Fire Research Note
No.646

FIRES IN A LARGE COMPARTMENT CONTAINING STRUCTURAL STEELWORK. DETAILED MEASUREMENTS OF FIRE BEHAVIOUR

by

A.J.M. HESELDEN, P. G. SMITH and C. R. THEOBALD

December, 1966

FIRE RESEARCH STATION

Fire Research Station
Borehamwood
Hertfordshire
Tel. 01.953 6177

F.R. Note No. 646
December, 1966.

FIRES IN A LARGE COMPARTMENT CONTAINING STRUCTURAL STEELWORK. DETAILED MEASUREMENTS OF FIRE BEHAVIOUR

by

A. J. M. Heselden, P. G. Smith and C. R. Theobald

SUMMARY

25 large-scale experimental fires have been carried out recently at the Joint Fire Research Organization in conjunction with the British Iron and Steel Federation. This report describes the measurements made during the fires, excluding measurements of the temperature of the steelwork exposed in the compartment, and gives the results in detail.

Discussion is reserved for later reports.

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

FIRES IN A LARGE COMPARTMENT CONTAINING STRUCTURAL STEELWORK. DETAILED MEASUREMENTS OF FIRE BEHAVIOUR

by

A. J. M. Heselden, P. G. Smith and C. R. Theobald

1. Introduction.

The tests described in this report were carried out by the Joint Fire Research Organization in conjunction with the British Iron and Steel Federation. Their main purpose was to compare the severity of actual fires with that of the B.S. 476 furnace test by determining the temperatures attained by various steel structural columns and beams, exposed both to fire and to furnace conditions. The experiments, however, provided much information of general importance on large scale fires and various additional measurements were made which are given in the present report. The experiments are particularly valuable because they form a series with systematic and balanced variation of fire load density and ventilation, and some variation in type of fuel and its disposition, and thermal insulation of the walls.

A report[1] has been published giving details of the steel temperature measurements made in some of the tests. The present report gives the measurements made on the fire itself including rates of burning, flame temperatures and rates of heat transfer.

There is little discussion of the results, this is reserved for a second report.

2. Design of programme.

The experiments were carried out in two stages. The first stage consisted of the 12 tests of the balanced incomplete design shown in Table 1, carried out in the date order shown in Table 5. Test C was anomalous and was repeated (Test U). The symmetry of the design of this stage was intended to facilitate statistical analysis of the effect of compartment, fire load density and window opening.

The next stage consisted of 11 tests in one of the fire compartments in which a number of additional variables were introduced (Table 2). It was thought that these experiments should be related to those of the Conseil International du Bâtiment (C.I.B.) International Co-operative Programme[2] in which data were being obtained on fires in much smaller compartments of various shapes including one similar to that of the present compartment, since if suitable scaling laws could be derived the data would have much wider application. Accordingly, some tests were carried out with variation in the thermal properties of the wall and in the fuel disposition (Tests MNOPQR).

At the lowest fire load density a test (S) was also carried out with the fuel entirely in the form of fibre insulating board, covering most of the walls and ceiling. In tests W and Y the wood fuel was replaced by petrol and kerosene respectively. Test V was made to explore further the effect of small window openings.

3. Compartment.

Tests were carried out in one or other of two compartments formed by dividing a square building into two compartments measuring internally 7.70 m wide, 3.73 m deep and 2.97 m high, one facing S.E. and the other N.W. Each compartment had two window openings each 3 m wide and 1.8 m high, making a total window opening of half the area of the compartment front wall. A number of tests were carried out with this window area reduced by asbestos-steel shutters placed so as to leave openings in the centre of the wall, (See Fig. 1.). The construction of the walls, ceiling and floor has been described elsewhere[1]. The conditions under which each test were carried out and the reference number and letter of each test are summarised in Table 2.

