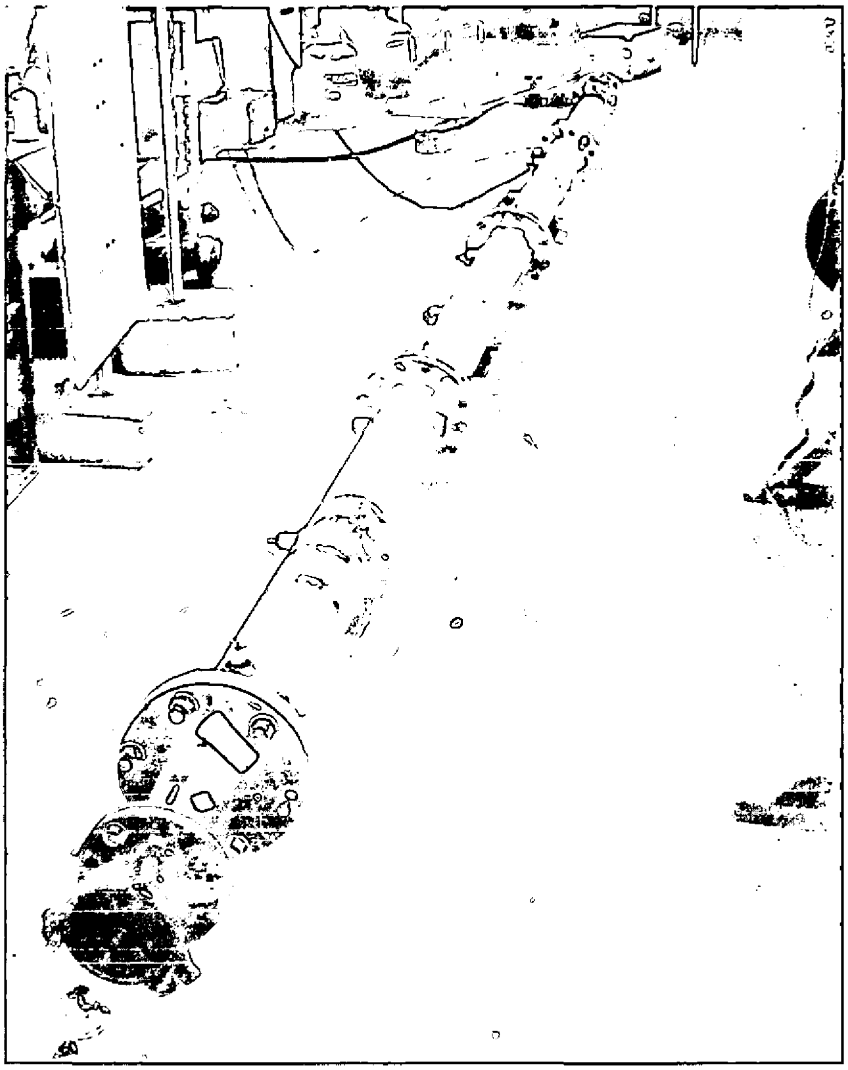

FIG 2. 7.3 M LONG PIPE ASSEMBLY WITH THE ARRESTER IN POSITION FOR TESTS.

