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SOME EXPERIMENTS ON CLOTHING FOR AIRCRAFT FIRE-FIGHTING

by

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Introduction

Aircraft fires on the ground can be divided into two categories, those associated with crashes and other fires. The aircraft crash fire is usually serious, since there is often a large spillage of fuel and the primary object in fighting the fire is to save life rather than to save the aircraft. In fact, no case could be made for the large expenditure of equipment and manpower needed to fight these large fires on the score of the relatively small saving in property, and it is with these intense fires that there is most need for special clothing. Most other fires associated with aircraft are often comparatively small and can often be dealt with before they have reached serious proportions.

It is important to keep this distinction clear as the size of fire and the time-scale of the fire-fighting will have a bearing on the clothing most suitable for fire-fighting duties.

It is interesting first to get some idea of the characteristics of aircraft crash fires. This is difficult at present, because crashes are mercifully few, and also because there is no uniform system of reporting such fires. It is hoped to remedy this in the next few years, with the co-operation of both the Services and the Ministry of Transport and Civil Aviation. In the meantime the only evidence available is that which can be obtained by measuring photographs of aircraft crashes in various parts of the world.

An analysis of forty aircraft crashes has shown that one-third had a ground plan area of 200 ft^2 or less, two-thirds an area of less than 1,000 ft^2 and the largest fire of the sample a ground plan area of 5,000 ft^2. The elevation areas of the fires were generally less, one-third having an elevation of less than 180 ft^2, two-thirds less than 600 ft^2, and the largest fire reported in the sample had an elevation of 1,600 ft^2. These figures are probably not very accurate but they give some idea of the orders involved, and it is hoped that as time goes on they will be improved.

There is even less evidence on which to base the time necessary for fighting such fires. This will be governed by the time of human survival, and the only reliable evidence is that from a series of tests carried out for the National Advisory Committee for Aeronautics in the United States and reported by Pesman (1). These results would suggest that for the severe crash fires studied, the maximum time for human survival would be about 5 minutes, and that in some cases it might be as low as 50 seconds. The requirement, therefore, is for clothing that will resist intense heat radiation for a short time, probably of the order of 10 minutes at the outside.

Experiments have recently been started at the Joint Fire Research Organization in order to decide which material assemblies show most promise for use in the design of clothing for fire-fighting. It is, of course, not possible to predict the performance of such clothing under field conditions, as in addition to the effect of the design of the clothing, both physiological and psychological factors will have to be taken into account. It is possible however to place the material assemblies in order of effectiveness.

The transmission of heat by materials

Because the outer layers of fire-fighting clothing have to take the greater punishment from the fire, the part played by undergarments is often overlooked. While the outer garment must have a high degree of resistance to flaming, and must form a barrier for the transfer of heat, it is the underlinings that can often be most effective in reducing heat transfer as their function is less specialized; that is they do not have to withstand such great temperatures.

In choosing suitable materials the most important physical property is the thermal conductivity, as this governs not only the maximum temperature reached by the interior clothing, but also the rapidity with which this temperature is attained. The thermal conductivity is also important because materials have a wide range of values depending on the amount of air enclosed by the fibres. The density and specific heats of materials are less important owing to the limited range of practical values available and also because they only control the time to reach the final temperature and not the temperature itself. Moreover a high density is usually associated with a high thermal conductivity, so that what is gained on one hand is lost on the other.

Experimental method

The experiments to date have dealt with materials to be used as various garments, and either or both of two types of test have been used according as to whether they would be appropriate for the garment in question.

Radiant heat has been applied to materials to be used as suiting, gauntlets and helmets, as these are associated with the upper parts of the body and would not usually be required to withstand flame. The suiting on other parts of the body e.g. the legs, boot soles and uppers and to a lesser extent gauntlets, may have to withstand flame conditions for some period, and these have been tested with flame impingement. This test is considerably more severe than the application of radiant heat alone.

Radiant heat

The experimental arrangement is shown in Fig. 1 in which it will be seen that the radiant heat is allowed to fall on the clothing assembly which is backed by horsemeat simulating human tissue. The material is subjected to a radiant intensity of 2 watts/cm^2, that is about thirty times the radiation from the sun under summer conditions, at which wood will rapidly char and emit combustible gases. It is representative of the intensity encountered close to a petrol fire. A typical curve showing the rise in temperature of the horsemeat as measured by fine wire thermocouples in the surface is shown in Fig. 2.

Resistance to flame

The experimental arrangement shown in Fig. 3 was as described above except that in this case the materials under consideration were exposed to flame instead of radiant heat. The flame was produced by burning a tray of petrol 5½ in. square, 4 in. below the sample under test.

