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A 50 LITRE PER MINUTE STANDARD FOAM BRANCHPIPE

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SUMMARY

Constructional details of a 50 litre per minute foam branchpipe are given. The foam properties using protein foam liquid at various concentrations and pressures, together with properties using a range of foam liquids in common use have been determined. A method for defining the performance of a branchpipe, which could be used in specifications, is also illustrated.

KEY WORDS: Branchpipe, foam.

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

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INTRODUCTION

The design and construction of a 5 l/min laboratory foam branchpipe have already been described[1], and it was a logical step to extend the project to the design of larger branchpipes. It was considered difficult to scale-up the 5 l/min branchpipe to 200 l/min (the smallest size in general use by the fire services) in one step, and that it would be more economical to develop first an intermediate size. Fifty l/min was chosen as a useful size for experimental fires. This size could also be used with a 19 mm ($\frac{3}{4}$ in) diameter hose reel, although at present it is not common practice for the UK fire services to make foam using their appliance hose reels.

The performance of branchpipes is assessed by measuring the physical properties of the foam they produce. Expansion, shear stress, and quarter drainage time measurements have been used in this research. The measurements are of limited value because they depend upon the quality of foam liquid used, and there is no standard foam liquid which can serve as a reference material. This can be overcome to some extent by comparing the foam properties, from the branchpipe being tested, with those using the same foam liquid at the same temperature and pressure, in the 5 l/min standard branchpipe. This approach has been adopted, and comparisons using a range of foam liquids have been obtained.

In addition to the physical properties of the foam, another important property of a branchpipe is the configuration of the 'jet' of foam. If the foam is applied forcefully to the liquid fuel surface, a proportion of fuel is dispersed throughout the foam, and this will continue to burn, so that the fire cannot be extinguished[2,3]. This problem has been mitigated in practice in several ways, one of which is to fit a device to the branchpipe to disperse the foam stream so that it will strike the fuel surface gently. It was therefore decided to design the new branchpipe with a dispersing device. This required a method of measuring the impact of the foam on the fuel surface. A measurement of the area of dispersion and the rate of application over that area would give an indication of the impact.

Besides the impact, two other factors are of practical importance. The dispersed jet must carry an effective distance and remain sufficiently compact to enable it to be directed where it is required. The measurement of dispersion in an array of bins would permit these properties of the foam stream to be quantified; this method was therefore adopted.

Ideally a branchpipe should have a dispersal device which enables the foam jet to be varied continuously from solid-stream to maximum dispersal, so that the fireman can select the jet configuration most appropriate to the particular circumstances. A dispersal device of this character complicates the engineering construction and is inappropriate on a branchpipe which is to be used as a reference standard. A fixed disperser was therefore adopted.

The assessment of the performance of the branchpipe, including comparison of the foam properties with those from the 5 l/minute standard branchpipe, and the dispersion measurements, provides a basis for writing a branchpipe performance specification, and an example is given later in this report. This promises to be a valuable outcome of the research, since an effective method of specifying branchpipe performance has long been required.

MATERIALS USED

In the development tests many different samples of foam liquid were used. A variable was first investigated using protein foam liquid and then the results were checked using several of the more expensive foam liquids. In the performance tests on the final design, the following foam liquids were used.

Protein A1) Protein A2)	- From UK Manufacturer A and conforming to Defence Standard 42-3.
Protein B1	- From UK Manufacturer B and conforming to Defence Standard 42-3.
Protein C	- From UK Manufacturer C.
Protein G	- Manufactured in Germany.
Fluoroprotein A	- From UK Manufacturer A and conforming to provisional Defence Standard 42-3.
Fluoroprotein B	- From UK Manufacturer B and conforming to provisional Defence Standard 42-3.
Synthetic C	- From UK Manufacturer C.
Synthetic D	- From UK Manufacturer D.
Fluorochemical E	- Manufactured in Belgium.

EXPERIMENTAL METHODS

General

A series of tests were first made with the 5 litre per minute branchpipe, increasing the orifice sizes to increase the throughput to 10 litres per minute, and varying the throat diameter, the tube diameter, and the outlet diameter. The effects of these changes upon the foam properties were noted and these observations, together with the dimensions and performance data from several existing 225 litres per minute branchpipes, were used to design a prototype 50 l/min branchpipe.

The prototype permitted the following variations to be made - orifice plate, foam tube length, outlet nozzle diameter and length, dispersal disc shape, size, and position. Approximately 50 tests were required to determine a design which gave a good performance without a disperser and a further 50 tests to select the disperser parameters. Two final models were then constructed and used for the performance test. They were constructed from aluminium alloy, with stainless steel orifice, filter plates and ball valve, and a brass disperser.

Foam production

Two hundred and fifty litres of a premixed foam solution was prepared, using potable water. This was pumped to the branchpipe by means of a portable fire-service pumping set. The operating pressure was indicated on a gauge immediately before the branchpipe. Samples from this premix were used in a pressurized container, when data from the 5 l/min branchpipe were required. Foam temperatures were measured for each experiment. These varied between 13 and 22°C but, in general, were within ± 2°C of each other for any one premix.

Foam samples were collected in a bin (0.61 m cube, fitted with a curved hood 0.61 m high) located with its back a distance of 4.5 m from the branchpipe outlet. On reaching the required pressure the foam was directed into the bin and collected for a period of between 15 to 20 s. Samples of foam were then taken from the bin, in order to obtain expansion, shear stress, and drainage time measurements.

Expansion

Expansions were determined by weighing a 2.5 l sample.

Shear stress

Shear stresses were determined using a torsional vane viscometer with a vane 31.8 mm wide x 31.8 mm high x 1.22 mm thick, rotating at 8.5 rpm.

Drainage rate

The quarter drainage times were determined in a 6.320 l pan (20 cm diameter x 20 cm height) as described in Fire Research Note 972[5].

DISTRIBUTION PATTERNS

Forty eight plastic bins were used to obtain a distribution measurement.

Each bin, of circular cross-section and tapered to facilitate storage, had the following characteristics:

Capacity	=	50 l
Internal diameter	=	0.4 m
Height	=	0.575 m
Av. weight when wet	=	2.13 kg

The branchpipe was adjusted to 15^{o} elevation, with the nozzle 0.6 m higher than the top of the bins. This was considered more representative of its use in practice on spill fires. The bins were arranged in a rectangular array (0.425 m between centres) in the most appropriate position to collect all the foam. The distance of the near and far rows of bins from the branchpipe outlet were measured. Foam was produced and when a steady operation was established at the required pressure the branchpipe was directed over the array of bins, and a stop-watch was started. Foam production was stopped just before any of the bins overflowed, and the time for foam collection was noted. This varied from 30 to 60 seconds. The weight of foam collected in each bin was then determined.

The net weights in each of the cross rows was computed to provide the data on the range of the foam stream. The weights in the individual bins were then converted to application rates and summed in groups of 5 l/m^2 min. This permitted density of discharge and compactness of discharge to be calculated.

All the calculations were interpreted on the total weight of foam collected in all the bins, and it was assumed that the foam which fell between the bins would be distributed in a like manner. A very small proportion of foam fell short of the bins and this was neglected. By calculation from the bin dimensions we would expect 70 per cent of the total foam discharge to fall in the bins. Experimental values varied from 66.5 per cent to 84.5 per cent. The high collection percentages probably resulted from the rectangular array permitting a foam stream with a dense central core to be aligned with a row of bins.

The 'compactness of discharge' calculations assume that the density of the foam pattern falls off symetrically from a dense central area. A different interpretation of the results would be necessary if, for instance, the disperser divided the stream into a vee shape with two separate dense areas.

Figure 1 illustrates the distribution pattern test equipment.

THE BRANCHPIPE DESIGN

Drawing Nos A618(A) and A618(A)/(1)-(10) give the details of the branchpipe construction and drawing No.A618(B) the modifications required to adapt the particular ball valve selected[6]. The drawing does not show the coupling required to be attached to the valve to match the hose reel coupling. Figure 2 shows the branchpipe dismantled.

Without the valve and coupling, the branchpipe has an overall length of 0.62 m and weighs 1.3 kg. With the valve and coupling the overall length is 0.72 m and the weight 1.9 kg. It is therefore easily handled by the fireman.

The design does not incorporate the induction of the foam liquid into the branchpipe, as this feature is not required on a branchpipe used for test purposes. If it is used for general fire-fighting, there are few circumstances where the use of an in-line inductor, adjacent to the appliance and remote from the fire, is not a preferred method to induction at the branchpipe.

The design has been kept simple so that it can be easily reproduced in other engineering establishments. Particular care is required, however, in the construction of the orifice plate with the three converging holes. They must be sharp-edged, otherwise droplets will be torn away from the issuing jets and some of these can impinge on the air inlet holes, so that dribbling occurs. The size of the orifices should be checked by a discharge rate measurement and if necessary adjusted to give 50 l/min $\pm$ $2\frac{1}{2}$ l, at 7 bar pressure.

One minor shortcoming of the branchpipe is that there is no guard to prevent the air holes being obstructed by the fireman's hands. A guard could be added but it was considered that the problem could be avoided by appropriate training and that the additional complication to the design was not justified.

The performance of the branchpipe is dependent upon the production of a good spray which efficiently induces the air into the foam liquid stream. In this design this has been achieved by the use of converging jets because this is a design which is easily defined and reproduced. In commercial adaptions of the design, alternative nozzles could be used, such as those based upon a swirl motion. These would have the advantage of a larger bore, less liable to blockage.

TEST RESULTS

The effect of discharge pressure

Figure 3 shows how the foam properties varied with the discharge pressure using 4 per cent protein solution.

The effect of concentration

Figure 4 shows how the foam properties varied with the concentration of protein at 7 bar discharge pressure.

Range

Figure 5 shows the range of the foam stream using 4 per cent protein at two pressures and 6 per cent fluorochemical at one pressure.

Density of discharge

Figure 6 illustrates the variation in application density, with 4 per cent protein liquid at 7 and 8 bar discharge pressure, and 6 per cent fluorochemical liquid at 7 bar discharge pressure.

Compactness of discharge

Figure 7 shows the compactness of the discharge pattern with 4 per cent protein liquid at 7 and 8 bar discharge pressure, and 6 per cent fluorochemical liquid at 7 bar discharge pressure.