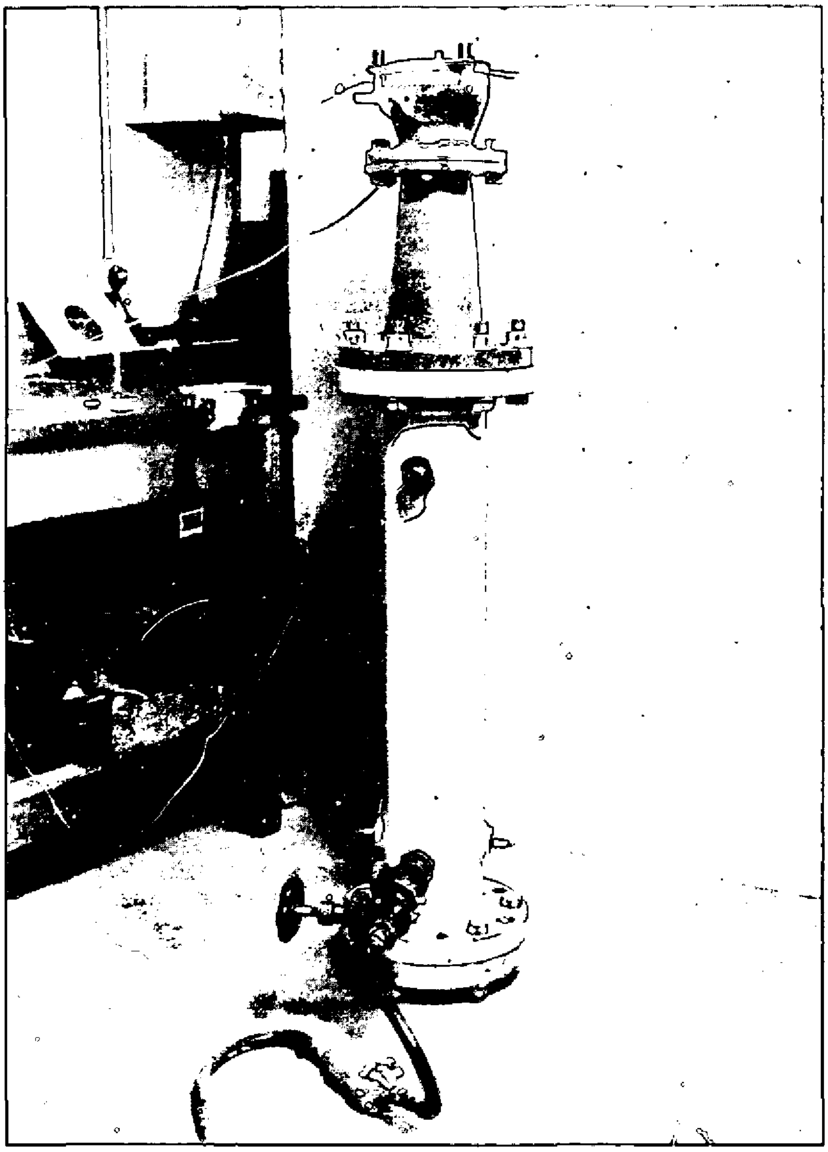

FIG 3. FLASH-BACK PIPE AND ARRESTER ASSEMBLY.

