Fire Research Note No 976

PART 1: THE EFFECT OF TEMPERATURE ON THE PHYSICAL PROPERTIES OF FOAM PRODUCED IN THE STIRRED JAR.

PART 2: THE EFFECT OF TEMPERATURE ON THE PHYSICAL PROPERTIES OF FOAM PRODUCED IN THE 5 l/min BRANCHPIPE

by

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July 1973

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SUMMARY

Temperature has been found to have an effect on the physical properties of foam. In this note the extent of this temperature effect is investigated and a method to eliminate it,for comparison purposes between foams, is described.

KEY WORDS: Foam, temperature, physical properties

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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INTRODUCTION

During recent tests on a batch of fluoroprotein foam, considerable variations in shear stress and 25 per cent drainage time were found between the results from two laboratories.

On investigation several factors were eliminated, leaving only two conditions which differed between the laboratories, that of water quality and temperature.

Although the water effect has still to be investigated it was found that, in any one laboratory a variation in drainage times and shear stress values could be obtained using the same water quality and so further investigations were made into the temperature effect.

Two other countries, Canada[1] and the United States[2] have also made some studies of the temperature effect on the physical properties of foam but their results cannot be directly related to foams produced in the stirred jar.

For practical convenience, in the work reported here, the stirred jar apparatus was used without modification. Although precise control of the temperature of the apparatus would have been desirable, it would have involved modification of the stirred jar and the procedure laid down for its use. Such modification was beyond the scope of the present work, but it would be a useful supplementary investigation.

EXPERIMENTAL

A 100 ml of 4 per cent fluoroprotein foam solution was made using water at a known temperature. This was then stirred for six minutes in the apparatus (Plate 1) as described in Fire Research Note No 863. The foam produced (Expansion 8) was then removed from the jar, placed in a container 70 mm in diameter, 74 mm high and its shear stress measured at 1 minute after stirring had stopped.

The premix temperature and the foam temperature were determined using a mercury in glass thermometer. When measuring foam temperatures the thermometer was kept in motion by a stirring action until a constant reading was obtained. Tests were made starting with a range of premix temperatures.

On completion of this set of tests, a further set were carried out measuring the 25 per cent drainage time of the foam at various temperatures. In this case after 6 minutes stirring the foam was left in the stirred jar and allowed to drain.

RESULTS

The results obtained were tabulated (Tables 1 and 2) and the points were then recorded on graphs of shear stress/temperature and 25 per cent drainage/temperature (Figs 1 and 2).

In both cases the points seem to form a linear relationship and so the data was then fed into a calculator, programmed for linear regression. The equation of the straight line of best fit for each graph was then found. The best fit being determined by minimizing the sum of the squares of the deviations of the data points from the line i.e. the programme calculated the constants m and b for the equation

$$Y = m X + b$$

PART 2: THE EFFECT OF TEMPERATURE ON THE PHYSICAL PROPERTIES OF FOAM PRODUCED IN THE 5 l/min BRANCHPIPE

INTRODUCTION

Following the experiments with the stirred jar foam, a similar series were carried out using foam produced in a 5 l/min branchpipe[3] (Plate 2).

In this case the expansion of the foam was also measured at each temperature as well as the shear stress and 25 per cent drainage time.

EXPERIMENTAL

A 9.1 litre mix of 4 per cent fluoroprotein foam liquid was made and its temperature recorded. The apparatus was used in the manner shown in Plate 3. A sample of foam was collected in a 2½ litre plastic jug and its expansion and temperature were measured. This was repeated three times and the average expansion and temperature noted.

Following this, a sample of foam was collected in a 6320 ml brass drainage pot (Plate 4). A stop watch was started on commencement of filling the pot, the 15 per cent drainage time of the foam and its temperature were recorded.

While the drainage was in progress a sample of foam was collected in the small jar (70 mm diameter, 74 mm high) and its shear stress measured using a viscometer[4], one minute after collection of the foam. The foam temperature was also taken.

A further four samples of foam were collected for shear stress readings and the average shear stress and temperature noted from the five readings.

The 25 per cent drainage was repeated once more and the two values of drainage and temperature recorded separately.

This whole experimental procedure was repeated, using 9.1 litre mixes at different temperatures.

RESULTS

After tabulation of the results (Tables 3, 4 and 5), the points were inserted on graphs of Expansion/Temperature, Shear stress/temperature and 25 per cent drainage/temperature (Figs 3, 4 and 5 respectively). The linear relationship found between these properties of the foam and temperature could again be seen, and so the line of best fit through each set of points was drawn. Use of the calculator was not thought necessary in this instance, as the points were few in number and the best line was obvious from observation.

