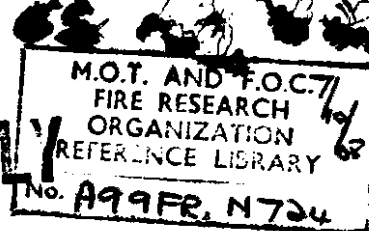




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No. 724

THE EXTINCTION OF INDUSTRIAL FIRES BY FOAMS

by

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RESEARCH
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MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

THE EXTINCTION OF INDUSTRIAL FIRES BY FOAMS

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P. Nash and D. W. Fittes

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Keywords

Foam
High-expansion
'Light water'
Fuel liquid
Surface
Generator

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1. Introduction

For many years foams have been used to extinguish flammable liquid fires in the process industry, by the formation of a layer or blanket over the burning surface of the liquid. For this purpose, chemical or mechanical foams have been used for non water-miscible liquids such as the hydrocarbons, having a fire point up to about 100°C, and special "all-purpose" foams have been developed to extend the use of foam to water-miscible liquids such as the alcohols. Other specially fortified foams have been developed for use on difficult fuels such as rocket propellants. Recently, "light water" foam has been developed in the United States as a potential replacement for the traditional chemical and protein-based foams.

The development of medium and high-expansion synthetic foams has extended the use of foams from liquid to solid fires, and in its high-expansion form, this type of foam is also used for dealing with fires in volumes, as well as on surfaces.

This paper gives an account of both the traditional and modern uses of foam in fire extinction, and of the equipment used for its generation and application. It endeavours to show what is the essential good practice in each application.

2. Types of foam

The types of foam considered in this paper are as follows:-

- (a) Chemical foam: This foam is made by the mixture of aqueous solutions of aluminium sulphate and sodium bicarbonate, together with a suitable foam stabiliser such as licquorice, saponin, protein-based foam liquid, etc. The carbon dioxide produced provides the gaseous filling for the bubbles. Portable hand extinguishers¹ operating on this principle may be used on non water-miscible flammable liquid fires, and fixed systems are available for larger risks such as dip tanks, storage tanks, etc. The method is, however, less convenient for installed systems than the use of mechanical foam, and has been largely superseded by the latter.

- (b) Mechanical or air foams: Mechanical foams are made by aerating and "working" an aqueous solution of a protein-based foaming liquid. Protein liquids are derived from waste materials such as blood, hoof-and-horn meal, fish scales, soya bean, chicken feathers, etc, and are used in 3-6 per cent solution. The foam is suitable for the extinction of non water-miscible liquids with fire points not exceeding 100°C. Portable extinguishers² using mechanical foams operate on this principle, and larger risks can be protected with self-aspirating branchpipes or fixed or mobile foam-making equipment. The use of mechanical foams is described in Sections 5, 6, and 7.
- (c) Fortified mechanical foams: Mechanical foams fortified with fluorocarbons are available which have a greater heat resistance than ordinary protein foams. They are especially useful for sub-surface application (Section 6) as they have a much larger resistance to submersion in hydrocarbon fuels than ordinary protein liquids.
- (d) All-purpose foams: These foams are based on protein materials as in (b), but are fortified with a bubble-wall stabiliser to prevent the extraction of the liquid by the water-miscible fuel. They are available for use in portable extinguishers, and larger risks can be protected with self-aspirating branchpipes or fixed or mobile equipment. Their use is described in Section 8.
- (e) "Light-water" foams: These foams³ are produced by aerating a 6 per cent aqueous solution of a perfluorinated surface active agent. They are available in portable extinguishers, and can also be produced by the same equipment as used for protein-based air foams. They are suitable for non water-miscible flammable liquids, and experiments have shown that they are also effective on at least some water-miscible liquids. Their use is described in Section 9.
- (f) High-expansion foams: These foams⁴ are produced from a 1 to 2 per cent aqueous solution of a synthetic foaming agent, and may be filled with air or an inert-gas. They can be of "medium" expansion, i.e. ratio of the volume of foam to the volume of solution used, of 100-500 units, or they may be of "high" expansion of 500-1000 units or more. The medium expansion foams are suitable for the

(f) High-expansion foams (cont'd)

extinction of fires in flammable liquids, and the high expansion foams can be used to fill volumes containing stacked goods. These foams are therefore suitable for flammable liquid and solid fires. Their use is described in Section 10.

3. Foam specifications and test methods

The Ministry of Public Building and Works has specifications for chemical⁵ foam charges and mechanical⁶ liquids. There are no U.K. specifications for all-purpose foams or "light-water" foams. A specification for high-expansion foam liquids is in preparation by the Fire Research Station on behalf of the Home Office⁷. The specification for high-expansion foam liquids will include a test for liquid drainage, as well as selected fire tests to represent typical practical fire situations.

Mechanical foam liquids are tested in accordance with the Ministry of Public Building and Works specification, which includes tests for chemical and physical properties, sludging and fire performance. The latter is determined by applying, for a period of 4 minutes, foam made for a 4 per cent solution of the foaming liquid and having typical branchpipe properties, to a test fire of "narrow-boiling point range" petroleum, having a free surface area of 3 ft² (0.28 m²) (Plate 1). The time to reduce the intensity of the heat radiation from the fire to $\frac{1}{10}$ th of its initial value, on application of foam of the appropriate properties at a rate of 0.68 l (0.15 g) of foam-making solution per minute, is termed the " $\frac{9}{10}$ th control time". This must not exceed a stipulated value (150 seconds), and the drainage of liquid from the foam in the first 10 minutes after the start of foam application must be less than about one-half of the total foam solution applied in 4 minutes of delivery (Fig. 1). The water-retention of the foam is, of course, a measure of its stability during and after extinction of the test fire, and hence gives a guide to the post-extinction protection provided by the foam layer against re-ignition of the flammable liquid. Other properties used to 'define' a protein-based foam⁸ are the " $\frac{1}{4}$ drainage time" or time taken for $\frac{1}{4}$ of its liquid to drain from a sample of foam in a dry metal pan, and the "critical shear stress" of the foam, that is, the stress exerted by a rotating flat metal vane in shearing the "cylinder" of foam which it sweeps⁹. These two properties are measures of the work done in forming the bubble structure, and hence of its stability.

While there are no official specifications for all-purpose foams and "light-water" foams, most of the Ministry of Public Building and Works test methods may be applied to them (Section 8 and 9).

4. Principles and practice of foam-making equipment.

The formation of mechanical, all-purpose, "light-water" and high expansion foams consists essentially of three stages. In the first stage, the foaming liquid is mixed in the appropriate proportions to form the aqueous solution. Mechanical, "light water" and high-expansion foam liquids can all be "pre-mixed", that is, they can remain stable in aqueous solution for substantial periods and still form an effective foam. All-purpose foam liquids must usually be mixed with water only a few seconds before the foam is formed, owing to problems of stability of the "bubble wall stabilizer" in dilute solution. With many types of equipment foam liquid is induced into the water stream just before foam formation, or it may be metered or pumped into solution.

The second stage of foam formation is the induction or injection of the air, and the third stage is the mixing of the air and foaming solution to form the bubble structure.

The simplest type of foam-making equipment for mechanical, all-purpose or "light-water" foams is the hand-held foam-making branchpipe (Fig. 2a), in which the water flow induces the input of foam liquid through a metering orifice. The foaming solution is ejected through a cluster of nozzles into the aeration chamber of the branchpipe, thus inducing the appropriate air flow, and the trunk of the branchpipe serves to mix the air and solution to form foam. This principle can also be used with premixed solutions, and for fixed equipment such as foam-making sprinkler heads for protecting installations.

The foam made by self-aspirating equipment usually has a solution strength of 4-6 per cent by volume, an expansion of 4-10 units and a critical shear stress of 100-200 dyn/cm². It is thus a fluid free-flowing foam capable of extinguishing a fire rapidly, but giving only a limited post-extinction protection.

Another form of self-aspirating equipment is the "mechanical foam generator" which is similar to the branchpipe in principle, but usually operates at a higher water pressure. It is connected into the water supply

line and induces its foam liquid supply from a separate tank or drum. The made foam is ejected from the "mechanical foam generator" into a foam delivery hose, and thence to a nozzle for application to the fire. Unlike the foam-making branchpipe, the "mechanical foam generator" is capable of working against moderate back-pressures of 1.05-1.76 kgf/cm² (15-25 lbf/in²) and is therefore suitable for connection to a dry riser on the side of a storage tank or other similar risk.

Foam may also be made by foam-making pumps as shown in Fig. 2b. Here the premixed or induced solution is injected into a vane-type pump which also induces air through another part. As the pump rotates, it mixes the air and foaming solution, and the made foam is ejected via a large-diameter hose onto the fire. Foam pumps give foams with expansions up to about 14 units, and critical shear stresses up to 600 dyn/cm². They are therefore less free-flowing but more stable than branchpipe foams.

