DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

AND

FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH NOTE

NO. 546

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO JET ENGINE. PART X. A COMPARATIVE STUDY OF HIGH EXPANSION FOAMS PRODUCED WITH AIR AND WITH THE J.F.R.O. INERT GAS AND FOAM GENERATOR

by

B. LANGFORD AND G. W. V. STARK

April, 1964.

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

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO JET ENGINE. PART X. A COMPARATIVE STUDY OF HIGH EXPANSION FOAMS PRODUCED WITH AIR AND WITH THE J.F.R.O. INERT GAS AND FOAM GENERATOR

by

B. Langford and G. W. V. Stark

Introduction

The effectiveness of high expansion foam with air was first examined by the Safety in Mines Research Establishment at Buxton(1) and later, a portable air-foam generator was developed in America(2). Some early tests of high expansion foam made with the J.F.R.O. Inert Gas and Foam Generator(3) are described elsewhere(4).

The extinguishing properties of high expansion foam depends mainly on the quantity of liquid, mainly water, transported to the fire, and the restriction of the supply of oxygen at the combustion zone.

The amount of water conveyed to a fire by high expansion foam can be maintained at a high level by the use of a foaming agent giving the requisite properties of low rate of break-down and drainage(5). The reduction in the oxygen content of the atmosphere surrounding the combustion zone depends upon the reduction in oxygen content produced by the evaporation of the water present in the foam, and also upon the initial oxygen content of the gas in the bubbles. The oxygen content of the gas filling the bubbles is lower than atmospheric concentration when the jet-engine exhaust gases are used for generation.

This note describes and presents the results of a series of experiments to investigate these factors, using high expansion foams made with air, and with gas from the J.F.R.O. Inert Gas Generator.

Experimental

The foam making attachment to the J.F.R.O. Inert Gas and Foam Generator is shown diagrammatically in Fig.1 and the foam making sock is shown in greater detail in Fig.2. The sock was made from a nylon mesh fabric with an effective hole diameter of about 1/12 in (2 mm). When generating foam, the sock was blown up by the stream of inert gas, and the foam making solution was sprayed from the nozzle manifold on to the distended sock. Foam was formed continuously as the gas passed through the solution-coated sock. Baffles were provided in the sock to improve the distribution of gas, and the end of the sock was made from closely woven materials for similar reasons. The nozzle manifold differed from that reported previously(4). The earlier manifold consisted of a steel pipe with a number of wide angle spray nozzles along its length. The present manifold was a lightweight flexible hose, into the wall of which were inserted 40 lightweight fan spray nozzles. For the majority of the tests reported here, the nozzles delivered foam solution at 170 gal/min (775 L/min). Gas was supplied from the inert gas generator at a temperature of 80°–90°C, at 27,000 ft^3/min (770 m^3/min). The gas contained 15 per cent oxygen, 65 per cent nitrogen, 1.5 per cent carbon dioxide and 18.5 per cent water vapour. However, the formation of foam extracted heat and moisture from the gas. The temperature of the foam was about 40°C and the gas at this temperature was provided at 21,000 ft^3/min (600 m^3/min) and had the composition of 17 per cent oxygen, 74 per cent nitrogen, 1.6 per cent carbon dioxide and 7.4 per cent water vapour. This foam will be referred to as inert gas generator foam. The inert gas generator foam was produced at about 10,000-12,000 ft^3/min (280-340 m^3/min), giving an efficiency of about 50 per cent.

The air-foam generator is shown diagrammatically in Fig.3. The generator consisted of a 38 in diameter axial-flow fan connected to a 6 ft long square section steel duct which expanded to a 4 ft square opening. The foam making screen was stitched concertine fashion over this opening to give an effective area of screen of 32 ft^2 (3 m^2). Foam solution was sprayed on to the screen from 5 impinging jet nozzles within the duct, arranged to give a fairly uniform distribution of solution over the screen. Air flow from the fan was controlled by sliding shutters at the air intake, and the flow of foam solution was controlled by varying the pressure of delivery. For the experiments described here, air was supplied at 10,000 ft^3/min (270 m^3/min) and foam-making solution at 67 gal/min (305 L/min). The air-foam was generated at about 6,000 ft^3/min (170 m^3/min), giving an efficiency of production of about 60 per cent.