OBSERVATIONS MADE FROM THE GRAPHS OBTAINED FROM THESE EXPERIMENTS

The temperature of the foam produced in either the stirred jar or the 5 l/min branchpipe, has a significant effect on the shear stress and 25 per cent drainage time, but very little effect upon the expansion of the foam from the branchpipe.

In Fig 1 shear stress/temperature for stirred jar foam the two maximum points, although plotted were not included when the line was calculated as ice sometimes formed in the premix when obtaining these low temperature foams.

All the graphs are represented by $Y = mX + b$ (i.e. a straight line) although both shear stress/temperature graphs (Figs 1 and 4) appear to show some deviation from linearity at low temperatures. There is also some evidence of this in the expansion/temperature graph (Fig.3).

In the tests with the branchpipe the air temperature was not controlled and it varied slightly around 16°C. The differences in foam temperature were obtained by varying the premix temperature. It is possible that the expansion may change with air temperature and this effect has not been assessed in this study.

In every case, an increase in foam temperature decreased the value of the physical property being measured.

An additional graph (Fig 6) was drawn to show all the shear stress and drainage curves on a single graph. At any one foam temperature the shear stress value was higher for stirred jar foam. This is because a higher level of energy is used to produce the foam in the jar (stirring for 6 minutes) and thus smaller bubbles formed.

In the case of the 25 per cent drainage times, the difference in readings at any one temperature was only slight. The energy difference in producing the two foams was offset by the drainage times being measured in pots of different heights. The stirred jar (from which the drainage was measured) is 12.7 cm deep, while the branchpipe sample was collected in a brass pot 20 cm deep. The slight difference in slope found between the two graphs was probably due to the drainage mechanism. The drainage time is composed of two parts, an initial period where there is no drainage but coalescence caused by diffusion is occurring and a secondary period during which coalescence continues and drainage also occurs. The diffusion in both periods is affected by temperature, and because of the temperature effect on the viscosity, the drainage rate in the second period is also altered. Since the two foams commenced with different bubble sizes, different times to the commencement of the drainage, and different sample depths through which the liquid must drain, identical changes with temperature would be improbable.

CONCLUSIONS

These graphs were obtained using a fluoroprotein foam, but it is reasonable to assume that similar graphs could be drawn for other types of foam.

It is therefore recommended that all determinations of shear stress and 25 per cent drainage time made for comparison purposes, be noted at a stated temperature (20°C) to eliminate the temperature effects.

Experimentally this would involve obtaining readings between 16°C and 24°C, drawing a graph and then reading the values of shear stress and 25 per cent drainage time at 20°C.

The expansion of branchpipe foam is very little affected by temperature and so this graphical procedure would not be necessary.

ACKNOWLEDGMENT

Thanks is given to Mrs K Morris who carried out a large proportion of experimental work.

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2. JABLONSKI, E.J. The influence of Temperature on the viscosity and drainage rates of mechanically produced fire-fighting foams. NRL Report 5598.
3. BENSON, S.P., GRIFFITHS, D.J., and CORRIE, J.G. A 5 litre per minute standard foam branchpipe. Fire Research Note No.971
4. Journal of Scientific Instruments. Vol 37, August 1960, Page 307. Foam Viscometer.

TABLE 1

The variation of shear stress with temperature for a fluoroprotein foam, produced in the stirred jar

Premix Temp. °C	Foam Temp. °C	Shear stress N/m^2
36.5	32	12.2
38.5	29	13.3
28	27	15.54
26	27	15
23	27	16.65
34	26	14.85
26	26	17.76
25	26	15.54
26	25	17.76
27	25	16.1
18	24	17.76
24	24	17.2
24	23	18.87
23	22	18.87
18.5	20.5	20.5
16	20	18.87
11.5	20	21.6
15.5	19.5	21.1
14	19	22.2
10	16.5	22.2
11	14	22.2
9	13	22.2
7	13	24.4
5.5	13	24.4
4	11.5	25.53
5	11	26.64
1	8	36.63
2.5	7.5	30
0	4.5	38.85

Table 2

The variation of 12.7 cm-25 per cent drainage time with temperature for a fluoroprotein foam produced in the stirred jar