Results of tests

In evaluating the various material assemblies it has been assumed that a temperature of about 60°C would cause discomfort. Although this would probably vary somewhat from subject to subject and at different parts of the body, pain would usually be experienced within 30 seconds, and this might be followed by blistering some time afterwards. The actual temperature used in the experiments was 62°C, that is a temperature rise of 25°C above the normal body temperature, 37°C. Heat takes a certain time to travel through protective clothing so that the heat will continue to be transmitted, Fig. 2, through the clothing even though the subject removes himself from either the flame or the radiated heat once conditions become uncomfortable. With this in mind, the heating was stopped once a temperature rise of 25°C occurred and the maximum temperature and the time of its occurrence noted. This overshoot is most marked with heavy clothing and in such cases some quick release fastenings should be incorporated, so that the clothing can readily be removed once discomfort is felt.

A few examples of the clothing which must withstand radiant heat have been selected from the clothing assemblies which have been tested so far, and the results of these tests are shown in Table 1.

Table 1

Performance of clothing assemblies when irradiated at an intensity of 2 watts/cm^2. The figures in parenthesis denote results when underwear (shirt and string vest) was included in the assembly

	Material	Time for temperature rise of 25°C sec	Maximum temperature rise °C	Further time to reach maximum temperature sec
Suiting	Fearnought	65 (255)	25 (25)	- (-)
	Lasting cloth/1 layer string spacer/lining	105 (320)	25 (26)	- (10)
	Lasting cloth/2 layer string spacer/lining	190 (350)	35 (28)	60 (55)
Gauntlets	2 layers leather	51	26	10
	Standard fire crash duty glove	65	27·5	15
	C2 gauntlet/knitted lining brushed cotton (brown)	580	25	-
	C7 gauntlet/knitted lining brushed cotton (grey)	645	25	-
Helmets	Marglas Fabric No. 1007/72 Neoprene coated and aluminium forced	84 (132)	25 (25)	- (-)
	Aluminium (foil) coated fabric flame-proofed cotton base	215 (264)	25 (25)	- (-)

The corresponding times when the assemblies were tested against flame were shorter. These assemblies included boot soles, boot uppers, suiting representing leggings, and gauntlets; the results are shown in Table 2.

Table 2

Performance of clothing assemblies against flame

	Material	Time for temperature rise of 25°C	Maximum temperature rise °C	Further time to reach maximum temperature
Boot Soles	Leather sole/foamed rubber/ leather sole/2 pairs socks	11 min 45 sec	Sole glowing	-
Boot Uppers	Aluminised fabric/leather/ woven asbestos cloth/ leather/2 pairs socks	8 min 45 sec	35	4 min 40 sec
	As above but without socks	4 min 50 sec	39	6 min 10 sec
	White leather/asbestos cloth/aluminium vynide laminate/goatskin	2 min 35 sec	45	2 min 45 sec
	As above but with 2 pairs of woollen socks	3 min 00 sec	37	1 min 00 sec
	As above but with no aluminium layer	3 min 05 sec	37	2 min 30 sec
	As above but with 2 layers of asbestos cloth	4 min 10 sec	39	3 min 30 sec
Suiting	Fear nought	30 sec	25	-
	Lasting cloth/1 layer string spacer/lining	30 sec	25	-
	Lasting cloth/2 layers string spacer/lining	65 sec	27·5	15 sec
Gauntlets	Standard fire crash duty glove	23 sec	31	8 sec
	C7 gauntlet/wool faced knitted lining	28 sec	29	19 sec
	Leather/foamed rubber	70 sec	85	36 sec

From the above tables it will be seen that at present the various items of clothing can be made suitable for fire-fighting for the approximate times given in Table 3.

Table 3

Approximate times for which various items of clothing will protect human tissue against rise of temperature of 25°C

Clothing item	Time sec	Type of test
Boot sole	700	Flame
Boot uppers	500	Flame
Suit without under clothing (representing leg covering)	60	Flame
Gauntlets	25	Flame
Suit	300	Radiation
Gauntlets	600	Radiation
Helmet	250	Radiation

It will be seen that the weakest item is the performance of gauntlets against flame, which is only 25 seconds as against 600 seconds for radiation. In choosing material for gauntlets a balance has to be struck between retaining some degree of manipulation and providing adequate thermal insulation. The actual time that gauntlets have to be used for handling flaming material is probably small, and most of the time they will be exposed to radiation.

