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A FIRE TEST IN WHICH FURNITURE WAS THE FUEL

by

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SUMMARY

A fire test in which furniture was used as the fuel was carried out in the fire compartment which was used for the investigation of the behaviour of structural steel in fires. The purpose of the test was to find out whether the wood cribs which were used as the fuel in this large programme of tests gave fires which were representative of the kind which would be expected from the occupancies which fall within the range of fire load densities used, namely, domestic, hospital, hotel and some office.

The results showed that the furniture fire fitted almost exactly into the pattern obtained for the wood crib fires both in respect of the fire temperatures and the temperatures reached by structural steel.

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*Assistant Divisional Officer Clark is a member of Glasgow Fire Brigade and assisted with this work while on secondment to J.F.R.O.

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

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INTRODUCTION

A large programme of experimental fires has recently been completed at the Fire Research Station in which the behaviour of Structural steel in fires has been studied, and the results obtained have been published in Fire Research Technical Paper No. 15.

In all of the fire tests of this programme the fuel used was wood cribs made up from sticks which were 4 cm ($1\frac{3}{4}$ in) square section and 1.1 m (3 ft 6 in) long. In a series of experiments of this nature where comparisons between fire tests are necessary a reproducible and standard fire load is essential and the use of wood cribs enables this condition to be realised. The size of stick used was chosen, from previous experience, as being the most likely to produce fires representative of those which are possible in the occupancies concerned, namely domestic, hospital, hotel and some types of office.

The purpose of the present experiment was to confirm this suggestion by carrying out a fire test in which all the conditions used were identical with those used in the main programme with the exception that instead of wood cribs as fuel, furniture was used.

The furniture was selected and disposed about the fire compartment in such a way that a living room in a house or flat was realistically simulated.

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The Test Building and Fire Compartment

The Fire Test was held in the south compartment of the two storey building used for all of the tests conducted in the large programme. Details of the size and construction are shown in Fig. 1.

The fire compartment, measuring 7.7 m x 3.7 m x 2.9 m high (25 ft 3 in x 12 ft 2 in x 9 ft 6 in high) is located on the ground floor of the building. Ventilation of the compartment was by means of two window openings in the front wall separated by a centre mullion. The maximum total area of these openings equals one half of the area of the front wall and this could be reduced by the use of metal sheathed shutters bolted to the window framework. In the test described here shutters were in use which reduced the window opening to one quarter of the total area of the side wall, i.e. to 5.6 m^2 (60 ft^2).

As in the tests of the main programme structural steel members were placed in the fire compartment. Their positions during the test are shown in Fig. 2 and details of their size and protection are given in Table 1.

Fire Load

The fire load used in the test consisted of the articles of furniture which are listed in Table 2. All of these were standard items normally available in any reasonably furnished dwelling house. These articles were weighed before placing in the fire compartment at the positions shown in Fig. 3, the layout being as closely representative of common practice as the interior of the fire compartment permitted. Plate 1 shows the furniture in the compartment immediately before the test and Plate 2 shows the mineral wool protection being applied to a steel column.

Before the test fire the fire load density was estimated to be 26.9 kg/m^2 (5.5 lbs/ft^2) but at the conclusion of the test 49 kg (108 lbs) of metal (springs from upholstered articles, hinges and handles from doors etc.) was recovered and when this was deducted from the total weight given in Table 2 a revised value of 25.4 kg/m^2 (5.2 lbs/ft^2) was obtained for the fire load density.

A window area of 5.6 m^2 (60 ft^2) was used in the test and therefore the value of fire load per unit window area was 131 kg/m^2 (26.8 lbs/ft^2).

Temperature measurements

The temperature in the fire compartment was measured in the same way as in the original programme. Ten thermocouples were used, four being placed 7.5 cm (3 in) from the ceiling and equally spaced along the east-west centre line of the compartment, three 7.5 cm (3 in) from the centre of the partition wall at heights of 0.6 m (2 ft), 1.5 m (5 ft) and 2.4 m (8 ft) respectively from floor and three more were placed centrally between columns C_{16} and C_{17} at heights from the floor of 0.6 m (2 ft), 1.5 m (5 ft) and 2.4 m (8 ft) respectively.

The temperature of the steel members inside the compartment was measured by means of four thermocouples on each. For the columns these were placed 0.6 m (2 ft) from the floor and 23 cm (9 in) from the ceiling, at the front and back of the columns at each of these positions, while for the beams the four thermocouples were spaced equally along them, two on the top flange and two on the lower.

Thermocouples were attached to the steel member by first welding the two wires to form the junction and then inserting them into an 0.25-cm ($^3/_{32}$-in) hole drilled in the steel member. Good thermal contact was ensured by driving copper tacks into the hole with the thermocouple wire and the insertion was held secure by a plaster sealing patch formed over the position.

Results

(1) The weather conditions which prevailed for this test were within the extremes of those which occurred during the course of tests in the main programme. In this latter it was shown that the variations of wind and ambient temperature had no significant bearing on the results obtained and in this respect therefore the results of the present test can be compared directly with the main programme.

(2) The average spatial temperature attained in the fire compartment during the test is shown in Fig. 4 in which it is compared with similar curves obtained in Tests H and G of the main programme.

In all three of these tests (H, G and the furniture test) the same window opening was used, namely $\frac{1}{4}$ of the area of the front wall of the compartment. The fire load densities and fire load per unit window area for each is given in Table 3, below, together with the maximum average spatial temperatures obtained in each test. The severity of the fire is illustrated in Plate 3 which shows the fire at its fully developed stage. Plate 4 shows the compartment at the end of the test, illustrating the completeness of the 'burn out'.

Table 3

Test	Fire load density	Fire load per unit window opening	Max. average spatial temp. ^{o}C
Test H	30 kg/m^2, 6.2 lb/ft^2	161.6 kg/m^2, 32 lb/ft^2	1042
Furniture	25.4 kg/m^2, 5.2 lb/ft^2	131 kg/m^2, 26.8 lb/ft^2	895
Test G	15 kg/m^2, 3.1 lb/ft^2	80.8 kg/m^2, 16 ln/ft^2	700

(3) The maximum average spatial temperature reached in the test compartment in the present (Furniture) test is plotted in Figs 5 and 6 and is compared with the temperatures reached in the whole series of tests of the main programme. In Fig. 5 the comparison is made with fire load density and Fig. 6 with fire load per unit window area and it is clear from both these graphs that the fire test in which furniture was the fuel fits into the same general pattern as the wood crib fire tests of the main programme.

(4) Similar comparisons to the above can be made with the temperatures reached by the steel members in the fire test.

The curves in Fig. 7 show the average temperatures reached by the free standing steel columns inside the fire compartment which were (a) unprotected C22, (b) protected with mineral wool slabs 1.3 cm ($\frac{1}{2}$ in) thick, C14, (c) protected with asbestos insulating board 1.9 cm ($\frac{3}{4}$ in) thick, C21, (d) protected with plasterboard 1.3 cm ($\frac{1}{2}$ in) thick, C15, (e) protected with timber 2.5 cm (1 in) thick, C16.

For comparison the average spatial temperature in the fire compartment is also shown.