Premix Temp. °C	Foam Temp. °C	25 per cent drainage time mins
31	31	4.15
30	31	3
28	29.5	4.5
32.5	27.5	5.15
31	27	6
26.5	27	5.2
29	27	5.25
27.5	27	5
29	25	6.5
20	23.5	6.25
25.5	23	6.65
19	22	8.75
22	22	7.65
19	21	7.25
15	20.5	7.6
18.5	20	6.6
16	20	5.75
16	19.5	7
16	19.5	7.65
15	19	8
10.5	18	8
14	17	7.25
13	16	8
13	16	7.4
10.5	14.5	8.25
10	14.5	8
11.5	14.5	8.5
4.5	14	11
3	13	12
4.5	13	10

TABLE 3

The variation of expansion with temperature for a fluoroprotein foam, produced in the 5 l/min branchpipe

Premix Temp. °C	Foam Temp. °C	Expansion
12	12.2	7.6
15.5	15.3	8.0
20	19.5	8.0
24	25.4	7.7
30.5	29	7.5

TABLE 4

The variation of shear stress with temperature for a fluoroprotein foam, produced in the 5 l/min branchpipe

Premix Temp. °C	Foam Temp. °C	Shear stress N/m^2
12	12.5	13.8
15.5	14.9	11.1
20	19	10.75
24	23.9	9.3
30.5	27.3	8.8

TABLE 5

The variation of 20 cm–25 per cent drainage time with temperature for a fluoroprotein foam, produced in the 5 l/min branchpipe

Premix Temp. °C	Foam Temp. °C	25 per cent drainage time–mins
12	12	9
12	12.3	8.6
15.5	15	8.15
15.5	15.2	8.20
20	19.4	7.35
24	25.5	6.3
24	25	6.1
30.5	28.8	5.65
30.5	29	5.65