Comparisons with various foam liquids and the 5 l/min branchpipe

Table 1 gives the foam properties obtained using a selection of foam liquids at 7 bar discharge pressure and shows how they compare with the foam properties of the 5 l/min branchpipe used at the same temperature. Figure 8 illustrates these tests.

DISCUSSION OF RESULTS

Discharge pressure

From Fig.3 it can be seen that a pressure of 7 bar is an appropriate operating pressure with protein A1. Increasing the pressure to 8 bar results in only a marginal improvement in the shear stress and drainage time. If the pressure is reduced below 7 bar, the drainage time falls quite rapidly and the shear stress falls at a progressively increasing rate as the pressure is reduced. However the branchpipe can be operated, with this protein, at 5 bar pressure and will produce a foam with an expansion of 7.4, a shear stress of 18.5 N/m^2, and a drainage time of 5 minutes which represent a foam which will still give a useful extinguishing performance.

Range of the foam stream

It would seem reasonable to regard the effective range of a branchpipe as the distance to which 75 per cent of the discharge carries when the branchpipe is held at an elevation typical of its use in practice. An elevation of 15° was selected because observations of the firemen's practice when fighting spill fires showed that the branchpipe is usually only raised slightly above the horizontal position. From Fig.5 it can be seen that on this basis the effective range of the branchpipe was:

7 m with protein at 7 bar
$8\frac{1}{4}$ m with protein at 8 bar
6 m with fluorochemical at 7 bar

We can postulate an acceptable effective range for the branchpipe thus: 3 l/m^2 min is minimum application rate that would be considered effective in a practical situation. The 50 l/min branchpipe could therefore only be used effectively on a 16.7 m^2 area fire = 4.6 m dia. fire. An attack distance of 1.5 fire diameters is required to limit the radiation to the firemen to a tolerable level; therefore an effective range of 6.9 m is required.

Density of discharge

No experience exists in measuring the density of discharge of foam jets and relating this to the problem of delayed extinction resulting from too forceful application. As an initial step it is proposed that an application density in excess of 50 l/m^2 min be regarded as indicating too forceful application. Referring to Fig.6 it can be seen that with protein foam and a pressure of 7 bar, 85 per cent of the discharge was above this criterion and 65 per cent over twice this application density. When, however, the discharge pressure was increased to 8 bar the dispersion was greatly improved and the suggested maximum permissible value was not exceeded. With the fluorochemical foam the dispersion was much better than with the protein foam and only 20 per cent of the discharge exceeded 50 l/m^2 min with the discharge pressure at 7 bar.

These results indicate that good dispersion is related to the shear stress of the foam, the foams with higher shear stresses requiring higher pressures, (which result in higher discharge velocities) to cause the foam stream to disperse well.

Compactness of discharge

If 75 per cent of the foam can be directed into one-fifth of the fire area this would seem an acceptable degree of precision. With a maximum fire area of 16.7 m^2 this requires 75 per cent of the discharge to fall within an area of 3.4 m^2. If we postulate that the fire is extinguished in 60 s the foam stream will have to be directed to a fresh area at 12 second intervals - which seems a reasonable interval in which to accomplish the movement of the branchpipe which is necessary.

Referring to Fig.7 it can be seen that:

For protein foam at	7 bar	-	75 per cent fell in	0.5 m^2	area
" " " "	8 "	-	" " " "	2.1 m^2	"
" fluorochemical at	7 "	-	" " " "	1.5 m^2	"

The protein foam at 7 bar gave a very compact jet which would permit precise direction but would require repositioning at less than 2 second intervals to cover the entire fire in 1 min. However this foam jet would not be accepted because of its high density of discharge considered above.

Concentration

The effect of concentration on the foam properties shown in Fig.4 is similar to that of most branchpipes. With the protein liquid used, a 4 per cent solution is the preferred concentration. Increasing the concentration above 4 per cent does not affect the expansion and has only a small effect upon the shear stress. The drainage time rises progressively with concentration because of increasing viscosity but the rate of increase is reduced above 4 per cent concentration.

Comparisons with the 5 l/min branchpipe using a range of foam liquids

From Table 1 and Fig.8 it can be seen that the 50 l/min branchpipe produced foams with drainage times and shear stresses very similar to those from the 5 l/min branchpipe while the expansion was about 1 less except with the synthetic foams with which it gave a higher expansion.

The overall averages were as follows:

	50 l/min properties as percentage of 5 l/min properties
Expansion	97
Shear stress	85.7
Drainage time	97.6

The 5 l/min tests were generally 2-4°C lower than the 50 l/min tests and this could account for perhaps 5 per cent of the difference in shear stress and drainage time.

The principle of assessing a branchpipe's performance by comparing the foam properties with those from the 5 l/min branchpipe is well supported by these results.

BRANCHPIPE SPECIFICATIONS

The test methods adopted to evaluate this 50 l/min branchpipe can be used as a basis for preparing a general branchpipe specification. Such a specification is presented in Table 2 and the values obtained with Protein A1 at 7 bar and 8 bar pressure are also shown. At 7 bar pressure the branchpipe met all the proposed requirements except that for compactness of the foam stream. At 8 bar pressure this shortcoming was eliminated but the discharge increased above the proposed requirement.

The branchpipe specification would be supported by appropriate details of the test methods, replication required, and other requirements such as maximum weight, overall dimensions, corrosion resistance, valve effectiveness, etc.

Besides having a separate specification for each size of branchpipe, compliance with a selection of foam liquids would be required for a branchpipe for general use. Different values could also be chosen when using a specific foam liquid or a branchpipe in specific circumstances. This would permit taking maximum advantage of the individual merits of foam liquids for defined hazards, as for instance when long range is particularly desirable or gentle application is essential, or a different operating pressure is more relevant.

GENERAL DISCUSSION

The design of a foam branchpipe with a dispersed jet, for routine use by the fire services or for experimental fire test necessitates making a number of compromises. Good dispersion will assist gentle application and efficient extinction but is difficult to achieve without reduction in range, compactness of the foam stream, and adversely affecting the foam properties. The 50 l/min branchpipe described represents one good compromise between these conflicting factors. Its most serious limitation may be poor dispersion with some protein foams. However, this can apparently be overcome in practice by a modest increase in discharge pressure.

Adaption of the test methods described to prepare a branchpipe performance specification is of great interest. Studies are well advanced on the design of a 200 l/min branchpipe.

CONCLUSIONS AND RECOMMENDATIONS

1. A 50 l/min foam branchpipe is described, which is simple to manufacture, and has good characteristics with a wide range of foam liquids.

2. The branchpipe will serve as a defined standard for conducting experimental fires in the size range 10-17 m^2 area.

3. With a foam liquid inductor (at the appliance) the branchpipe could be used with fire service hose reel equipment. In 1971 there were over 6,000 vehicle fires in the UK involving flammable liquids. Many of these fires would be within the capacity of a branchpipe of this size; there will be many other such fires, not only in vehicles, and many spill situations presenting a fire hazard for which foam from the hose reel would be adequate.

4. A method of specifying the performance of a foam branchpipe is presented and this might be developed so that UK specifications for branchpipes can be established.

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4. Defence Standard 42-3/issue 1/24 Jan. 1969. Foam liquid - fire extinguishing. Directorate of Standardization, Ministry of Defence, First Avenue House, High Holborn, London, WC1.

5. BENSON, S P, MORRIS, K and CORRIE, J G. An improved method for measuring the drainage rate of fire-fighting foams. Department of the Environment and Fire Offices' Committee Joint Fire Research Organisation Fire Research Note 972 1973.

6. Argus NK8 Hexagon Ball Valve - $\frac{3}{4}$ in size No.590/20/8BB - 1973. Powerite Ltd. 27A Queen Street, Wolverhampton.

TABLE 1

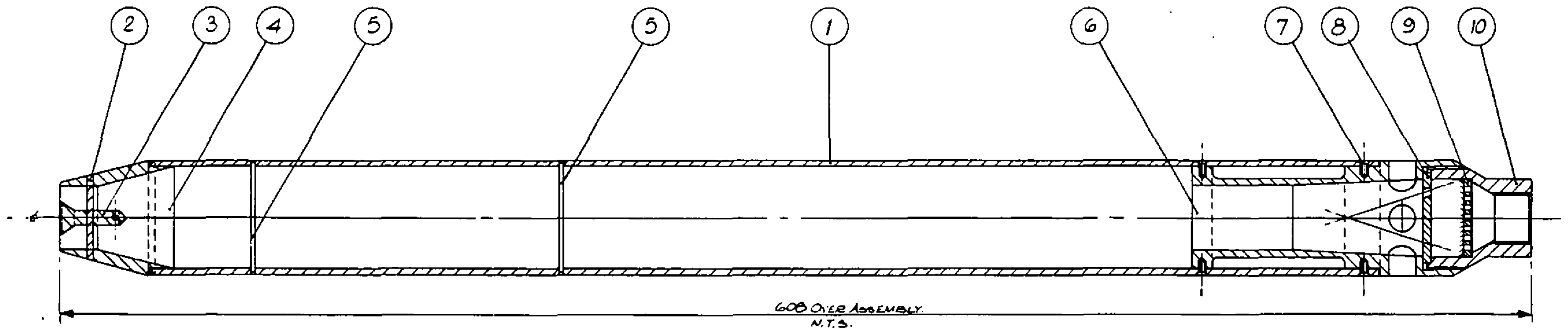
Comparison of foam properties - 5 l/min and 50 l/min branchpipes