4. Details of fuels

4.1. Tests with wood fuel

For most tests the fuel was wood and consisted of sticks of Pinus sylvestris, stored until use under cover. A stick thickness of 4 cm was chosen to give a compromise between the need for a reasonable certainty of fire development and the need to reduce the number of sticks handled to a minimum. There was insufficient space to store all the fuel that was needed for all the tests, and the supplier was asked to set aside the required quantity and deliver it in two batches. Unfortunately, sticks in the first batch to be delivered measured on average 104 cm x 4.3 cm x 4.6 cm and in the second batch 104 cm x 4.1 cm x 4.1 cm. By the time the second batch was delivered too many tests had been carried out to permit the thinner wood to be mixed with the thicker and it was therefore decided to use the thicker sticks for the 7.5, 15 and 60 kg/m^2 fire load density tests and a combination of about $\frac{3}{8}$ by weight of thicker sticks (placed at the base of the crib) with $\frac{5}{8}$ of thinner sticks, for all the 30 kg/m^2 fires. A repeat of one of the 60 kg/m^2 tests had, however, to be made with mainly thinner sticks. The average density (with equilibrium moisture content) of both batches was 0.54 g/cm^3. However, the thicker sticks were always placed with the longer side vertical and this was continued throughout the series so that the bulk density and stick spacing of cribs made of both thick and thin wood was almost the same. Further, experiments carried out in an international co-operative programme of experiments on fires in compartments[3] suggest that for the conditions of these experiments and a fireload density of at least 15 kg/m^2 a difference in stick thickness of this magnitude would not affect rate of burning significantly.

The sticks were placed in square cribs, 12 sticks per layer, the lowest layer perpendicular to the window wall. The balanced design of 12 tests (Table 1) was carried out with 8 cribs 104 cm square covering roughly $\frac{1}{3}$ of the floor area (see Fig. 2), since at the lowest fire load densities if the fuel had been placed evenly over the whole floor area the fire would probably not have spread over all the fuel.

The position of the 8 cribs on the floor was chosen to permit tests to be also made with the fuel placed in 18 similar cribs (see Fig. 2 and Plate I) without having to alter the position of the weighing apparatus. Some cribs had to be cut away slightly to fit round the columns; the wood cut away was added to the top of the cribs.

The wood cribs in the tests shown in Table 1 and tests O, P, U, V and X were all ignited at the same time by lighting strips of fibre insulation board (1 cm x 1.5 cm x 100 cm) soaked in kerosene placed in each gap of the bottom layer of sticks of each crib.

Tests M, N, Q and R were carried out with 18 cribs covering about $\frac{2}{3}$ of the floor area. In these tests ignition was effected by lighting the row of 6 cribs nearest the window wall by means of kerosene-soaked fibre insulation board strips 1.2 m long inserted into each of the spaces in the lowest layer of sticks. These sticks projected into the front of the second row of cribs so that both the row of cribs nearest the window wall and the front of the second row were ignited. Just before each test the moisture content of the wood fuel was measured with a "moisture in timber" meter, in which the electrical resistance between two pins driven into the wood gave a measure of moisture content.

The average moisture content of the wood used for the cribs was about 12.5 per cent.

Test X cannot be regarded as an exact replicate of test G since the large amount of unprotected steelwork (all the steelwork was uncovered in this test except columns C21* and C22*) of low thermal resistance and high capacity will have abstracted much more heat from the flames than when most of the steelwork was protected and will therefore give lower flame temperatures than in Test G.

Tests O, P, Q and R were carried out with the ceiling and walls covered by mineral wool insulation (See Plate II) similar to that used for cladding the steelwork but 2.5 cm thick. Some of the insulation was destroyed in test R and the areas in worst condition were patched with new insulation. The insulation was attached only to the plastered areas of the walls and the concrete ceiling and none of the steelwork was covered by it.

4.2. Test with fibre insulation board lining (S)

Test S was carried out with sheets of fibre insulation board covering most of the ceiling and walls (but not the floor). The board was nailed on to the plastered wall or concrete ceiling surfaces and did not cover up the steel columns embedded in the rear wall. The quantities used are shown in Table 3, the total weight of fibre insulation board used being 198 kg.

* In Test X C21 was covered with asbestos board, and C22 with mineral wool insulation (see Fig. 3). In all other tests C22 was left bare.

The board was lit by kerosene-soaked strips of fibre insulation board, 30 cm wide, placed on the floor, touching the sheets on the walls. Those strips at the back of the compartment were lit first, then quickly those at the side and at the front. Three gallons of kerosene, about 10.6 kg, were used for ignition. The fire load density was 7.5 kg/m^2.

The mean moisture content of the board was about 13 per cent.

