DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

AND

FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH NOTE

No. 511

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO-JET ENGINE

PT. V

THE PRODUCTION OF HIGH EXPANSION FOAM

BY

B. LANGFORD, G. W. V. STARK and D. J. RASBASH

This report has not been published and should be considered as confidential advance information. No reference should be made to it in any publication without the written consent of the Director of Fire Research.

December, 1962.

Fire Research Station.
Boreham Wood.
Herts.
('phone ELStree 1341)

F.R. Note No. 511

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO-JET ENGINE

Pt.V

THE PRODUCTION OF HIGH EXPANSION FOAM

by

B. Langford, G. W. V. Stark and D. J. Rasbash

SUMMARY

Tests with small scale apparatus indicated that foam could be produced at an expansion of about 1000:1 from solutions of detergents under conditions simulating generation with the inert gas generator.

Tests of foam production with the inert gas generator showed that foam could be produced with good efficiency with the generator delivering about half its maximum output of inert gas. A foam making screen in the form of a sock of open mesh absorbent cotton fabric was used. The efficiency of production increased as the uniformity of the velocity of the gas stream through the foam-making screen increased.

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO-JET ENGINE

Pt. V

THE PRODUCTION OF HIGH EXPANSION FOAM

by

B. Langford, G. W. V. Stark and D. J. Rasbash

Introduction

Tests by the Safety in Mines Research Establishment, Buxton, have shown that high expansion foams, produced from ventilation air using a solution of a foaming agent, can extinguish fires in mine roadways(1).

The present note describes tests conducted at the Fire Research Station to examine the feasibility of generating a similar high expansion foam, using the hot gas from the jet engine inert gas generator(2).

Experimental

Tests were made firstly, using small scale apparatus to examine the feasibility of the process and secondly, on the full-scale using the inert gas generator.

The small scale tests were made with the apparatus shown diagrammatically in Fig.1. Two sizes of ducting, 3 in dia, and 8.5 in dia were used. The bulk of the tests were made with air at ambient temperature, but some tests were made with combustion gases from a gas burner introduced into the air intake of the centrifugal fan to simulate the effect of the hot gases produced by the inert gas generator. The large scale tests were made with apparatus shown in Fig 2.

Preliminary tests on materials for the foam making screen showed that an an absorbent open mesh cotton fabric was the most satisfactory. The synthetic fibre mesh fabrics tested were not as good as cotton mesh fabrics for making foam but the mesh pattern and size were not the same as with the cotton fabrics used. The fabric used in the most of the tests weighed 6.6 oz/yd^2 and had 20 holes, about $^1/10$ in dia per square inch. However, provided that similarly dimensioned holes in the mesh were similarly separated by a thick section of cotton fibres, no difference in performance between cotton fabrics was detected*.

The foam was generated by the gas stream blowing through open mesh fabric over which a solution of foaming agent, the foaming solution, was sprayed from a nozzle or nozzles. The fabric was fixed at right angles to the gas flow as in Figs 1 and 2a, or in the form of a sock distended by the exhaust gases as in Fig 3b.

In the small scale tests the foaming solution was supplied from a pressure vessel and sprayed through a single spray nozzle. In the full-scale tests the foaming solution was pumped from open tanks to the nozzle systems.

The foaming agents investigated in the small scale apparatus, are called compounds A and B; compound B and a third compound, C, were used in the full-scale tests. Properties of these and other compounds will be published later.

The tests made at Safety in Mines Research Establishment had shown that

---

*Cotton cloth was found to weaken and rupture after an hour or so in later tests, reported elsewhere.

the gas velocity was a limiting factor for the efficient generation of foam, and that at velocities greater than 15 ft/sec, the efficiency fell off sharply. In the full scale apparatus, Fig.2, the conical extension fitted to the inert gas outlet was dimensioned to give mean gas velocities in the range of 5 to 20 ft./sec. The maximum velocity is high, but to reduce it further would have meant constructing an impracticably large conical extension.

The socks, Fig.2, were constructed to enable a large area of mesh fabric to be developed without an excessively large overall diameter. The socks used in the present series of experiments varied from 2 ft 6 in to 5 ft 6 in in diameter and 5 ft 6 in to 10 ft 6 in long and had surface areas varying from 48 ft^2 to 106 ft^2 giving mean gas velocities of 2 to 20 ft/sec.

Results

Small scale tests

Tests were made using the 3 in duct to establish the relationship between the Expansion Ratio* of foam and the concentration of foaming agent in aqueous solution. The Expansion Ratio is the ratio of the volume of foam produced to the volume of foaming compound solution; when expressed as foam volume divided by liquid volume this quantity is known as the Swelling Index, i.e. Expansion Ratio 1000 to 1 $\doteq$ Swelling Index 1000. The tests were made at a constant gas velocity and flow rate, and the flow rate of foaming solution was adjusted by the control valve to the mimimum rate to give a complete foam plug issuing from the net. The results are shown in Fig.4 which indicates that the expansion ratio increased with concentration of foam-agent to a maximum at 5% and then decreased.