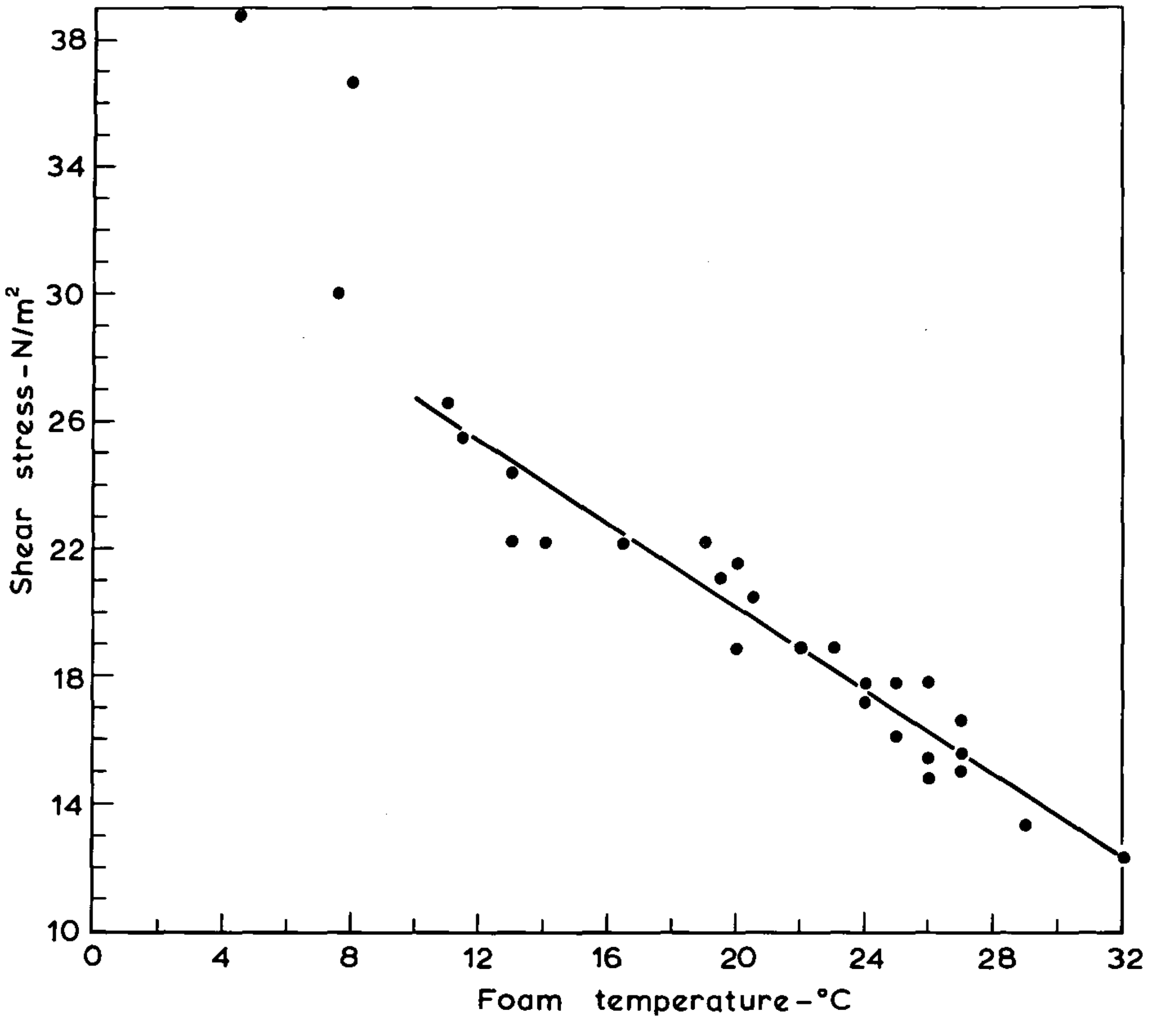


Figure 1 Shear stress/temperature for a fluoroprotein foam produced in the stirred jar

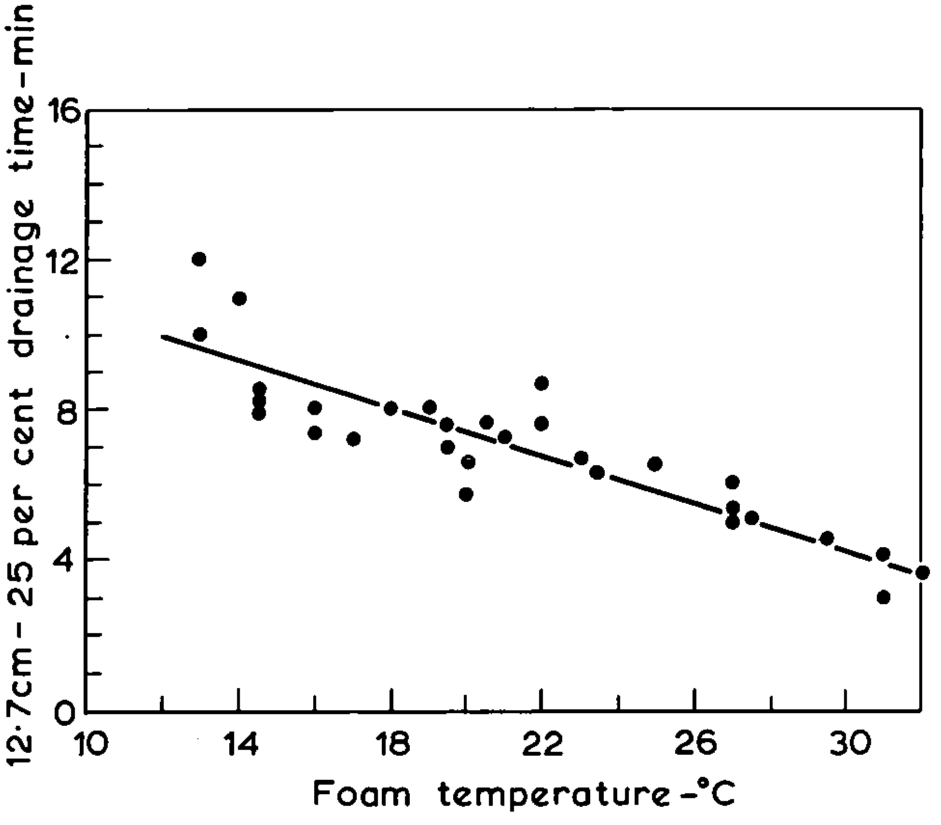


Figure 2 12·7cm – 25 per cent drainage time/temperature for a fluoroprotein foam produced in the stirred jar

