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FLASH BACK THROUGH CRIMPED RIBBON ARRESTERS

by

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SUMMARY

In some applications flame arresters after stopping an explosion flame may have to resist for some time a premixed flame burning on the arrester surface. It is important that such a flame does not penetrate the arrester matrix. This Note describes the performance of crimped ribbon arresters under those conditions. Crimped ribbon arresters of suitable crimp height may safely hold such flames for considerable periods of time.

KEY WORDS: Flame arresters, flame, behaviour

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INTRODUCTION

The performance of various arresters as barriers to flames travelling along pipes has been widely investigated. More recently however arresters have been successfully applied to protect lightweight containers functioning in flammable atmospheres[1–4].

While carrying out these duties the arresters, after each explosion, may need to resist a resident premixed flame burning close to the arrester surface. Such a flame can be caused by the flammable gases entering the vessel after the explosion has ceased, and the combustion products cooled to create a slight sub-atmospheric pressure within the vessel. In industrial use the possibilities of long duration flames burning on the arrester surface are rare. If however there is a possibility of this occurring some users may require the arrester to resist a stationary flame burning on the arrester surface for a specified period of time.

This note describes tests evaluating the performance of crimped ribbon arresters in resisting the flash back from such stationary flames.

APPARATUS AND MATERIALS

Burner

The test apparatus is shown in Fig 1; it was essentially a burner. Arresters were mounted in a removable section A and this was followed by a 300 mm length of 35 mm internal diameter steel tube B, which was connected by pipe fitting to a mild steel arrester holder C safeguarding the metering apparatus.

Flammable gas

Premixed 4.2 per cent propane – air or 6.5 per cent ethylene – air were used with the following velocities at the arrester outlets: 24.5, 16.5 and 8.2 cm/sec.

Arresters

All arresters were commercial products of the crimped ribbon type. They consisted of alternate crimped and flat metal ribbons wound round a central core and mounted in an appropriate length of brass tube. The crimped ribbon formed channels 38 mm, or in one case 18 mm, long and the diameter of the crimped ribbon area was 30 mm. The ribbon metal was cupronickel brass-based alloy and it was 0.05 mm thick. Arresters having a crimp height of 1.0 and 0.5 mm were tested.

TEST PROCEDURE

The required flow of the premixed flammable mixture was metered and ignited at the arrester. The combustion was observed for a period of up to 60 min unless flash-back occurred before that time. When the ribbon was glowing its temperature was measured using a disappearing filament pyrometer.

RESULTS

Table 1 gives a summary of the results. The flame held by the arrester had a structure similar to that with a Bunsen or Meker burner. There was a clearly distinguishable blue flame zone close to the arrester surface, and this was followed by a 50-80 mm long luminescent zone. With lower flow rates of the gaseous mixtures, such flames persisted throughout the test without any glow on the surface of the arrester. As the speed of the flammable mixture was increased, the surface of the crimped ribbon would glow, but the luminosity outside the arrester remained unchanged. With both crimp heights further increase in the flow rate produced some local heating of the arrester matrix. With ethylene-air mixtures the flames could in some cases retreat within the hot patches of crimped ribbon and in some tests no visible luminosity would then be seen outside the arrester body. Once this type of combustion was established flash-back followed. In most tests the visible surface of the arrester appeared undamaged. However the upstream side of the crimped ribbon in all but one test with flash-back was extensively damaged by melting and oxidation. Fig 2 shows photographs of damaged arresters. One arrester 18 mm long and 0.5 mm crimp height did not sustain any such damage and no flash-back occurred during the 60 min test, another specimen 38 mm long and 1.0 mm crimp height when tested with ethylene-air failed in 2 min 30 sec without any damage occurring and the combustion zone in this test established itself within the crimped metal over the whole of the cross-sectional area. With propane-air mixtures no flash-back occurred with both crimp heights. The finer crimp however produced some glow while the coarser crimps remained dull throughout the tests.

With the highest velocity of the flammable mixture there was a certain amount of flame lift-off both with propane and ethylene flammable mixtures. Increase of the maximum velocity of the propane-air mixture to 33 cm/sec, caused a lift-off of 5 mm.

Fig 2 shows the downstream and upstream sides of the arresters that failed to stop flash-back and sustained damage. In damaged areas there was little melting but there was an extensive localised oxidation of the ribbon and the central brass spindles of the arresters with finer crimp melted. One specimen with 1 mm crimp height, where there was no localised heating, appeared totally undamaged. In all arresters which failed there were numerous deformations of the crimped ribbon, which increased the crimp height of some of the channels by up to 60 per cent of the original value.