Tests were then made using the 8.5 in duct with compound A in 3% solution to find the effect of gas velocity on the expansion ratio. In these experiments the gas velocity was varied by operating the valve in the duct. At each gas velocity the flow rate of foam agent was adjusted to the minimum to give a complete foam plug and the expansion ratio was measured. The relationship is shown in Fig.5, which indicates that expansion ratios tended to increase with increasing gas velocities up to about 10 ft/sec. Above this velocity the rate of increase fell and at velocities in excess of 15 ft/sec complete foam plugs were not formed.

A further series of experiments were made in the 8.5 in duct using 3% solutions of foaming agents A and B, to find the volume ratio, i.e. $\left(\frac{\text{gas flow rate}}{\text{foaming solution flow rate}}\right)$ which would give the maximum expansion ratio measured at the mesh fabric. In each set of experiments the gas velocity was kept constant and the flow rate of the foaming solution was varied.

During the course of these tests it was noted that some of the foaming solution was not converted to foam. The duct was therefore modified by drilling a drain hole in the bottom of the duct immediately before the mesh fabric, to drain off the excess unconverted foam solution. The results for both the modified and unmodified ducts are given in Fig.6. The loss of liquid unconverted to foam increased from 33 to 45 percent, as the volume ratio increased from 500 to 1100 to 1. A volume ratio of 1100 : 1 was the maximum at which a complete foam plug was formed.

A few comparative tests were made to examine the effect of increased temperature and of combustion products on the production of foam. The

---

*For description of the method of measurement see Appendix.

increased temperature and combustion products were obtained by allowing the combustion products from a gas burner to be drawn into the air intake of the centrifugal fan. The tests showed that at temperatures of up to 70°C, and in the presence of combustion products a continuous plug of foam was formed in the same way as when air alone was used.

Full scale tests

Following the small scale tests, the requirements laid down for foam generation with the full scale apparatus were

(i) The volume ratio to be 1000 : 1
(ii) The concentration of foaming agent in the foaming solution to be between 3 and 5 per cent
(iii) Gas velocities through the mesh fabric to be less than 15 ft/sec.

The first tests were made with the apparatus shown in Fig.2a. Tests with Compound A, at 4.5 per cent concentration, and a gas flow of 14500 ft^3/min at 100°C, showed that foam could be produced with 60 per cent of the inert gas being converted to foam (mean of 6 tests). The ratio of volume of foam produced to volume of gas used as a percentage (volume efficiency), was calculated, after making due allowance for the reduction in temperature of the gas as foam was produced (from 100°C to 50°C) and the consequent reduction in gas volume. The volume efficiency decreased rapidly with increasing gas flow. Incomplete plugs of foam were formed at mean gas velocities of 8.7 ft/sec. An investigation of the gas velocity at the mesh showed it to be non-uniform. In some areas the velocity was less than 1 ft/sec and in others the velocity reached 20 ft/sec. Foam was not produced at those areas where the velocity was highest. In view of the non-uniform velocity at the mesh, tests with the cone extension were discontinued.

The apparatus shown in Fig.2b was used thereafter. Different sizes of mesh sock were used to vary the surface area of mesh fabric and hence, the gas velocity through it. During the tests described the foaming solution was pumped from a tank to the nozzle manifold which was sited between the middle and top of the bag, preliminary tests having shown that this position gave more efficient foam generation than the middle of the bag. The foam was generated into a space bounded by a 4 ft high barrier, for 1 min. periods. The amount of foam produced was estimated from the area of floor covered and the mean height of foam, indicated by markers placed in it. The results are summarised in Table 1.

Compound C showed poor compatibility with the hard mains water; the stock solution lost its capacity for making foam in a few days. In view of this finding, tests with the compound were discontinued.

Table I

Performance of Sock Foam Generator
Ratio Gas Flow/Liquid Flow 1000 : 1

Test No.	Foam Solution	Inert Gas Flow ft^3/m at 100°	Converted Flow ft^3/m at 50°C	Area of Sock ft^2	Mean Gas Velocity at 700°C ft/s	Foam Produced ft^3/m	Volume Efficiency per cent
1	4% A	14500	11850	48	5.1	5000	42
2	"	14500	11850	48	5.1	9500	80
3	"	19800	15700	48	6.8	12500	80
4	"	25000	19650	88	4.8	5500	28
5	"	19800	15700	88	3.8	4500	29
6	"	19800	15700	106	3.1	12500	80
7	4% C	19800	15700	106	3.1	2500	16
8	"	14500	11850	106	2.3	5500	46

Tests 4 and 5 were made with a 2 ft 6 in dia. sock, 10 ft 6 in long. Foam was not generated well over the first 5 ft or so of the bag and hence the volume efficiency was low. It was observed in test 7 that foam was not made uniformly over the sock, suggesting that the gas velocity was non-uniform.

A few measurements were made of the reduction in the depth of the foam with time with compounds A and C. These were used to plot the curves in Fig.7.

Tests were then made to assess the ability of the foam to extinguish fires of liquid fuels. The results are presented in Table II. In these tests, the separation between the end of the net sock, and the nearmost point of the fuel tray, was 23 ft. The progress of extinction of a methylated spirit fire with compound A is shown in Plate 1.

Table II

Extinction of liquid fuel fires

Foam Solution	Converted Gas flow ft^3/m at 50°C	Volume Ratio	Liquid Fuel	Diameter of Fire ft	Time for extinction sec
4% A	15700	1000 : 1	Gas oil	2	2
"	"	1000 : 1	Petrol	6.25	10
"	"	1000 : 1	Methylated Spirit	6.25	14

The expansion ratio of the foam produced, measured during generation 15 ft from the end of the net sock, was 1500 : 1.