	5 l/min Branchpipe					50 l/min Branchpipe					50 l/min results as percentage of 5 l/min results		
Foam liquid	Expansion	Shear stress N/m^2	20 cm - 25% drain time min	s	Foam temp °C	Expansion	Shear stress N/m^2	20 cm - 25% drain time min	s	Foam temp °C	Expansion per cent	Shear stress per cent	20 cm - 25% drain time per cent
4 per cent Protein A1	8.5	28.5	9	52	16.8	7.5	23.3	7	34	19.8	88.5	82	77
6 per cent Protein A2	8.8	36.7	10	53	17.0	8.3	27.7	11	15	18.0	94.5	75.5	103.5
4 per cent Protein A2	9.0	32.2	9	40	17.5	7.9	28.9	9	44	19.5	88	90	101
3 per cent Protein A2	8.0	21.6	7	26	17.5	7.4	24.4	8	03	20.0	92.5	113	108.5
$2\frac{1}{2}$ per cent Protein A2	7.7	20.6	6	44	17.7	6.1	12.8	6	09	20.5	79.5	62.5	91.5
4 per cent Protein C	7.7	16.7	7	29	13.0	7.0	17.8	7	34	16.2	91	107	101.5
4 per cent Protein G	7.1	33.3	8	35	13.5	6.0	32.2	9	48	17.7	84.5	97	114.5
4 per cent Fluoroprotein A	8.4	26.6	9	50	13.5	6.8	18.8	9	30	16.6	81	71	97
4 per cent Fluoroprotein B	8.6	13.3	9	32	13.5	8.5	11.0	9	36	17.5	99	83	101
3 per cent Synthetic C	9.1	14.4	14	00	13.6	13.9	12.2	12	39	18.0	153	85	90.5
3 per cent Synthetic D	8.9	11.6	13	02	14.3	10.3	10.0	11	36	17.5	116	86.5	89
6 per cent Fluorochemical E	9.6	5.0	4	46	16.4	9.3	3.8	4	34	18.2	97	76	96
Average					15.4					18.3	97	85.7	97.6

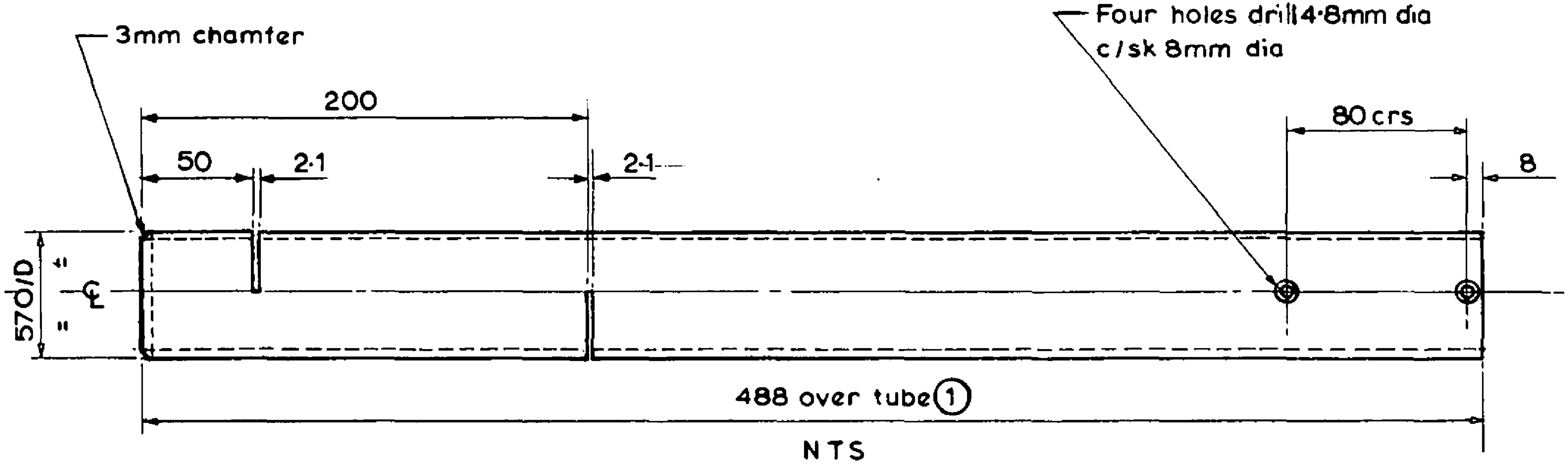
TABLE 2

Example of a foam branchpipe performance specification

	Proposed requirement	Found with 4 per cent Protein A1	
		At 7 bar	At 8 bar
1. <u>Discharge rate</u> When operated with water at 7 bar pressure and 15–25°C the discharge rate is to be not less than 47.5 and not more than 52.5 l/min.	47.5 - 52.5 l/min	51	54.5
2. <u>Expansion</u> Not less than 85 per cent of that obtained with the standard 5 l/min branchpipe at the same temperature $\pm$ 3°C	$\not<$ 85 per cent	88.5	87.5
3. <u>Shear stress</u> Not less than 75 per cent of that obtained with the standard 5 l/min branchpipe at the same temperature $\pm$ 3°C	$\not<$ 75 per cent	82	78
4. <u>20 cm 25 per cent drainage time</u> Not less than 75 per cent of that obtained with the standard 5 l/min branchpipe at the same temperature $\pm$ 3°C	$\not<$ 75 per cent	77	82
5. <u>Effective range</u> When operated at 15° elevation and 7 bar pressure, 75 per cent is to carry a distance of not less than 7 m	$\not<$ 7 m	7	8.2
6. <u>Maximum density of discharge</u> When operated at 15° elevation and 7 bar pressure the application density in any 0.12 m^2 area of the foam pattern is not to exceed 50 l/m^2 min	$\not>$ 50 l/m^2 min	124	45
7. <u>Compactness of foam stream</u> When operated at 15° elevation and 7 bar pressure, 75 per cent of the discharge is to fall in an area not exceeding 3.5 m^2	$\not>$ 3.5 m^2	0.5	2.2



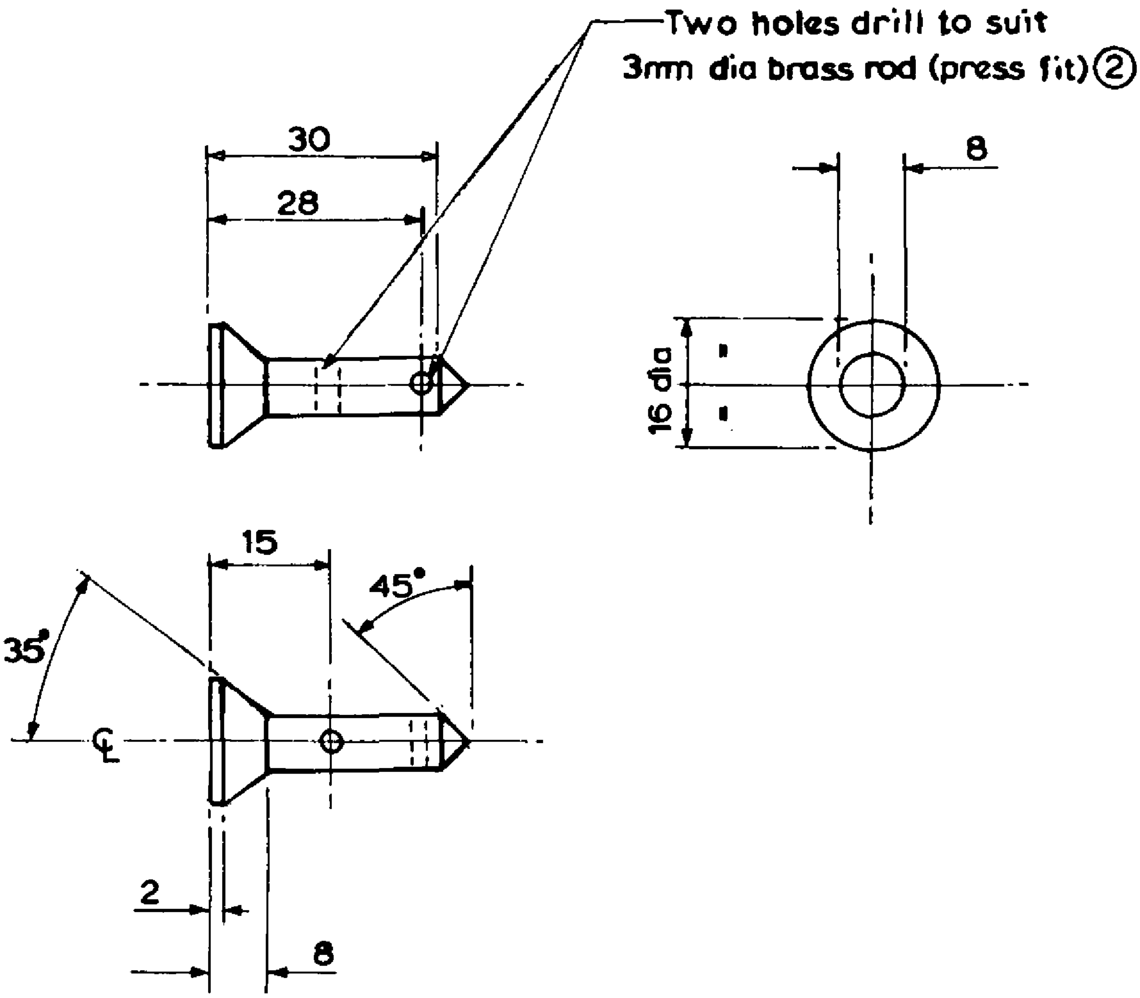
Drawing No A618 (A)