4.3. Tests with liquid fuel (W and Y)

Test W was carried out with petrol fuel, a total of 26.3 gal ($\sim$ 88 kg) being used. This has approximately the same potential heat output as an equivalent fire load density of wood fuel in the compartment of 7.5 kg/m^2, assuming the calorific value of wood to be 0.4 times that of petrol. The petrol was placed in 8 trays as nearly as possible the same size and in the same position as the cribs in the wood fuel tests. There was a small variation in tray size (7 trays were square with sides between 0.75 and 1.0 m, the eighth tray was circular, 0.9 m diam.) since only trays already available were used, but the quantity of petrol placed in each tray was proportional to its area, to give equal burning times, and the largest trays were placed next to the smallest ones. The total exposed area of petrol was 6.33 m^2 (68 ft^2) giving a depth of petrol of 1.89 cm.

The trays contained a depth of several centimetres of water. Just before ignition the petrol was added and the top of the tray was covered with polythene sheeting and secured all round the tray edge. The trays were ignited simultaneously by means of electrical igniters, two to each tray, placed to burn through the plastic sheeting and ignite the petrol underneath.

In test Y, 26.6 gal ($\sim$ 89 kg) of kerosene fuel were placed in the same eight trays used for the petrol fire of test W. Measurements of duration of flaming, height of flames, temperatures of steel columns and some gas temperatures were made but no other thermal measurements were made during this test.

5. Measurements.

The measurements made are listed in Tables 4a, b and c. Further details of some of the measurements are given in the following sections.

5.1. Weighing arrangements for cribs.

Usually three or four cribs were weighed in each compartment during a test, except in some of the earlier tests. The positions for weight measurement (Fig. 2) were chosen to give an indication of variation in burning rate from side to side, rear to front and side to centre of compartment. Each weighed crib was placed on a heavy steel platform 107 cm square, insulated on the top and sides with asbestos wood. The platform was supported close to the floor on three legs which in turn rested on three load cells placed at the bottom of 70 cm deep holes in the floor. Each load cell contained four strain gauges, 2 mounted on the inside and 2 on the outside of a ring. The gauges were connected as a Wheatstone bridge, the three load cells being connected in parallel. The power supply and out of balance voltages were carried along mineral-insulated copper cable covered with extra thermal insulation. This ran along the floor to junction boxes in a fourth cavity under the platform from which leads ran through buried conduits to each load cell. The platforms were calibrated before each test by adding and removing known weights.

5.2. Heat flow within and above crib

The heat flow to cold receivers placed both inside and above one of the wood cribs nearest the rear wall was measured. The receivers were attached to the copper pipe shown in Fig. 4 and Plates I and II which passed through the rear wall and was 'stepped' to permit receivers to be mounted horizontally facing upwards at different heights. A high rate of flow of water was maintained through the pipe.

Each receiver (Fig. 5) consisted essentially of a block of nichrome* soldered between the copper pipe and a copper foil lead, the whole assembly forming a thermocouple. A flow of heat through the block gave rise to a temperature difference across the block and therefore an electrical signal from the thermocouple. A guard ring of nichrome protected the sides of

---

* constantan would have been a better material but was not available.

the block. The narrow gap between guard ring and block was filled with silicate cement and the surface of the block was coated with black paint. The copper foil lead was joined on to a copper wire lead which ran back along the outside of the tube under a layer of asbestos wool insulation. The elements were calibrated at an intensity of about 0.6 cal $cm^{-2}s^{-1}$ by comparison with a J.F.R.O. Moll thermopile[6] using a Schwank surface combustion gas radiant panel as source.

In view of the principle of operation of the receiver it is likely that its sensitivity does not vary markedly with intensity but this will be checked at a later date.

In view of the close correspondence shown in the higher fire load density tests in Fig. 6 between the heat flux measured by the upper horizontal receiver and the intensity of radiation in the plane of the window opening any change of sensitivity with intensity is unlikely to be large.

5.3. Heat flow to walls and ceiling

The rate of flow of heat into the walls was measured from the temperature gradient in the wall at the surface by a method suggested by Dr. P. H. Thomas. The gradient was estimated by means of thermocouples embedded at various depths in blocks of plaster of the same kind as that used to coat the wall. These blocks were let in to the wall plaster. One block was attached to the ceiling. The temperature gradient at the surface was estimated from the slope of a polynomial fitted to the measured temperatures. The thermal conductivity of the plaster was measured separately. Within the precision of measurement the thermal conductivity was found to be independent of temperature and was 0.57×10^{-3} cal $cm^{-1}s^{-1}degC^{-1}$ for mean temperatures of the plaster between 200°C and 900°C. The emissivity of the plaster was also estimated as being about 0.9.

