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MATERIALS SUITABLE FOR CLOTHING AIRCRAFT FIRE CRASH RESCUE TEAMS - PART I

by

R. W. Pickard and D. L. Simms

Summary

Three tests have been designed to assess the suitability of protective materials for aircraft crash rescue teams. Experiments have been carried out to determine flammability both with and without supporting radiation, and also the thermal protection afforded against conducted heat to the skin from flames and from radiation.

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1. Introduction

Aircraft crash fires often burn vigorously and fire-fighting is greatly hampered by thermal radiation and by flames. The rescue teams must therefore have clothing that will give them adequate protection and at the same time allow them sufficient freedom of movement for their work to be done efficiently. This paper examines the first part of the problem only.

Three tests have been devised in order to assess the relative merits of a number of clothing assemblies developed for the Ministry of Supply. The first test was designed to assess their ease of ignition by a flame in the presence of supporting radiation, the others to estimate the protection given by the clothing against conducted heat when exposed separately to heat radiation and flames. In the latter two tests human flesh was simulated by horse meat placed in contact with the unexposed face of the assembly. The protection was measured by the time taken for the meat surface in contact with the clothing to rise by 25°C., corresponding to a skin temperature of just above 60°C. Though there is some uncertainty about the maximum acceptable rise in temperature the object of the work was to classify the various fabrics in order of effectiveness rather than to make measurements of the protection time. This of course would involve other factors and a **final** assessment could only be made as a result of field trials.

The clothing assemblies tested have been divided into four groups as follows:-

(1) Suiting

(2) Gauntlets

(3) Helmets

(4) Footwear.

TABLE 1

Materials used together with their weights per unit area and thickness

	SPECIMEN	COMPOSITION	Wt/unit area -gn/cm^2	Thickness - mm.
Prototype boot	White leather		0.14	2.3
Prototype boot	Open weave asbestos cloth		0.77	2.0
Prototype boot	Aluminium vynide laminate	P.V.C. on a cotton base with aluminium coating	0.069	0.6
Prototype boot	White goatskin		0.069	0.9
	Asbestos cloth	Asbestos bonded to cotton with rubber	0.081	1.1
	Socks	Wool	0.043	1.5
	Lasting cloth	Wool	0.029	0.9
	String vest	Diameter of string 2 mm. String made of cotton	0.092	5.4
	Lining	Acetate rayon	0.010	0.3
	Raschel netting	Cotton	0.033	2.3

TABLE 1 (contd.)

	SPECIMEN	COMPOSITION	Wt/unit area - gm/cm^2	Thickness - mm.
Standard duty glove	(Asbestos cloth		0.12	1.9
	(Canvas interlayer	Jute	0.092	1.6
	(Cotton lining		0.021	0.6
	C2 Gauntlet	Aluminium faced asbestos cloth	0.083	1.4
	C7 Gauntlet	Aluminium faced asbestos cloth	0.12	2.0
	Brushed knitted cotton lining (brown)		0.025	1.8
	Brushed knitted cotton lining (grey)		0.031	1.9
	Lining canvas lining	Linen	0.086	2.0
	Space fabric	Polyvinylidene chloride and polythene	0.13	10.5
	Marglas fabric 1007/72	13 oz. glass fibre fabric coated both sides with neoprene - aluminium faced	-	-
	Aluminium foil coated fabric	13 oz. aluminium foil on a flame proofed cotton base	-	-
	Fearnought	Wool treated with borax and boric acid	0.085	3.0
	Sole leather -		-	4.2
	Insole leather		-	3.5
	White sole leather		-	3.0
	Expanded rubber		0.21	3.1
	(Chromium plated steel		-	1.2
	(Upper leather		-	1.3
	(Expanded rubber		0.21	3.1
	(Perforated Leather		-	2.5
	Gauntlet leather (palm)			
	Gauntlet leather (back of hand)			

Only the lower sections of suiting, the gauntlets and the footwear were subjected to the flame test as these alone would be likely to be exposed to a hazard of this kind. All the groups were tested for flammability and protection against heat radiation with the exception of the footwear which had to pass the more severe flame test.

2. Experimental procedure and results

(a) The flammability test

A specimen of each outer fabric 12 in. x 2 in. was hung vertically and a small petrol flame was allowed to play on the lower end of the specimen. It was exposed to radiation at an intensity of 2 watts/cm^2 characteristic of a temperature of 850°C. Any vertical spread of flame over the specimen was noted.