Note

Dimensions in mm

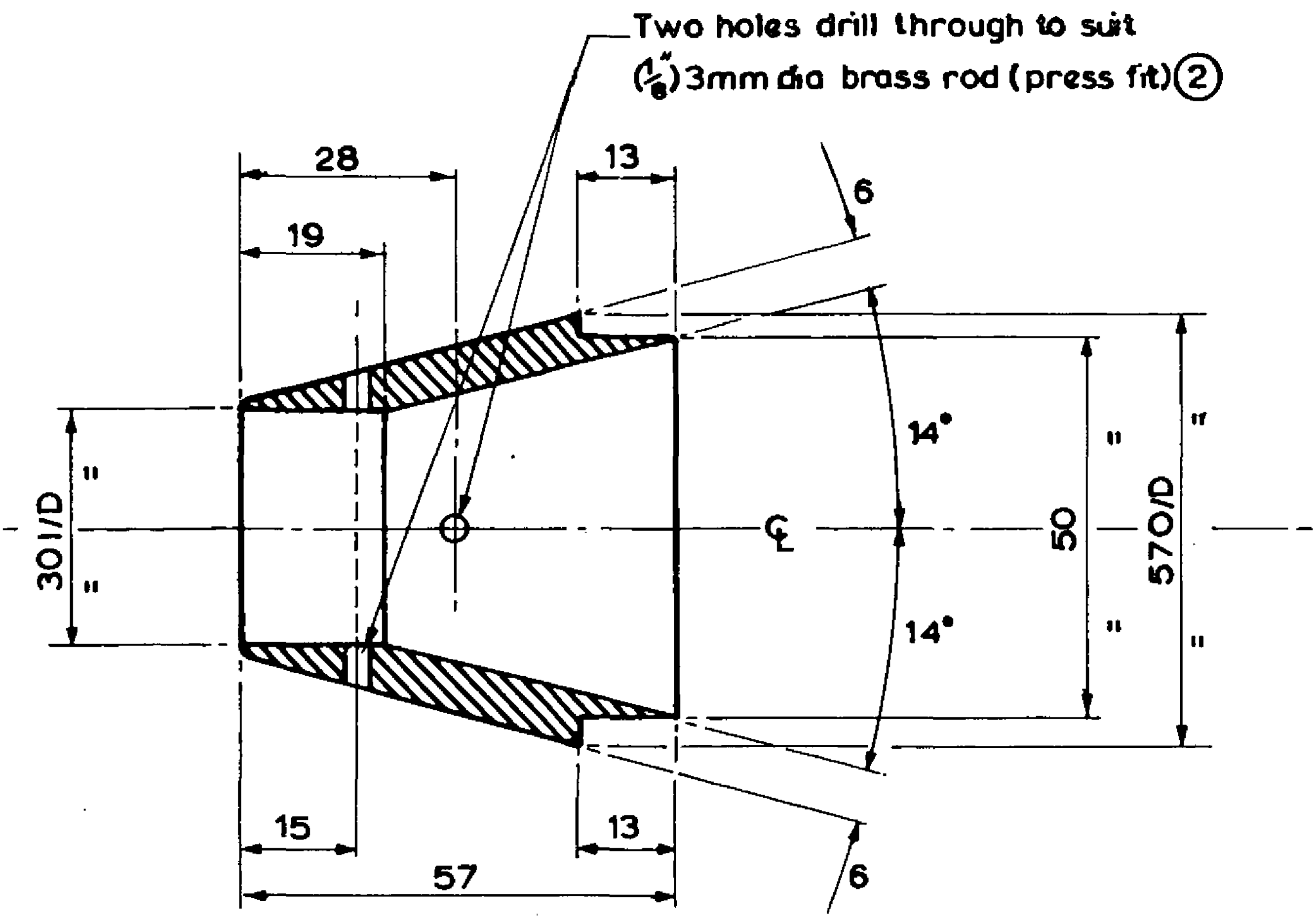
Drawing No A618(A)/1



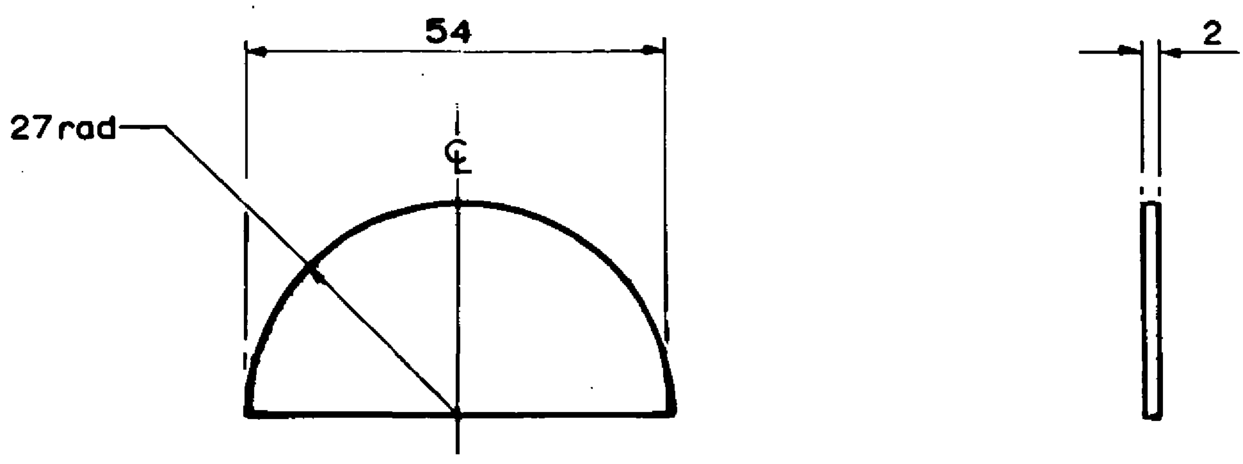
3 Dispersing cone mat[l] brass

Note
Dimensions in mm

Drawing No A618(A)/2 and 3



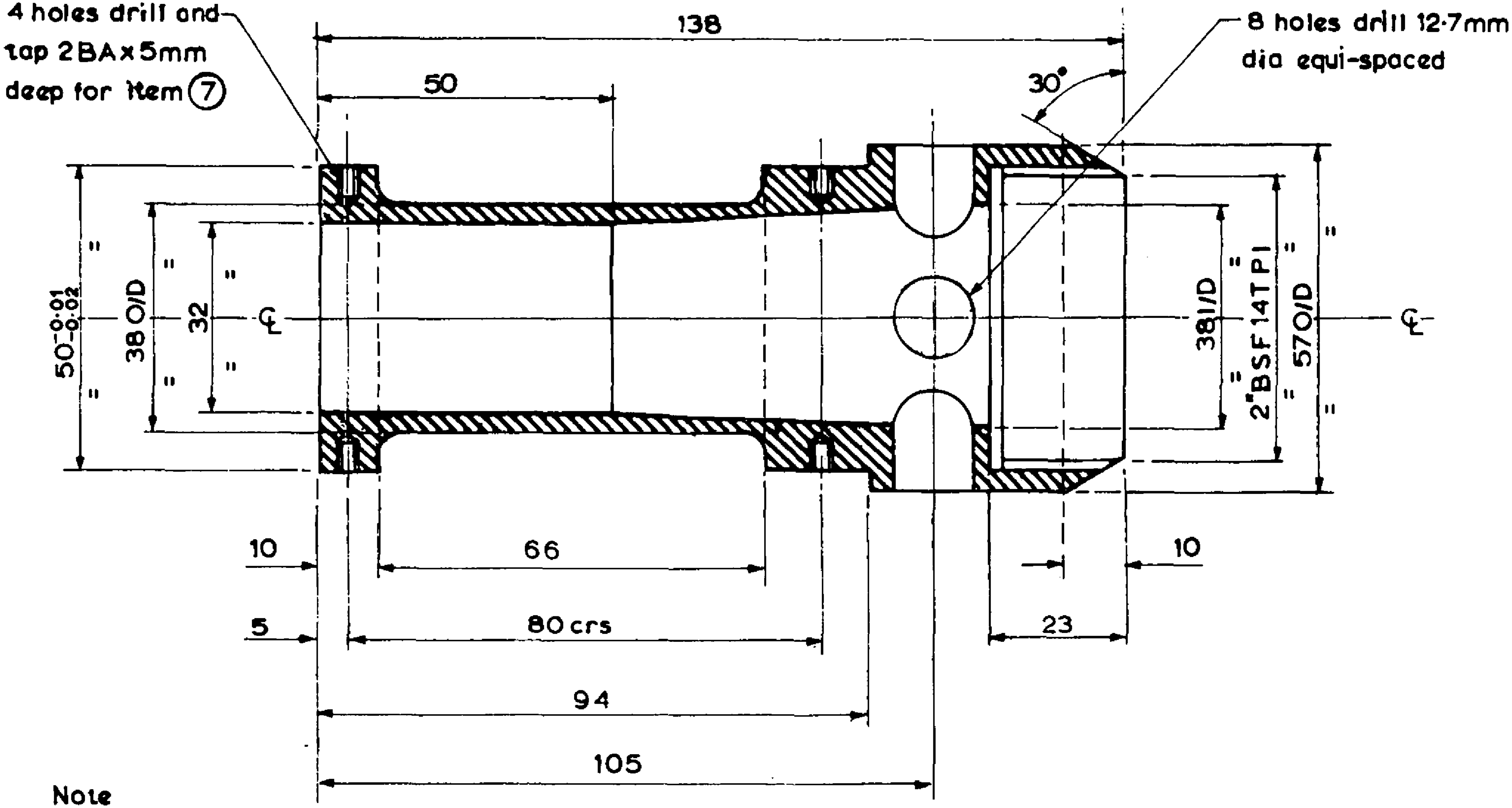
(4) Outlet nozzle matl- Dural



Note
Dimensions in mm

(5) Baffle plate matl- Dural
Two off required

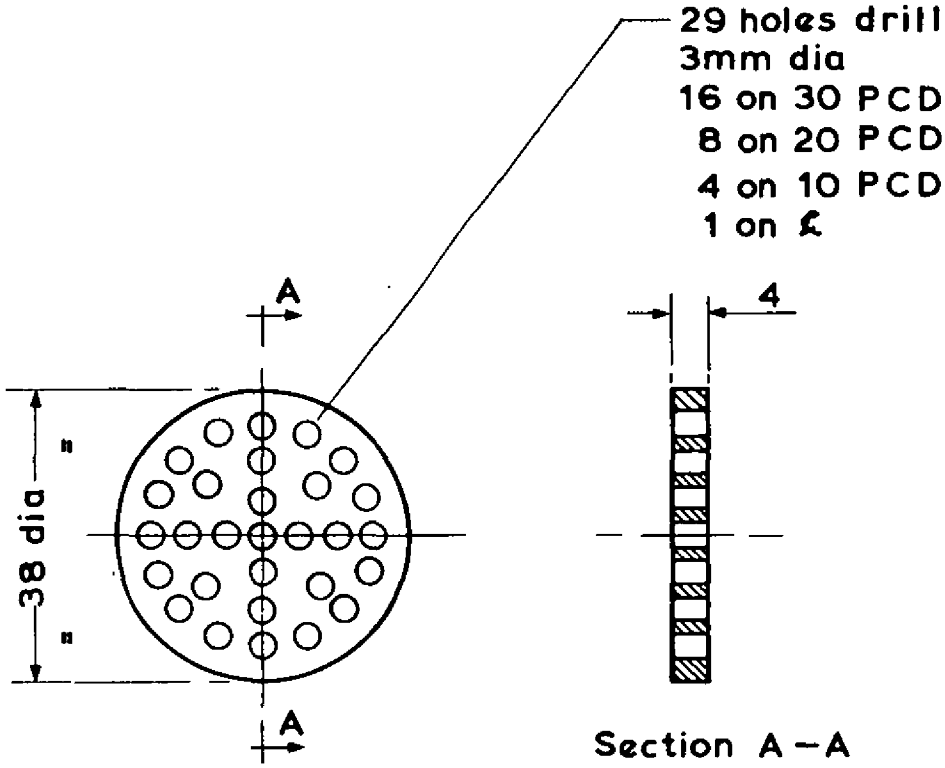