5.4. Heat flow to wall above window (external)

The heat flow to the outside surface of the wall above the west window of each compartment was measured by means of a heat flux meter. This consisted of a circular slab of stainless steel, 6 mm thick with its front face blackened. The rate of flow of heat through the slab was measured by the difference in temperature between the front and back faces which was found by means of a differential thermocouple. The slab was mounted, with a guard ring to protect its edges, on a thin steel plate attached to the wall. It was calibrated using radiation from a gas-fired radiant panel by comparison with a J.F.R.O. Moll thermopile[6].

5.5. Recording instruments

For the first 20 tests most of the electrical outputs from the instruments were connected through switching units to one of 3 amplifiers and 3 pen recorders. Readings over a period of 3 s were obtained every 75 s. Later in the series a data logger was delivered and this was used in tests S, W and V. This instrument scanned the electrical outputs and recorded them in digital form on a punched tape which was later processed by a digital computer.

5.6. Gas composition measurements

For completeness this report also includes measurements of the composition of the gases in the compartment made by the Chemistry and Chemical Engineering Section. In some of the tests gas samples were withdrawn and stored in glass gas pipettes at intervals from two points in the ceiling both 50 cm from the inside of the window wall and 12 cm and 60 cm from the beam B3 or B6[1]. The samples were subsequently analysed on a dry basis by means of gas chromatography. These results will be analysed in a separate paper.

6. Results

Values of the quantities measured have been calculated at 5 min or shorter intervals over the whole period of flaming combustion, and mean values have been formed from values calculated at more frequent intervals (usually $1\frac{1}{4}$ min) for the period when the weight of fuel was falling from 80 to 30 per cent of its initial weight. This period was chosen because previous experiments with wood cribs in compartments of various scales and shapes have shown that during this period the burning rate is characteristic of the period of flaming combustion since the growth period at the start of the test and the period at the end when much charcoal is burning are largely excluded.

This period has been further sub-divided into an 80/55 and a 55/30 period. The variation with time of a number of important variables is shown for a few tests in Figures 6a to 6g.

Mean values for 80/30, 80/55 and 55/30 periods are given in Table 5.

The growth at the start of test C was much slower than in other tests which had almost similar conditions (for example test L which had identical cribs of wood but larger windows) although until the fire had grown large enough for the size of window to affect internal conditions appreciably, the rate of growth should have been similar. Further, the temperatures in test C were much higher in the east side of the compartment than in the west, presumably because of the effect of a strong cross wind which could be seen to blow the flame inside the compartment towards the east side. The most likely explanation for the slow initial growth is that the cross wind during ignition retarded the flames from the base of the crib from travelling up higher into the crib. A repeat test (U) was carried out on a much calmer day and gave a more rapid initial growth.

6.1. Flame conditions during tests

Table 6 describes the appearance of the flames during the tests. One observation which has a bearing on the hazard to the storey above a compartment concerns the effect of wind on the flame emerging from a compartment. With the larger window openings the flame usually only emerged from one or the other opening and with a cross wind there was a clear tendency for the flame to emerge from the opening on the windward side and then to travel upwards diagonally across the building.

6.2. Burning rate and fire duration

6.2.1. Individual cribs

Figure 7 shows the variation of weight with time for one of the weighed cribs. In any one test the maximum variation between the burning rates measured for each weighed crib was not greater than 2 : 1 and the variation of time to end of luminous flaming for the individual cribs was similar.

As well as the variations in burning rate from one side of the compartment to the other caused by a cross wind, the times to the end of luminous flaming show that for the 60 kg/m^2 fire load density tests there was a tendency for cribs to burn faster at the front and centre of the compartment and slower at the sides and back. This was also apparent in the 30 kg/m^2 fire load density tests with $\frac{1}{4}$ window opening but not for the $\frac{1}{2}$ window opening or for the lower fire load density tests. This is probably because for large amounts of fuel and small window openings there is a tendency for the window opening to restrict air supply to the fire and for the zone of intense combustion to be set up just inside the window opening, rather than at the fuel. This will be discussed more fully in a later paper.