The results showed that flames spread rapidly over the surface of lasting cloth* and severe flashing was observed with Fearnought.* No flame spread was observed with the asbestos gauntlet gloves and the helmet fabric though slight flashing was observed with the latter.

(b) The radiation test

The clothing assemblies were mounted on a metal frame (Plates 4 and 5) so that an area 2½ in. x 2½ in. was exposed to radiation from the gas fired panel. Behind these a 28 S.W.G. copper-constantan thermocouple was placed between the material and a piece of horse meat, simulating human tissue. The incident radiant intensity was again 2 watts/cm^2.

The specimen was initially shielded from the radiation and then rapidly moved into position in front of the panel. The output from the thermocouple was recorded automatically. The specimen was exposed to the radiation until a temperature rise of 25°C. was recorded. The radiation was then cut off and any further rise in temperature noted.

The additional protection provided by underwear consisting of a shirt and string vest was assessed by carrying out the test both with and without these additional layers. The results are given in Table 2.

TABLE 2

Time for the temperature on flesh behind different clothing assemblies to rise by 25°C. when irradiated at an intensity of 2 w/cm^2. (The figures in parentheses denote the results obtained when underwear 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)	- (-)
SUITING	Lasting cloth/1 layer string vest spacer/lining	105 (255)	25 (25)	- (10)
SUITING	Lasting cloth/2 string vest spacer/lining	190 (350)	35 (28)	60 (55)

*These materials had been treated with a fire-retardant preparation, normally this prevents propogation of flame, but not however, in the presence of supporting radiation of the intensity used (2).

TABLE 2 (contd.)

	Material	Time for temperature rise of 25°C. (sec.)	Maximum temperature rise °C.	Further time to reach maximum temperature (sec.)
SUITING (contd.)	Lasting cloth/spacer fabric/ lining	40 (60)	31 (30)	20 (10)
	Lasting cloth/1 layer Raschel netting spacer/lining	70 (280)	25 (25)	- (-)
	Lasting cloth/2 layers Raschel netting spacer/lining	55 (310)	26 (25)	10 (-)
	Lasting cloth/1 layer string vest	40	25	-
	Lasting cloth/2 layers string vest	190	25	-
GAUNTLETS	Standard fire crash duty glove	65	27.5	15
	C2 gauntlet/brushed knitted cotton lining (brown)	580	25	-
	C2 gauntlet/brushed knitted cotton lining (grey)	210	25	-
	C2 gauntlet/linen canvas lining	435	25	-
	C7 gauntlet/brushed knitted cotton lining (brown)	430	25	-
	C7 gauntlet/brushed knitted cotton lining (grey)	645	25	-
	C7 gauntlet/linen canvas lining	270	25	-
	Leather/foamed rubber (palm)	130	31	105
	2 layers leather (back of hand)	51	26	10
HELMETS	Marglas Fabric No.1007/72 Neoprene coated and aluminium faced	84 (132)	25 (25)	- (-)
	Aluminium (Foil) coated fabric flame-proofed cotton base	215 (264)	25 (25)	- (-)

(c) <u>The flame test</u>

The apparatus used for these tests is shown in Figure 1 and Plates 6 and 7. It was designed to expose the clothing assemblies to flames from a petrol fire. The suiting and gauntlet specimens were mounted on the frame shown in Plate 1 and inserted into a square hole $2\frac{1}{2}$ in. x $2\frac{1}{2}$ in. cut in the asbestos wood shield A (Figure 1). The rear of the specimen was protected from flames by the asbestos board B. The slightly modified apparatus for the footwear specimens is shown in Figure 1.

The petrol fire was obtained by burning about 150 cc. of petrol floated on water in the metal tray C. The shield A was mounted so that its front face was vertical and 2 in. beyond the edge of the tray C. The petrol was ignited and allowed to burn until a temperature rise of 25°C., measured in the manner already described, was recorded. The fire was then extinguished and any further rise in temperature noted. The results of these experiments are given in Table 3. Except where stated the footwear specimens were all tested with two layers of knitted woollen socks.

TABLE 3

Time for the temperature on flesh behind different clothing assemblies to rise 25°C.