Drawing No A618(A) 2,4 and 5



Note
Dimensions in mm

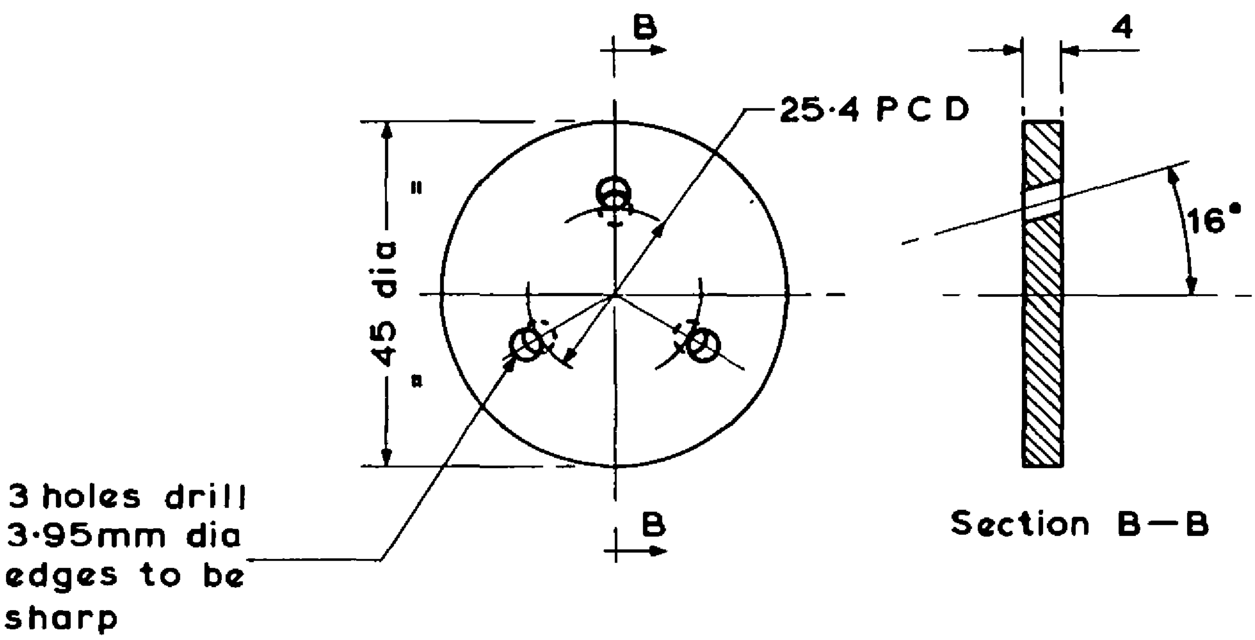
(6) Air inlet throat – mat^{L} Dural

Drawing No A618 (A) / 6 and 7



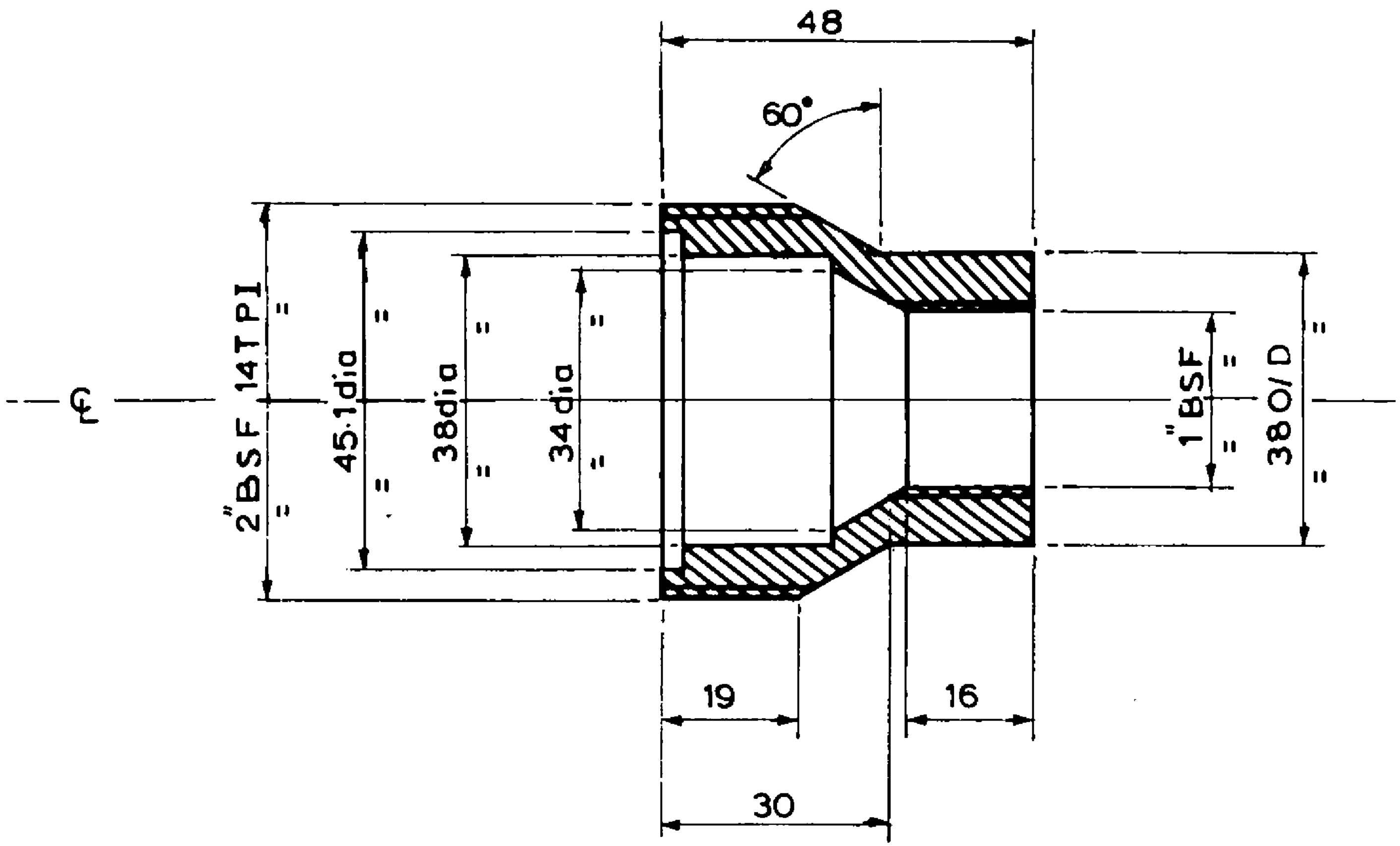
⑨ Filter disc – mat! s/st

Note:
Dimensions in mm



⑧ Orifice plate – mat! s/st

Drawing No A618 (A) / 8 and 9

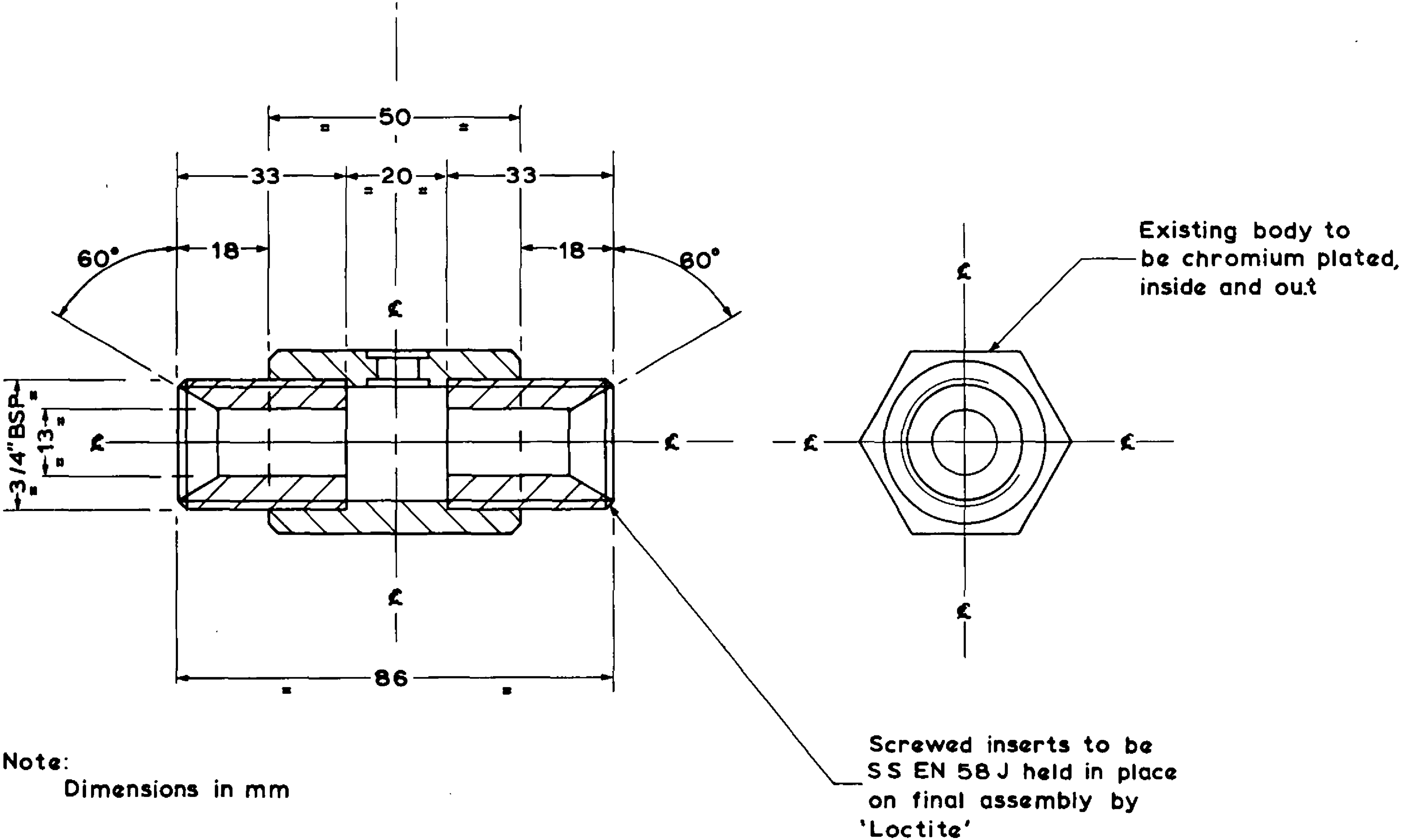


Note

Dimensions in mm

(10) Filter inlet - mat^{L} Dural