A modification of the self-aspirating branchpipe is the pressurized branchpipe or foam-maker, in which the air is pumped into the aspirating chamber. This equipment gives an expansion up to 18 units, and a critical shear stress of 150-600 dyn/cm². It is illustrated in Fig. 2c. Foam pumps and pressurized foam-makers are used on installed equipment or large mobile appliances.

High-expansion foams are made at much higher volume rates than mechanical and "light-water" foams, and therefore require equipment which can handle a much greater throughput of air per unit volume of solution. As the foams are of a more highly expanded and transitory nature, the foam-making areas in the equipment are proportionately larger, but the energy input per unit volume of made foam is much less. Simple self-aspirating equipment can be used in which the solution is sprayed onto a net through which the air also passes (Fig. 3a), and the foam is formed at this net. More complex equipment uses the solution stream to drive an air fan, whence the solution and air again passes through a net where the foam is formed (Fig. 3b). In larger portable equipment, the air is pumped by a motor-driven fan through a duct to a mesh screen onto which the foaming solution is sprayed at the appropriate rate. The design of screen must be such that the air velocity through it does not exceed about 1.5 m/s (5 ft/s), (Fig. 3c). The output of high-expansion foaming equipment ranges from 28.3 m³/min (1000 ft³/min) at expansion 150 units for hand-held units to 849 m³/min (30,000 ft³/min) at expansion 1000, from large mobile units.

5. Surface application of mechanical foams to non water-miscible fuels

Normal mechanical or air foams are suitable for application to the surface of non water-miscible fuels such as petrols, paraffins, light diesel and lubricating oils etc. They will not form a foam layer on liquids having fire points above 100°C, but the water in the foam may still extinguish the fire by cooling. There may be a danger of "frothing over" if the water drained from the foam boils beneath the surface, as can occur with hot-zone forming flammable liquids. The time to control or extinguish a given fire is characterized by a "critical rate of application"⁹ of foaming solution per unit area of burning liquid surface. Below this rate, which is approximately $0.016 \text{ l m}^{-2} \text{ s}^{-1}$ ($0.02 \text{ gal ft}^{-2} \text{ min}^{-1}$) for petrol and low fire point oils, the fire cannot be extinguished. Above this rate, the control time reduces rapidly with increasing rate of application, but at the higher rates, the rate of reduction falls off. The quantity of foaming solution used to control or extinguish a fire is characterized by the same "critical rate of application", and may also exhibit an "optimum rate", usually about 2-4 times the critical rate, at which the least foam solution is used. (Figs 4a and 4b). Thus if no life risk exists, foam should be applied at about the optimum rate, but if there is life risk the application rate should be as high as possible to obtain the quickest control and extinction. The performance of protein-based foams on various aviation and motor fuels has been examined¹⁰ and found to vary by a factor of up to 3 to 1 in control time (Table 1). On all the fuels tested, however, the foam gave at least an adequate performance.

Protein-based foams, while having a fairly neutral pH value, will corrode equipment if it is not washed through with clean water after use. It is important that the hose is thoroughly cleaned also, as diluted foam can promote the growth of fungus, which, while it may not attack synthetic fibres, is unpleasant and evil-smelling.

6. Sub-surface application of mechanical foams to non water-miscible fuels

Storage tanks and other containers of flammable liquids can be protected by the sub-surface application of mechanical foam. In this method, which is sometimes described as "base-injection", the foam is injected into the tank through a product line or other suitable line, so that it floats to the surface of the fuel as discrete globules, which then spread out to form a foam layer on the surface. The layer forms first at the periphery and

gradually "fills in" towards the centre. The method has other incidental effects, such as the promotion of circulation within the fuel in the tank, so that cold layers of fuel are brought up from the depths to the surface. This will help in the extinction of fuels of the higher fire points (above 45°C) which can be extinguished by cooling alone. Sub-surface application has the advantage that it is not liable to damage in the case of explosion, as may occur to top pourers and applicators.

The foam, in floating to the surface, picks up fuel which remains as globules in the foam layer, and which will ignite and burn as individual points of flame when the primary fire is extinguished. If the volume of this fuel exceeds 10 per cent of the volume of liquid in the foam layer, the fuel globules will not burn off before the layer is destroyed, and the fire will reignite at the fuel surface. To keep the fuel pick-up below 10 per cent, the foam must be injected with a low expansion (about 3 for a 9.14 m (30 ft) depth of fuel between inlet and surface), and with as low a drainage rate as possible. The foam drains as it rises, and its expansion will therefore increase to approximately 6 as it reaches the surface. It is this "surface expansion" which actually controls fuel pick-up. Mechanical foams fortified with fluorocarbons (Section 2c) are much more tolerant of fuel pick-up than ordinary protein foams and can absorb up to 40 per cent of fuel by volume before fire extinction becomes impossible. The close control of foam properties and the limit of fuel depth of 9.14 m (30 ft) are therefore not applicable to them. Another factor affecting fuel pick-up is the position of the foam inlet. It should be as near the vertical axis of the tank as possible in order to minimize fuel pick-up.

Sub-surface application of foam has been used successfully at the Fire Research Station¹¹ to extinguish fires in tanks containing petrol, the surface of the fuel being 8.53 m (28 ft) above the central inlet point. The method used in these experiments to make foam of suitable properties is shown in Fig. 5, the foam being generated at a mechanical foam generator from a premixed solution, and being passed via a centrifugal pump into the tank. This method not only keeps the foam at a low expansion, but provides a considerable energy input to assist in foam stability and to inject the foam against the back pressure of the fuel in the tank.

Sub-surface application is capable of being just as efficient as surface application, in terms of foam application rate and quantity of liquid used. In practice, it may even be more efficient as foam is not wasted against the updraught of the flames, or by the difficulty of reaching the tank surface by branchpipes, monitors or mobile pourers.

A method of "sub-surface" application developed in Sweden¹² is one in which the foam is injected into a nylon "stocking" flaked within a container fixed within the tank. On applying the foam, the foam pressure opens the sealing cap at the top of the container and pushes out the nylon sleeve which floats to the surface. Here the fire burns off the top of the stocking and the foam flows directly onto the surface of the flammable liquid without coming into contact with the body of the liquid. One of the difficulties of sub-surface application - contamination of the foam by the flammable liquid - is thereby avoided, and with it the need to control the foam properties so exactly, or to limit the depth of application to not more than 9.14 m (30 ft) below the surface. Protection of higher storage tanks is thus possible. One disadvantage is the difficulty of inspecting the foam injection equipment within the liquid stored, and the need to drain the tank for any servicing or replacements.

7. Surface application of mechanical foams to mixtures of hydrocarbons and water-miscible fuels.

Ordinary mechanical foams can be used for mixtures of hydrocarbons and water-miscible flammable liquids, but with some diminution in performance. Thus, in a series of experiments¹³ in which ordinary protein foams were applied both gently and forcefully to the surface of petrol containing ethyl alcohol in the range 0-20 per cent by volume of the mixture, it was found that the critical rate of application of the foam increased by a factor of up to 3, where the foam was applied gently, and up to 8 where it was applied forcefully. The time to control the fires at rates above the critical were found to increase by similar factors. Fortified foams would be unlikely to suffer such a large performance reduction.

8. Surface application of all-purpose foams to water-miscible fuels

Ordinary protein-based mechanical foam liquids are totally unsuitable for use on water-miscible fuels, as the fuel extracts the water from the bubble walls and causes rapid foam collapse. All-purpose foams have been developed for these fuels^{14, 15} based on protein foam liquid but including special

bubble-wall stabilisers to prevent extraction of the water. They may be used successfully in ordinary foam-making equipment since with this, the necessary time limits between making and applying the foam complied with Section 2d.

The performance of modern all-purpose foams on petrol and various water-miscible fuels are shown in Table 2, in terms of critical rate of application and quantity of solution to control a fire. It may be seen that while their performance is not always equal to that of ordinary protein foam on petrol, it is always within the range of practical usefulness, whereas the breakdown rate of protein foam on any of the water miscible fuels makes its use quite impracticable.

9. The use of "light water" foams on flammable liquid fuels

"Light water" foams³, made from a 6 per cent aqueous solution of a perfluorinated surface active agent, can be used for surface application to hydrocarbon fuels with fire points up to about 100°C. They can also be applied successfully to water-miscible fuels. These foams can be generated in normal foam-making equipment, and their performance improves greatly with an increase of expansion¹⁶. Thus a "light water" foam of expansion 20 was found to be twice as effective as one of expansion 4, whereas changes in the expansion of protein-based foams have been found to have little effect on their performance when applied to the surface of flammable liquids. In general, "light water" foam was found to give slightly lower critical rates than protein foams, and to be more economical at rates above the critical. This "economy ratio", measured in terms of the minimum quantity of foaming solution to control a given fire, varied from 2 to 4 according to the fuel used. A 9.09 l (2 gal) protein-foam hand extinguisher is capable of extinguishing some 0.93-1.39 m² (10-15 ft²) of petrol fire, whereas a 9.09 l (2 gal) "light-water" extinguisher can extinguish up to 465 m² (50 ft²). Comparison of the performance of "light-water", protein foam and all-purpose foam on various flammable liquids is given in Table 3.