Discussion

The results of the small scale tests indicated that foam of high expansion could be readily generated at mean gas velocities of up to 15 ft/s, and that increasing the temperature of the gas, and including combustion products in the gas did not materially influence the efficiency of generation. The maximum expansion ratios obtained were however substantially less than the volume ratio; a proportion of the gas escaping without producing foam. This loss of gas should be minimised by adjusting the distribution of foaming solution over the mesh fabric. This may be achieved by suitably selecting nozzles and arranging their disposition.

Some of the foaming solution flowed unconverted into foam from the bottom of the mesh fabric screen; this loss appeared to be due in part to the spray striking the metal duct. Such losses, which depend on the perimeter/area ratio of mesh fabric screen would be less with larger sizes of foam generator. The use of a mesh fabric screen in the form of a sock would further reduce such losses.

With the systems tested, with the jet engine inert gas generator, gas distribution and hence gas velocity was not sufficiently uniform to permit efficient generation at mean velocities higher than 8 ft/sec, that is, at the higher outputs of the jet engine generator. Thus, before foam can be generated at the maximum rate, it will be necessary to devise a means of improving the uniformity of gas flow through the net material. Gas losses appeared less and the calculated volume efficiency was higher on the full scale tests when the mean gas velocity was less than 8 ft/sec, than on the small scale tests, at similar gas velocities, although a complete plug of foam was formed over the mesh fabric in the small scale tests.

Direct measurement of wastage of foam solution was not attempted on the full scale tests. Some loss was observed on the cone generator, Fig.2, but could not be seen on the sock generators because these rested on the floor.

The volume efficiencies given in Table 1 are under-estimates, as they take no account of the rate of break-down of foam (Fig.6) or of the further break down that took place as it advanced over the floor.

Conclusion

The tests reported herein have shown that it is possible to produce large volumes of high expansion foam with the inert gas generator. Further work on the design of the foam generating attachment to the inert gas generator will be needed before the maximum gas flow from the generator can be used efficiently.

The foam compounds used have generated foam satisfactorily, but the life of the foam produced could be increased with advantage. In addition, the foam compound needs to be compatible with hard or soft water.

Work is therefore continuing, with a view to attaining the maximum output of foam, and to selecting foam producing agents giving high stability foams, and having compatibility with hard and soft waters.

References

(1) H. S. Eisner, P. B. Smith and E. T. Linacre, S.M.R.E. Research Report Nos. 130, 171, 179, 182 (1956-1959).

(2) F.R. Note No. 507. Control of Fires in Large Spaces with Inert Gas and Foam produced by a Turbojet Engine Part 1. Introduction and Properties of Inert Gas and Foam, by D. J. Rasbash.

Acknowledgements

Mr. J. F. Richardson and Mr. A. Lange assisted with the experimental work.

Appendix

Method of determining expansion ratio

In all experiments using the 3 in and 8½ in ducts the expansion ratio was measured by collecting the foam in a polythene dustbine of 61 litre capacity and known weight. When the bin was full excess foam was removed from the top of the dustbine and the sides were wiped dry. The bin was then re-weighed. The volume of foam in ml per unit weight of foam in grammes was calculated. This was taken as the expansion ratio, since the density of the foaming solution was very nearly 1 gm/ml.

Measurements on the small scale apparatus were taken only when a complete foam plug was issuing from the mesh fabric, the whole plug being led into the sampling bin. Expansion ratios were measured in large scale tests using the same sampling method. It was necessary to collect the foam rapidly and in such a way that it flowed into the bin. This was relatively easy with the small scale generators, but less so on the full scale generators. The foam could not be scooped into the bin, as the tenacious character of the foam produced airlocks and the bin could not be completely filled. If the foam was allowed to flow for periods longer than needed to fill the bin, drained liquid was collected as well as the foam, and a falsely low expansion ratio was obtained.