Two foam making agents were used. These, referred to as compounds A and C in an earlier note, were a mixture of sodium dodecyl benzene sulphonate with non-ionic additions and ammonium lauryl sulphate respectively. The agents were made up to 1 per cent active content solutions in mains water for use. Compound A drained more rapidly than Compound C and also gave a less stable foam.

Comparative tests of the efficacy of the high expansion foames were made by generating foam into an enclosure bounded by 4 ft high walls, the width of which was such as to give similar rates of progress of foam from the generators. Fires of 6¼ ft dia, of scrap wood, or petrol or alcohol were placed within the enclosure in the path of the foam. The wood fire was allowed to burn for 10 min, the petrol fire for 1 min, and the alcohol fire for 30 sec, before foam was generated, so as to ensure well developed fires.

Additional tests were made with the inert gas generator foam on simultaneous fires of acetone, alcohol, petrol and wood.

Results

The results of the comparative tests with air foam and inert gas generator foam are given in Table 1. The times of extinction given here are the times from the foam first reaching the 6 ft diameter fire, until it was clear that the fire was out. In many of the tests, with air foam particularly, fires would continue burning under a complete cover of foam and would only become apparent when hot gases, often but not always accompanied by visible flames, burst through the foam.

Table 1

Performance of Air and Inert Gas Foam

Agent	Fuel	Extinction time, secs.	
		Air foam	Inert gas generator foam
Compound A	Wood	N.E. in 120	N.E. 120
	Ethyl Alcohol	N.E. in 120	14°
	Petrol	100	10
Compound B	Wood	90	100
	Ethyl Alcohol	90*	NT
	Petrol	29	NT

N.E. = Not extinguished
NT = Not tested

*In a test where foam passed over the fire for 65 seconds, the fire was covered by 3 to 4 ft of foam, but slowly burned through. At the end of the reported test, the layer of fuel and water left in the burning tray would not reignite.

°The layer of fuel and water left in the burning tray was flammable and could be reignited.

The tests with air foam were members of a series made to determine the critical conditions for extinction. Two minutes was the maximum time of generation used, as the walled area confining the foam was then full.

These tests were followed by large scale tests with the J.F.R.O. Inert Gas and Foam Generator in which high expansion foam made with Compound C was allowed to flow over a third of the floor of the Models Laboratory, 2,000 ft^2, on which were arranged fires of ethyl alcohol, acetone, petrol and wood. Plate 1. In these tests all the fires were extinguished; the approximate times for extinction are given below.

Table 2

Extinction times of fires with Inert Gas, Compound C Foam

Fire	Dia. ft	Times, Sec.
Wood	5	60
Ethyl Alcohol	4	5
Acetone	2	3
Petrol	3	7

It was observed during the tests with Compound A foams that extinction of alcohol fires took place with only a thin foam covering for the inert gas generator foam, but that extinction did not take place with air foam, although the foam was up to 6 ft thick over the fire. (Plate 2). In the latter case the foam cover over the fire was often unperforated for some seconds, but then a hole would form over the fire, and hot gases would escape, generally accompanied by thin flames. A similar difference in the thickness of cover with foam was observed for petrol fires. Such differences were not observed for wood fires, as about 5 ft thickness of foam was needed to cover the fire for either inert gas, or air foam. The depth of foam obtained with Compound C was much greater than with Compound A, because of the greater viscosity of the foam produced.