Drawing No A618(A)/10



Note:
Dimensions in mm

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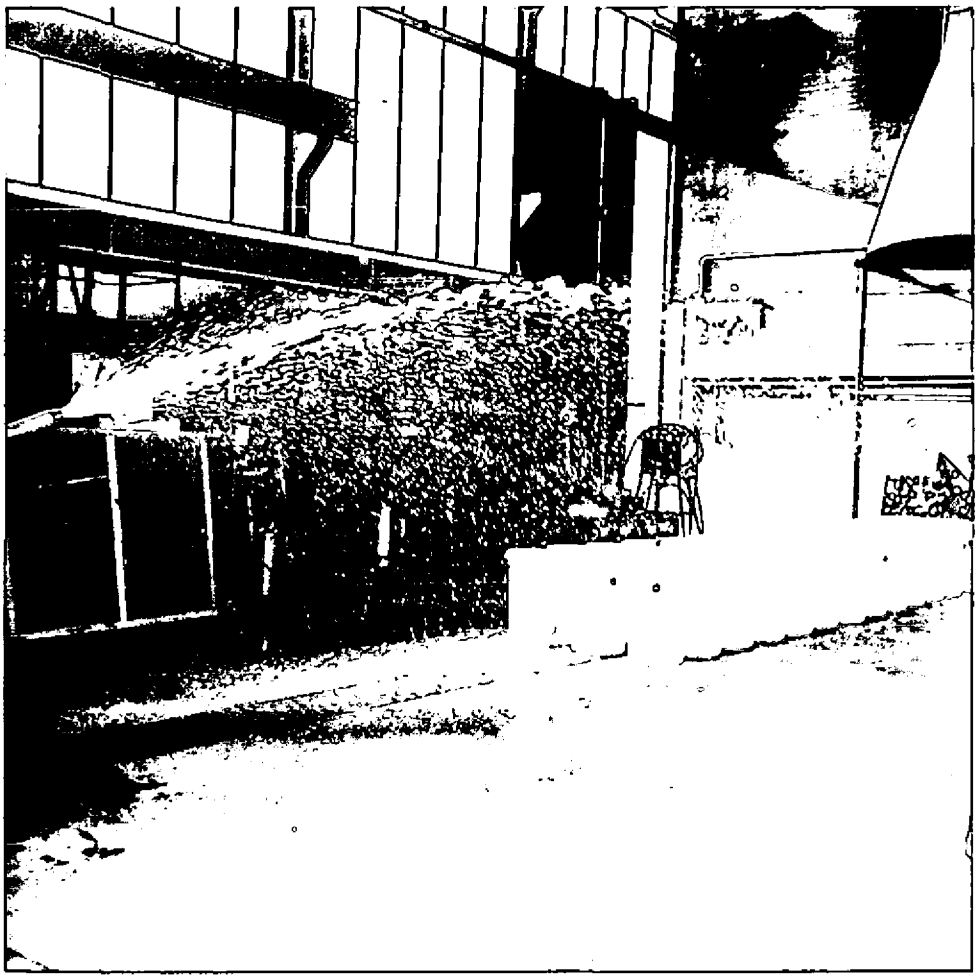

FIG.1 THE DISTRIBUTION PATTERN TEST

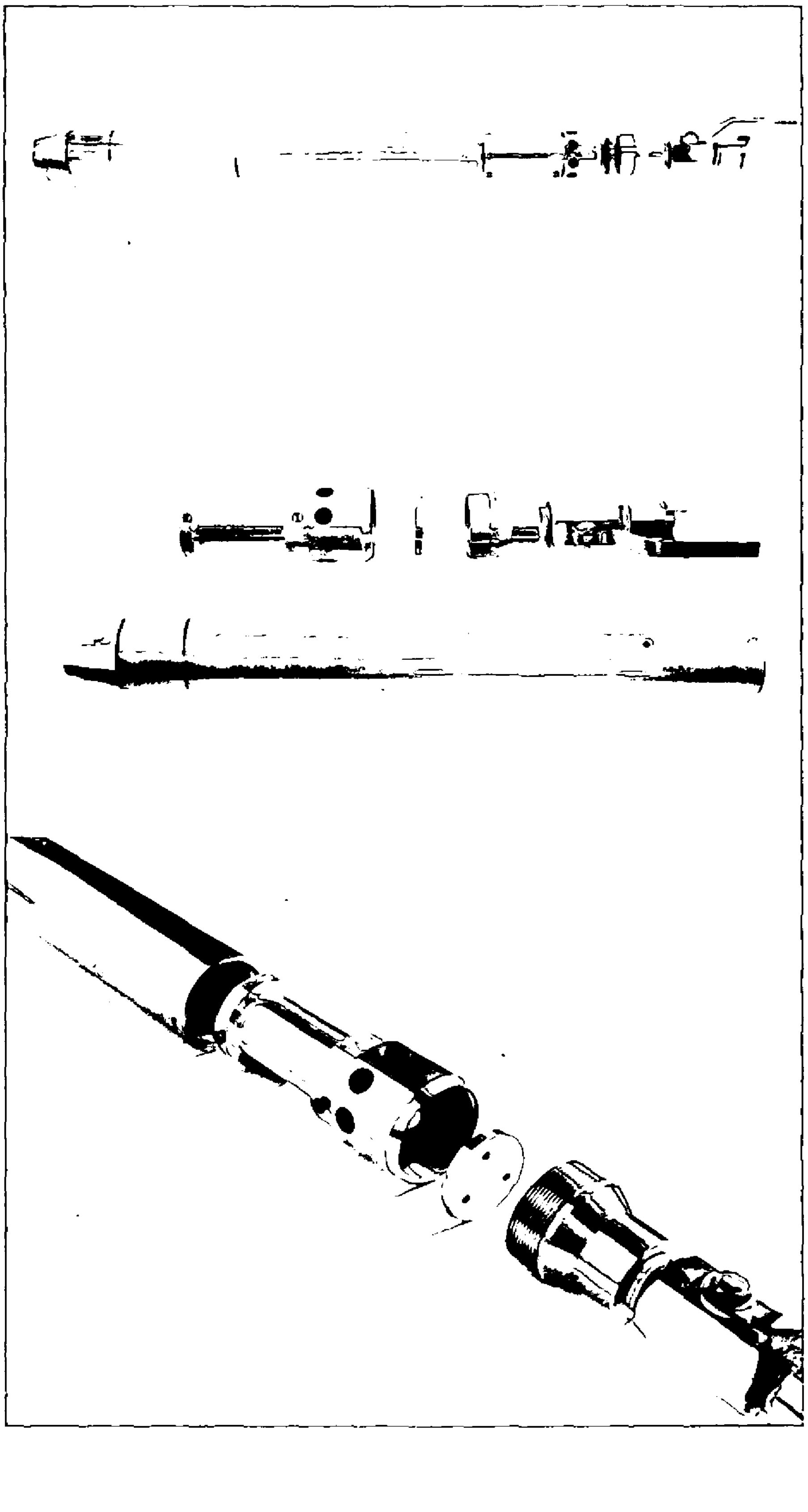

FIG.2 THE BRANCHPIPE DISMANTLED TO SHOW ITS COMPONENT PARTS

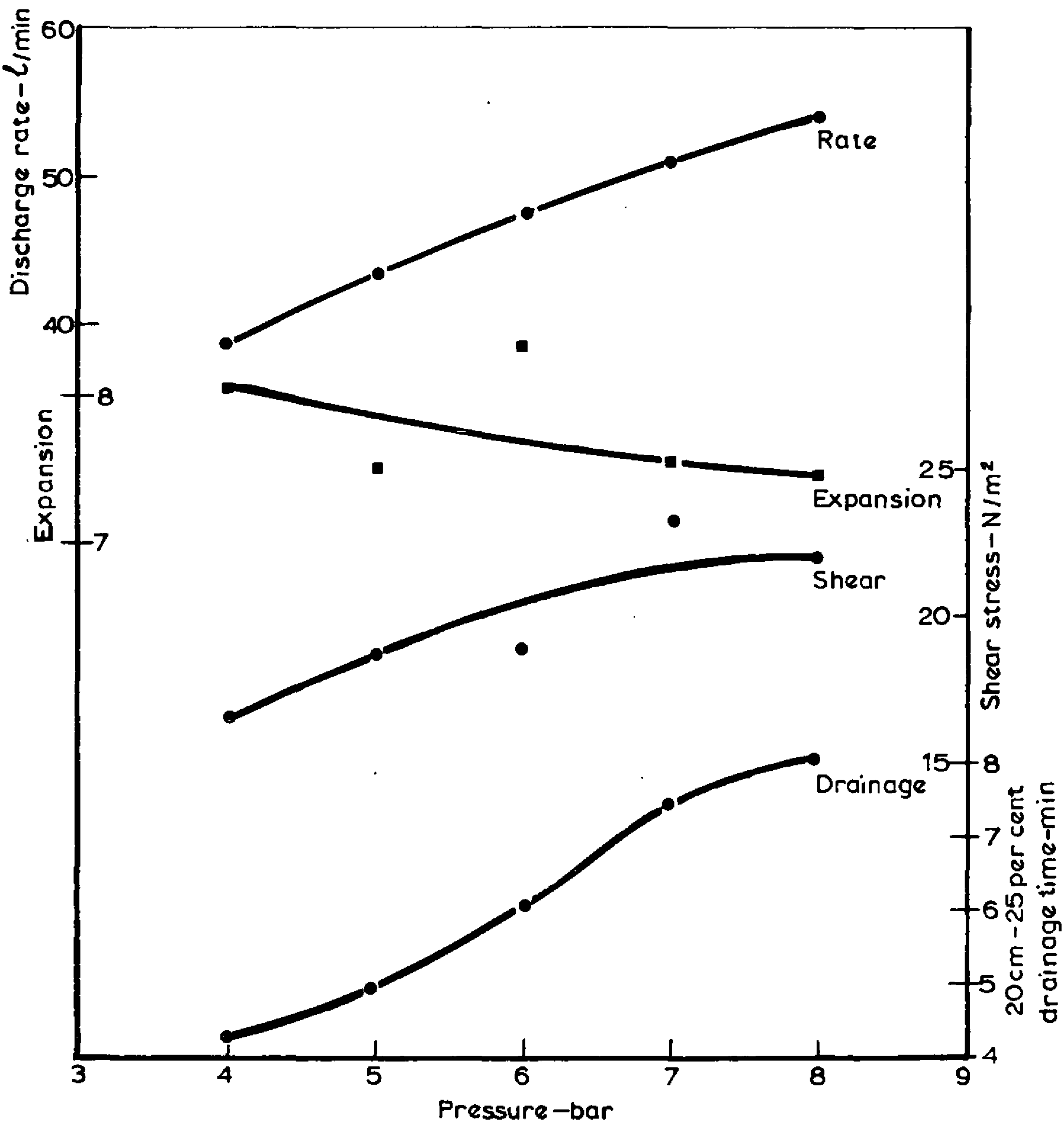

Figure 3 The effect of pressure on discharge rate and foam properties – 4 per cent protein A1