	Material	Time for temperature rise of 25°C. (sec.)	Maximum temperature rise °C.	Further time to reach maximum temperature (sec.)
SUITING	Fearnought	30	25	-
	Lasting cloth/1 layer string vest spacer/lining	30	25	
	Lasting cloth/2 layers string vest spacer/lining	65	27.5	15
	Lasting cloth/spacer fabric/lining	35	25	-
	Lasting cloth/1 layer Raschel netting spacer/lining	20	25	-
	Lasting cloth/2 layers Raschel netting spacer/lining	40	25	-
GAUNTLETS	Standard fire crash duty (asbestos) glove	23	31	8
	C2 gauntlet (aluminised asbestos)/brushed knitted cotton lining (brown)	15	30	8
	C2 gauntlet/brushed knitted cotton lining (grey)	7	29	3
	C2 gauntlet/linen canvas lining	13	30	4
	C7 (aluminised asbestos) gauntlet/brushed knitted cotton lining (brown)	14	25	-
	C7 gauntlet/brushed knitted cotton lining (grey)	28	29	19
	C7 gauntlet/linen canvas lining	19	35	16
	Leather/foamed rubber	70	85	36
	2 layers leather	53	31	14

TABLE 3 (contd.)

	Material	Time for temperature rise of 25°C. (sec.)		Maximum temperature rise °C.	Further time to reach maximum temperature (sec.)	
		min.	sec.		min.	sec.
FOOTWEAR	Sole leather/foamed rubber/perforated leather/asbestos cloth/leather	9	45	Sole glowing		
	Insole leather White/foamed rubber/White sole leather	11	45	"		
	Aluminium vynide laminate/white leather/open weave asbestos cloth/foamed rubber/upper leather	8	45	35	4	40
	As above but without socks	4	50	39	6	10
	(Toe cap) Chromium plate/upper leather/foamed rubber/white leather	6	20	35	5	50

3. Discussion of results

The results of the flame test show that this was a more severe test than the radiation test as comparable protection times were shorter. Aluminised fabrics give extra protection against radiation, Table 2 (gauntlets). However, this is not true for exposure to the flame test, as the flame rapidly blackened the aluminium surface. The heavier standard gauntlet provided longer protection time than the C2 and C7 gauntlet assembly (Table 3, gauntlets).

The thermal resistance of the gauntlet that can be obtained by increasing the thickness of the linings is limited by the loss of manufacture power.

The most satisfactory method of increasing the protection time is by increasing the thermal resistance of the clothing assembly. Increases in the time of protection against radiation of up to five times can be obtained by wearing underwear consisting of a shirt and string vest. Similarly, Table 3 (footwear) shows that increased protection is obtained by wearing two pairs of socks. The poor protection given by the assembly including a "space fabric", Table 2, (suiting) was due to the fact of the fabric melting and ceasing to fulfil its intended function of providing an air gap.

Some other points were noted during the tests. When leather was exposed directly to heat it became brittle and cracked exposing the underlying layers to radiation and flames though the protection time remained relatively long. This was also true of some of the garment fabrics which disintegrated on heating and ceased to provide any protection, the exceptions being the woven asbestos cloths. The foamed rubber material used as a waterproofing layer readily ignited in the flame test when placed directly behind the outer leather layer (Table 3, footwear) and continued to burn after the petrol fire had been extinguished.

In some assemblies, the temperature at the surface of the meat continued to rise after the source of heat had been removed. If such materials were adopted it would be necessary to provide quick release fastenings.

This temperature rise was generally smaller in those garments which had an air-gap and was considerably reduced by string underwear. This air gap is furthest there, from the source of heat , its most effective position (3).

4. Conclusions

The most effective garments tested were :-

(1) suiting - lasting cloth/2 layers string vest spacer/lining on both tests.

(2) gauntlets - all the aluminised fabrics were very effective on the radiation test; there was little to choose between any of the materials tested against flame impingement.

(3) helmets - aluminium (foil) coated fabric on a flame-proofed cotton base.

(4) footwear - the orthodox sole leather/perforated leather/open weave asbestos cloth/sole leather would give a protection time in excess of that of the materials of other garments; this in fact would apply to any conventional shoe sole.

From the test results the following general conclusions can be drawn on the design of protective clothing.