"Light-water" has less heat-resistance than protein foam and so will not resist "burn-back" so well if a large fire area is reopened. It will, however, seal small areas more readily. It costs some thirty times as much as protein foams when made up into solution, but this factor must be reduced by the "economy ratio" applicable to the fuel to be extinguished, and to incidental savings on the provision and manning of standby equipment.

Plate 2 shows a 4.65 m^2 (50 ft^2) petrol fire being extinguished by "light-water" foam.

10. Use of medium expansion and high-expansion foams

Medium and high-expansion foams, made from 1-2 per cent aqueous solutions of synthetic foaming agents, can be used in the extinction of flammable liquid and solid fuel fires. Such foams may have a bubble filling of inert gas, produced by a combustion gas generator, or may be filled with a cold inert gas or with air. In practice, air-filled high expansion foam is adequate for extinguishing most types of fire except those involving deep-seated smouldering of solid combustibles.

Medium and high-expansion foams extinguish by a combination of smothering and cooling. On flammable liquid fires, extinction is mainly by smothering of the fire with sufficient foam to ensure that the supply of air to the fire is cut off and the combination of excess fuel vapour and combustion products in the fire zone leads to extinction. With solid combustibles, the water in the foam also adds its cooling effect.

The best foams for extinction of flammable liquids are those with an expansion of 100-500, particularly for outdoor use, as they are less readily blown off the fire by wind or lifted off by the rising heated air (Plate 3). Expansions up to 1000 can however be used for flammable liquid fires within buildings. The "critical rate of application" of high-expansion foams can be measured in terms of the minimum rate of build-up of foam in metres or inches per minute to extinguish the fire, and the maximum quantity can be expressed in terms of the minimum depth of foam over the fire. For a foam of expansion 1000, these quantities have been found to be 0.15 m/min (6 in/min) and 0.30 m/min (12 in/min) respectively to extinguish a petrol fire in a tray of area 1.86 m^2 (20 ft^2) burning on the floor of a room of 18.58 m^2 (200 ft^2) area. Corresponding quantities can be measured for the extinction of solid fuel fires, mixed fires of flammable liquids and solids, e.g. an oil-filled transformer fire, and for flammable liquid fires burning above the foam in such a way as to subject the rising layers of foam to intense heat radiation.

One of the problems with high-expansion foam is the difficulty of distribution over large areas, and this may lead to the development of dispersed generation points throughout a building in which a process is being carried out. Such points might consist of small motor-driven generators

mounted at high level in the walls of the building, or could be a matrix of points spread throughout a building or process hall at ceiling level and operated on demand by the heat or smoke rising from the fire. Such a system is illustrated in Fig. 6.

11. Acknowledgement

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12. References

1. Portable fire extinguishers of the foam type (chemical). British Standard 740 : Part 1 : 1948.
2. Portable fire extinguishers of the foam type (gas pressure). British Standard 740 : Part 2 : 1952.
3. TUVE, R. L. et al. A new vapor securing agent for flammable liquid fire extinguishment. U.S. Department of Defense Naval Research Laboratory Report No. 6057. Washington, 1964.
4. BUTLIN, R. N. High expansion air foam - a survey of its properties and uses. Joint Fire Research Organization Fire Research Note No. 669/1967.
5. Chemical foam charges. Ministry of Public Building and Works Specification MW/CS/312.
6. Foam liquid, fire extinguishing. Ministry of Public Building and Works Specification MW/CS/439.
7. RASBASH, D. J. Notes for a specification for high expansion foam liquid. Joint Fire Research Organization Fire Research Note No. 706/1968.
8. NASH, P. Recent research on foam in United Kingdom. Instn Fire Engrs Q., 1961, 21 (41) 14-23.
9. FRENCH, R. J. Foam viscometer. J. Scient. Instrum., 1960, 37 (8) 307-8.
10. FITTES, D. W. and RICHARDSON, D. D. Performance of protein-based foams on various fuels. Joint Fire Research Organization Fire Research Note No. 608/1965.
11. NASH, P., HIRD, D. and FRENCH, R. J. Base injection of foam for fuel storage tanks. Instn Fire Engrs Q., 1961, 21 (42) 116-22.
12. Oil tank fire extinguishing. Svenska Skumsläcknings Aktiebolaget Report No. 109/1960. Stockholm, 1960.

12. References

13. FITTES, D. W. and RICHARDSON, D. D. The influence of alcohol concentration on the effectiveness of protein foams in extinguishing fires in gasoline/alcohol mixtures. J. Inst. Petrol., 1963, 49 (473) 150-2.
14. NASH, P. and FRENCH, R. J. Foam compounds for use against fires in water miscible solvents. J. Inst. Petrol., 1961, 47 (450) 219-22.
15. FITTES, D. W. and NASH, P. Use of foam on fires involving water miscible solvents. Instn Fire Engrs Q., 1964, 24 (54) 148-58.
16. FITTES, D. W. and NASH, P. Light water. "Research into its effectiveness compared with protein foam. Fire 1968, 61 (759) 170-1, 195.

13. Figures

1. Ministry of Public Building and Works requirements for fire control and foam drainage.
2. { a. Self-aspirating branchpipe.
b. Foam-making pump.
c. Pressurized foam maker.
3. a. Self-aspirating portable high expansion foam generator.
b. Fan-aspirating portable high-expansion foam generator.
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1. Ministry of Public Building and Works fire test for protein foam performance.
2. Extinction of 50 ft² (4.65 m²) fire by "light water".
3. Extinction of 120 ft² (11.15 m²) fire by medium expansion foam.

Table 1 - Performance of protein foams on various fuels*

Fuel	Drainage in 10 min (ml)		Drainage in 10 min (ml)		9/10 control time	
	No fire		Fire		(Seconds)	
	Batch No. A ₁	Batch No. B ₁	Batch No. A ₁	Batch No. B ₁	Batch No. A ₁	Batch No. B ₁
NBP [/]	1200	800	1850	1100	65	100
AVTUR	1150	800	1900	1000	35	55
AVTAG	1250	750	2300	1150	95	75
AVGAS	1350	950	2050	1300	75	100
AVPIN	-	-	-	-	190	45
	Batch No. A ₂	Batch No. B ₂	Batch No. A ₂	Batch No. B ₂	Batch No. A ₂	Batch No. B ₂
NBP	1100	850	1300	1150	45	105
PETROL X	1000	900	1550	1450	140	145
PETROL Y	900	800	1600	1150	130	100
PETROL Z	950	900	1750	1350	160	155

*Joint Fire Research Organization Fire Research Note 608

[/]Narrow boiling point range petroleum.

Table 2. Performance of foams on petrol and various water-miscible fuels

Foam liquid	Petrol	Industrial methylated spirit	Methanol	Isopropyl alcohol	Acetone	Methyl ethyl ketone
Normal Protein	1) 0.02 (0.016) 2) 0.03 (1.5)	} Very rapid breakdown. Unsuitable for practical use.				
All-purpose	1) 0.10 (0.080) 2) 0.08 (3.9)	} Not tested	0.02 (0.016) 0.025 (1.2)	} Not tested	Not tested	0.06 (0.048) 0.05 (2.4)

1) Critical rate of application - $\text{gal ft}^{-2}\text{min}^{-1}$ ($1 \text{ m}^{-2}\text{s}^{-1}$)

2) Minimum quantity to control fire - gal/ft^2 ($1/\text{m}^2$)

Table 3. Comparison of light water and protein-based foams on various fuels
 Figures apply to 3 ft² (0.28 m²)

Type of foam	Fuel	Critical rate gal ft ⁻² min ⁻¹ (l m ⁻² s ⁻¹)	Optimum rate gal ft ⁻² min ⁻¹ (l m ⁻² s ⁻¹)	Minimum quantity gal/ft ² (l/m ²)
Protein foam (Expansion 8)	NBP Petrol	0.015 to 0.020 (0.012 to 0.016)	0.07 (0.057)	0.06 (2.9)
	AVTUR	0.015 to 0.020 (0.012 to 0.016)	0.08 (0.065)	0.04 (2.0)
	AVPIN	-	-	-
	Motor spirit	0.015 to 0.020 (0.012 to 0.016)	0.07 (0.057)	0.04 (2.0)
	IMS*	Unsuitable due to rapid breakdown		
All-purpose foam	IMS*	0.045 (0.037)	0.17 (0.140)	0.08 (3.9)
Light water (Expansion 8)	NBP Petrol	0.015 (0.012)	0.03 (0.024)	0.05 (2.4)
	AVTUR	0.01 to 0.015 (0.008 to 0.012)	0.04 (0.033)	0.02 (1.0)
	AVPIN	0.01 to 0.015 (0.008 to 0.012)	0.04 (0.033)	0.01 (0.5)
	Motor spirit	0.015 (0.012)	0.03 (0.024)	0.05 (2.4)
	IMS*	0.04 to 0.05 (0.033 to 0.041)	0.17 (0.138)	0.03 (1.5)

*Industrial methylated spirit.