Fig 3 shows photographs of three arresters after encapsulating in an epoxy resin and sectioning. The upstream side of the arresters is always at the bottom of the picture. These cross-sections reveal substantial damage to the ribbon both by melting and oxidation with subsequent ablation of the oxide. Some damaged portions of the arrester were in the form of internal cavities not evident before cross-sectioning. Where the central brass core melted, parts of molten metal were displaced by the expanding ribbon.

DISCUSSION

There has been little experimental work published on the resistance of arresters to flash-back. However, various publications[6,7] indicate that the problem was appreciated in the past, and various preventive measures are known. One investigation was carried out with the arresters constructed from metal foam[5]. The report described various temperature measurements of the arrester matrix while holding the flame, and the authors concluded that with coarser metallic foams, flame reaction took place within the matrix of the arrester. This occurred after the flame burning close to the arrester surface, heated the arrester to the temperature when the reaction could take place within the voids of the arrester.

A similar mechanism operated with crimped ribbon arresters. The slot quenching distances for propane are within the limits 2.28 – 1.75 mm and one value of 1.25 mm is given for ethylene. Assuming the slot quenching distance varies inversely with the square root of absolute temperature these at 1000°C become 1.15 – 0.90 mm for propane air and 0.6 mm for ethylene-air flammable mixtures. Also assuming that a triangular cross-section is equivalent to $1\frac{1}{3}$ of the slot quenching distance, all of these distances are too small for propane-air flammable gas to react within all arrester matrices and 0.6 mm is too small for the reaction of ethylene-air mixture to take place. The last assumption was contradicted by experimental evidence where the flame zone did enter within the matrix of finer arresters. This however happened only in selected localities, after intense heating with distortion of the crimp being apparent. Once this reaction within the matrix was established, it was completed with no luminosity outside the arrester.

In order to make the combustion possible within the arrester it was essential that the ribbon was preheated by the flame burning outside the arrester. Thus largely, the whole process is dependent on efficient heat transfer to the ribbon. The arrester matrix will reach the required temperature if two conditions are satisfied a) there is adequate supply of heat b) there is reasonably efficient heat transfer to the ribbon. These two conditions can be antagonistic. A large fuel supply may cause lift-off of the flame zone and seriously reduce the heat transfer. Since lift-off is a function of the burning velocity there will be a critical speed of flammable mixture for every gaseous composition at which the lift-off can commence. Apparently with propane-air mixture it was not possible to heat the ribbon adequately for the reaction to occur within the arrester matrix. At low velocities the energy input was too low, and when the velocity of flammable gas was increased lift-off of the flame occurred.

PRACTICAL APPLICATION

In selected industrial situations good performance against flash-back may be required of the arrester. The present work gives a broad indication of the relevant tests that may be needed. The maximum velocity of the flammable gas used in these experiments is probably the most critical. However scale effects are largely unknown, and the type of mounting used may also affect performance.

TABLE 1

<u>Summary of the flash-back test results</u>

Crimp Height mm	Velocity of gas cm/sec	Flammable gas: 4.2 per cent propane-air	Flammable gas: 6.5 per cent ethylene-air
1.0	8.2	Flame close to the arrester. Ribbon dull.	Flame close to the arrester. Ribbon glowing faintly.
	16.5	Flame close to the arrester. Ribbon dull.	Flame close to the arrester. Ribbon glowing faintly.
	24.5	Flame 1 mm away from the arrester. Ribbon dull.	a) Arrester glowing temperature 1125°C flame entered the matrix. Arrester failed after 15 min. b) As a) failed at 24 min. Temperature 1000°C.
0.5	8.2	Flame close to the arrester, ribbon glowing. Temperature ≃ 1000°C.	Flame close to the ribbon. Dull glow over small area.
	16.5	Flame close to the arrester, ribbon glowing. Temperature ≃ 1000°C.	Flame close to the ribbon. Ribbon glowing. Temperature 1000°C.
	24.5	Flame close to the arrester, ribbon glowing. Temperature ≃ 1000°C.	a) Arrester glowing. Temperature 1125°C. Flame entered within the matrix failed at 5 min. b) Arrester glowing test stopped at 60 min (18 mm long).

Duration of test 30 min unless indicated otherwise.