(5) The comparison between the temperatures reached by the structural steel in the present test is conveniently compared with those attained in the main programme by comparing the maximum average temperatures reached in both cases with the fire load per unit window area. Figs. 8, 9, 10 and 11 show these comparisons.

In figure 8 the maximum average temperatures for an internal unprotected column are shown, figures 8 and 10 give the values for internal steel columns protected with mineral wool slabs and asbestos insulating board respectively and figure 11 shows the maximum average temperatures reached by the beams B_4, B_5 and B_6. (B_4 and B_5 lie along the top of the dividing wall and B_6 spans the compartment centrally.)

(6) In all of the comparisons shown in these four figures (Figs 8, 9, 10 and 11) it is clear that the maximum average temperature reached by the steel member in the furniture test is very close to the value that could be predicted from the values obtained in the main programme of tests.

Conclusions

The fire test in which the fuel was furniture, arranged so that a normally furnished living room was represented produced fire and structural steel temperatures which correspond very closely to the temperatures obtained in the main programme of tests in which the fuel was arranged as wood cribs.

Conversely then it can be said that the main programme of tests (described in Fire Research Technical Paper No. 15) gives a reasonable representation of realistic fire conditions for the range of building occupancies covered by the fire load densities used. These are, for example, domestic, hotel, hospital and some offices.

Acknowledgements

The authors wish to acknowledge the help of the British Iron and Steel Federation, who supplied the furniture for the test and of Messrs. C. Shore, P. Fardell and C. Keefer during the preparation and the carrying out of the test.

Table 1

Size, Position and Details of Structural Steel Members

No.	Type	Size	Position	Protection
C_{10}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment, free standing, against walls in NW corner of compartment.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool secured by asbestos string over exposed flange and web.
C_{11}	Universal Column	31.0 cm x 12.5 cm x 48 kg/m (12 in x 5 in x 32 lb/ft)	Built into partition wall 1.9 m (6 ft 3 in) from west wall Flange flush with wall in south compartment but web and flange projecting into north compartment.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool secured by asbestos string over exposed flange.
C_{12}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Built into partition wall at its centre point. Supports one end of B_3 and B_6, B_4 and B_5 are bolted to it.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool secured by asbestos string over exposed flange.
C_{13}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Built into partition wall 1.9 m (6 ft 3 in) from east wall. Flanges flush with wall in each compartment.	Unprotected.
C_{14}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment, free standing, 1.35 m (4 ft 5 in) from south wall, 2 m (6 ft 6 in) from west wall.	1.3 cm ($\frac{1}{2}$ in) plasterboard nailed to wood battens with 2.5 cm (1 in) gap all round steel column.
C_{15}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment, free standing, 1.1 m (3 ft 7 in) from partition wall, 2 m (6 ft 6 in) from west wall.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool secured by asbestos string.

Table 1 (cont'd)

No.	Type	Size	Position	Protection
C_{16}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment, free standing, 1.2 m (3 ft 11 in) from partition wall, 2 m (6 ft 6 in) from east wall.	2.5 cm (1 in) tongued and grooved wood plank encasement nailed to wood battens leaving 2.5 cm (1 in) air gap all round steel column.
C_{18}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment free standing against south wall at centre of central brick mullion. Supporting one end of B_6.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool, secured by asbestos string over exposed faces.
C_{21}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment free standing, 1 m (3 ft 3 in) from partition wall and 3.25 m (10 ft 8 in) from west wall.	1.9 cm ($\frac{3}{4}$ in) asbestos insulating board screwed at 15 cm (6 in) centres.
C_{22}	Universal Column	20.6 cm x 20.4 cm x 52 kg/m (8 in x 8 in x 35 lb/ft)	Inside south compartment, free standing, 1 m (3 ft 3 in) from partition wall, 3.25 m (10 ft 8 in) from west wall.	Unprotected.
B_4 & B_5	Universal Beam	25.6 cm x 14.6 cm x 37 kg/m (10 in x $5\frac{3}{4}$ in x 25 lb/ft)	Inside building lying along top of partition wall bolted to C_{12}. Web and edge of flange exposed.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool secured by asbestos string over exposed web and flange.
B_6	Universal Beam	25.6 cm 3 14.6 cm x 37 kg/m (10 in x $5\frac{3}{4}$ in x 25 lb/ft)	Inside south compartment supported by C_{12} and C_{18} and spanning compartment centrally just below ceiling.	1.3 cm ($\frac{1}{2}$ in) slab mineral wool secured by asbestos string over exposed bottom flange and both sides of web.

Table 2

List of Furniture used in Test

Item	Weight		Calorific Value		Total Calorific Value	
	kg	lbs	kilo calories per kg	B.T.U. per lb.	k. cals.	B.T.U.
Items largely of wood						
Wardrobe	53	117	4437	8,000	235,972	936,000
Coffee Tables (3)	9	20	"	"	40,320	160,000
Bookcase	18.5	41	"	"	82,656	328,000
Standard Lamp	7	15	"	"	30,240	120,000
Pictures (3)	6	13	"	"	26,208	104,000
Dining Chairs (5)	36.5	80	"	"	161,280	640,000
Sideboard	52	115	"	"	231,840	920,000
Dining Table	20.5	45	"	"	90,720	360,000
Dresser	36.5	80	"	"	161,280	640,000
Chairs, (bamboo & deck)	13.5	30	"	"	60,480	240,000
Chairs (fireside, 3)	29.5	65	"	"	131,040	520,000
Wardrobe	41	90	"	"	181,440	720,000
Wood sticks (added to represent contents of cupboards, bookcases etc)	88.5	195	"	"	393,120	1,560,000
Items partly of wood (assumed 75% wood, 25% wool)						
Lounge chairs (4)	134	295	4574	8,250	613,305	2,433,750
Settee	51	112	"	"	232,848	924,000
Fireside chairs (4)	96	212	"	"	440,748	1,749,000
Glazed bookcase (assumed 95% wood)	28	62	4437	8,000	118,692	471,200
Other Items						
Newspapers and magazines	27	60	3881	7,000	105,840	420,000
Fireside Rug	6.5	14	4934	8,900	31,399	124,600
Linoleum	4.5	10	7044	13,500	34,020	135,000
Kerosine (for ignition)	3.5	8	9979	18,000	36,288	144,000
					3,439,786	13,649,550

Total Fire Load (Wood equivalent) = 755.5 kg (1706 lbs)

Floor Area = 29 m^2 (310 ft^2)