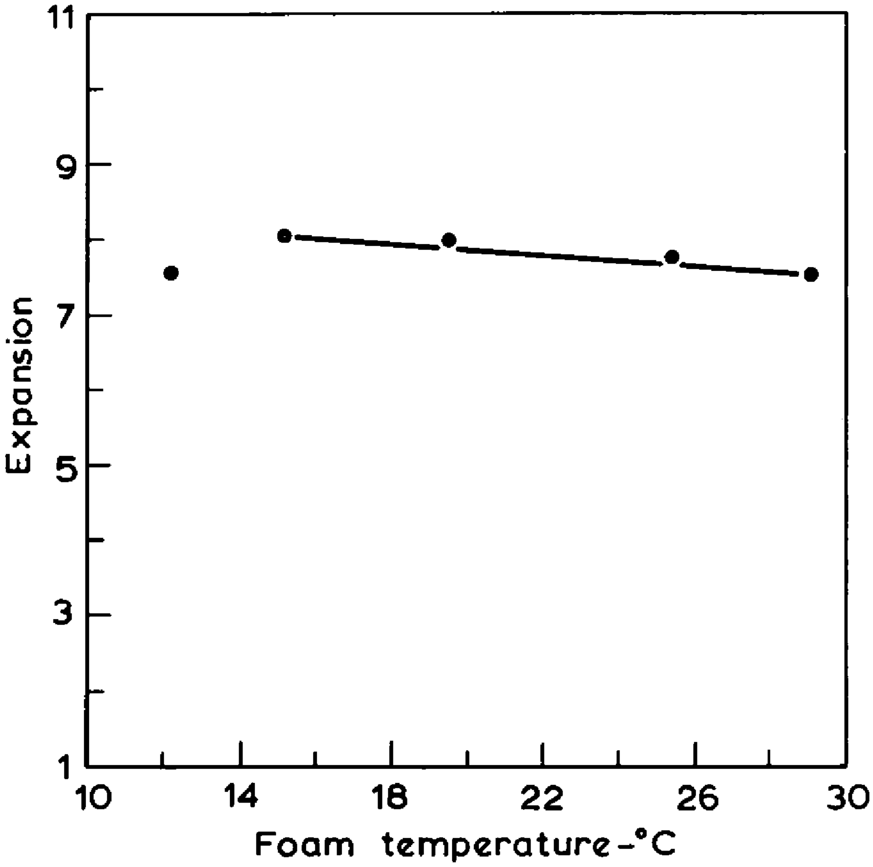


Figure 3 Expansion / temperature for a fluoroprotein foam produced in the 5 l/min branchpipe

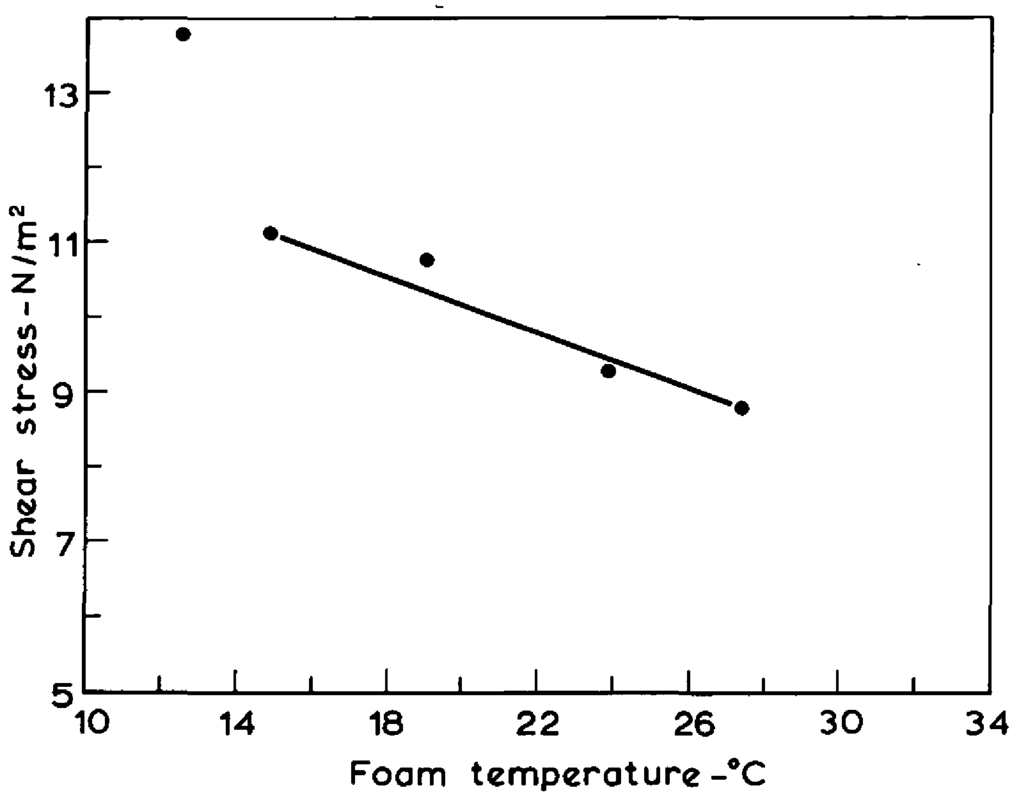


Figure 4 Shear stress/temperature for a fluoroprotein foam produced in the 5 l/min branchpipe