The performance of the suit without underclothing against flame is also low. This test was carried out to see what would be the effect of leggings in which underclothing was not included. The results suggest that it would be necessary to wear underclothing round the legs, possibly in the form of long string under-pants; there would also be an advantage in using a boot, the upper of which covered the calf. With this in mind it would appear that clothing could be designed to withstand severe fire conditions for about 4 minutes. This does not allow for any advantages that might accrue from wetting-down the clothing during fire-fighting operations.

One point which must be borne in mind in selecting materials, is that as the protective value of the clothing is increased, the more serious will be the conditions that the outer layers have to withstand. It is possible that the tests which have been used so far for flameproof clothing are no longer adequate, for example, any material which emits combustible gases when subjected to radiant heat is likely to burn in the presence of a flame and it may be that it would be necessary for outer garments to be incombustible rather than flameproof.

From the tests which have been carried out several points have emerged of a general nature which are useful in designing flameproof clothing:-

(1) Aluminium-faced fabric offers no advantages when used between layers of materials.

(2) Reflecting materials are of great value in protecting fire-fighters against radiant heat, but are of little value for protection against flame, as they rapidly become sooty and thereafter absorb heat well.

(3) Space fabrics such as woven string are very valuable in reducing heat transmission either as linings for fire-fighting clothing or as underclothing. Fusible plastics are not suitable for this purpose as they rapidly melt and their thermal resistance disappears.

(4) Leather is not ideal as an external material as under fire conditions it shrinks and splits, exposing the linings of boots, but it is probably the best compromise with regard to durability and waterproofness.

(5) In most of the assemblies tested the temperature continued to rise, even though the source of heat was removed, and it would be desirable that any clothing should be able to be discarded fairly rapidly after discomfort was felt.

Acknowledgements

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References

(1) Pesman, G. T., Appraisal of hazards to human survival in airplane crash fires. U.S. National Advisory Committee for Aeronautics Technical Note 2996. 1953.

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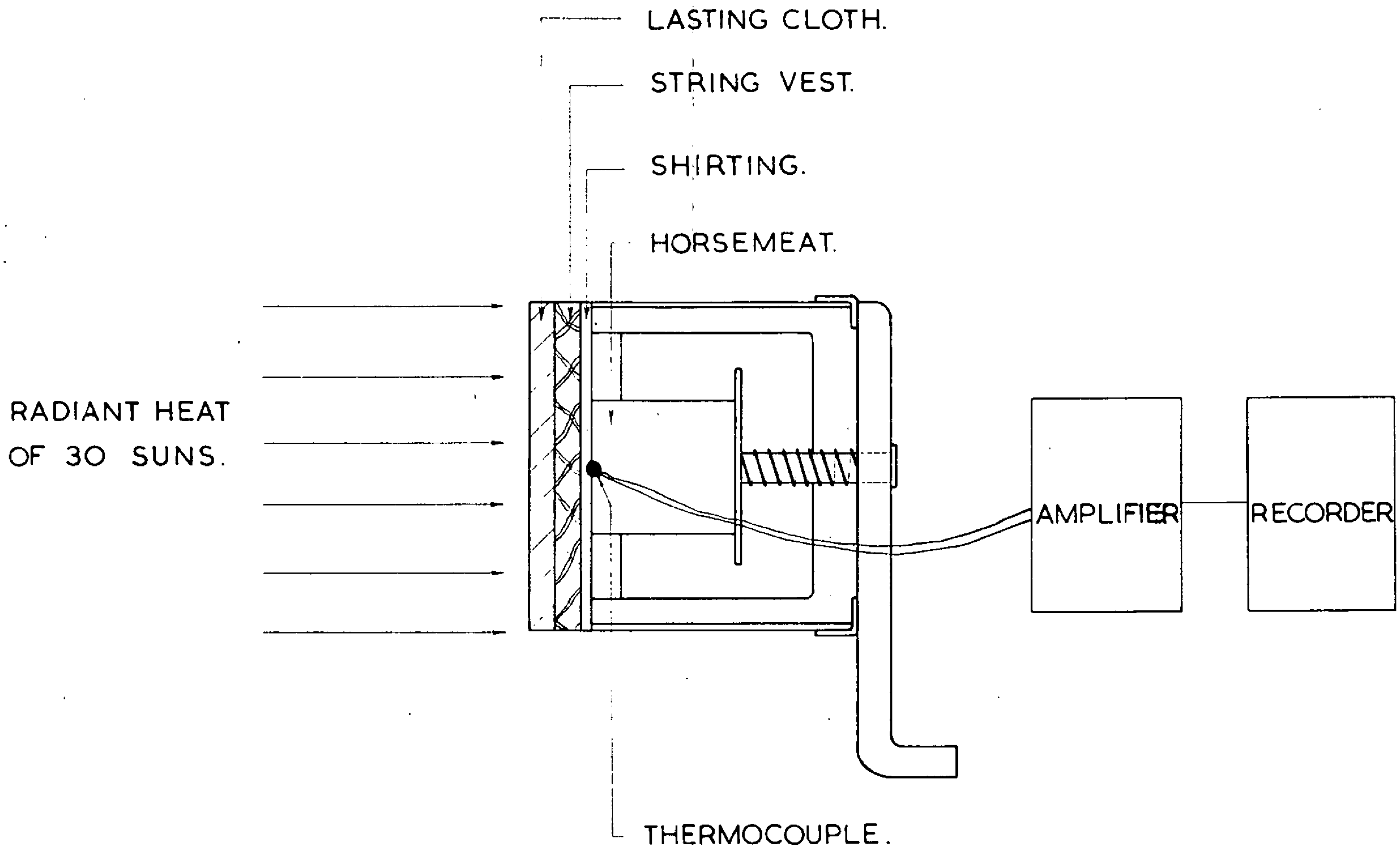