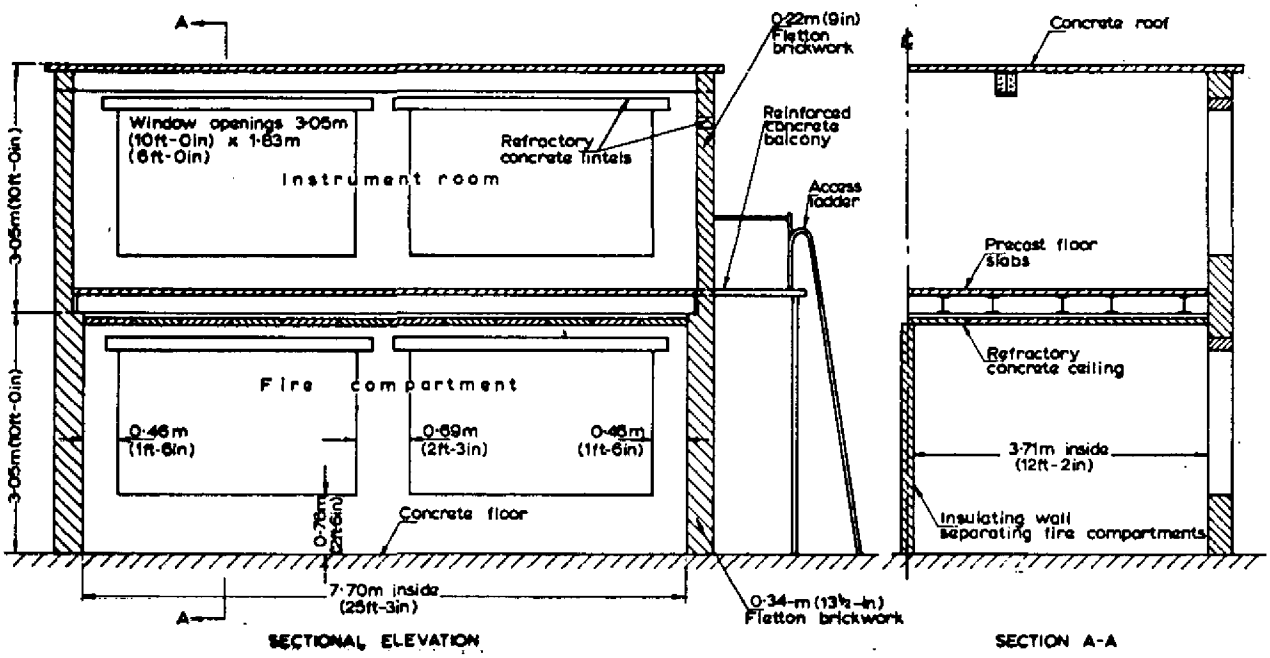
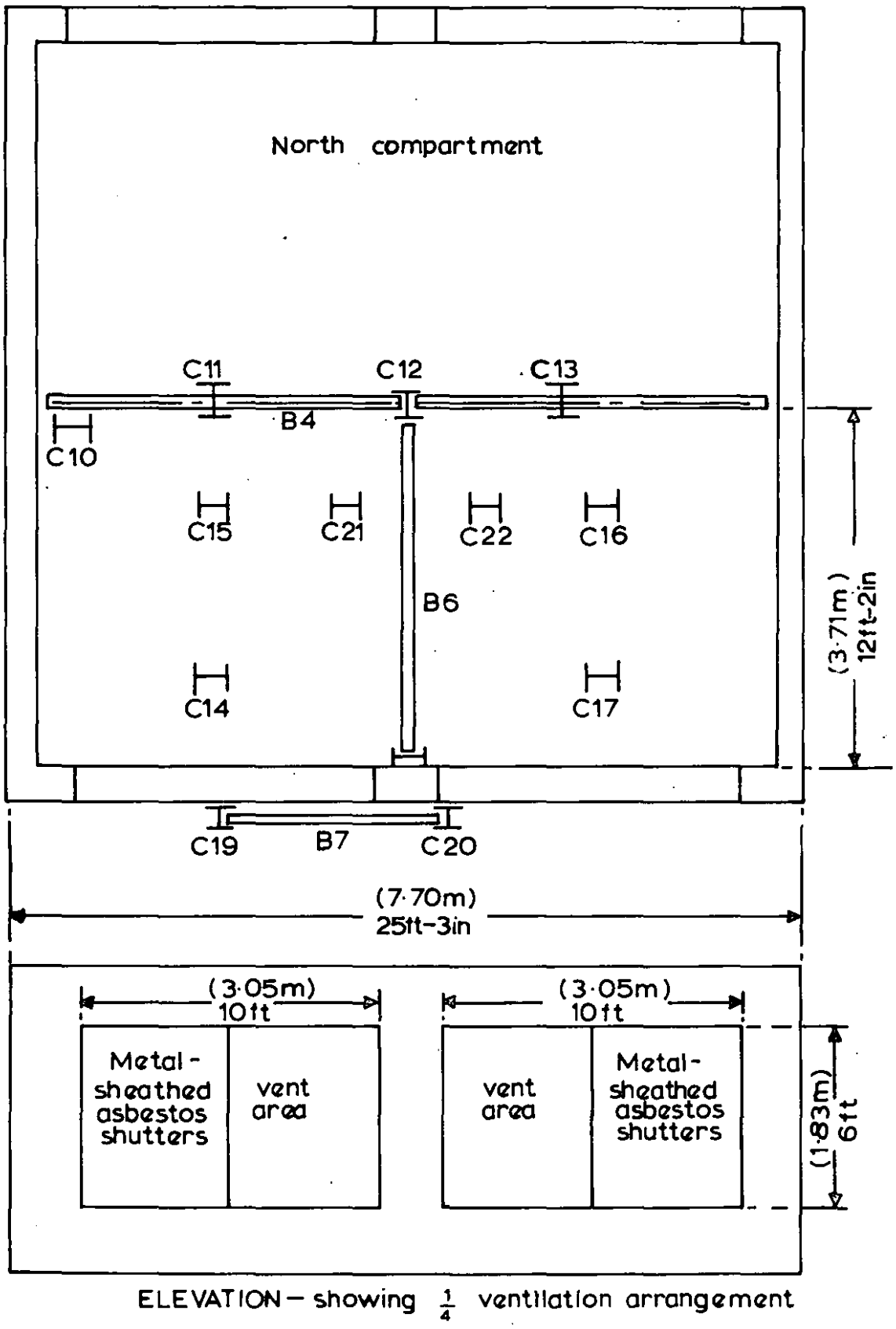