1. Materials which propagate flame even if only in the presence of supporting radiation should not be used.

2. Materials which disintegrate on exposure to flame are unsatisfactory.

3. An aluminised outer fabric is valuable when the rescue worker is exposed to radiation but is of little value when in contact with sooty flames.

4. Air gaps in the outer garment assembly, such as that provided by string vest fabric increase the protection time, but synthetic "spacer fabrics" with low melting points should not be used.

5. It is advisable to wear underclothing consisting of a shirt and string vest or having the equivalent thermal resistance, particularly with sections which are likely to be exposed to flames. This provides an air gap at its most effective position.

6. The temperature of the inner layers of some assemblies continues to rise after the wearer is no longer exposed to the source of heat and such clothing should be designed to be removed as quickly as possible.

7. The thermal resistance of the gauntlets may be increased by using additional or thicker linings; the limit is the loss of manipulative power.

8. The results of these tests are comparative only. The actual protection times could only be determined by field trials.

5. References

1. Pesman, G.J. Appraisal of hazards to human survival in airplane crash fires. N.A.C.A. Tech. No. 1996. Washington, Sept. 1953.

2. Simms, D.L. and Walters, J.E.L. Joint Fire Research Organization F.P.E. 60/1951.

3. McGuire, J.H., The Thermal Insulation of Air gaps in the vertical plane, Joint Fire Research Organization, F.R. No. 108/1954.