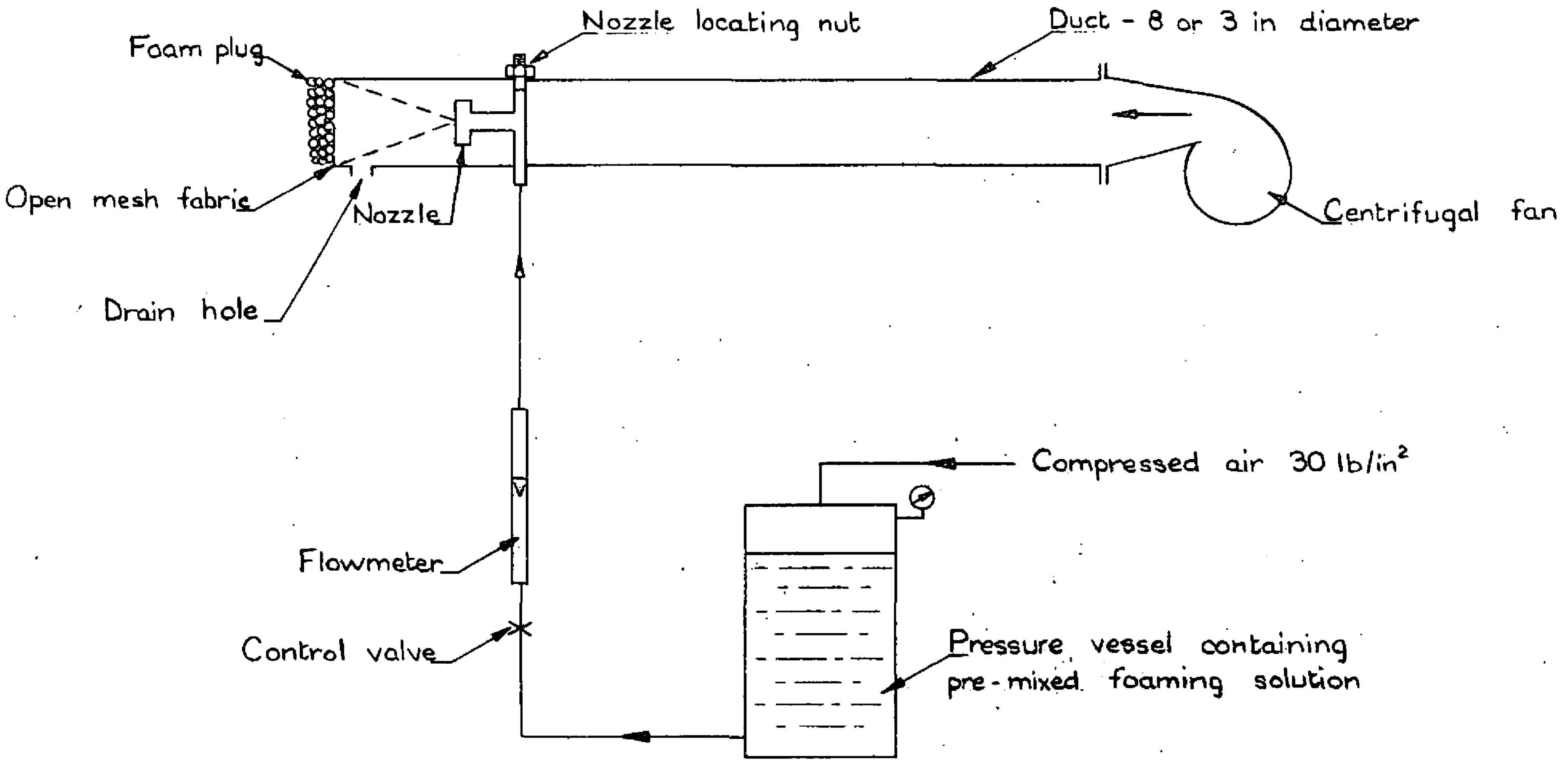
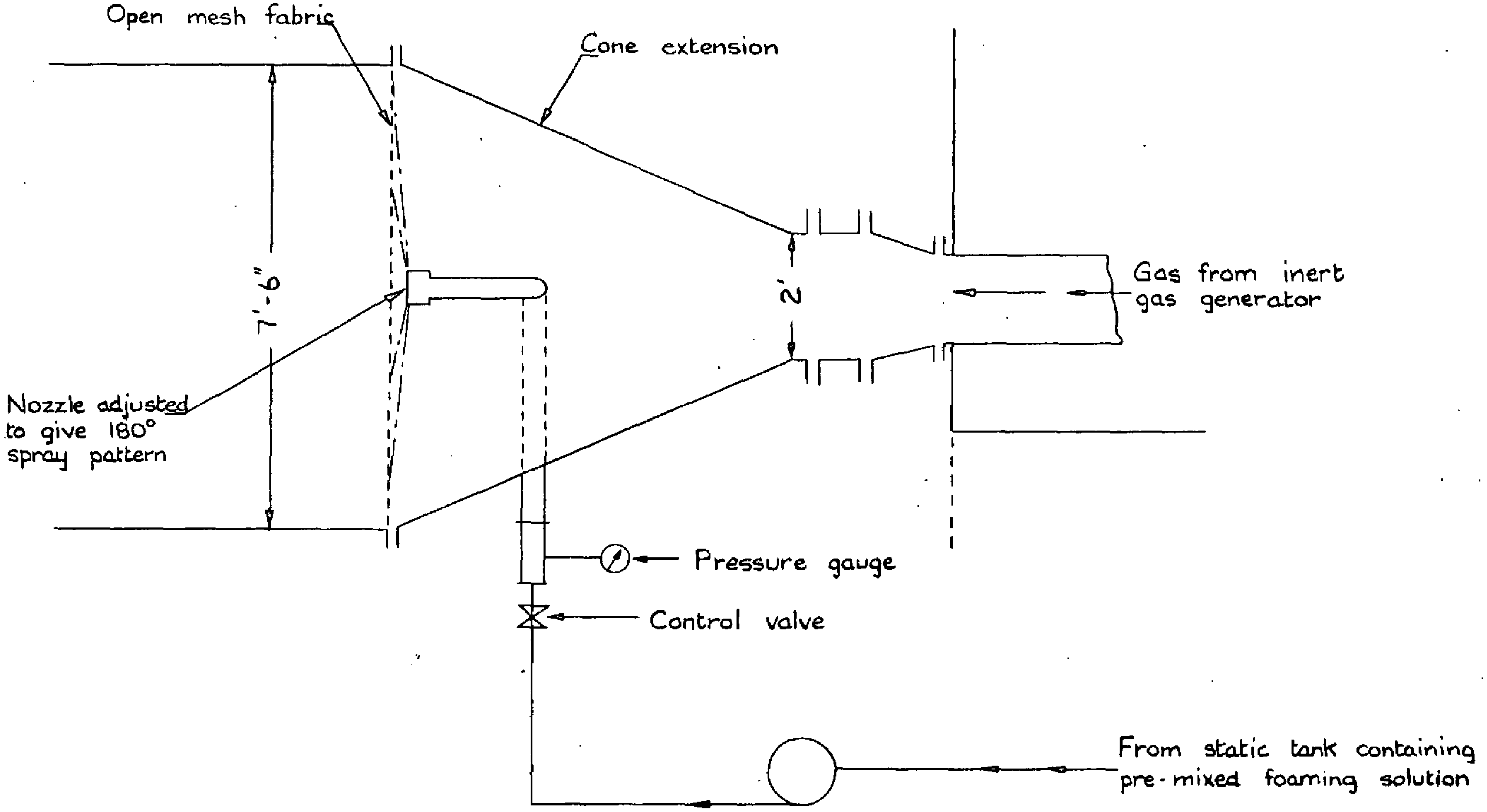