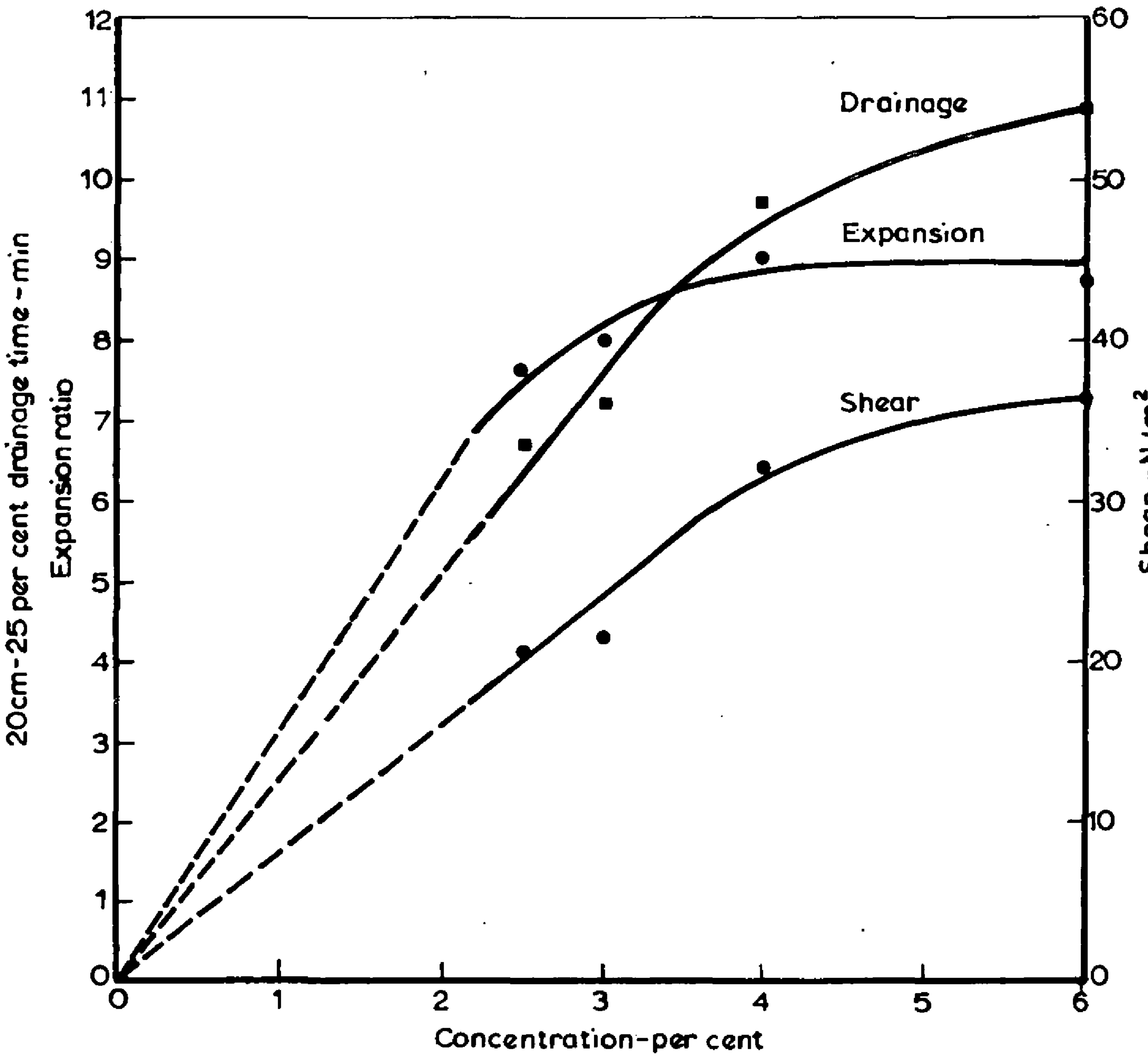

Figure 4 The effect of concentration on foam properties with protein A2 solution at 7 bar discharge pressure