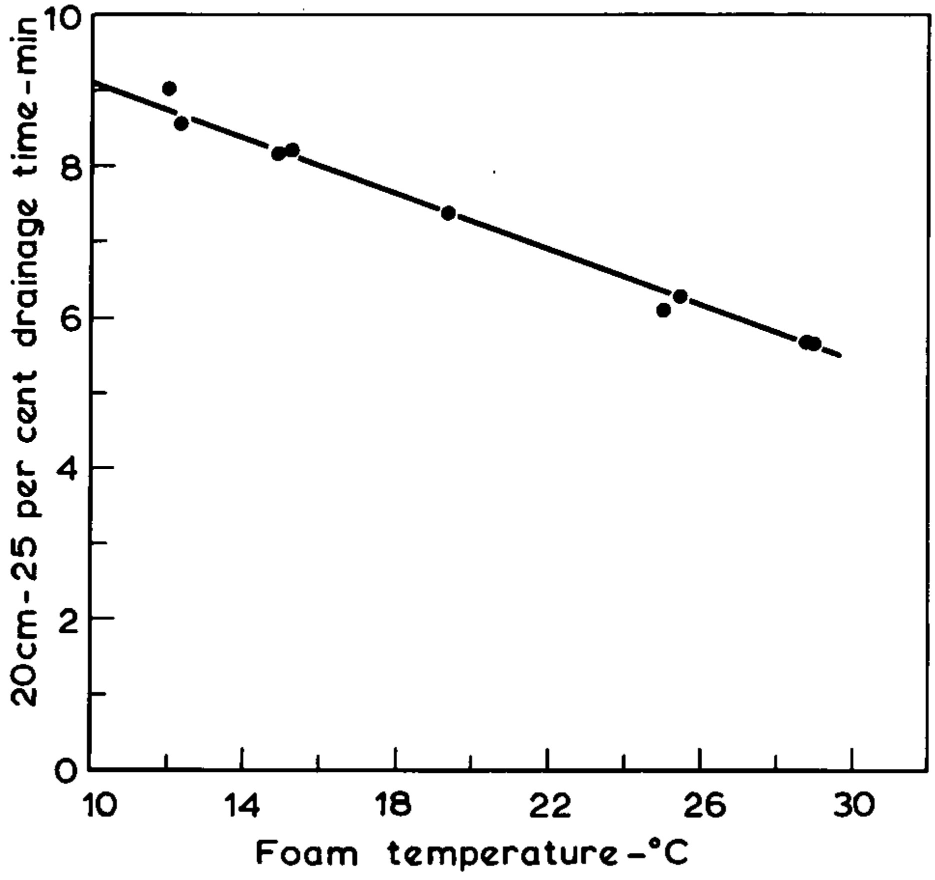


Figure 5 20cm-25 per cent drainage time/temperature for a fluoroprotein foam produced in the 5 l/min branchpipe