6. Acknowledgment

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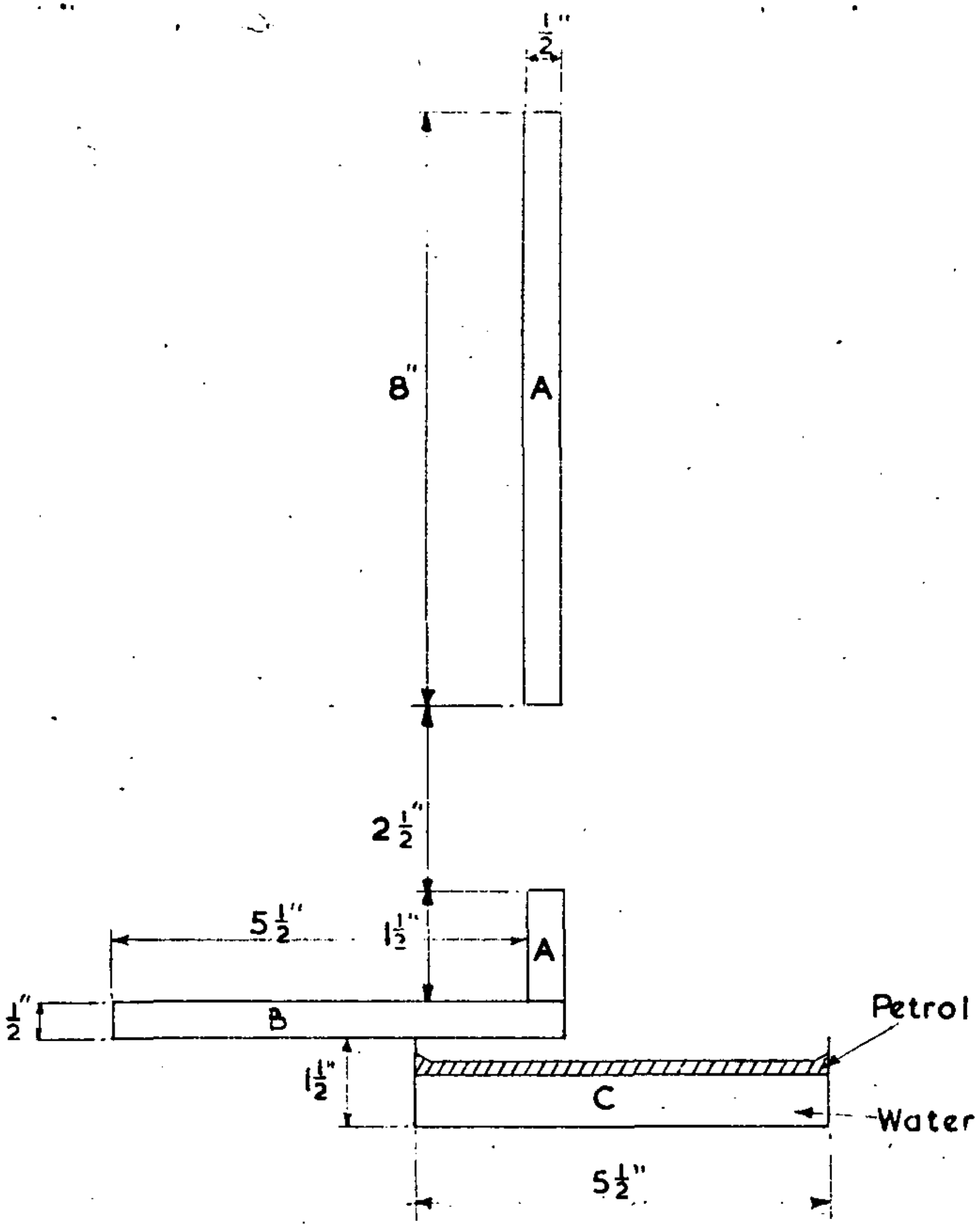
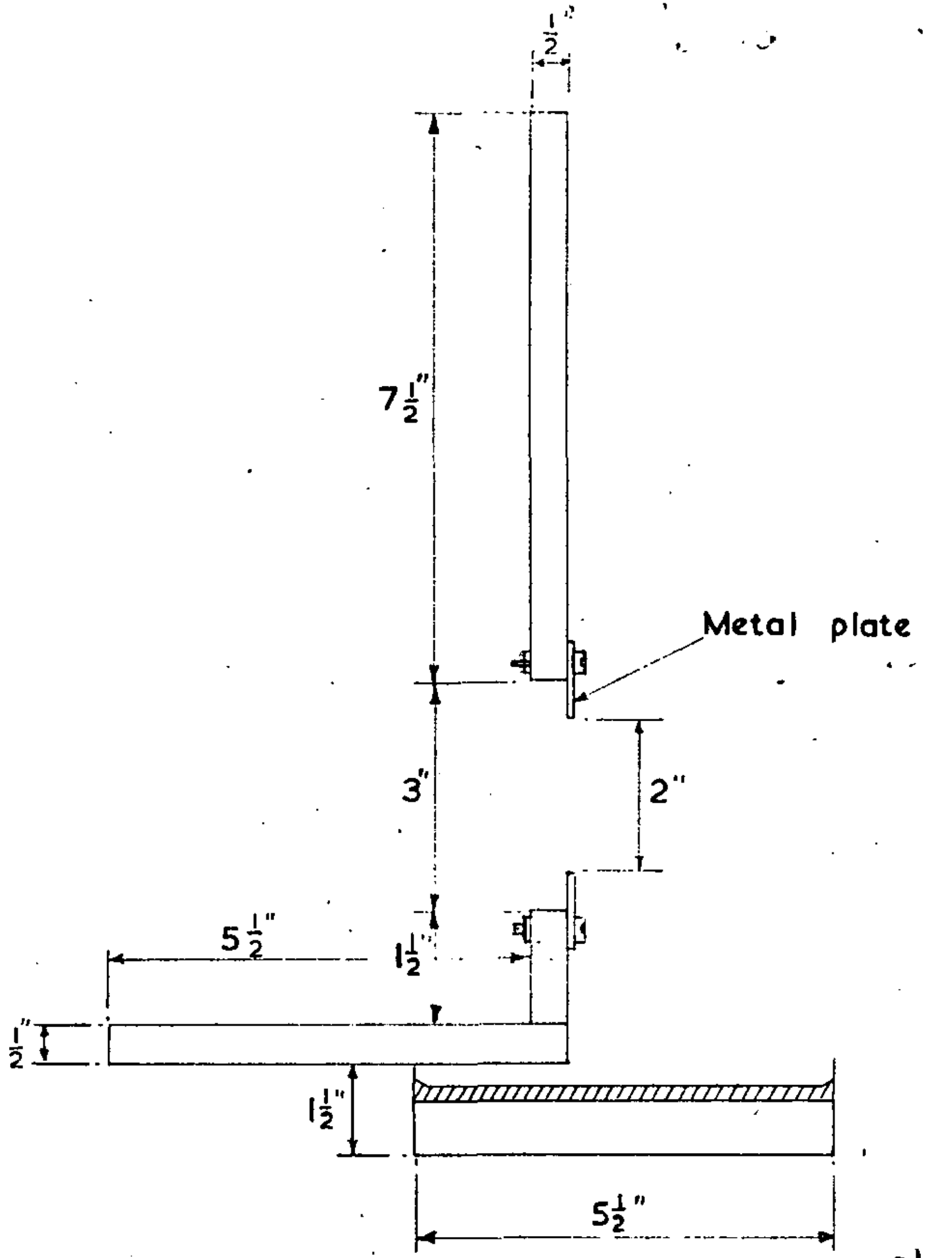