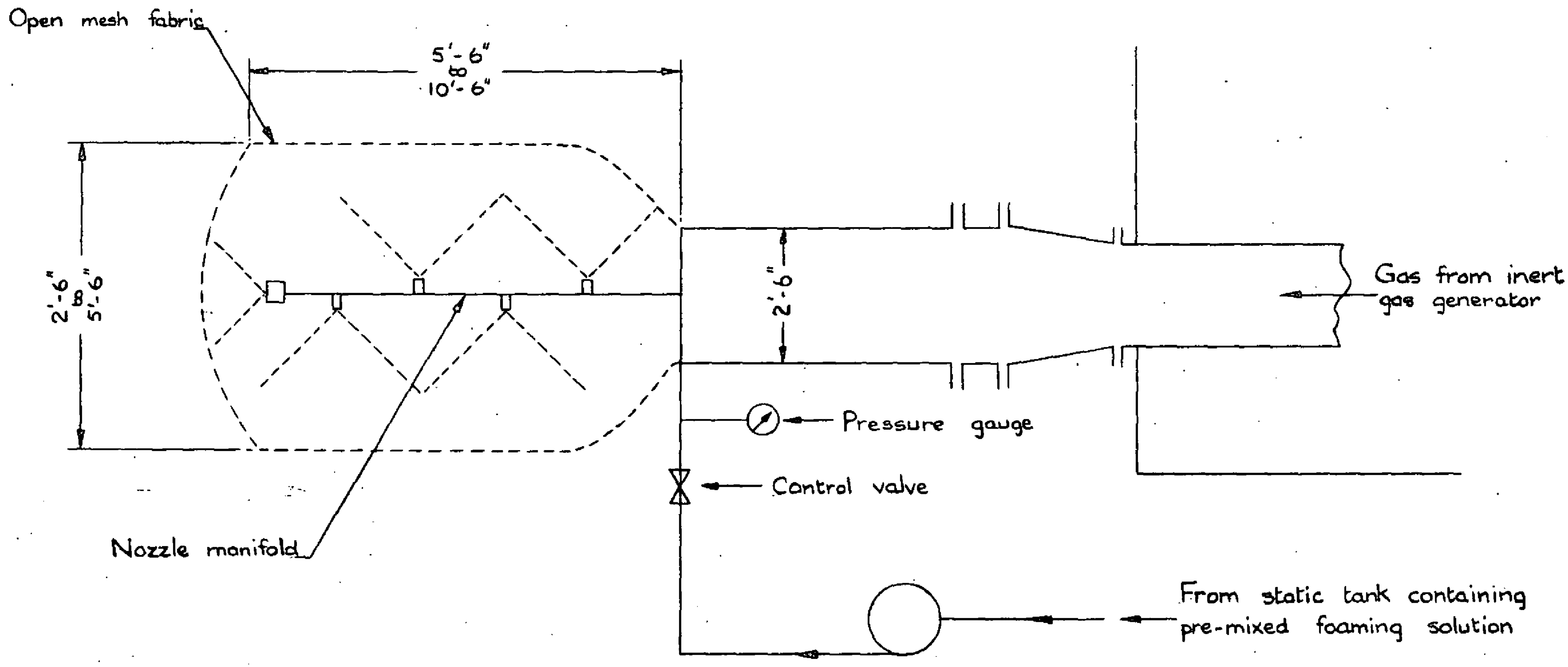