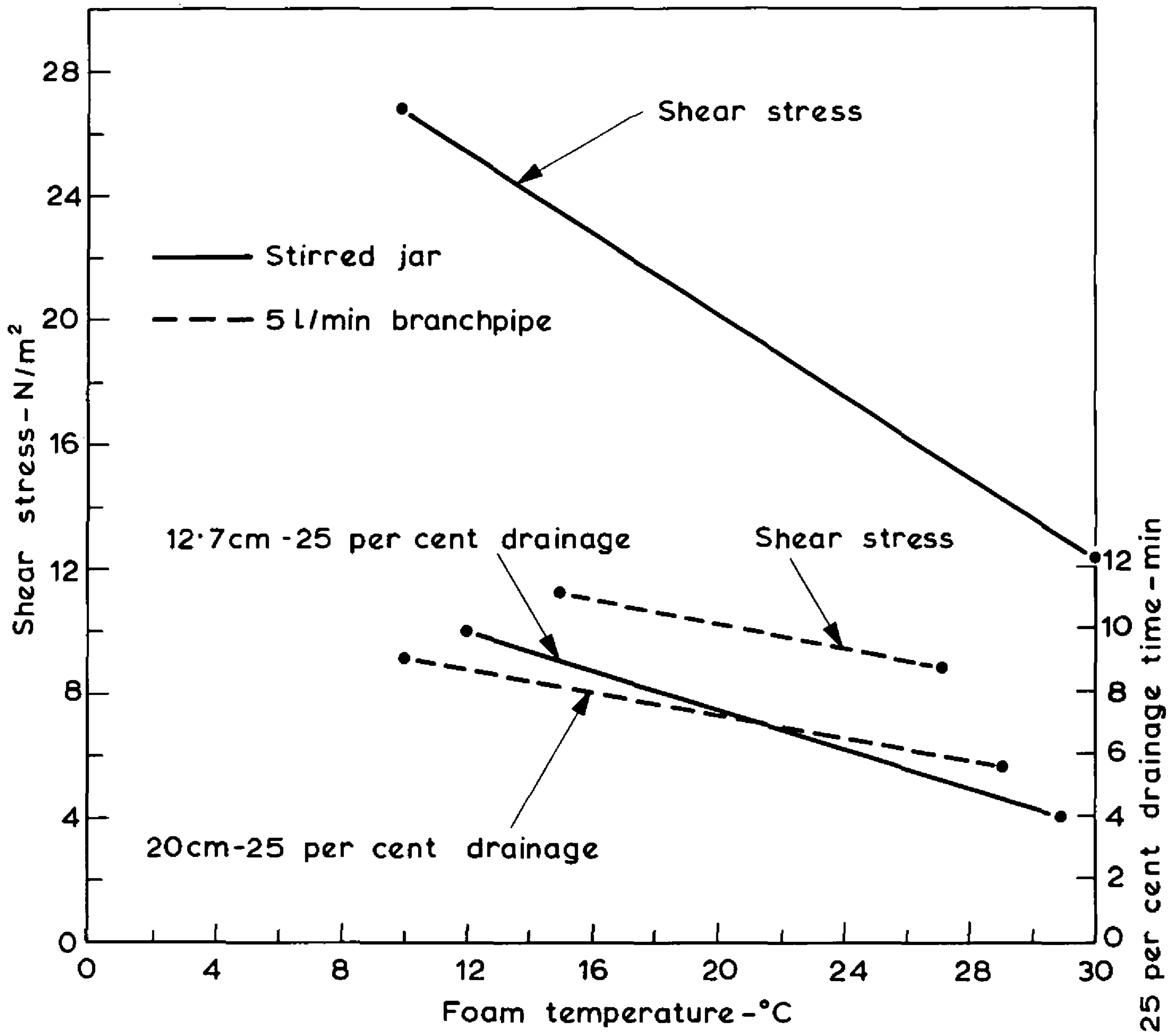
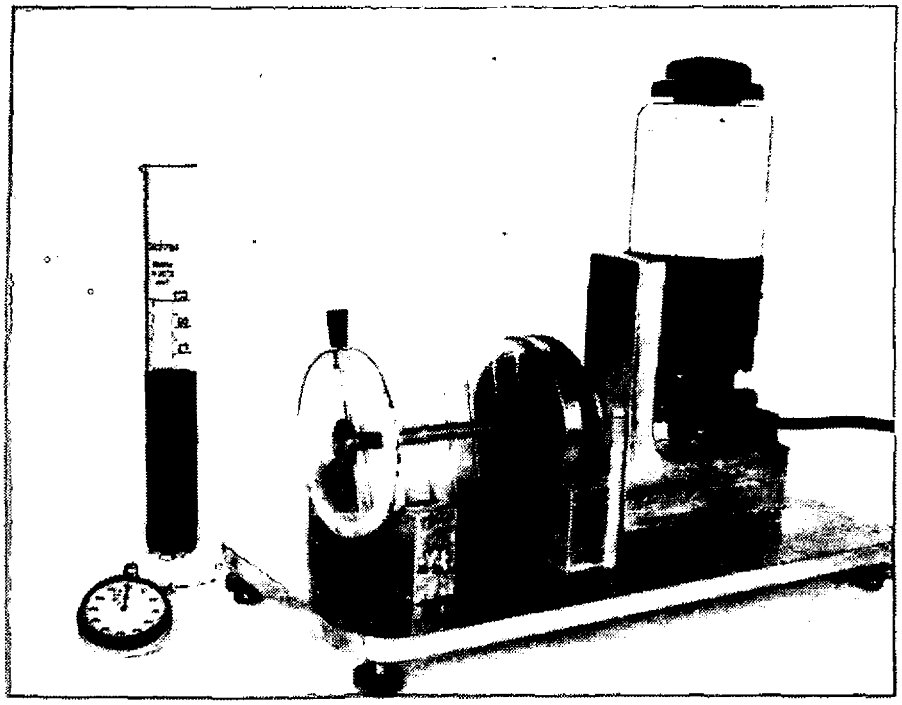