6.2.2. Burning rate of compartment as a whole

For any given test the burning rate for the compartment as a whole was estimated from the weight loss measurements and the observed times at which each crib ceased to flame. The times at which 80, 55 and 30 per cent of the original weight of each weighed crib remained were normalised by dividing by the time at which the crib ceased to flame. These normalised times were reasonably constant for all the weighed cribs. The times at which 80, 55 and 30 per cent of the whole of the fuel in the compartment remained (t_{80}, t_{55} and t_{30}) were assumed to be given by multiplying the normalised times averaged over all the weighed cribs by the mean time for all the cribs to cease flaming. The average burning rates over the 80/30, 80/55 and 55/30 periods could then be found directly.

Where less than three cribs were weighed, normalised times were obtained from a combination of these data with weight measurements in the tests with the most similar ventilation and fire load densities.

The mean burning rates over the 80/55 period were 10 to 30 per cent larger than in the 55/30 period. This effect has been noted before with thick sticks[7] and is probably due to the insulating effect of a charcoal layer.

The mean burning rate in test S was found approximately by assuming that $^5/_6$ of the fuel burned between flashover and end of flaming, i.e. between $1\frac{1}{2}$ and $6\frac{1}{2}$ minutes, (see Table 7). This value of $^5/_6$ is derived from experiments with model corridors lined with fibre insulation board, carried out by P. L. Hinkley[8]. To permit averaging of temperatures etc, the period 2 to 5 minutes was taken as an approximate 80/30 period.

An estimate of the burning rate of the fuel in test W was found by assuming that the burning rate was constant over the average period of substantial flaming of all the trays (15 s to 4 min 40 s from first ignition). The delay of 15 seconds at the start after the first ignition was because the polythene sheeting which covered the trays had sunk down and was touching the petrol surface in the centre, so that at first burning could not take place over the whole tray area. Values for t_{80} and t_{30} were also found, with the above assumption.

6.3. Effects of compartment aspect and wind

Before the results of all tests could be directly compared it was necessary to discover whether there were any systematic differences between the results obtained in tests in the North and in the South compartments.

The experimental design had been drawn up with the intention of analysing the results by a variance analysis method[9], but since the design could not be strictly adhered to the method of analysis had to be altered. There were a few missing values of some variables (for example in tests J and K the radiometers were obstructed at times by spectators and the mean values for radiation intensity are therefore too low) and it was necessary to carry out test U in the south instead of the north compartment, so that the original symmetry was partly upset. However, the results were analysed by multiple regression and indeed this method permitted the dependence on a number of variables including wind speed and direction to be included. The original experimental design, which was only slightly deviated from, gave the benefit of sufficient spread in the values of the important independent variables to permit correlations with the dependent variable to be found. The use of a computer enabled more independent variables to be dealt with than could have reasonably been included by desk machine calculation.

The number of experiments, though large for a large scale test series, was too small to permit variation with many factors to be explored and only those most likely to influence the fires could be included. The dependent variables taken were:-

1. Average burning rate over the period when the weight of the fuel was falling from 80 to 30 per cent of its initial weight.
2. Average temperature rise above ambient of the gas within the compartment formed by averaging readings from six thermocouples over the 80/30 period.

3. Average temperature rise above ambient of the gases leaving the compartment formed by averaging readings from four thermocouples over the 80/30 period.
4. Average over the 80/30 period of the intensity of radiation in the plane of the window opening, formed by dividing the readings of the radiometer shielded from flames above the window by its configuration factor with respect to the window opening.
5. Equivalent fire duration, i.e. total weight of fuel divided by average burning rate over the 80/30 period.

Logarithmic transformations were made of variables 1, 2, 3 and 4. No transformation of variable 5 was made. Baldwin[10] has found such a logarithmic transformation to be appropriate for burning rate and intensity of radiation in similar experiments on a smaller scale. He found that a wide range of transformations could be used for temperature, including no transformation at all. However, in the present experiments the range of temperature was much larger than in those of his analysis and since the differences in mean temperatures between replicate experiments appeared to be approximately proportional to the temperature, a logarithmic transformation was made, which was within the range of possible transformations found by Baldwin.

No significant variation of rate of burning, equivalent fire duration or either of the temperatures was found with wind speed, wind direction or aspect of the compartment, i.e. whether it faced North or South. No significant variation of rate of burning or either of the temperatures was found with fuel moisture content. The effects of fire load and ventilation were more complicated. A significant variation of rate of burning, equivalent fire duration and the two temperatures with fire load, a $(\text{fire load})^2$ term and an interaction term, window area x $(\text{fire load})^2$ was found.