APPARATUS FOR SUITING AND GAUNTLETS



APPARATUS FOR FOOTWEAR

FIG. 1. FLAME TEST APPARATUS

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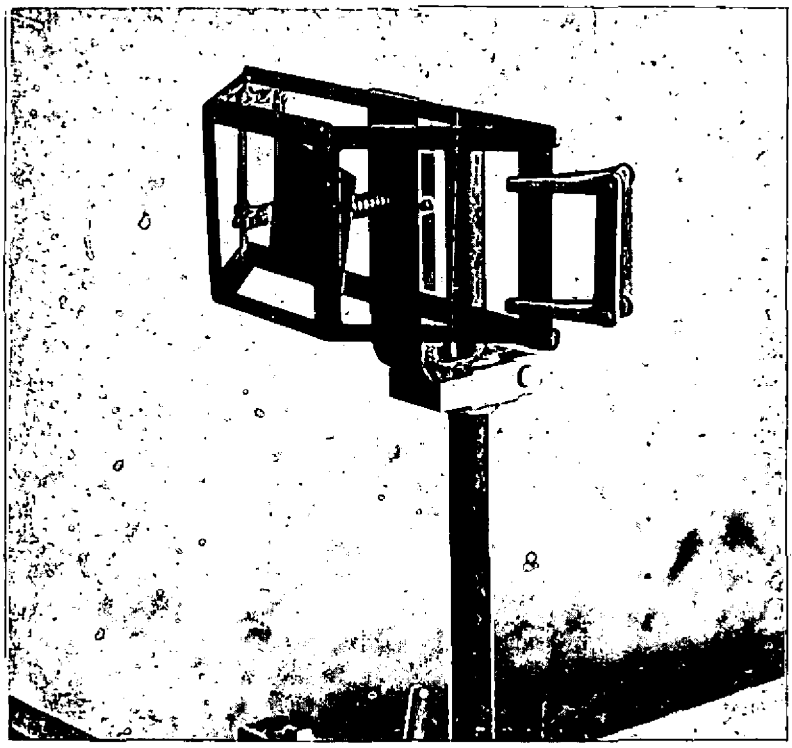