Figure 6 Summary of the graphs obtained for shear stress and 25 per cent drainage time with a fluoroprotein foam produced in the stirred jar and the 5 l/min branchpipe



P LATE 1. THE STIRRED JAR USED FOR FOAM PRODUCTION

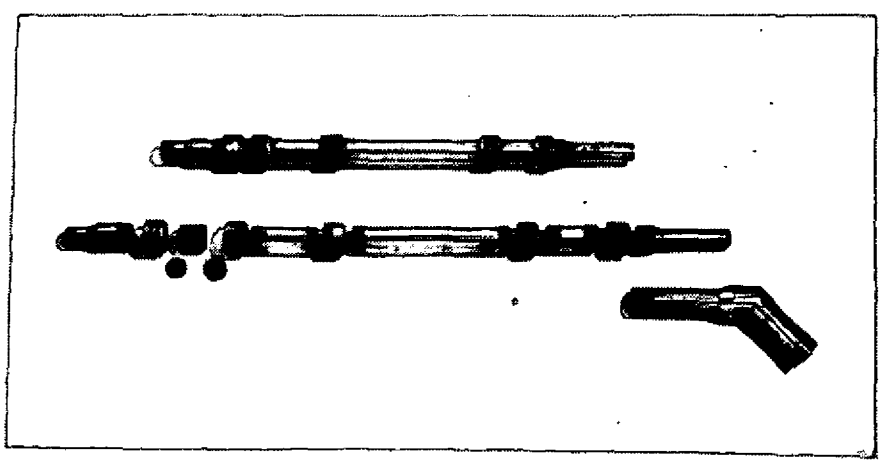


PLATE 2. 5 L/MIN BRANCHPIPE USED FOR FOAM PRODUCTION

PLATE 3. 5 L/MIN BRANCHPIPE CONNECTED TO EXTINGUISHER, CONTAINING 9.1 LITRES OF 4 PER CENT FOAM SOLUTION AND PRESSURIZED BY AIR LINE CONNECTION

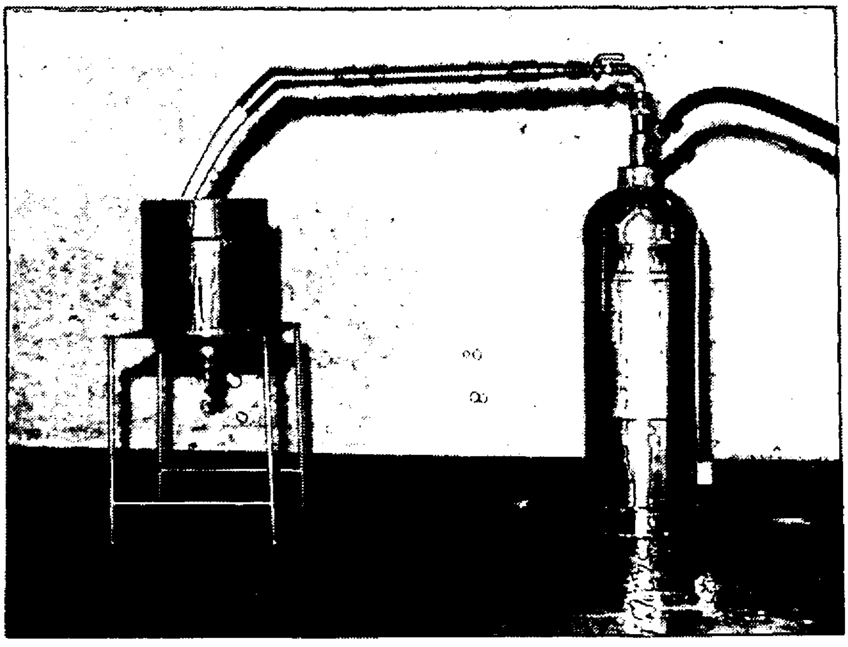


PLATE 4. COLLECTION OF A SAMPLE OF FOAM (PRODUCED IN THE BRANCHPIPE) IN THE 6,320 ML BRASS DRAINAGE POT

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