FIG. 1. APPARATUS FOR RADIATION TESTS OF MATERIALS.

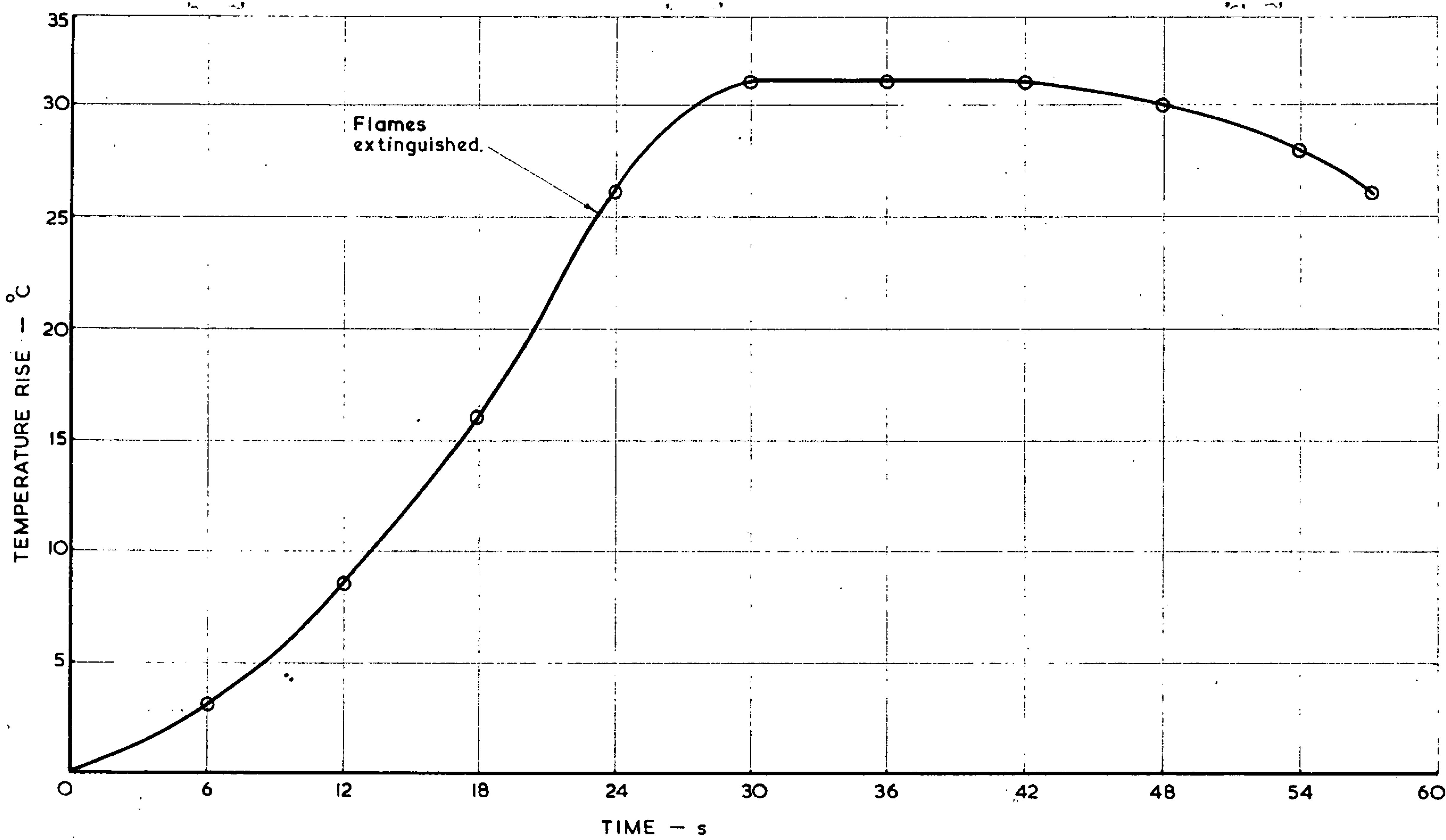

FIG. 2. FLAME TEST. STANDARD FIRE CRASH DUTY GLOVE.