It was more difficult to deal with the intensity of radiation in the plane of the window, because in two tests, J and K, the radiometer was obstructed by spectators, giving an imbalance in the experimental design. The intensity of radiation was found to depend on fire load and window area, but it was not possible to test whether the intensity of radiation also depended on the aspect of the compartment and the wind speed and direction. However, 99 per cent of the variation could be accounted for by fire load, (fire load)^2, window area and window area x (fire load)^2 terms. Since radiation intensity must depend on temperature within the compartment and since no difference in the temperatures between fires in the North and South compartments was found, it is unlikely that intensity of radiation could depend on the aspect of the compartment. Similarly, since no effect of wind speed or direction was found on temperature or rate of burning, it is unlikely that radiation intensity could also have been affected.

These results do not, of course, imply that a fire in a compartment is always independent of an external wind since these tests were only carried out when the wind speed was low. At higher wind speeds some effect might well be produced and experiments at the J.F.R.O. with fires in small compartments have shown that the rate of burning can be increased by wind speeds of 8 m/s.

Some secondary effects were produced by the wind. It was noticed that when there was a large component of wind velocity parallel to the plane of the window openings more air appeared to be entering one opening than the other and more flame and smoke to be leaving the other opening. For example, with a wind from the west more flame would be emitted from the west than the east window and more air would appear to enter the east than the west window. This is no doubt a consequence of the pressure distribution created around the building by the wind.

With the lower fire loads the circulation produced in the compartment by a cross wind could be seen from the way the flames from each crib were blown by the wind.

There was a tendency for cribs to burn faster on the side in which more air appeared to be entering. This was more pronounced with a $\frac{1}{2}$ than with a $\frac{1}{4}$ window opening.

6.4. Heat transfer to unprotected steel column

The rate of temperature rise of the unprotected steel columns can be used to estimate the rate of heat transfer to the column, provided due allowance is made for heat loss, and this will be compared later with the other measurements of heat transfer rate within the compartment.

6.5. Suction pyrometer readings

Table 8 compares gas temperatures measured with the suction pyrometer at various times during the tests with the temperatures attained by unshielded thermocouples.

7. Acknowledgements

The tests described in this report were carried out by the Ignition and Growth Section with the assistance of the Structural Fire Protection Section, which was mainly concerned with the measurement of steel temperature. It is a pleasure to record the contribution to the conduct of these experiments and the processing of data from them, of Mr. G. K. Bedford, Mr. N. Darrington, Mr. C. Gilmore, Miss Lynda Griffiths, Mr. M. North, Mr. M. Woolliscroft and Mr. H. G. H. Wraight, and the co-operation of the Structural Fire Protection Section. Mr. Bedford measured the thermal conductivity of the wall plaster, described in Section 5.3.

8. References

(1) BUTCHER, E. G., CHITTY, T. B. and ASHTON, L. A. The temperature attained by steel in building fires. H.M.S.O. London (1966).

(2) HESELDEN, A. J. M. Determining the fire-resistance requirements for buildings using models (C.I.B. Model Tests). VFDB 2nd International Fire Protection Seminar (1964) Vol.II p.7.

(3) Results of 1st International C.I.B. Models Programme. To be published.

(4) McGUIRE, J. H. and WRAIGHT, H. Radiometer for field use. J. Sc. I. 37, p.128 (1960).

(5) HINKLEY, P. L. and HESELDEN, A. J. M. An improvement to a radiometer for field use. J. Sci. I. 40, p.379 (1963).

(6) SIMMS, D. L., PICKARD, R. W. and HINKLEY, P. L. Modified Moll thermopiles for measuring thermal radiation of high intensity. J. Sc. I. 39, p.204 (1962).

(7) WEBSTER, C. T., RAFTERY, MISS M, and SMITH, P. G. The burning of well ventilated compartment fires. Part III. The effect of wood thickness. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No.474.

(8) HINKLEY, P. L. Private communication.

(9) GAUNT, J. E. Private communication.

(10) BALDWIN, R. Private communication.