FIG. 1. GENERAL ARRANGEMENT OF 3 in AND 8 in FOAM GENERATORS



CONE GENERATOR

FIG. 2a. FOAM GENERATOR USED WITH INERT GAS GENERATOR



SOCK GENERATOR

FIG. 2b. FOAM GENERATOR USED WITH INERT GAS GENERATOR

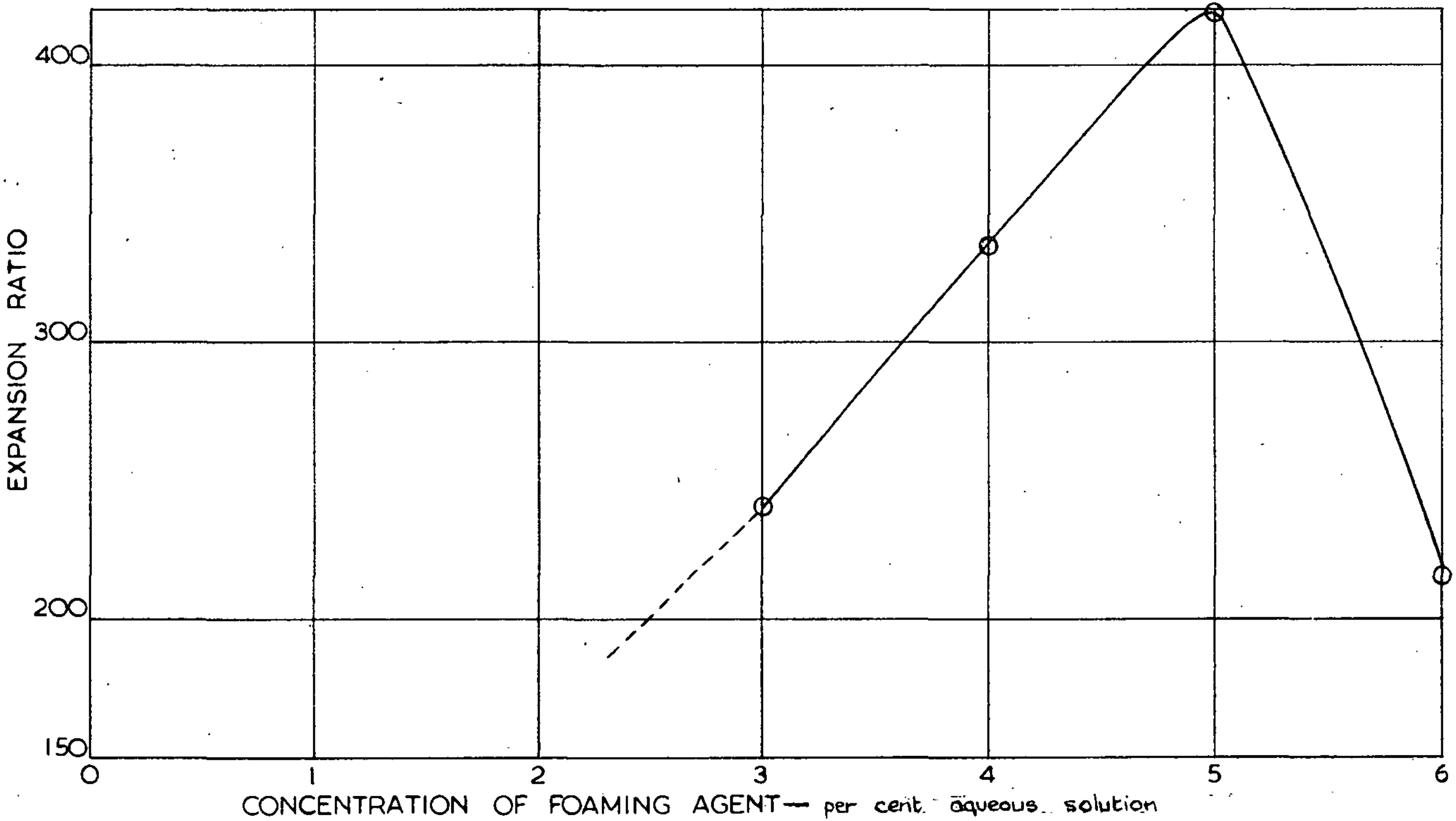


FIG. 3. EFFECT OF CONCENTRATION OF FOAMING AGENT ON EXPANSION RATIO IN 3″ DUCT

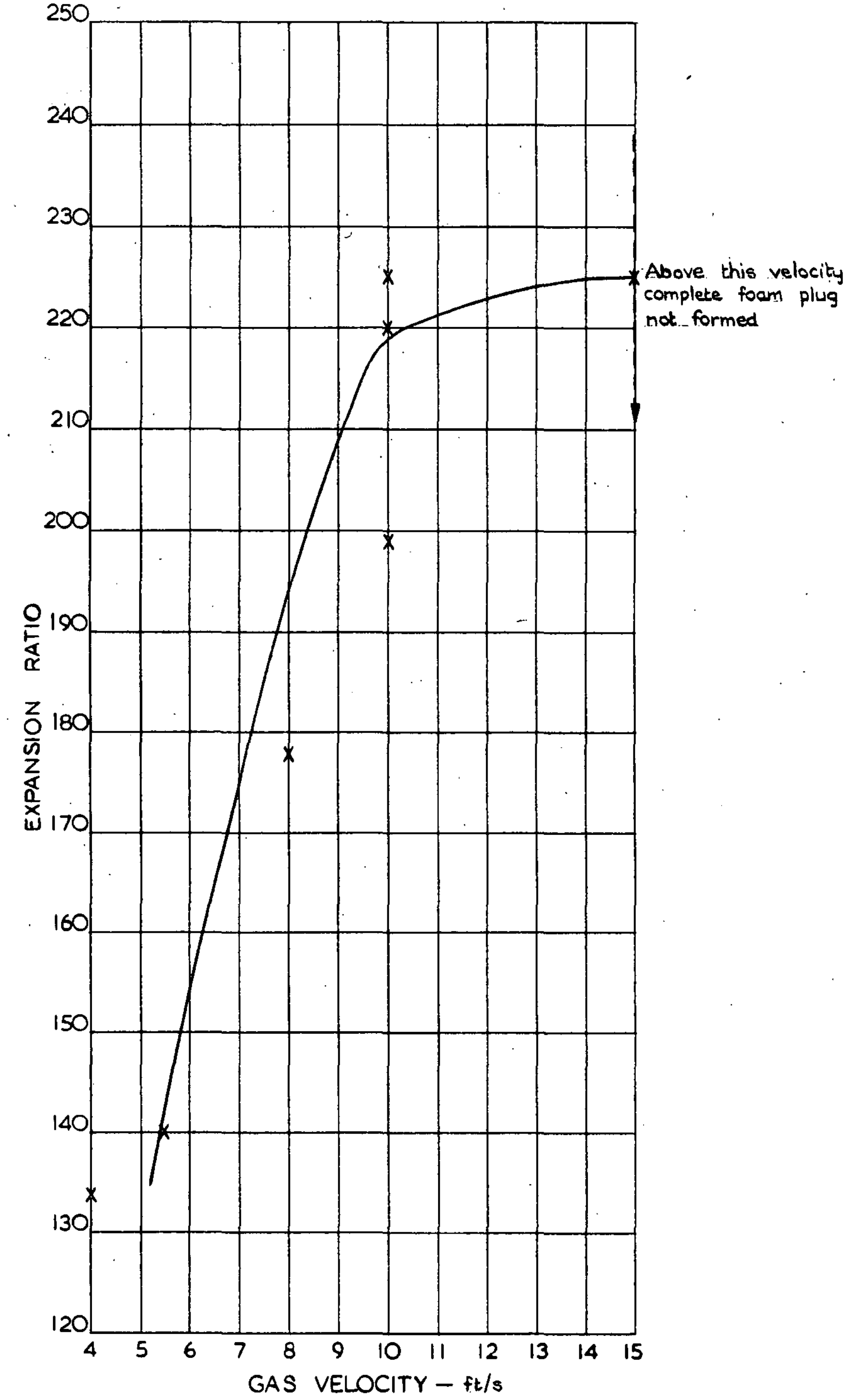


FIG. 4. EFFECT OF GAS VELOCITY ON EXPANSION RATIO IN 8" DUCT