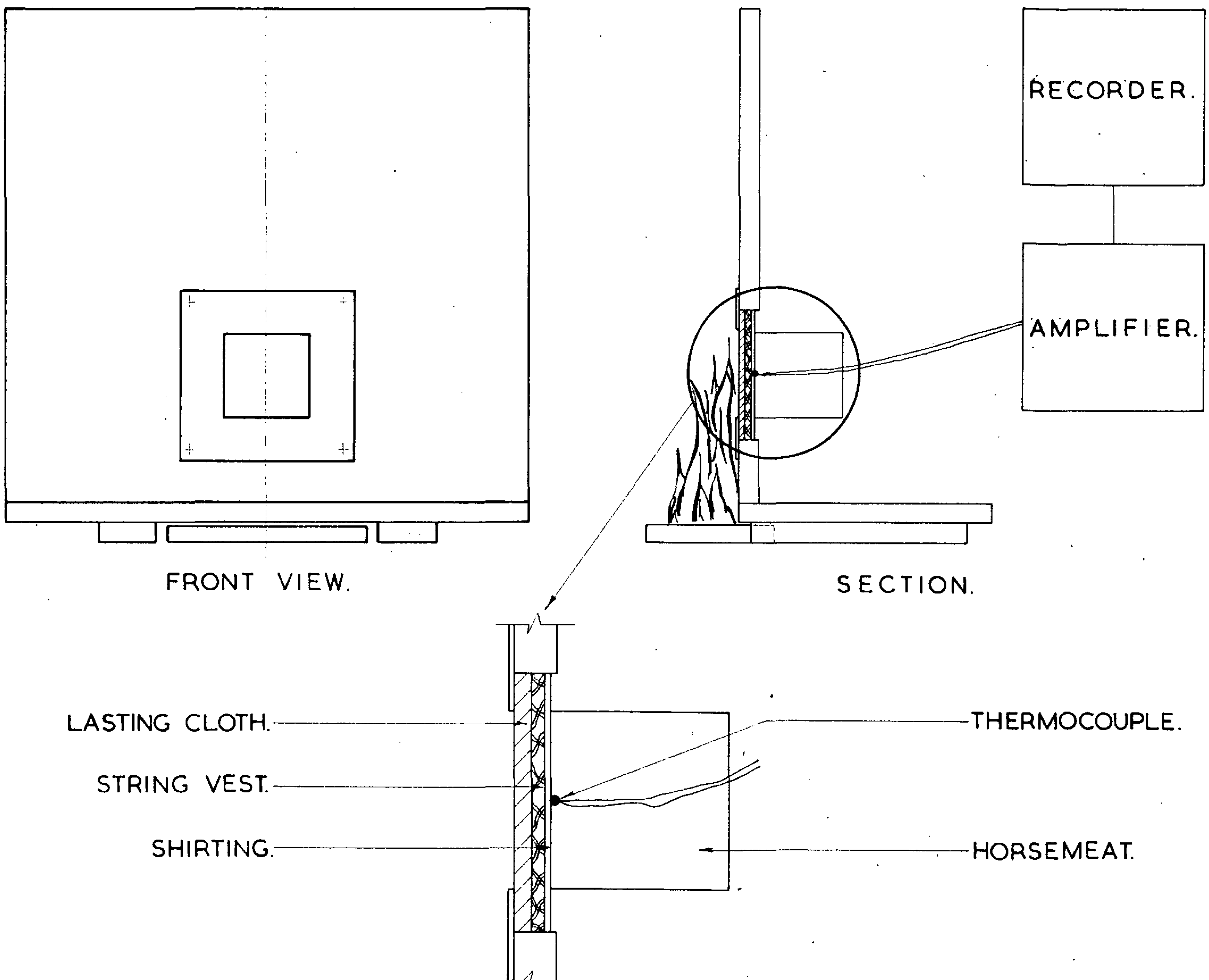

FIG. 3. APPARATUS FOR FLAME TESTS OF MATERIALS.

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