PLATE. I. SPECIMEN MOUNTING FRAME

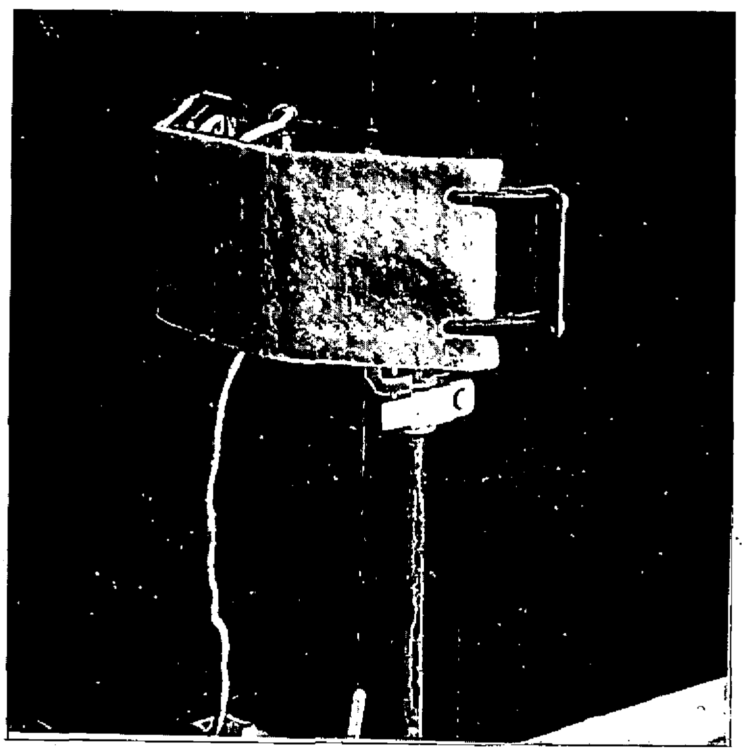

PLATE. 2. SPECIMEN MOUNTED ON FRAME

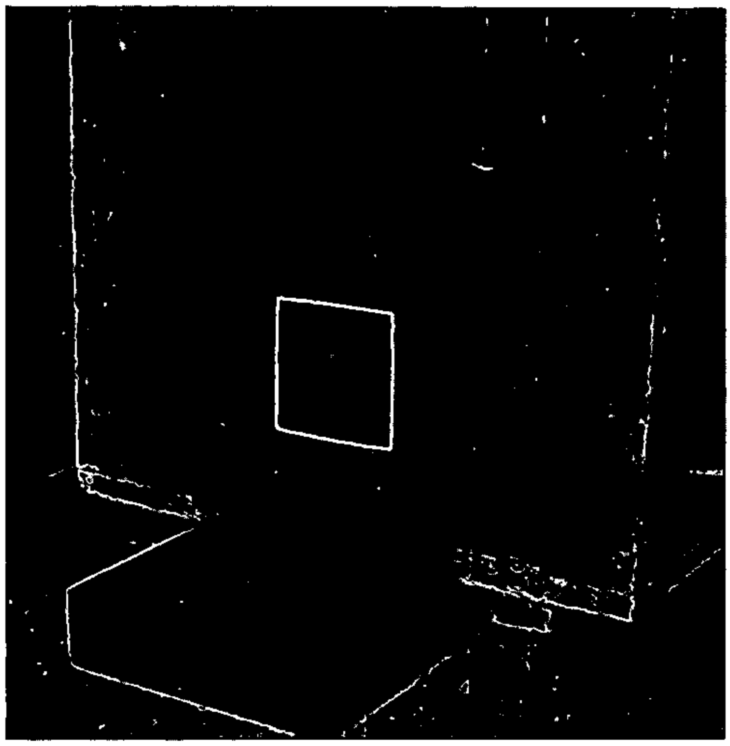

PLATE.3. FLAME TEST APPARATUS

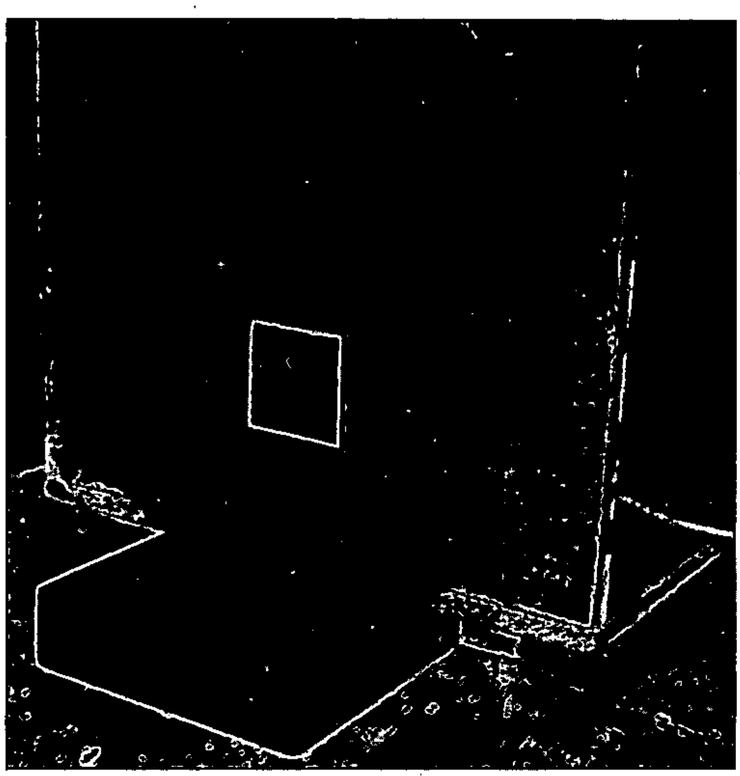

PLATE.4. FLAME TEST APPARATUS MODIFIED FOR FOOTWEAR SAMPLES

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