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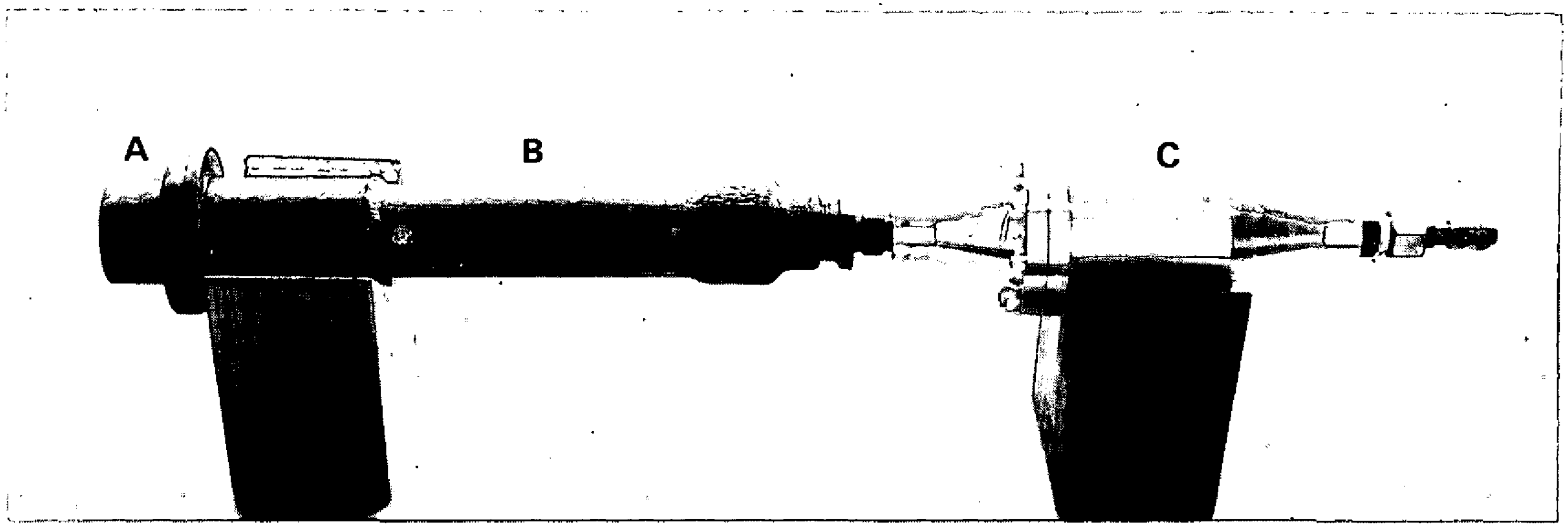