CORRECTIONS TO DIAGRAMS

1) Fig 2a. FOAM-MAKING BRANCHPIPE

For "Swivel chamber" read "swirl chamber".

2) Fig. 2b. FOAM-MAKING PUMP

Axis of rotor should be off-centre in pump chamber.

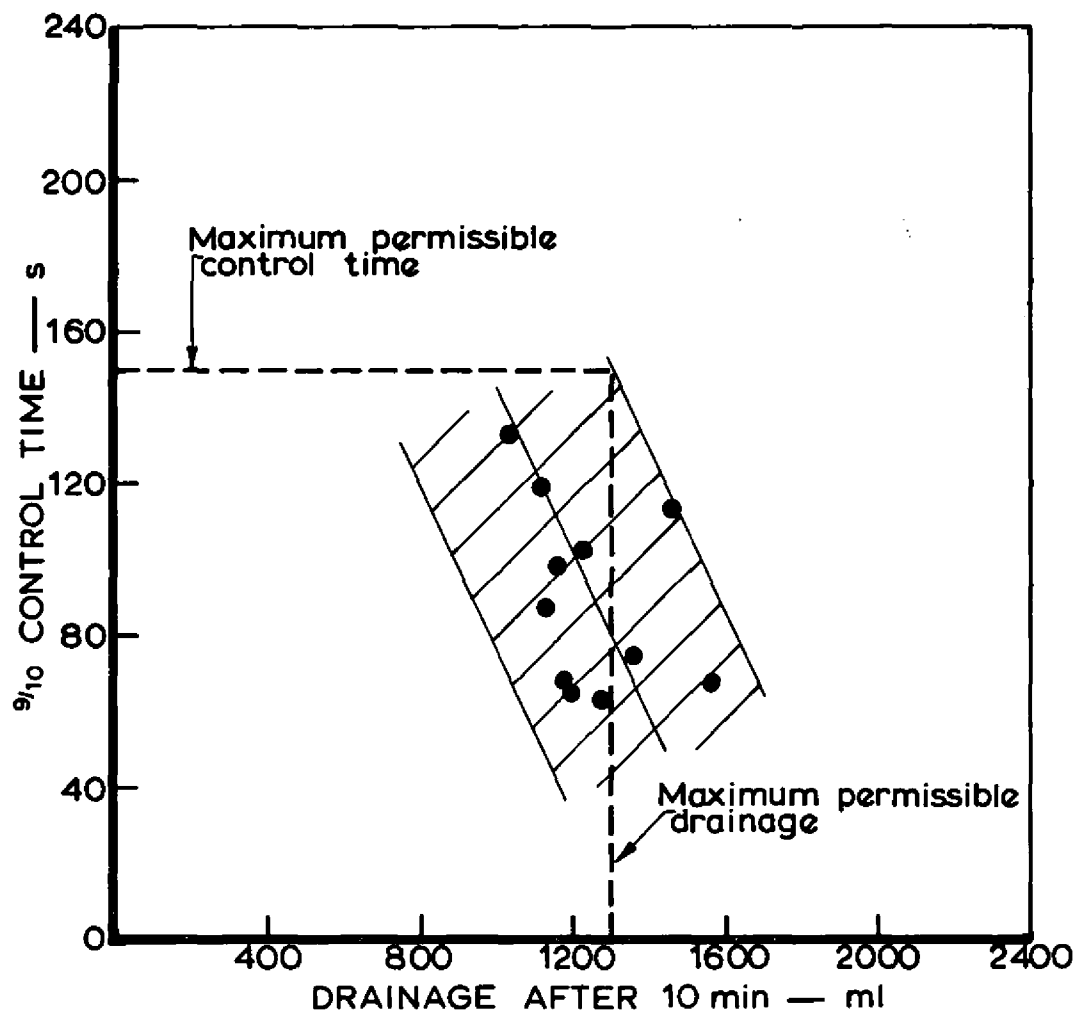
3) Fig. 2c. PRESSURISED FOAM-MAKING SYSTEM

The vanes of the air-blower should be aligned with the axis of the rotor.

4) Fig. 5. APPARATUS FOR... BASE-INJECTION INTO FUEL STORAGE TANKS.

Add words, at first pump:

"Centrifugal pump, capacity Q gal/min of solution."



Points represent performance of typical proprietary foam liquids

FIG.1. MINISTRY OF PUBLIC BUILDING AND WORKS REQUIREMENTS FOR FIRE CONTROL AND FOAM DRAINAGE

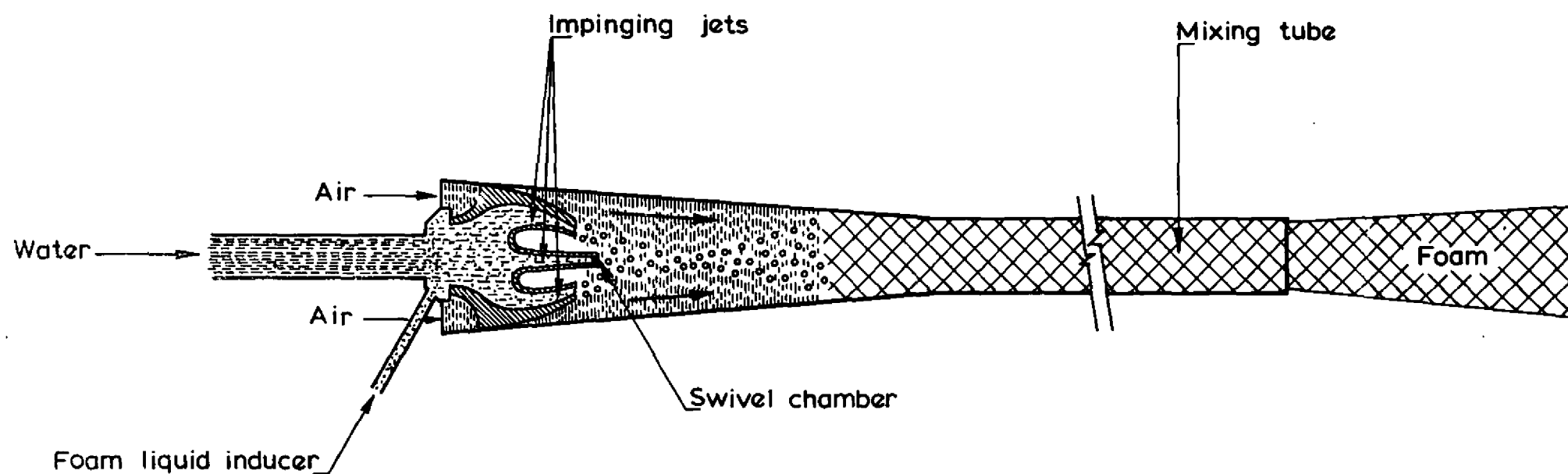
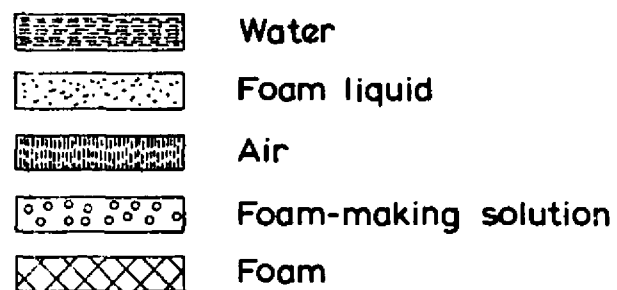