Discussion

The difference in performance of foams made with different foam agents and different gases depends upon the amount of water conveyed to the fire in the walls of the foam bubbles, and upon the composition of the atmosphere surrounding the fire produced by vaporisation of the foam liquid, principally water. Foam agent C has much lower drainage and break-down rates than agent A[5], and therefore can convey more water in foam to a fire. Flames are extinguished when the atmosphere surrounding them has an oxygen content of 16 to 14 per cent, but, before burning wood can be extinguished, the smouldering of the solid material must be stopped. This smouldering can continue at very low oxygen concentrations and extinction at low oxygen concentrations takes a long time. However, rapid extinction can be achieved by the direct wetting and cooling of the burning solid material. The reduction of oxygen content of the atmosphere contained in inert gas generator foam required to bring about flame extinction is only 1 to 3 per cent, and this reduction would be produced by the vaporisation of a small proportion of the water in the foam. With air foam, the oxygen content of the atmosphere must be reduced by 5 to 7 per cent - requiring the vaporisation of a high proportion of the water in the foam. This is shown by the results for petrol fires with agent A, Table 1. Petrol has little effect on the stability of foam, and therefore the extinction of petrol fires is unaffected by breakdown of foam other than by the effect of heat and flame. Alcohol, in liquid or vapour state disrupts foam, and can therefore reduce the amount of water available for dilution of the atmosphere. This may explain in part the difference in performance, Table 1, between alcohol and petrol fires with air foam. The difference in times of extinction for alcohol and petrol fires with the two inert gas foams are hardly significant, and suggest that with each type of foam water was vaporised in sufficient quantity to dilute the atmosphere in the foam to allow flames to be extinguished. However, in all the tests with alcohol, the foam was sufficiently stable to cover the fire completely in times of the same order as for petrol fires. In this respect, the performance of the high expansion foam system reported here is better than that of the conventional protein fire-fighting foam systems. Differences in the alcohol resistance of the foaming agents, in the rate of application and in the structure and thickness of the foam blanket may each contribute to the difference in performance.

Measurement of the oxygen content of the atmosphere under the foam in the vicinity of the fires was not made in the tests reported here. However, the content of oxygen was probably much greater than the calculated minimum values of 6 per cent and 8 per cent for inert gas generator-and air-foam respectively. Higher values would be expected because of the drainage of water from the foam and because of the destruction of foam by thermal and chemical processes. The oxygen content would therefore be substantially higher than that needed to extinguish smouldering combustion, about 2 per cent. The times for extinction of wood fires, 90 and 100 secs for air and inert gas generator foams made with agent C, Table 1, are not significantly different, bearing in mind the difficulty of assessing the time of extinction of a fire that is covered with a blanket of foam. The drainage rate of a cool foam, however, is less than that of a warm foam[5], so that rather less water would be conveyed to a fire by the latter foam. The similarity of the times for extinction suggest that the same mechanism was operating. In each test the fire was covered by foam in about 50 seconds, and at the end of each test the foam was a foot or so higher than the top of the timber stack. The difference between the time for extinction and the time to cover the stack is much greater than the time required to extinguish liquid fires (Table 1 and 2) suggesting that, during this time, wetting and cooling of the timber was taking place. The results for foams made with agent A, which convey much less water to the fire, support this hypothesis.

Conclusions

The tests described in this note indicate that high expansion foam made with the inert gas generator can extinguish both wood and liquid fuel fires efficiently, and that alcohol and water miscible fuels fires are extinguished nearly as readily as those of hydrocarbon fuels. High expansion foam made with air is much less efficient than inert gas foam for extinguishing liquid fuel fires but has similar efficiency for extinguishing wood fires. Extinction of liquid fuel fires is brought about by a reduction in the oxygen content of the atmosphere surrounding the fire, and of wood fires by the wetting of the solid material.

For maximum efficiency, the foam produced must have high stability, and convey the maximum amount of water to the fire. Ammonium lauryl sulphate has been found to be a suitable foam agent.

Acknowledgements

Thanks are due to Mr. J. F. Richardson who designed and tested the air-foam apparatus and to Mr. D. Freeman and Mr. A. Lange who assisted in the experimental programme.