FIG.1. BUILDING USED FOR INVESTIGATION OF STRUCTURAL STEEL IN FIRES



ELEVATION – showing $\frac{1}{4}$ ventilation arrangement

FIG.2. POSITION OF STEELWORK AND VENTILATION AREAS IN FIRE COMPARTMENT

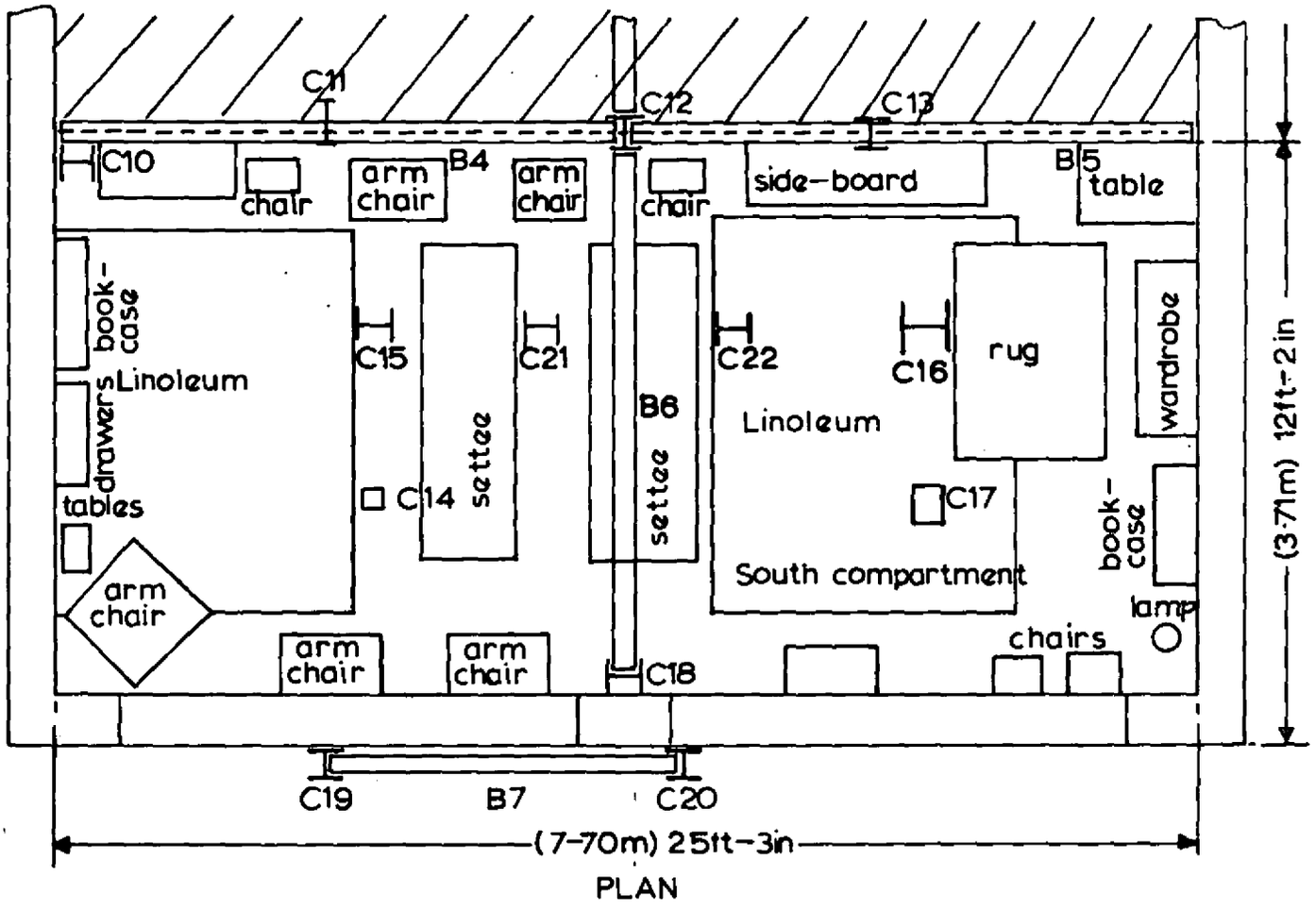


FIG.3. FIRE COMPARTMENT WITH FURNITURE IN POSITION