FIG. 2a. FOAM-MAKING BRANCHPIPE

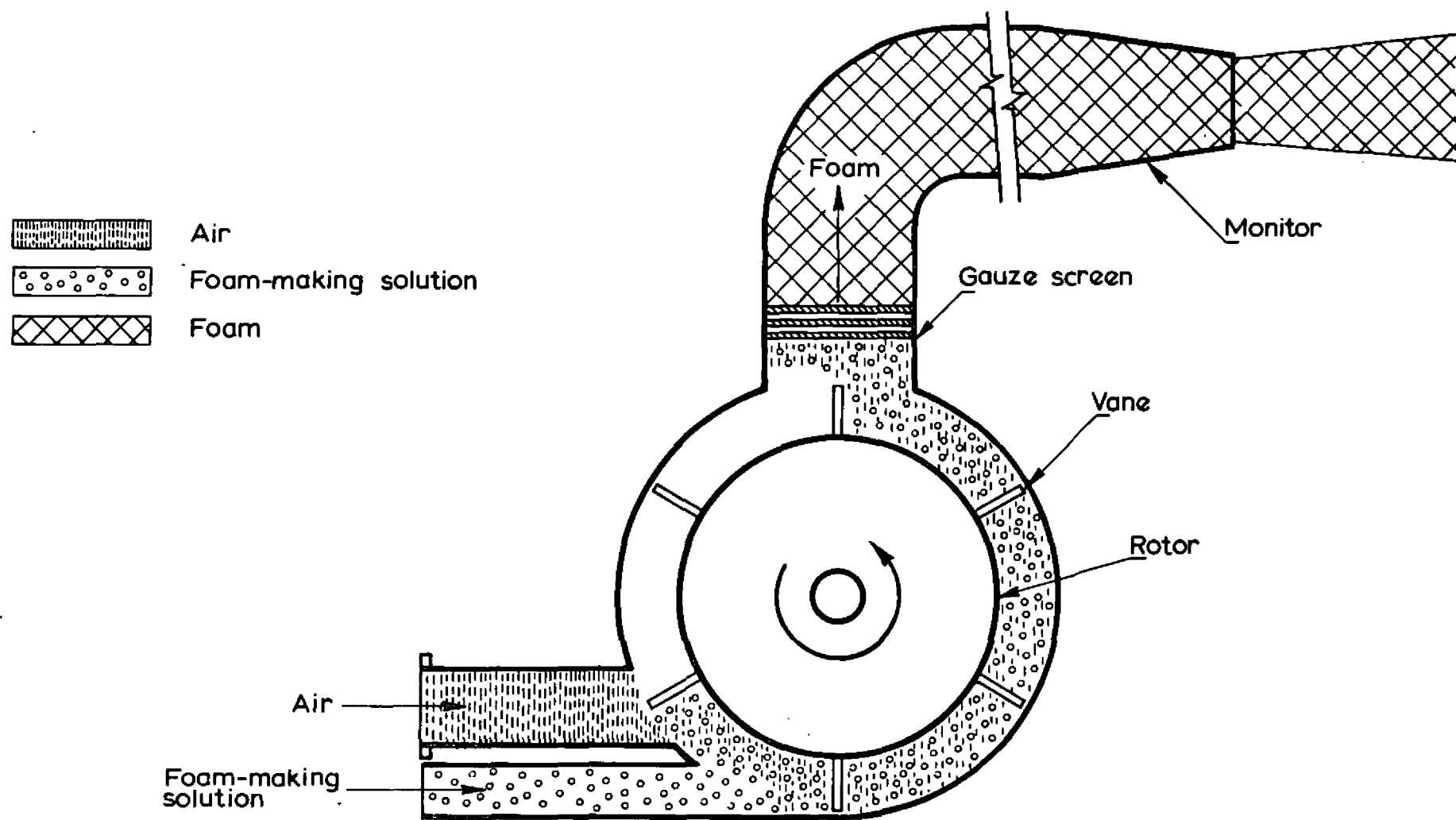


FIG. 2b. FOAM-MAKING PUMP

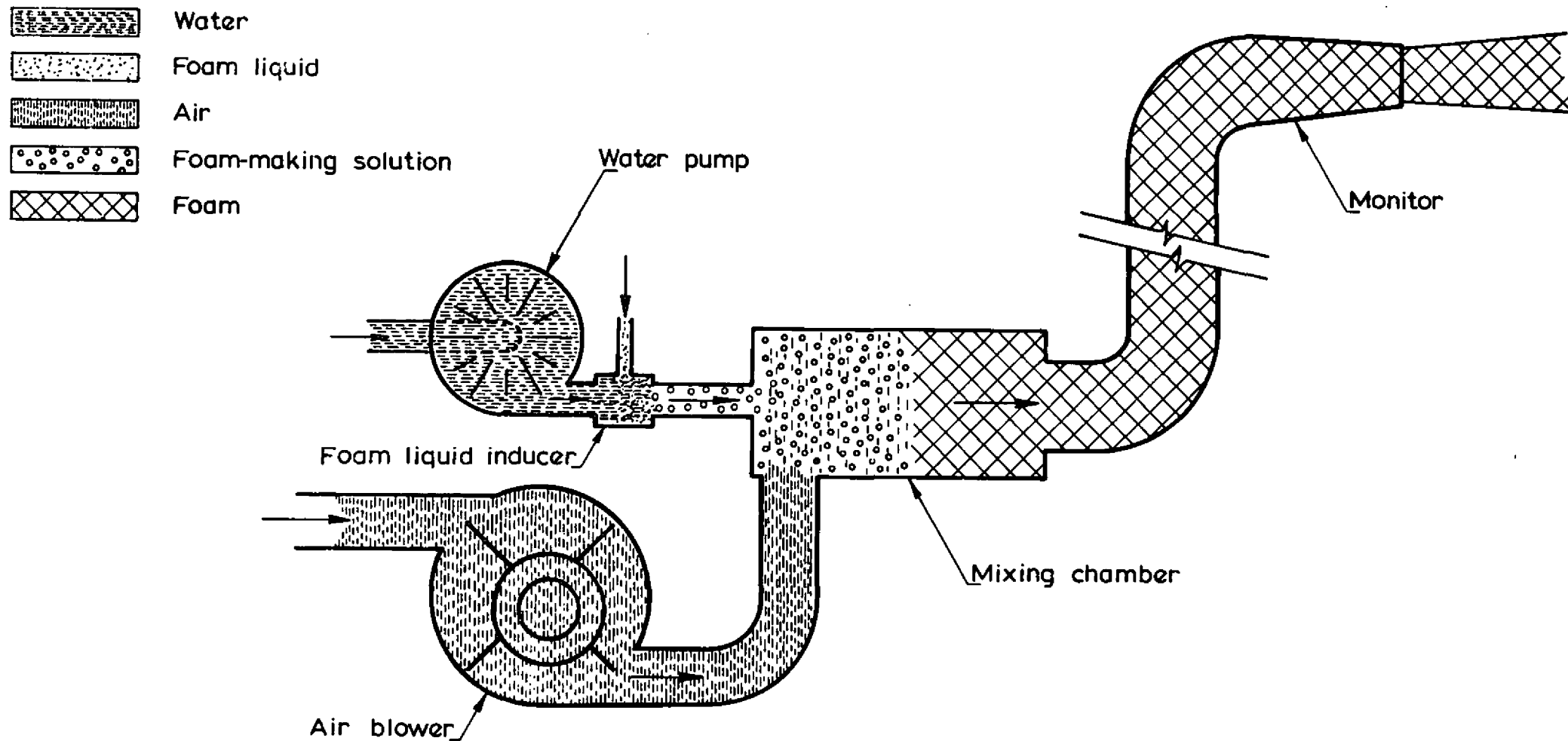


FIG. 2c. PRESSURISED FOAM-MAKING SYSTEM

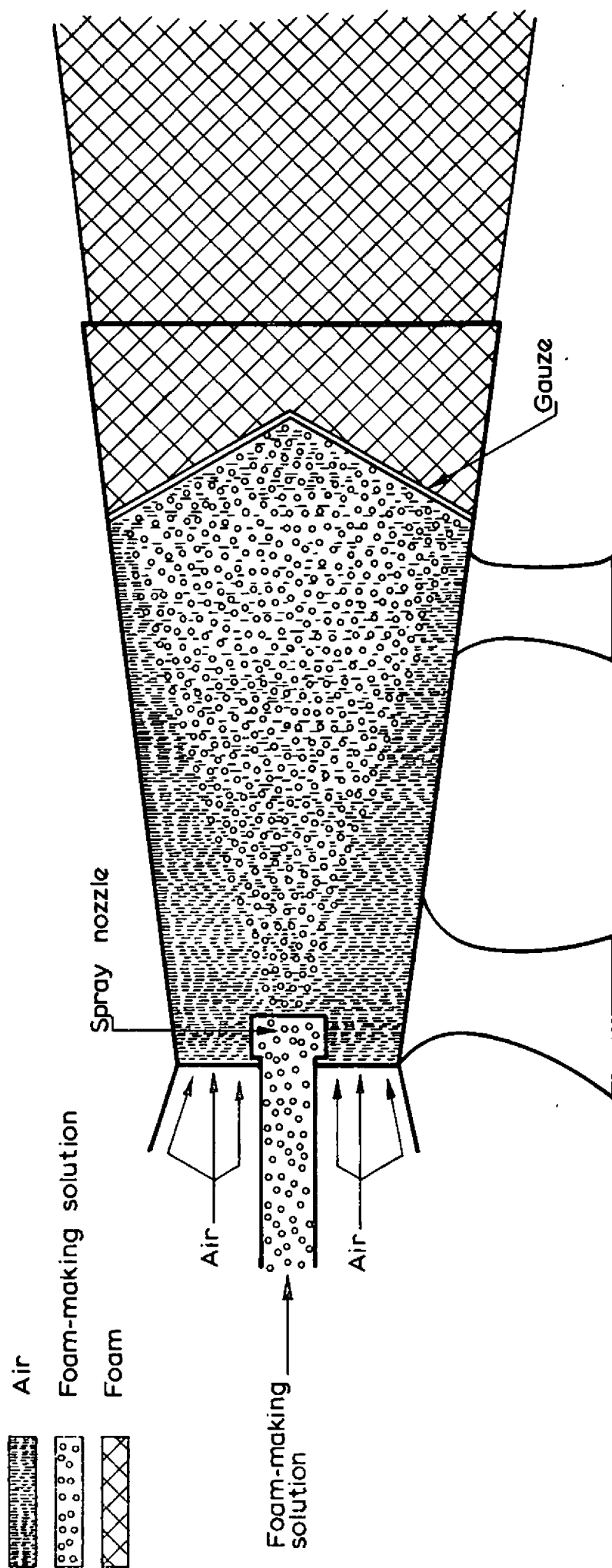


FIG.3a. SELF-ASPIRATING PORTABLE HIGH EXPANSION FOAM GENERATOR