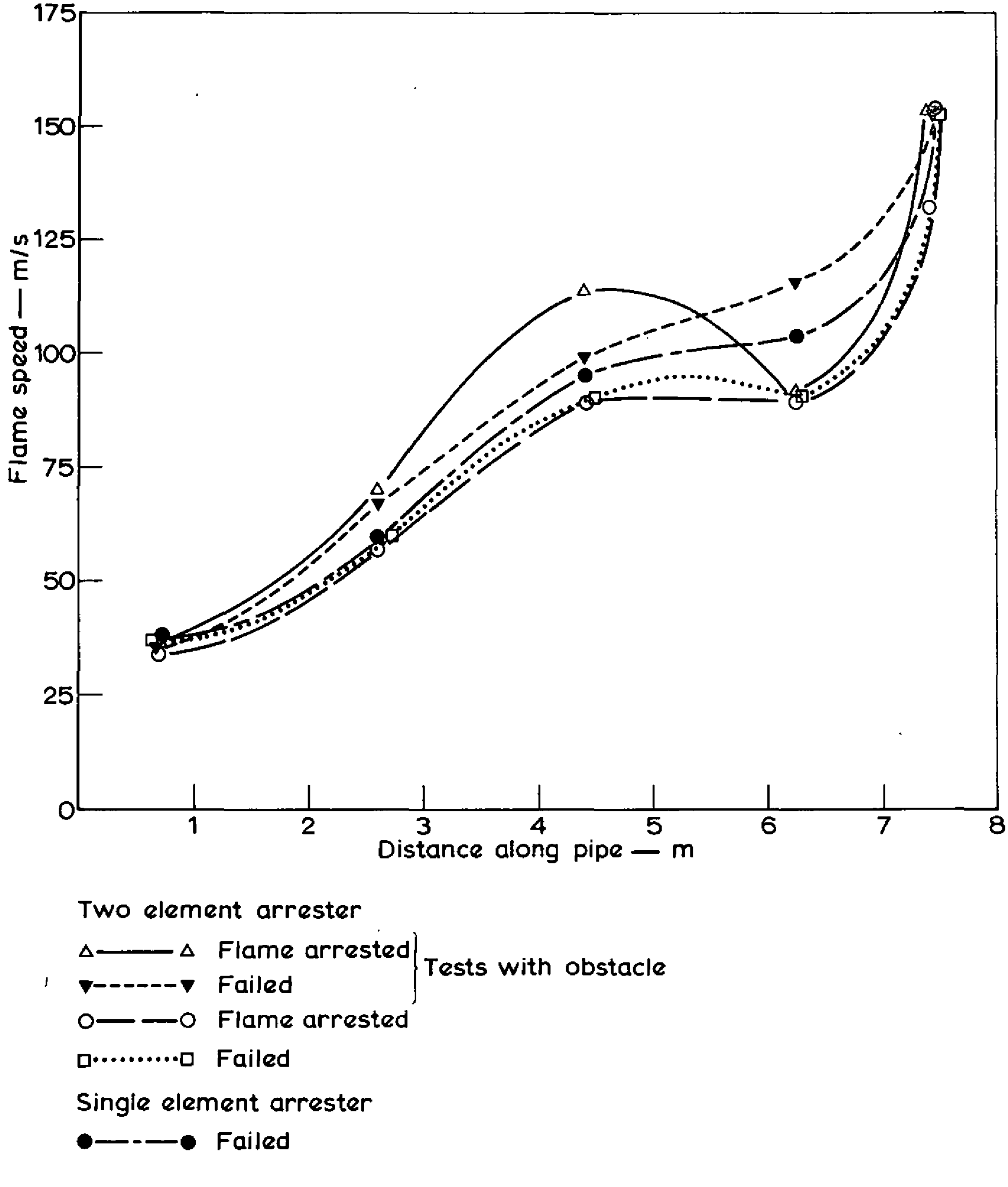

Figure 4 Average flame speeds along pipe

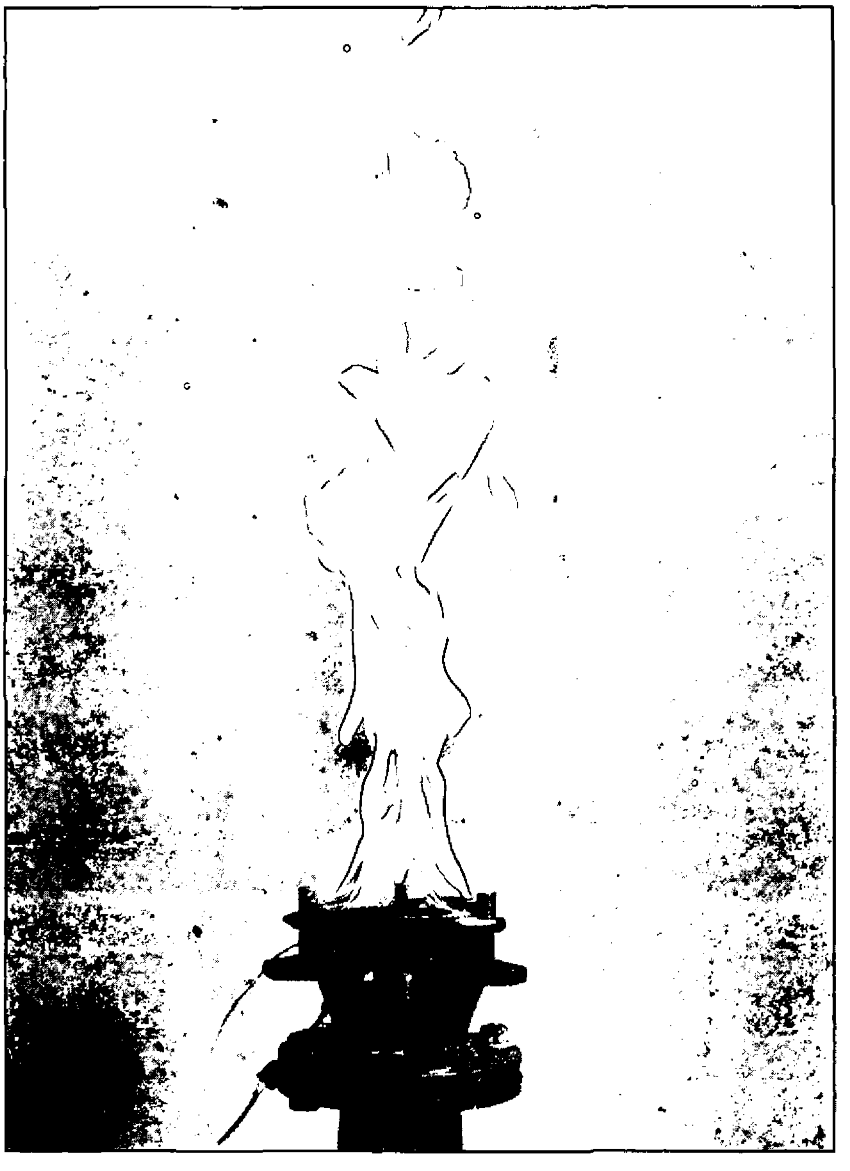

FIG 5. DIFFUSION FLAME OF PROPANE FLOWING AT THE RATE OF 101/mm.