References

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

(2) Safety Development Corporation. Greensberg, Pennsylvania, U.S.A.

(3) STARK, G. W. V. Control of fires in large spaces with Inert Gas and Foam produced by a turbo-jet engine. Part 3. The Design and Operation of Inert Gas Generator. F.R. Note No.512.

(4) LANGFORD, B., STARK, G. W. V. and RASBASH, D. J. Control of Fires in Large Spaces with Inert Gas and Foam Produced by a Turbo-jet Engine. Part V. The Production of High Expansion Foam. F.R. Note 511.

(5) LANGFORD, B. and STARK, G. W. V. Control of Fires in Large Spaces with Inert Gas and Foam Produced by a Turbo-jet Engine. Part VII. The Selection of Suitable Foaming Agents for the Production of High Expansion Foam. F.R. Note 519.

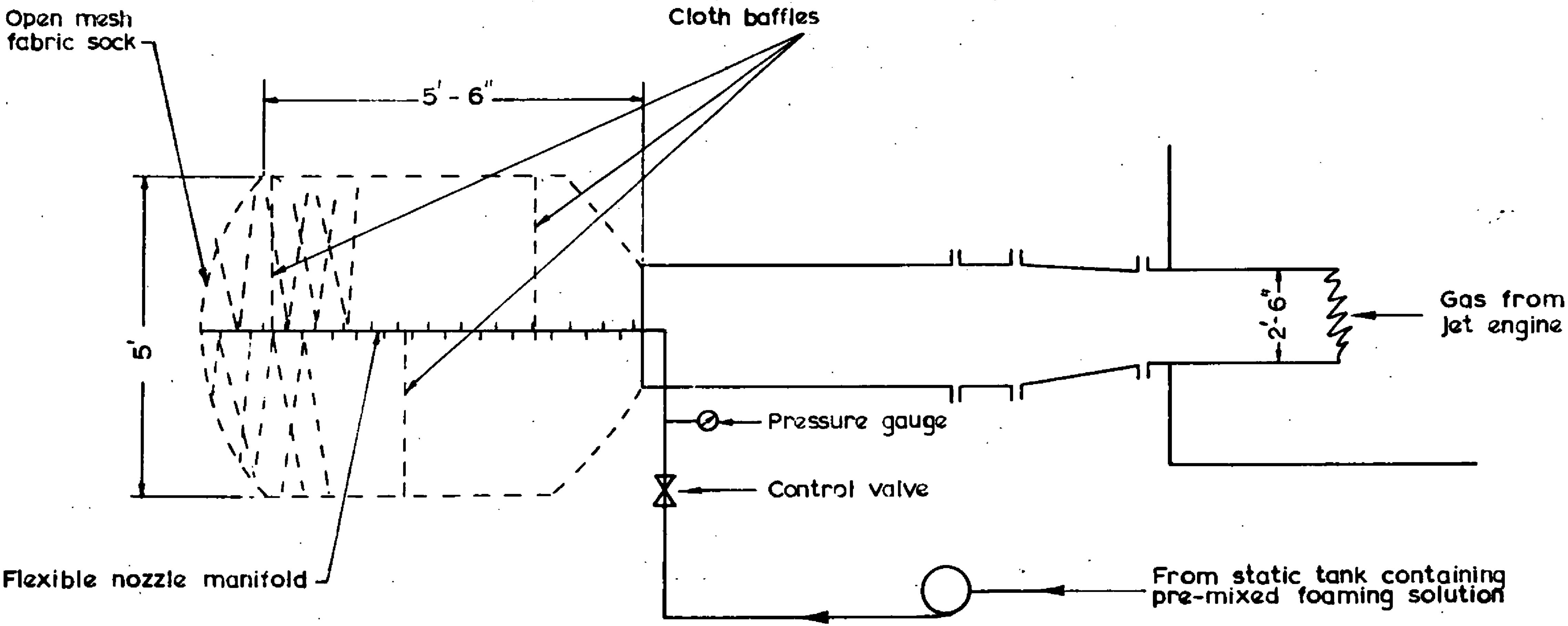