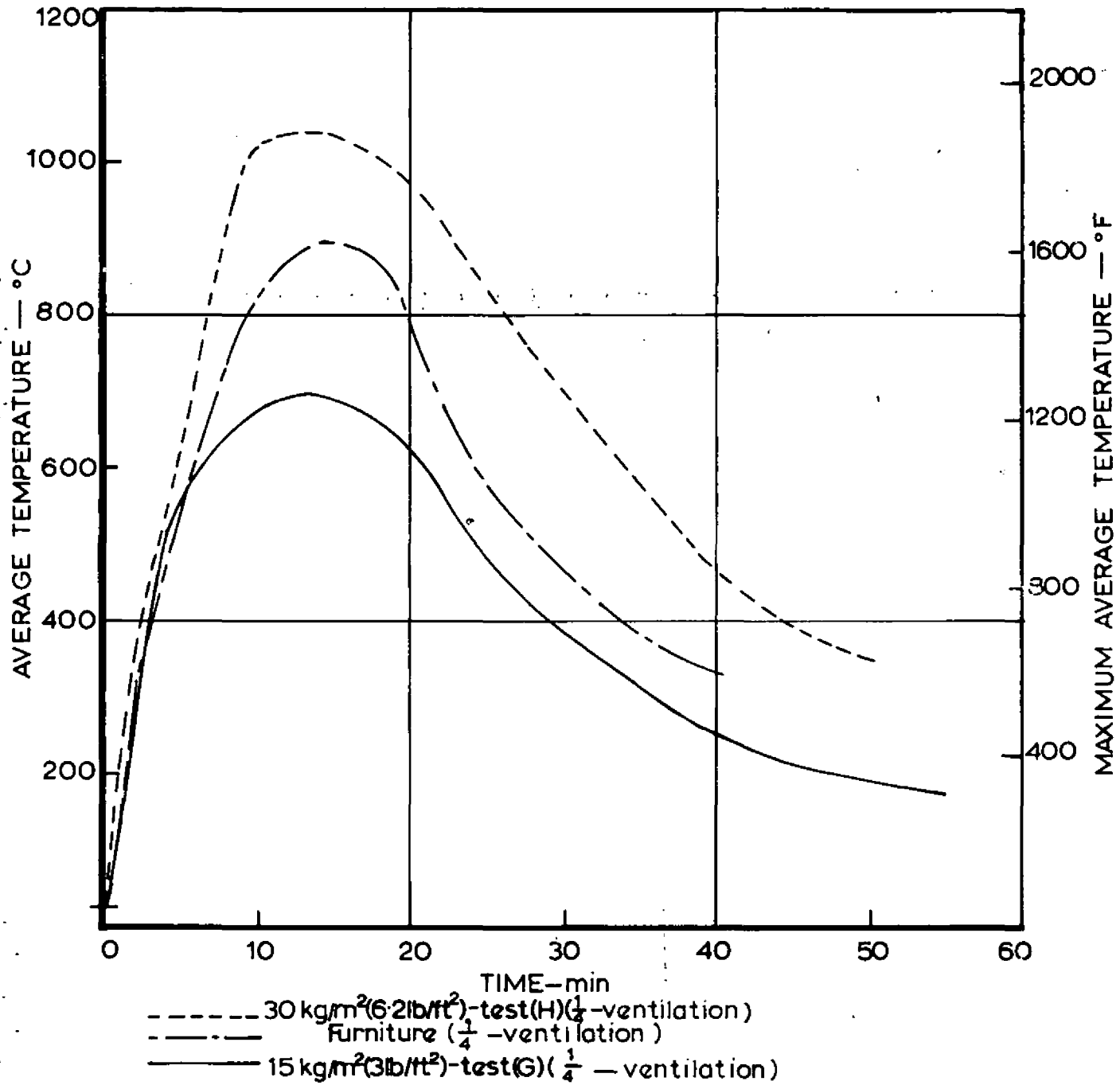


FIG. 4. AVERAGE SPATIAL TEMPERATURE IN COMPARTMENT DURING FURNITURE TEST COMPARED WITH TWO TEST FROM MAIN PROGRAMME

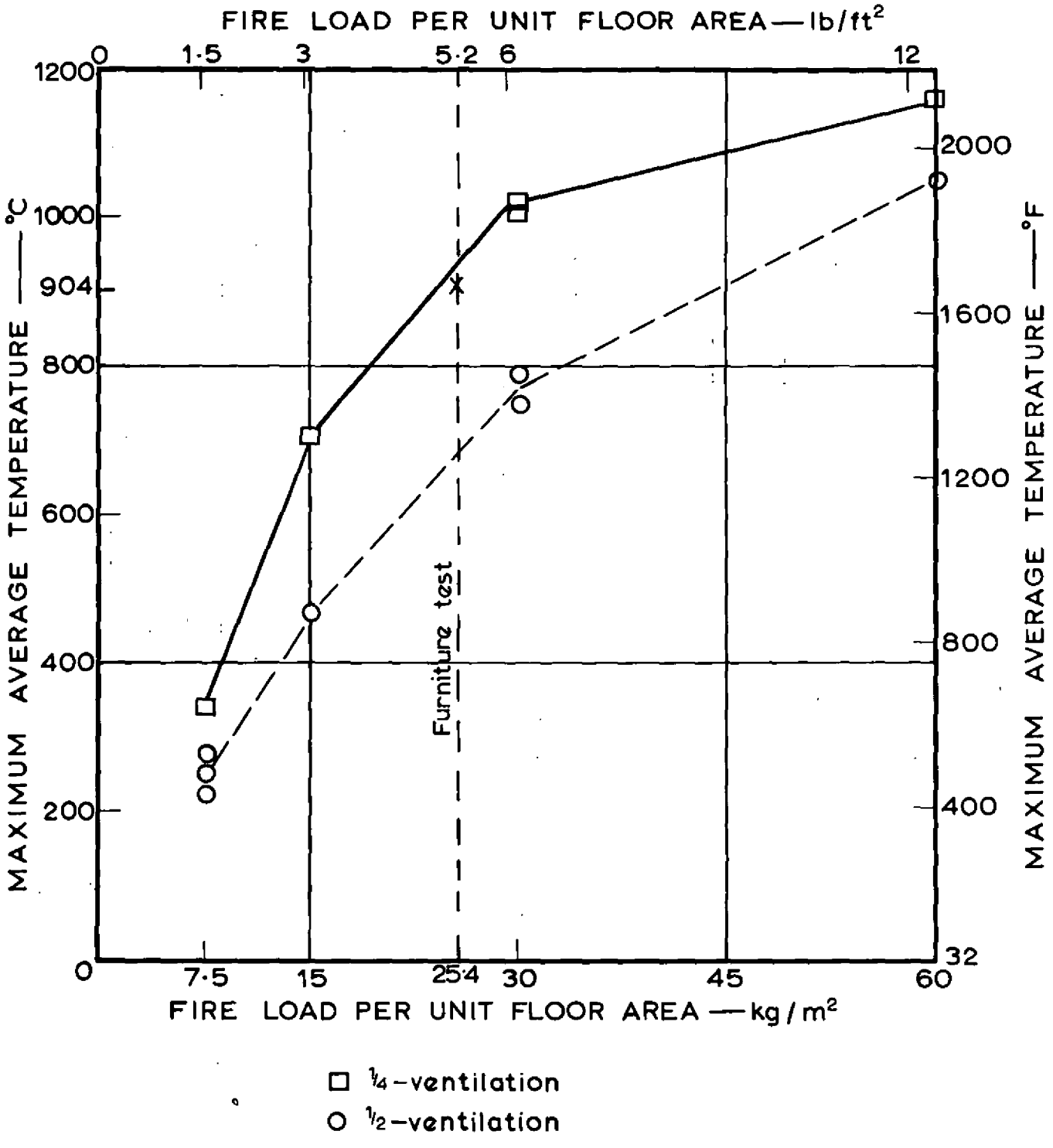


FIG. 5. MAXIMUM AVERAGE SPATIAL TEMPERATURES INSIDE FIRE COMPARTMENT COMPARED WITH FIRE LOAD DENSITIES