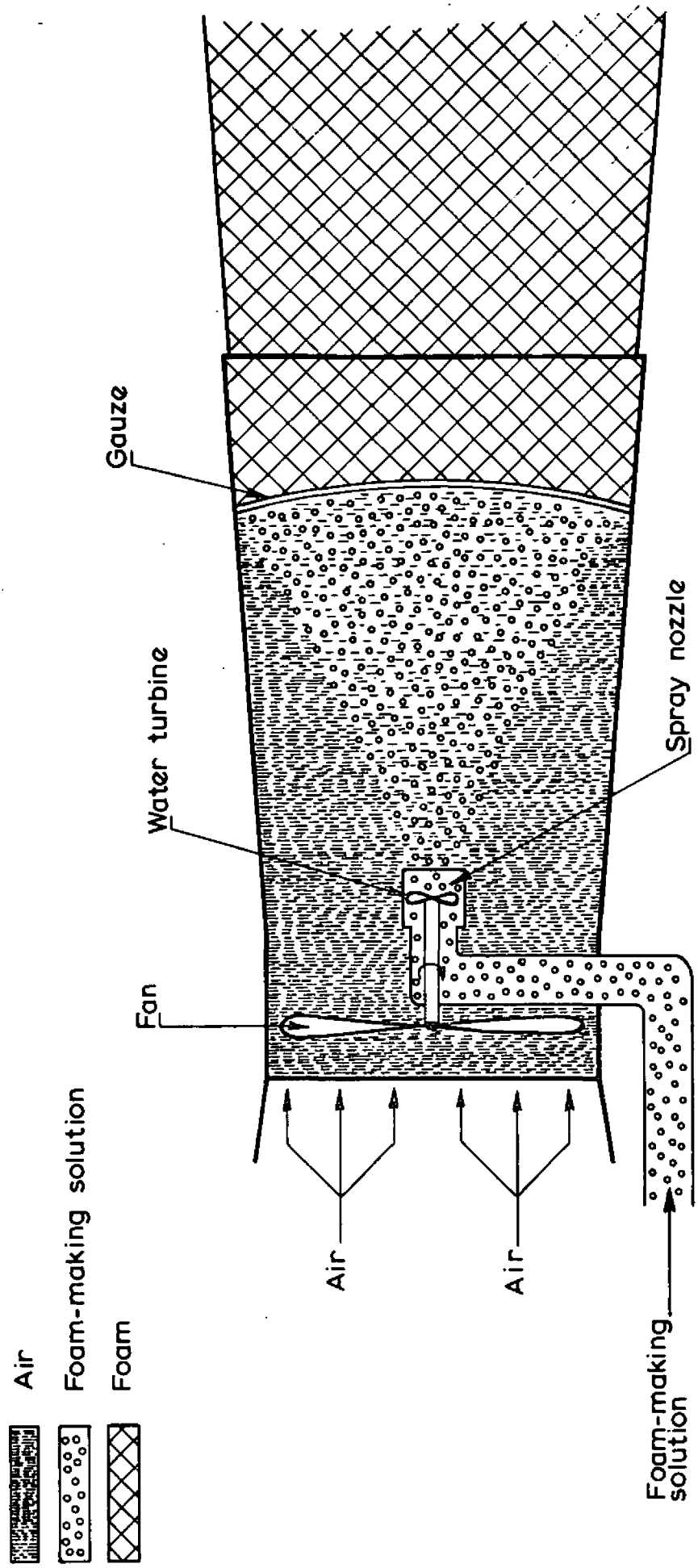


FIG. 3b. FAN-ASPIRATING PORTABLE HIGH EXPANSION FOAM GENERATOR

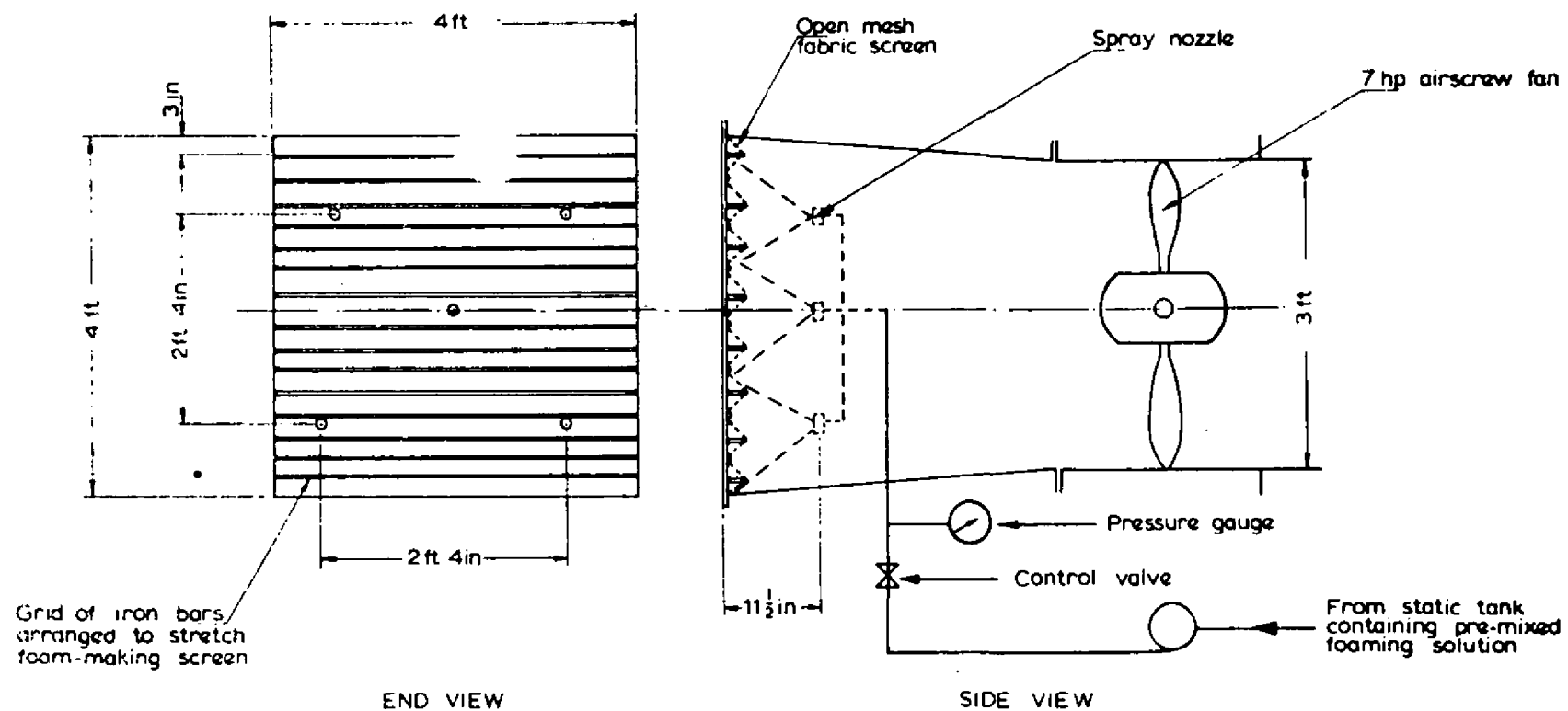


FIG. 3c. FAN-ASPIRATING MOBILE HIGH EXPANSION FOAM GENERATOR

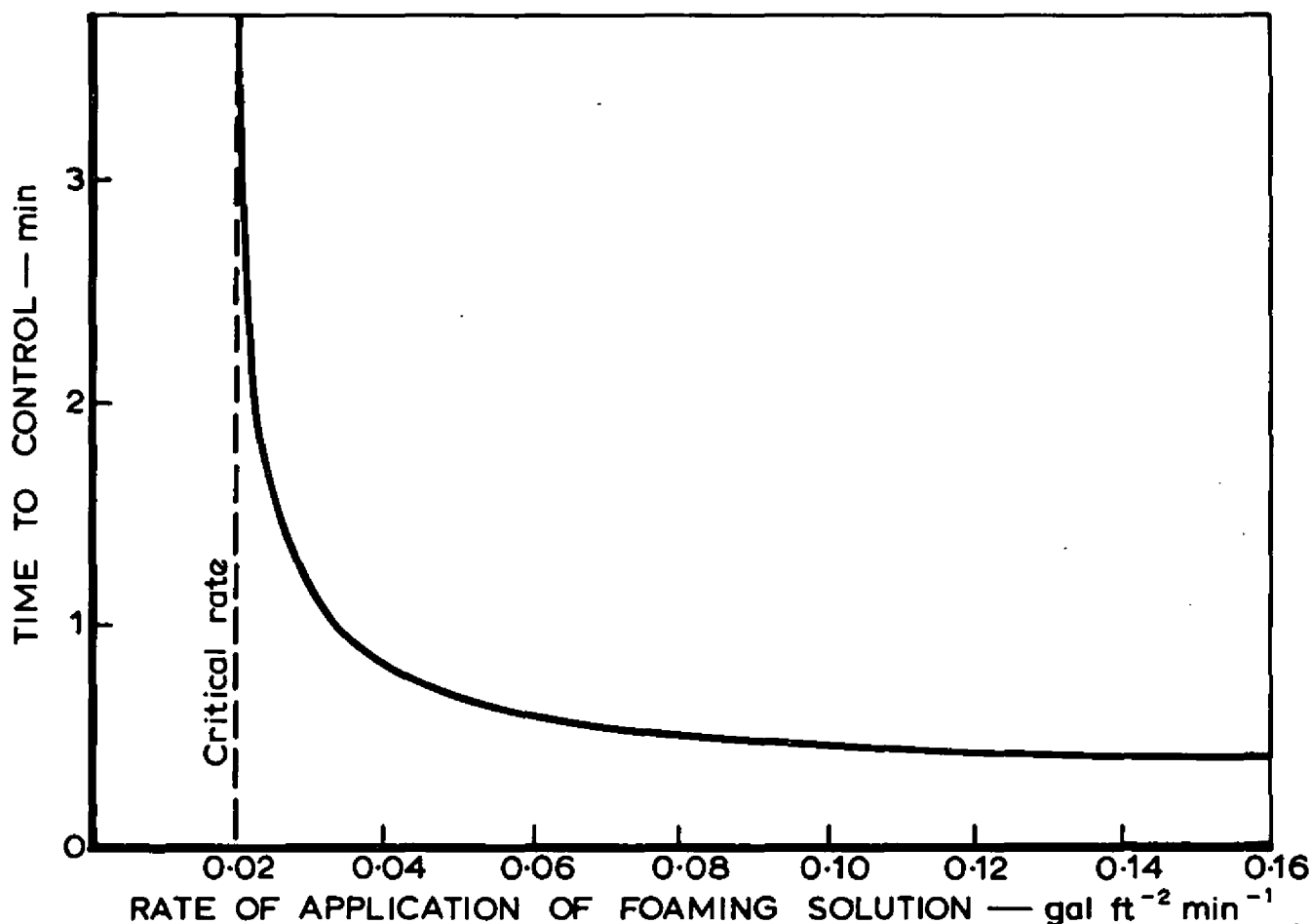


FIG. 4a. TIME TO CONTROL FIRE AT VARIOUS RATES OF APPLICATION OF SOLUTION