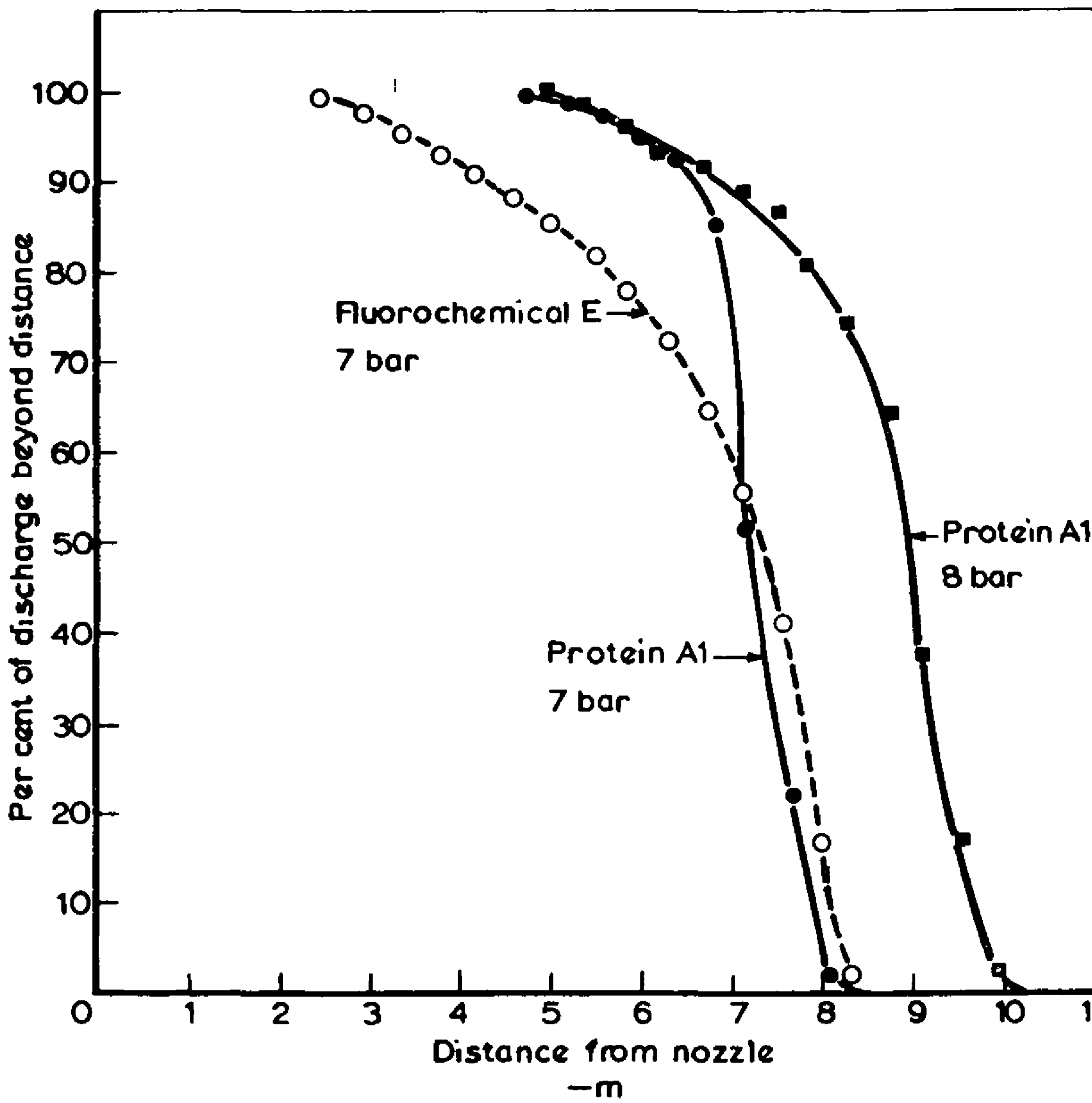

Figure 5 Range of foam stream

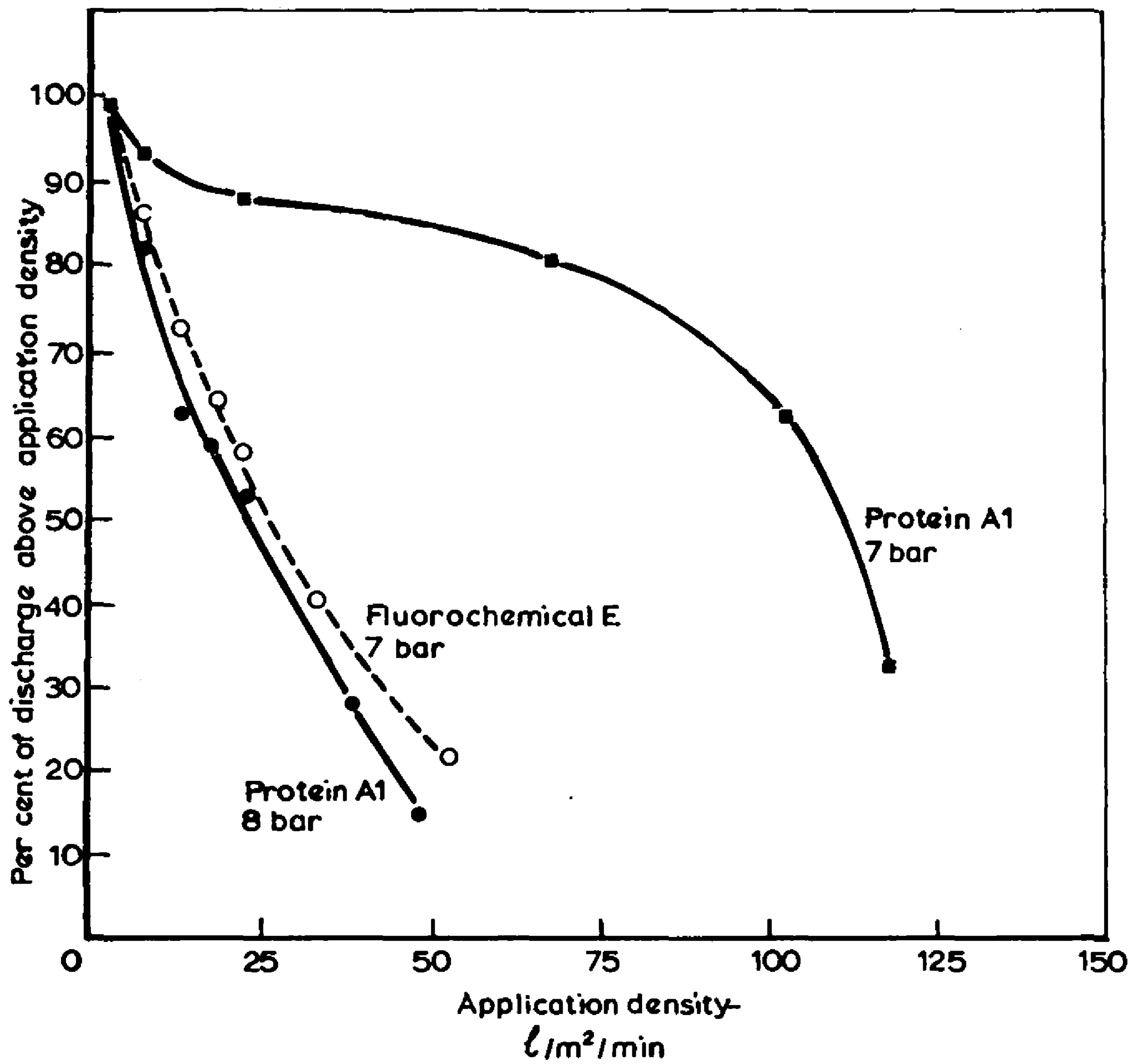

Figure 6 Density of discharge

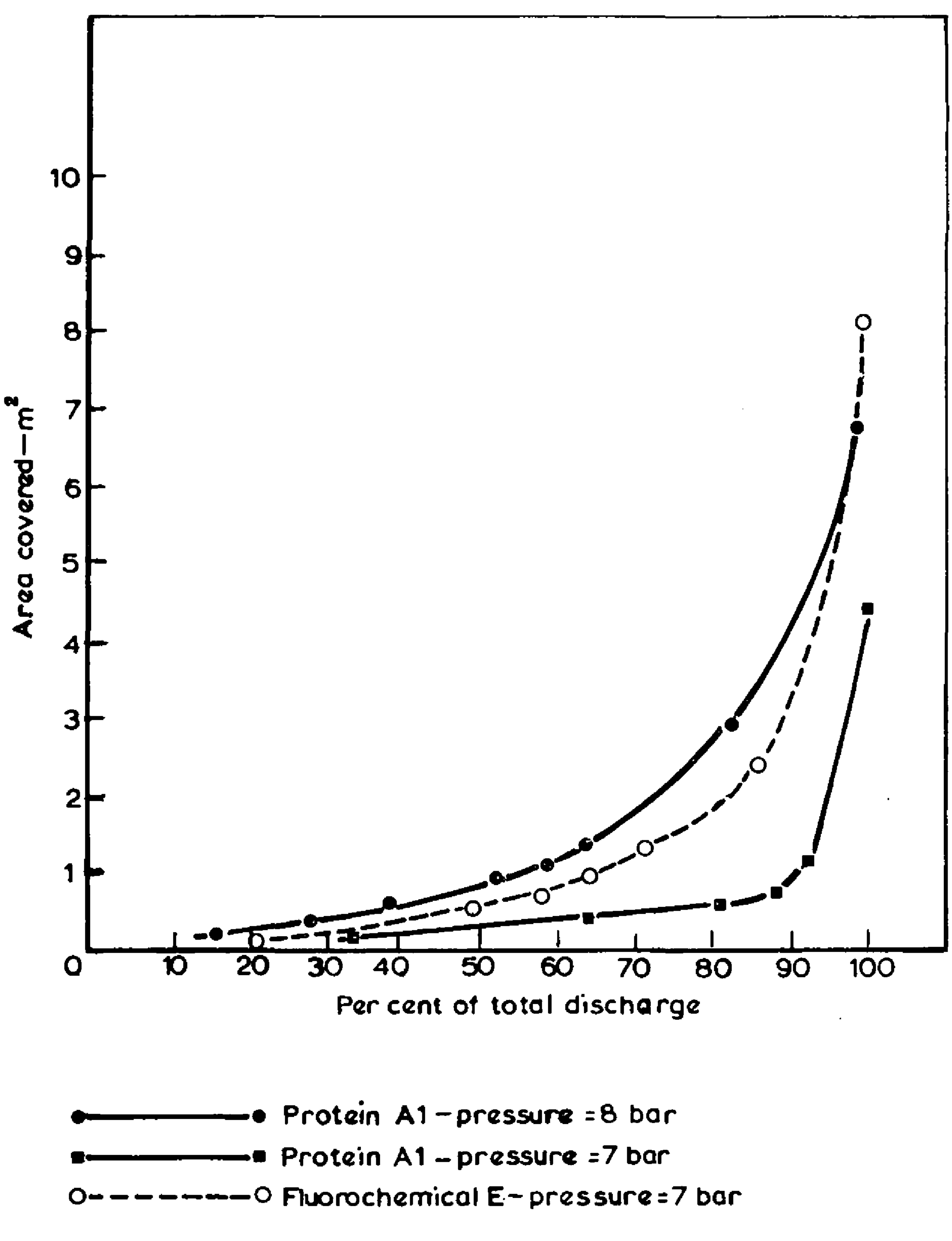

Figure 7 Compactness of discharge

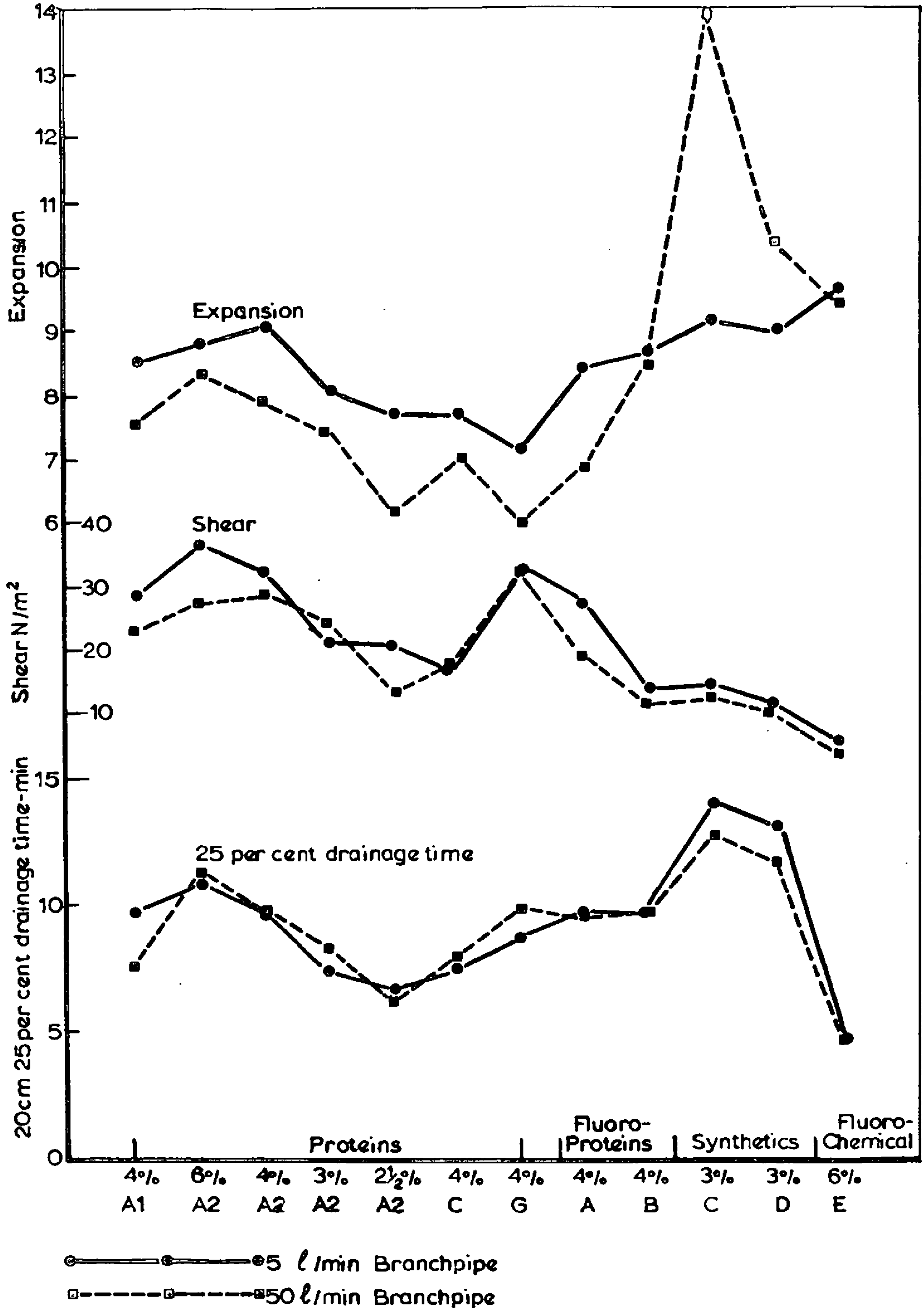

Figure 8 Comparison of foam properties

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