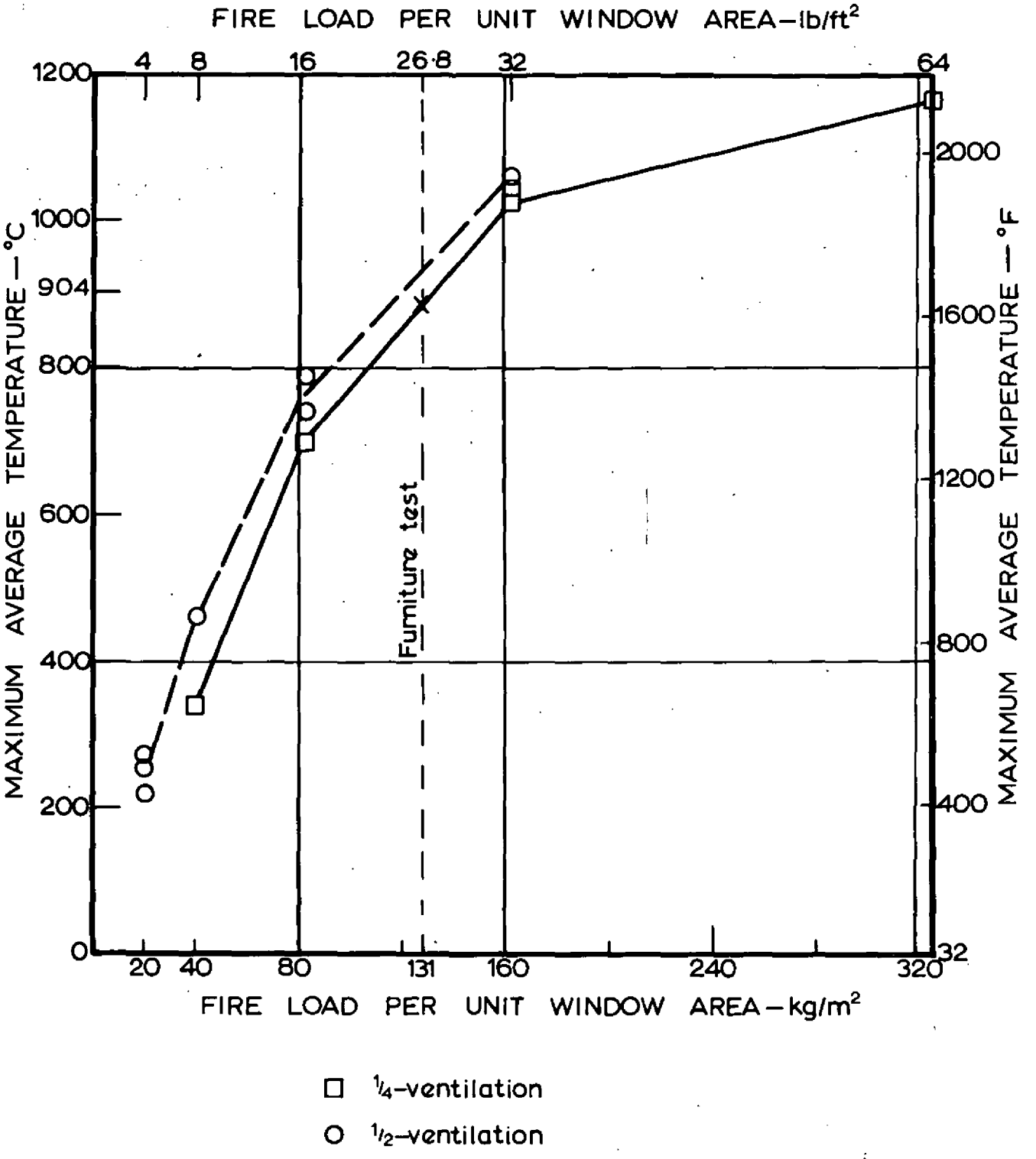


FIG. 6. MAXIMUM AVERAGE SPATIAL TEMPERATURES INSIDE FIRE COMPARTMENT COMPARED WITH FIRE LOAD PER UNIT WINDOW AREA

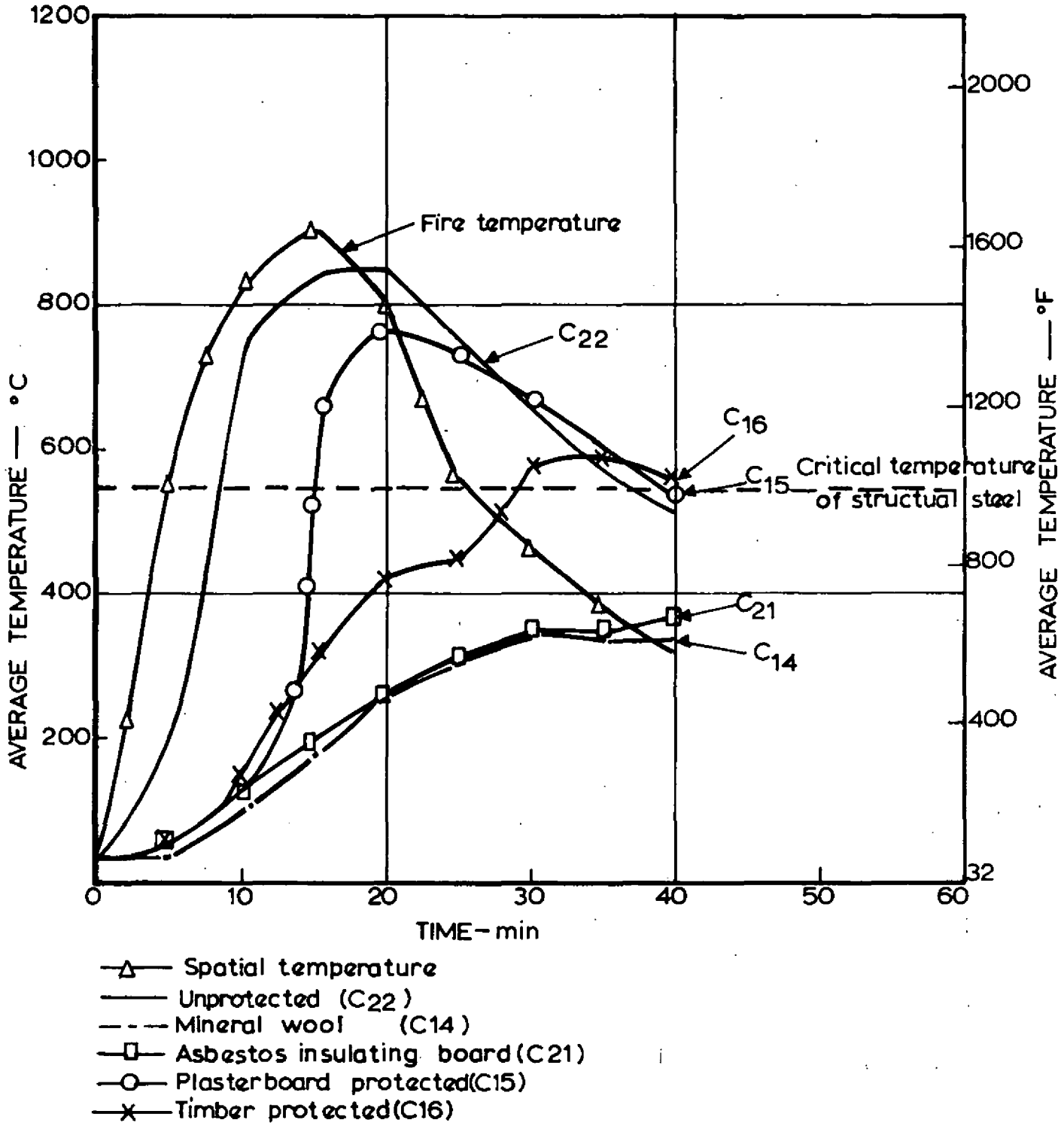


FIG.7. AVERAGE SPATIAL AND STEEL TEMPERATURES FOR FURNITURE TEST–FREE STANDING COLUMNS C_{14} C_{15} C_{16} C_{21} C_{22}