Table 1

Design of first stage of programme

The letters in the table are test code letters

Compartment	Ventilation opening (m^2)	Fire load density (kg/m^2)			
		7.5	15	30	60
North	5.6	A,B	-	-	C*
	11.1	-	D	E,F	-
South	5.6	-	G	H,I	-
	11.1	J,K	-	-	L

*Anomalous. Replaced by repeat test (U)

Table 2

Complete programme of tests

The letters in the table are test code letters

<table>
<tr><th rowspan="2">Ventilation opening area m^2</th><th rowspan="2">Fuel and layout</th><th rowspan="2">Compartment lining</th><th colspan="4">Fire load density kg/m^2</th></tr>
<tr><th>7.5</th><th>15</th><th>30</th><th>60</th></tr>
<tr><td rowspan="7">11.1 ("$\frac{1}{2}$ ventilation")</td><td rowspan="2">Wood 18 cribs (Approx. $\frac{2}{3}$ floor covered)</td><td>None</td><td>-</td><td>-</td><td>N</td><td>-</td></tr>
<tr><td>Mineral wool insulation</td><td>-</td><td>-</td><td>R</td><td>-</td></tr>
<tr><td rowspan="3">Wood 8 cribs (Approx. $\frac{1}{3}$ floor covered)</td><td rowspan="2">None</td><td>J</td><td rowspan="2">D</td><td>F</td><td rowspan="2">L</td></tr>
<tr><td>K</td><td>E</td></tr>
<tr><td>Mineral wool insulation</td><td>P</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Petrol 8 trays</td><td>None</td><td>W</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Kerosene 8 trays</td><td>None</td><td>Y</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="6">5.6 ("$\frac{1}{4}$ ventilation)</td><td colspan="2">Fibre insulating board</td><td>S</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Wood 18 cribs</td><td>None</td><td>-</td><td>-</td><td>M</td><td>-</td></tr>
<tr><td>Mineral wool insulation</td><td>-</td><td>-</td><td>Q</td><td>-</td></tr>
<tr><td rowspan="3">Wood 8 cribs</td><td rowspan="2">None</td><td>A</td><td>G</td><td>H</td><td>C</td></tr>
<tr><td>B</td><td>X</td><td>I</td><td>U</td></tr>
<tr><td>Mineral wool insulation</td><td>O</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2.6 ("$\frac{1}{8}$ ventilation")</td><td>Wood 8 cribs</td><td>None</td><td>-</td><td>-</td><td>-</td><td>V</td></tr>
</table>

Table 3

Areas of fibre insulation board used in Test S

Position	Area of fibre insulation board	
	m^2	ft^2
Ceiling	25.9	278
Rear wall	14.9	160
Side wall (E)	8.9	96
Side wall (W)	8.2	88
Front wall (below window)	4.5	48
Floor (for ignition)	5.5	59
Total	67.9	729

Table 4(a)

Measurements made in tests

Variable	Measurement	Position of measurement	Method or apparatus used
Weather conditions	Wind speed	$1\frac{1}{2}$ m above ground level in open field near compartment	Integrating cup anemometer. Spot readings with vane anemometer before and after test
	Wind direction	"	Wind vane
	Air temperature	In shade near compartment	Wet/dry bulb whirling arm hygrometer
	Relative humidity	"	
Rate of growth and duration of fire	Times of various stages of growth and development including flashover	-	Visual
	Burning rate	Some cribs weighed in most of tests	Platforms supported on load cells. See Section 5.1
Flame height	Height of flame above window opening	-	Visual and by photographs at 5 or 10 s intervals
	Height of flame above crib (only for low fire loads when flames from separate cribs did not merge)	All cribs	Visual

Table 4(b)

Measurements made in tests

Variable	Measurement	Position of measurement	Method or apparatus used
Temperature of fire	Temperatures in flames or hot gases	At $\frac{1}{4}$ and $\frac{3}{4}$ of compartment height in centre and on each side (See Fig.3)	Bare chromel/alumel thermocouples
		8 cm from ceiling	"
		8 cm from rear wall	"
		8 cm from column C9 or C16	"
		In effluent gases, two in plane of front of each window opening (See Fig.3)	"
		Above crib at rear of compartment at various heights	Multiple-wall refractory-shield suction pyrometer* (sheathed Pt - Pt 13 per cent Rh thermocouple) and with chromel/alumel thermocouple some 5 cm to one side of shield
	Temperature of inner surface of wall and ceiling	Near centre of rear and W side wall and centre of ceiling	Chromel/alumel thermocouples embedded in surface
	Temperature of surface of mineral wool insulation on walls and ceiling	"	"
	Temperature of surface of mineral wool insulation on a column	About 90 cm from floor on column C9 or C16, facing rear wall	"