FIG.1. LAYOUT OF JET ENGINE FOAM GENERATOR

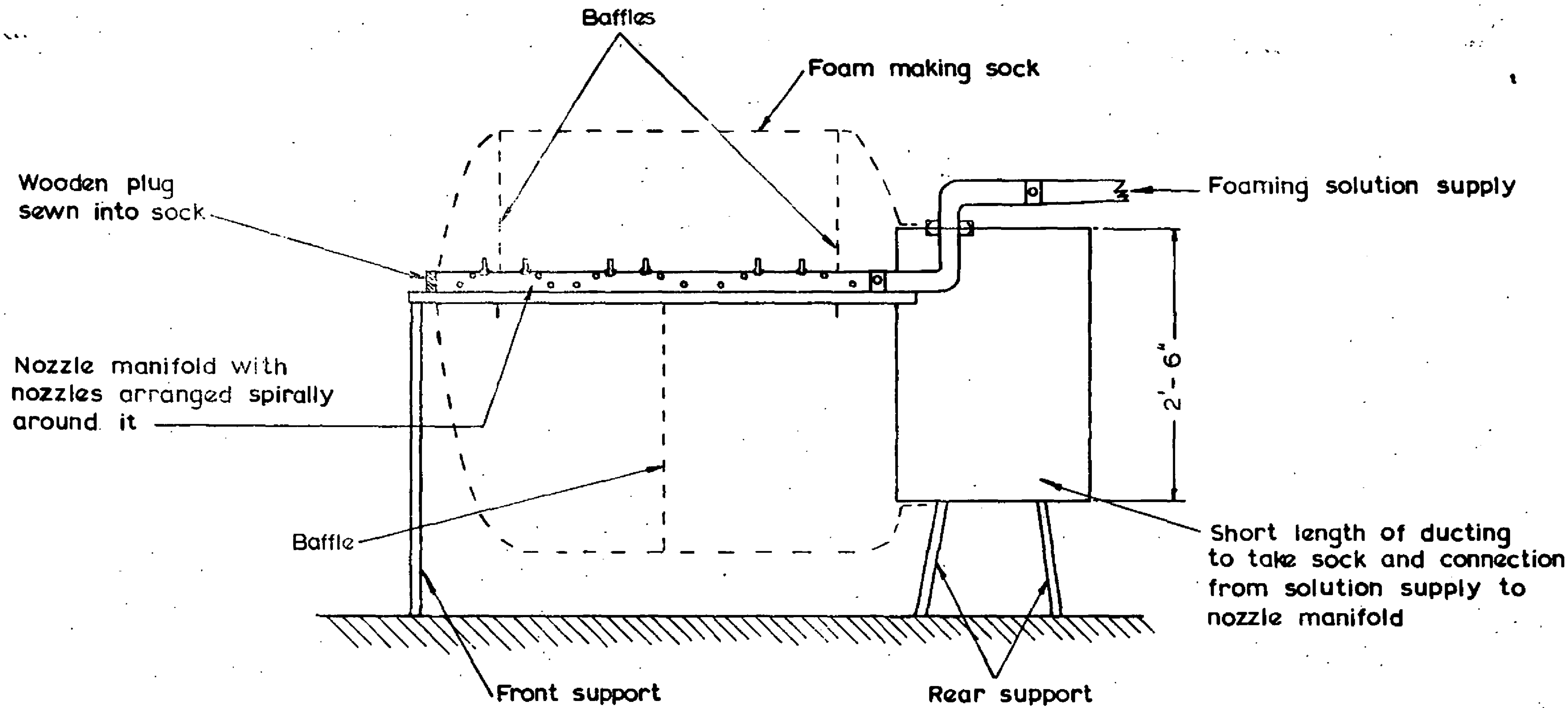


FIG.2. FOAM MAKING SOCK AND FLEXIBLE NOZZLE MANIFOLD

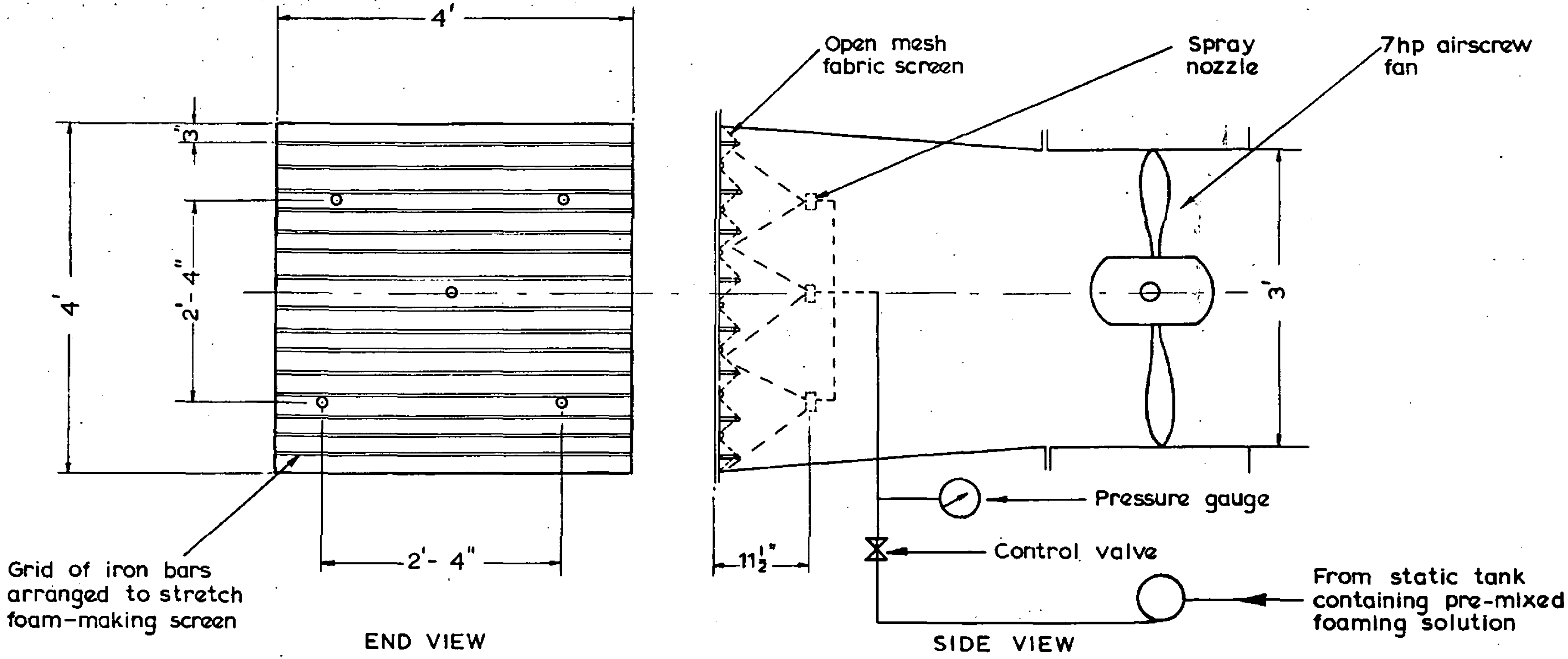
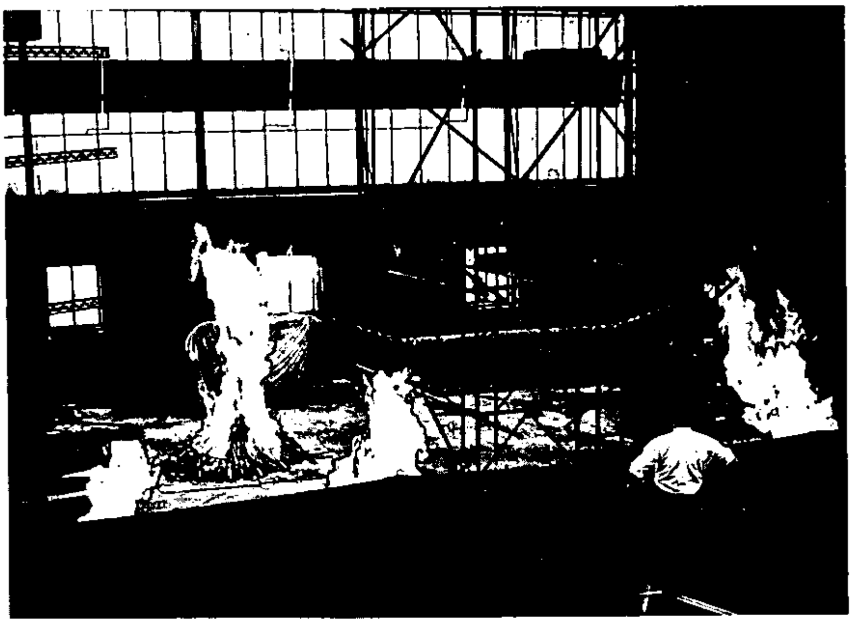
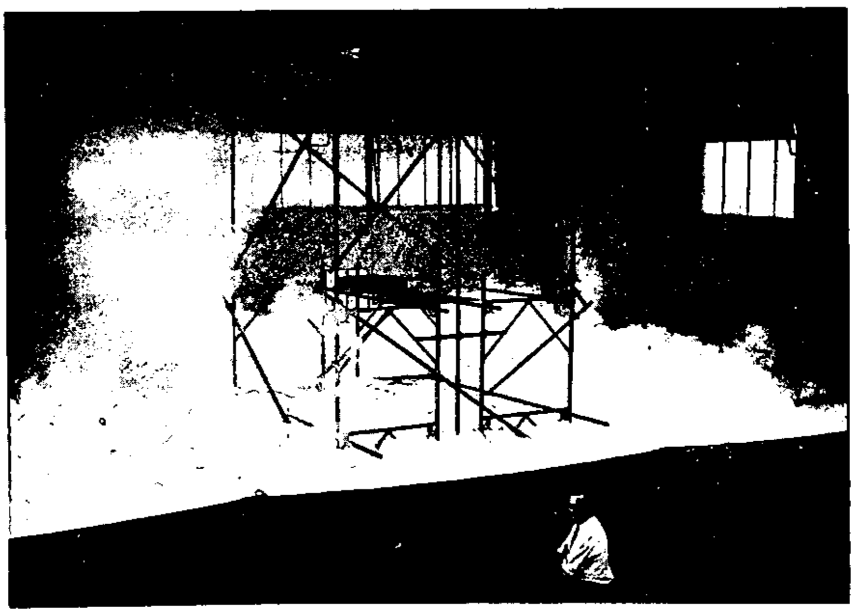


FIG. 3. LAYOUT OF AIR FOAM GENERATOR



acetone fire — alcohol fire — petrol fire — wood fire

A. View of fires, gas inlet ducting and foam-sock



B. Extinction of fires. Foam applied for 2 min. Plate taken about 3 min, later

EXTINCTION OF LIQUID AND SOLID FUEL FIRES
WITH FOAM FROM THE J.F.R.O. INERT GAS AND FOAM GENERATOR

PLATE 1

A. Alcohol fire covered by foam
45 sec. application of foam

B. Alcohol fire burning freely
5 mins after applying foam

EFFECT OF AIR FOAM ON ALCOHOL FIRE,
6 ft. DIA FOAM COMPOUND

PLATE 2.