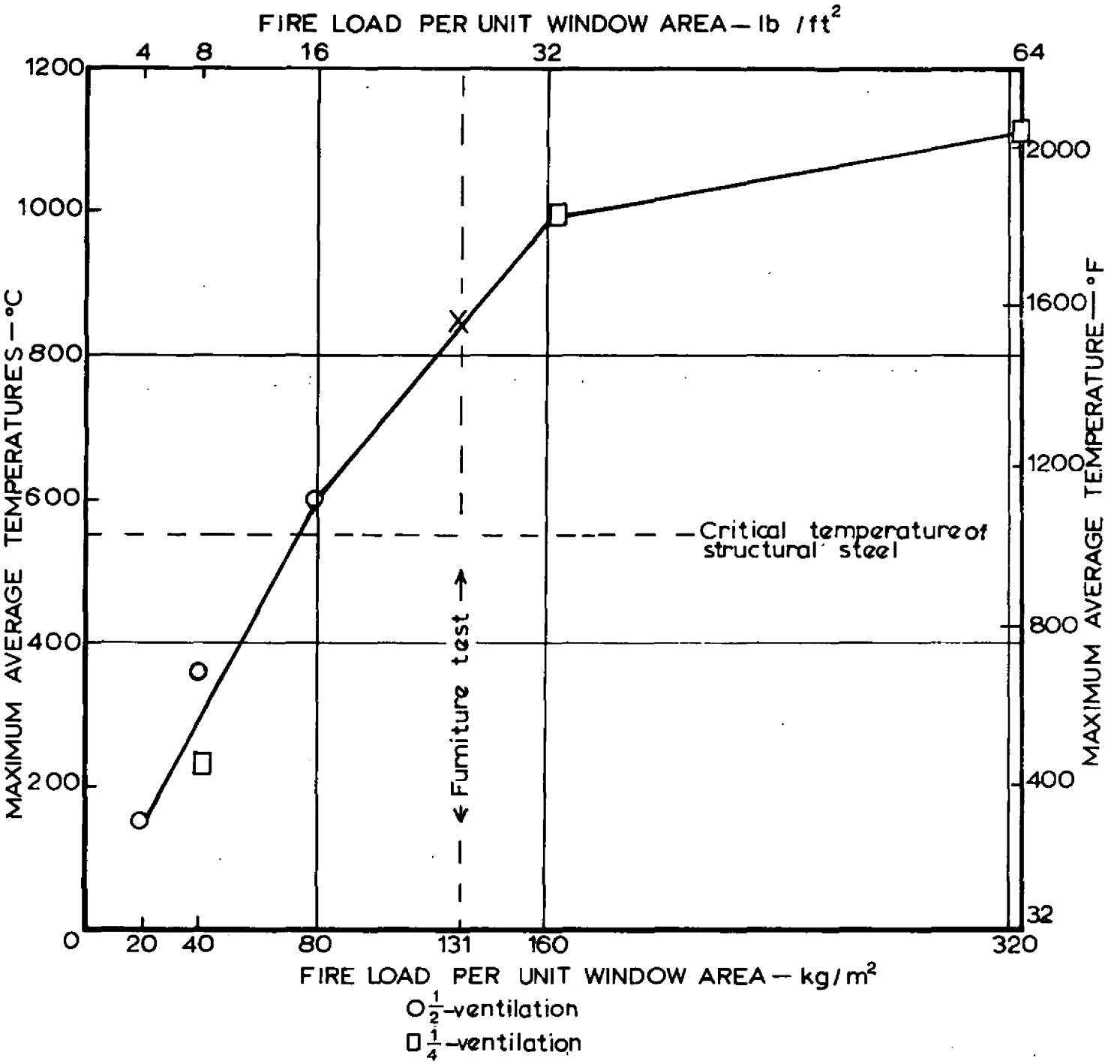


FIG.8. MAXIMUM AVERAGE TEMPERATURES REACHED BY INTERNAL UNPROTECTED STEEL COLUMN C_{22}

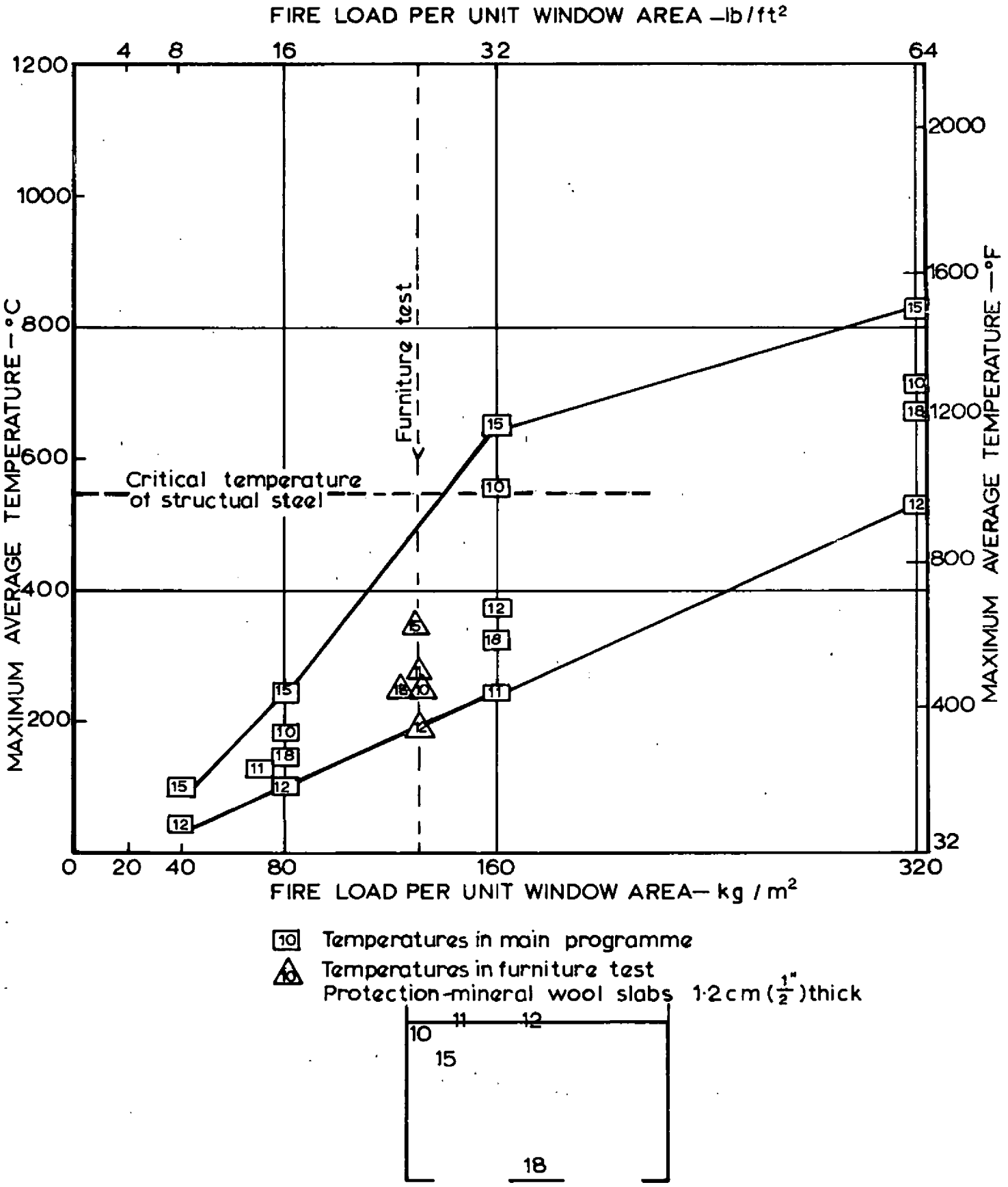


FIG.9. MAXIMUM AVERAGE TEMPERATURES OF INTERNAL PROTECTED STEEL COLUMNS C_{10} C_{11} C_{12} C_{15} C_{18}

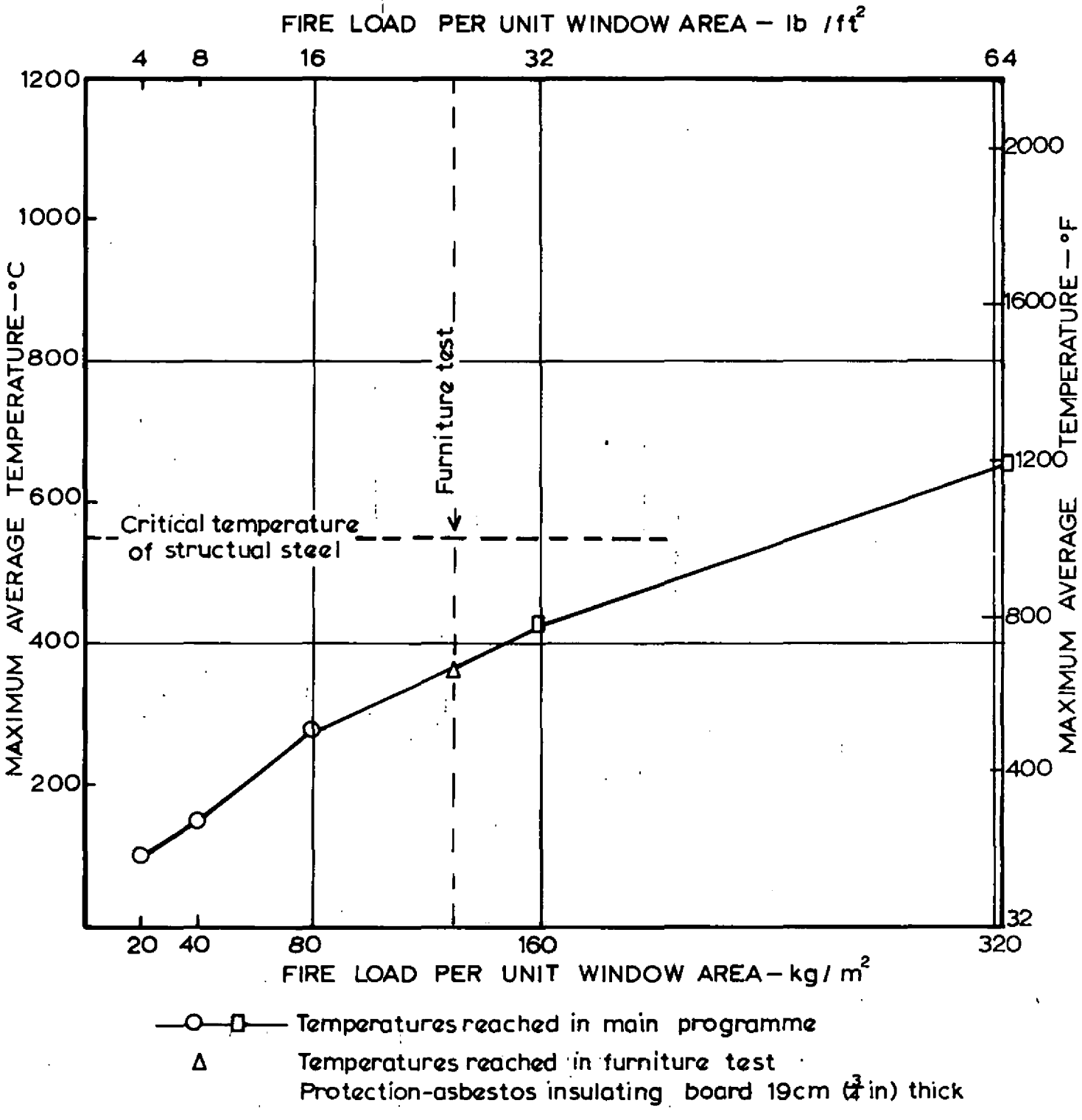


FIG.10 MAXIMUM AVERAGE TEMPERATURES OF INTERNAL PROTECTED COLUMN C_{21}