FIG. 1. TEST APPARATUS

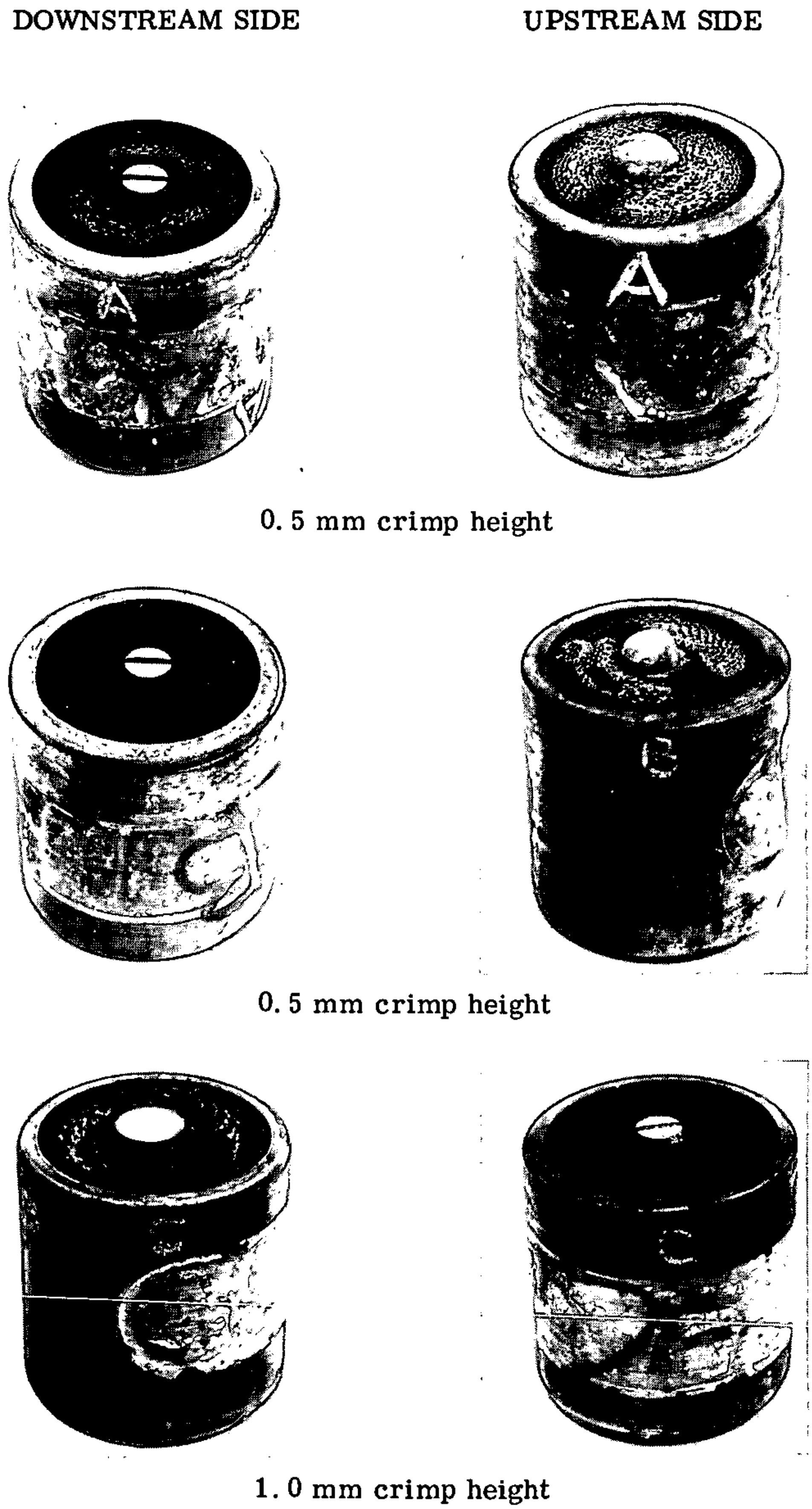
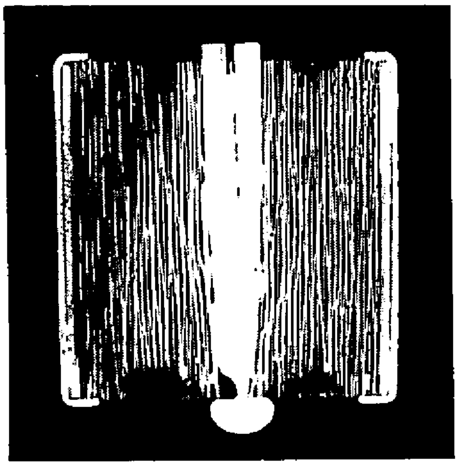
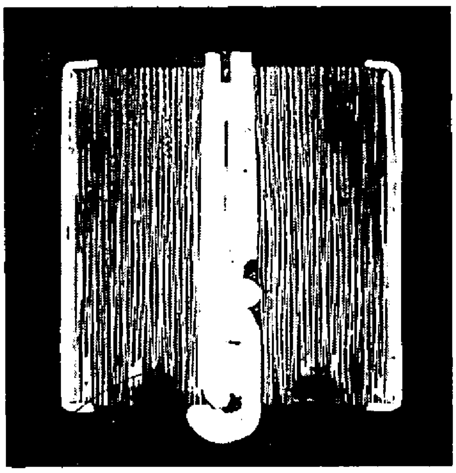


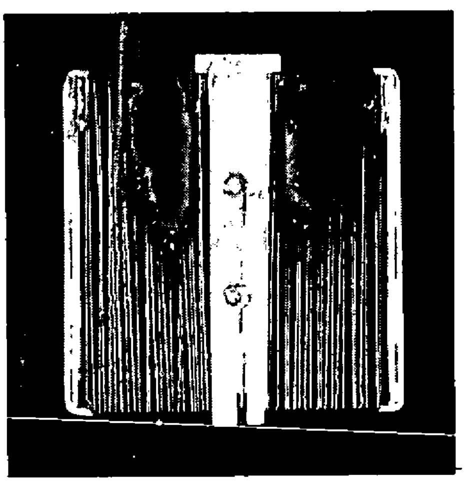
FIG. 2. DAMAGED ARRESTERS



0.5 mm crimp



0.5 mm crimp



1 mm crimp

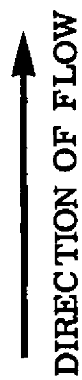


FIG. 3. DAMAGED ARRESTERS SECTIONED AFTER POTTING IN RESIN