FIG 6. PREMIXED FLAME BURNING ON THE DOUBLE ELEMENT ARRESTER ASSEMBLY BEFORE FLASH-BACK.

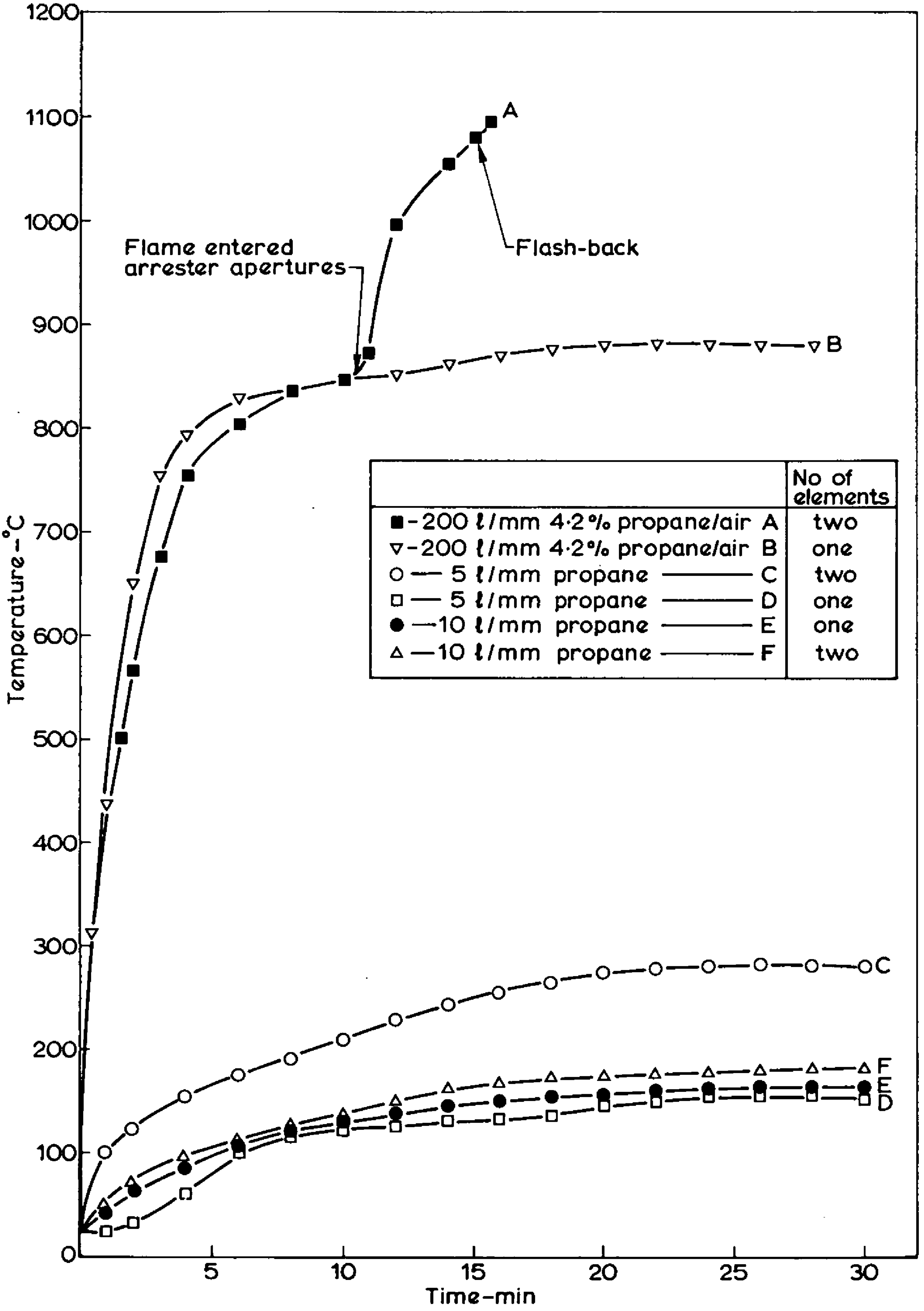

Figure 7 Temperature measured within the arrester matrix