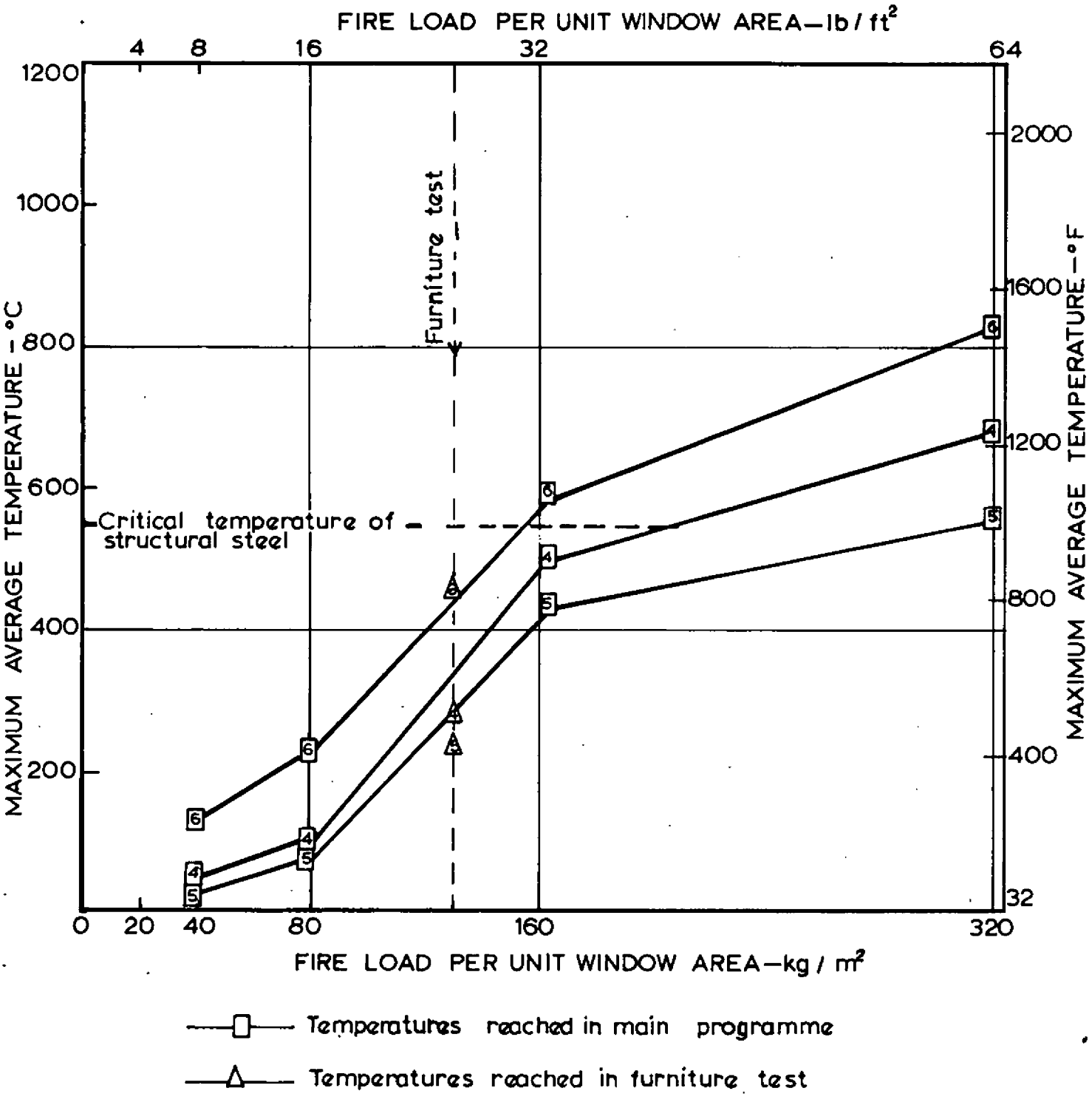


FIG.11. MAXIMUM AVERAGE TEMPERATURES OF INTERNAL PROTECTED STEEL BEAMS B_4, B_5, B_6,

PLATE 1. ARRANGEMENT OF FURNITURE IN TEST COMPARTMENT BEFORE FIRE

PLATE 2. APPLYING MINERAL WOOL PROTECTION TO STEEL COLUMN

PLATE 3 FIRE TEST IN PROGRESS

PLATE 4. TEST COMPARTMENT AFTER TEST
SHOWING THE COMPLETE BURNOUT