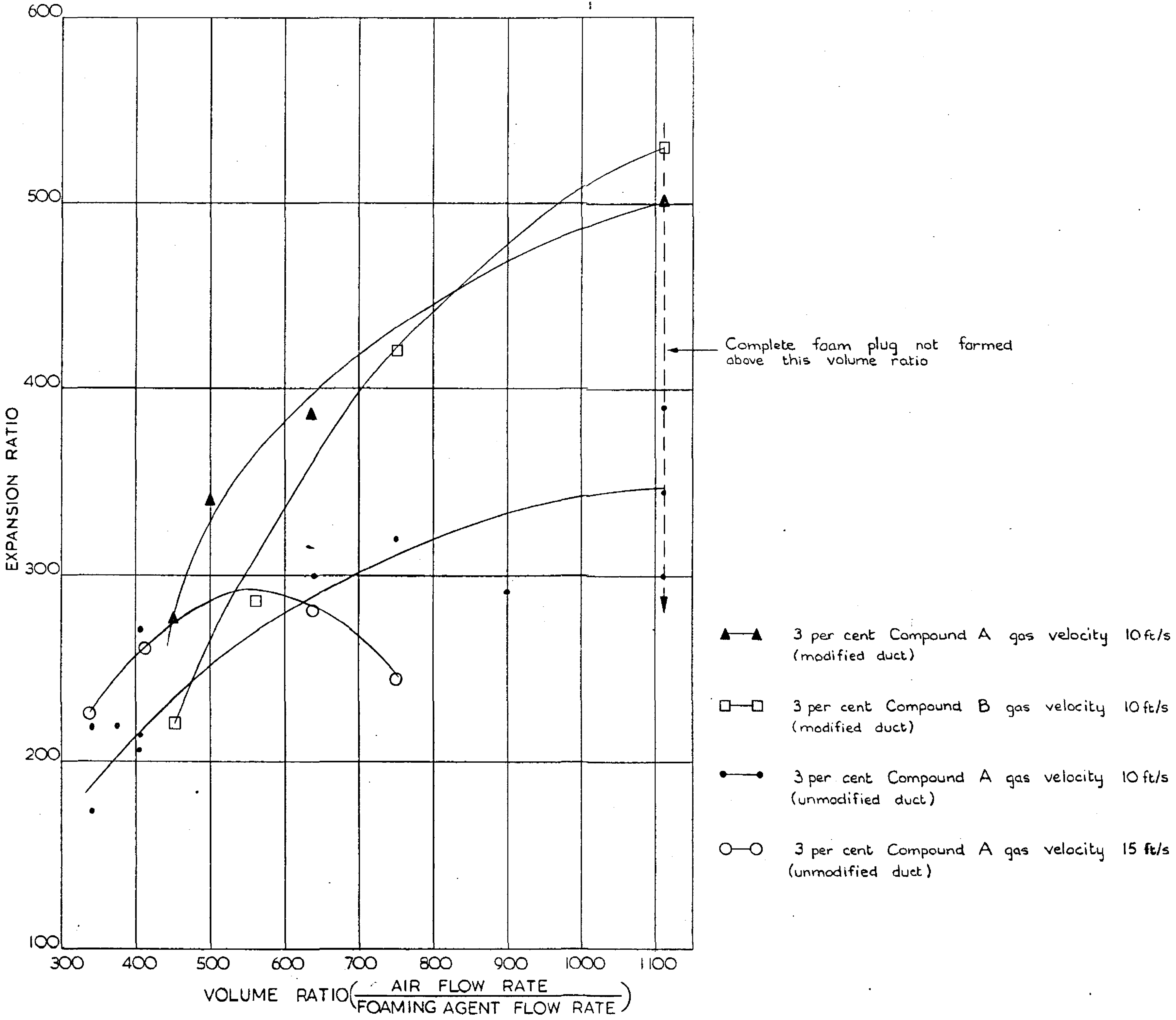


FIG. 5. RELATIONSHIP BETWEEN MEASURED EXPANSION RATIO AND NOMINAL EXPANSION RATIO IN 8" DUCT

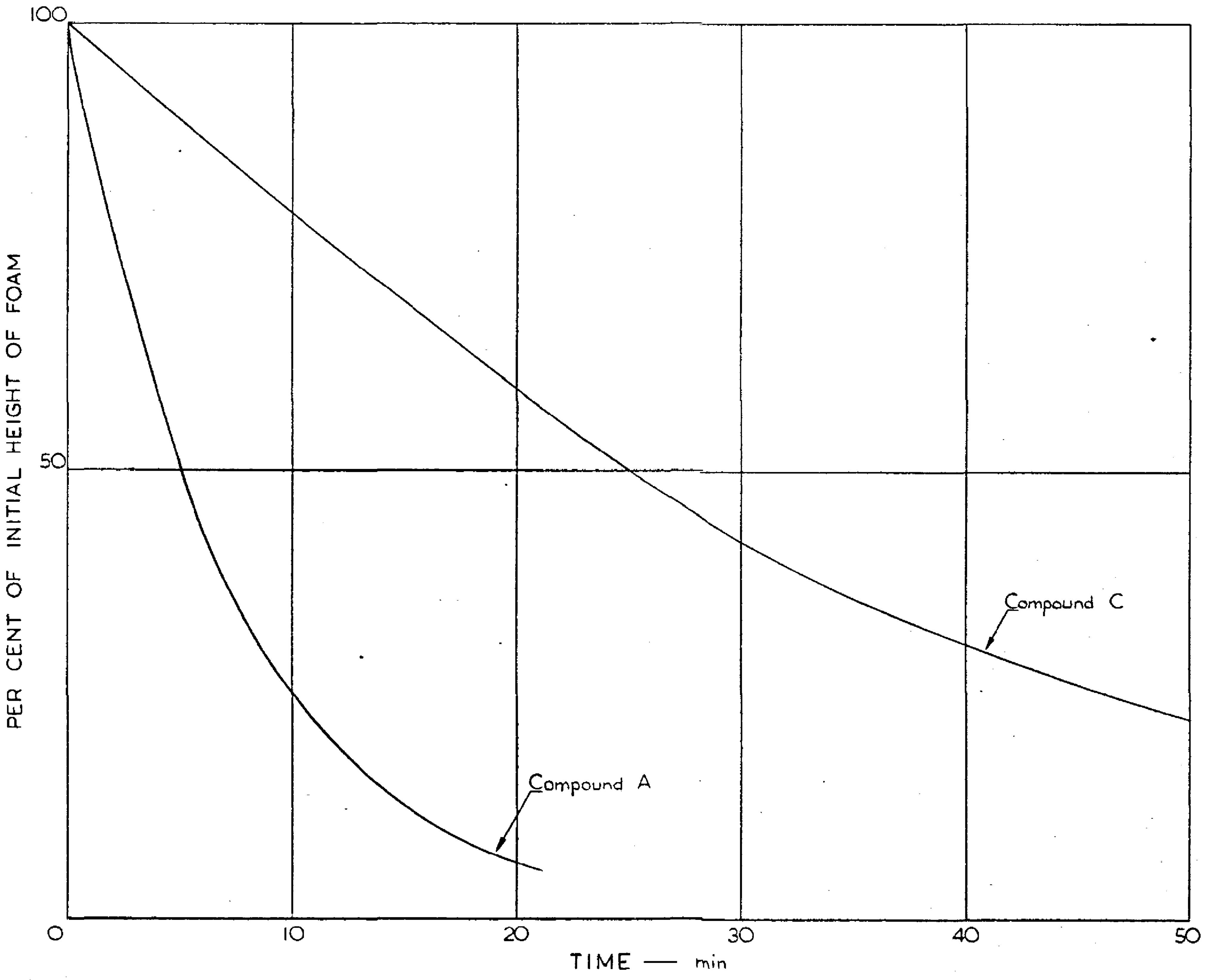


FIG. 6. THE COLLAPSE OF FOAM