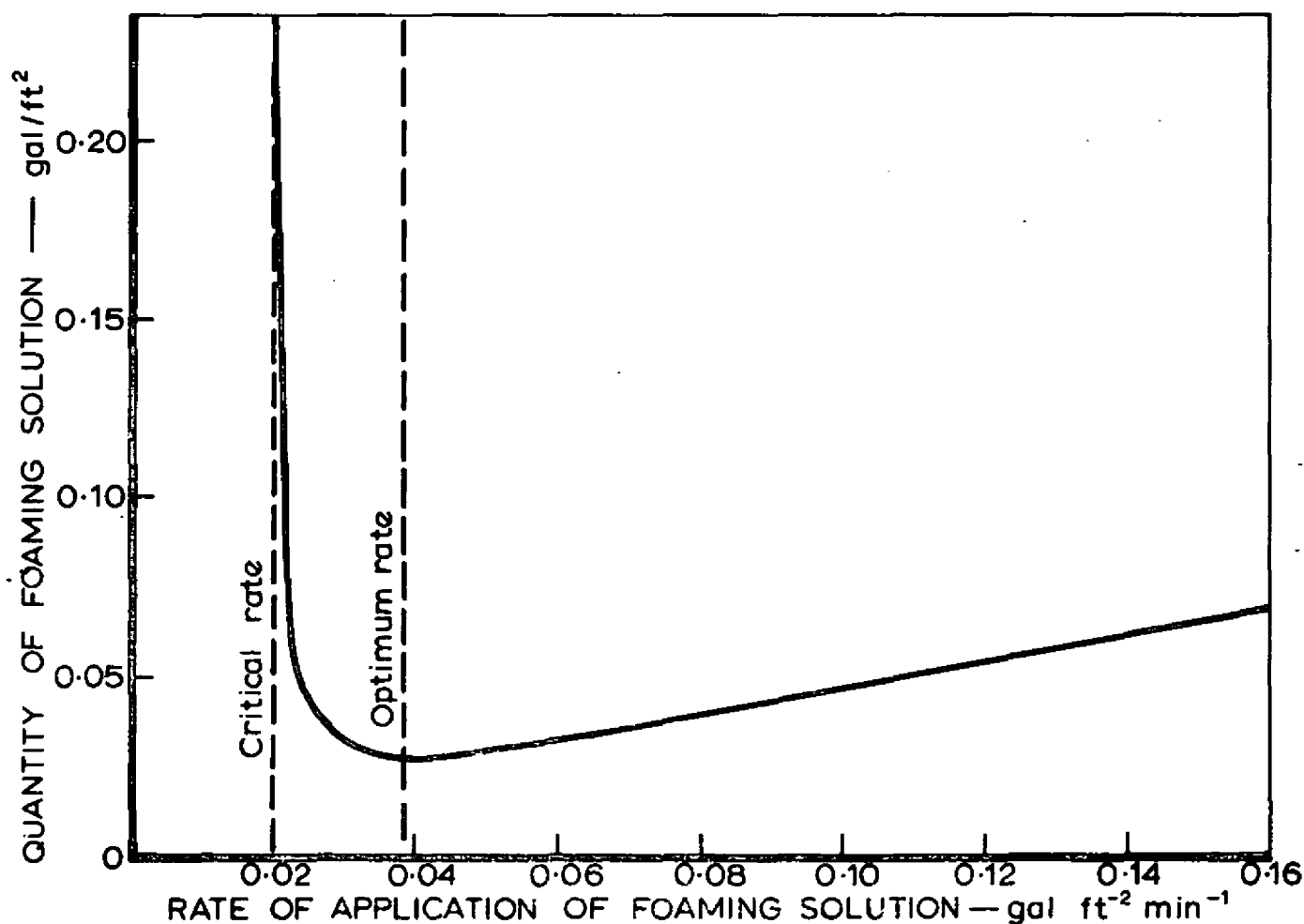


FIG. 4b. QUANTITY OF FOAMING SOLUTION TO CONTROL FIRE AT VARIOUS RATES OF APPLICATION

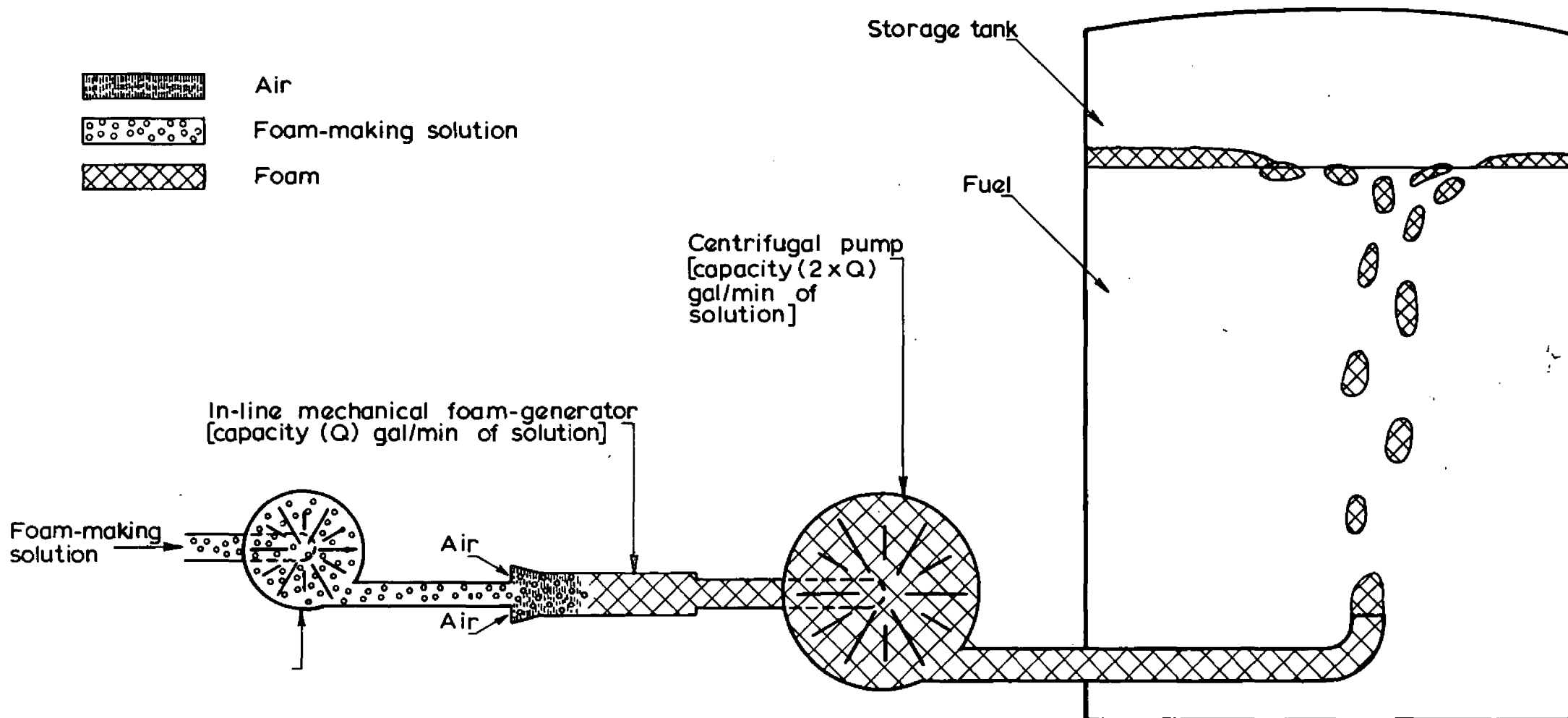


FIG. 5. APPARATUS FOR PRODUCING FOAM FOR BASE-INJECTION INTO FUEL STORAGE TANKS

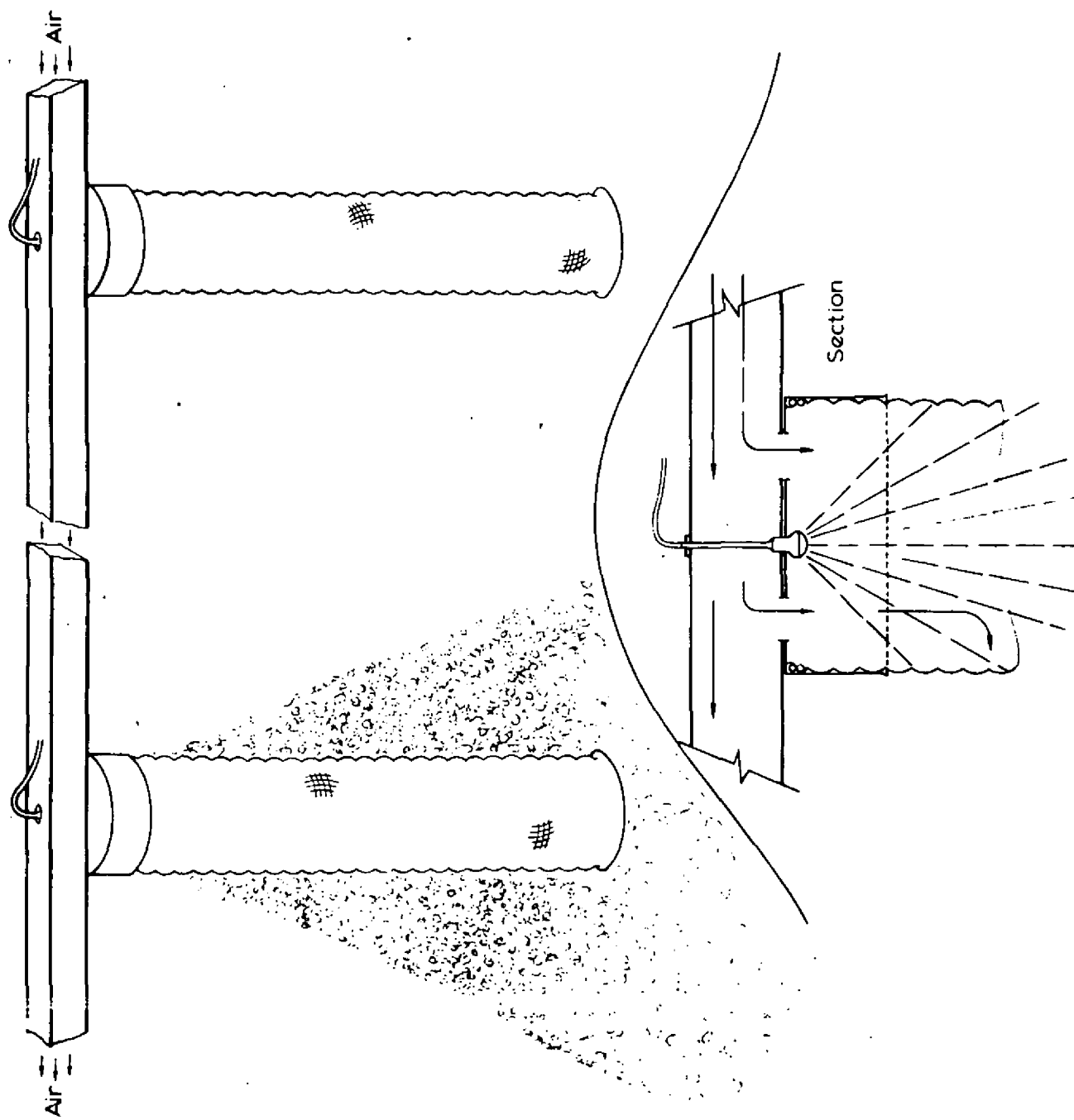
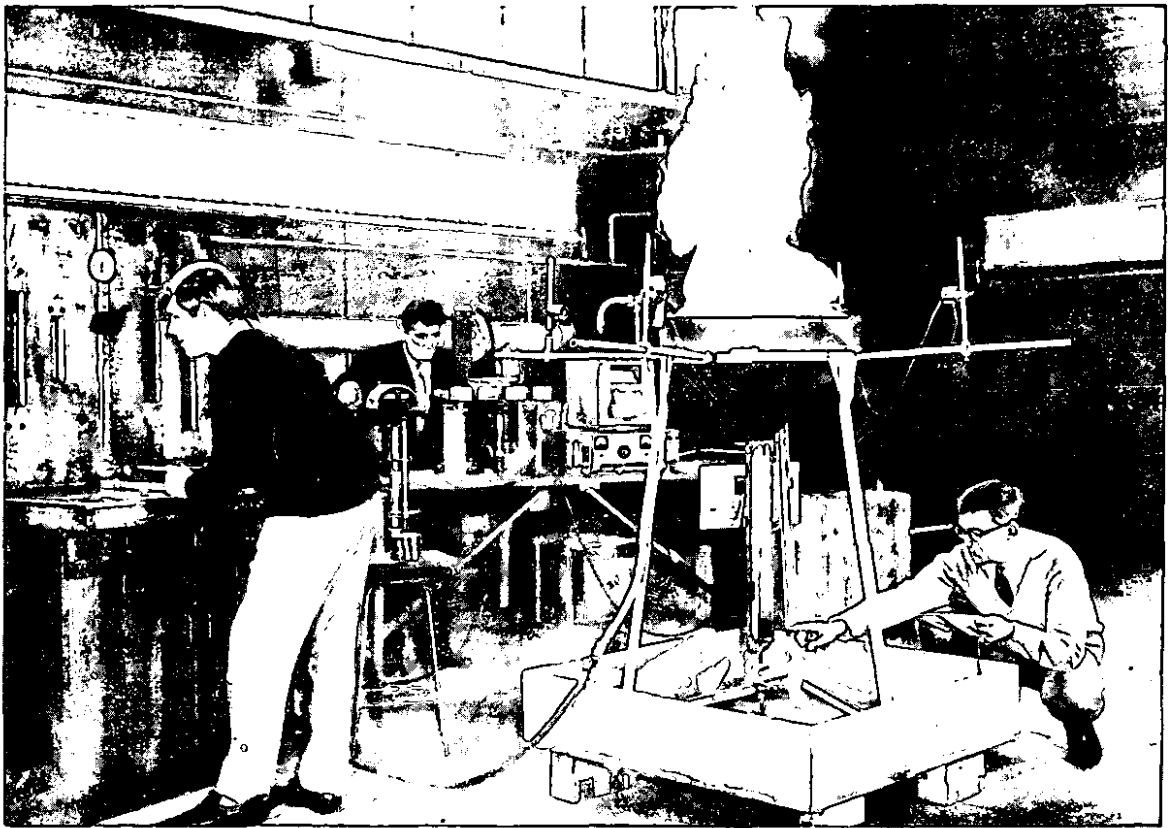


FIG. 6. DISTRIBUTION OF HIGH EXPANSION AIRFOAM



Ministry of Public Building and Works fire test
for protein foam performance

PLATE 1



Extinction of 4.65 m² (50 ft²) petroleum fire by light water

PLATE 2



Extinction of 11.15 m^2 (120 ft^2) petroleum fire
by medium expansion foam

PLATE 3