*Maximum rate of extraction of gas about 10 g/s

Table 4(c)

Measurements made in tests

Variable	Measurement	Position of measurement	Method or apparatus used
Heat transfer rate within compartment	Heat flow above and inside crib at rear of compartment	To heat flow elements mounted horizontally and vertically at various heights near vertical line through crib centre	Heat flow discs mounted on water-filled copper pipe. See section 5.2
	Heat flow into walls and ceiling	Near centre of rear and W side wall and centre of ceiling	Plaster heat flow blocks. See section 5.3
Heat transfer rate outside compartment	Intensity of radiation from window opening	4-7 m from plane of opening, directly in front of openings	Two radiometers (4,5) one with a shield to cut off radiation from flame above the window
	Intensity of radiation from flame above crib	Pyrometer sighted on area about 75 cm diameter just above crib at rear of compartment	Total radiation pyrometer (Angle of view 1 in 10). Arsenic trisulphide lens
	Heat flow to wall above window	55 cm above top of W window, 75 cm from the line of the inner edge of the W window	Heat flow block. See section 5.4
Gas composition	Concentration of O_2, CO_2, CO, H_2 and CH_4 in gases within compartment	Samples withdrawn from two positions near ceiling. See section 5.5	Analysis by chromatographic apparatus

<u>Index to Table 5</u>

	Contents	Column number
General		
	Compartment aspect	1
	Date of test	2
	Weather conditions	3 to 7
	Air temperature	3
	Relative humidity	4
	Wind speed and direction	5 to 7
	Fuel moisture	8
	Unprotected steel members	9
Development of fire		
	Time for flames to touch ceiling	10
	" " " " emerge from window	11
	" " flashover	12
	" to lose various fractional fuel weights	13 to 15
	" to peak temperatures	37
	Burning rate	16 to 19
	Flame height	20
	Period of longest flames	21
	Mean duration of flaming	22
	Equivalent fire duration	23
Temperature rise		
	Compartment gases	
	80/30 mean	32
	80/55 and 55/30 means	55 and 56
	Peak	36
	Suction pyrometer	34, 57 and 58
	(Height of suction pyrometer)	38
	(Height of crib under suction pyrometer)	39
	Exit gases	40 to 46 and 61 to 62
	80/30 mean	46
	80/55 and 55/30 means	61 and 62
	Wall and ceiling surfaces	47 to 50 and 63 to 70
	80/30 mean	47 to 50
	80/55 and 55/30 means	63 to 70
	Surface of mineral wool insulation	51 to 54 and 71 to 78

TABLE 5

A key to the experimental conditions is given on page 43.

Notes on Table 5 (see also footnotes)

Column	Symbol	Note
6 and subsequent	≠	No record is available, or time of event is not well defined.
9	*	In tests M, N, O, P, Q, R, S, U, V, W, X and Y two extra steel columns (C21 and C22) were installed in the South compartment. C21 was covered with 1.8 cm thick asbestos insulating board; C22 was left unprotected in all tests except X in which it was covered with mineral wool insulation.
10 and subsequent	-	Event never occurred, or not applicable.
12	(Heading*)	'Flashover' is taken here as the time when flames from individual cribs merged together and produced a massive flame occupying a large fraction of the volume of the compartment.
12	(Tests E* and F)	Flames largely filling rear half of compartment.
12	(Test* G)	Flames not fully merged.
16 to 19	(Heading*)	Burning rate 80/30, 80/55 and 55/30. These are the mean burning rates over the period when the weight of fuel was falling from 80 to 30, 80 to 55 or 55 to 30 per cent respectively of its initial weight.
22	(Heading*)	Mean time of all cribs or liquid fuel trays to cease luminous flaming (i.e. not counting flames of carbon monoxide), defined as the time when flames became less than 15 cm high.
23	(Heading*)	Total quantity of fuel ÷ mean burning rate over 80/30 period.
86	(Heading*)	This has been determined with respect to the inner edge of the window opening; obstructions in the window (e.g. exterior columns and mountings for the sheets used to close part of the window opening) have been taken into account.

TABLE 5(a)

	Aspect of compartment	Date of test	WEATHER CONDITIONS Average over period of test				
			Air temperature °C	Relative humidity per cent	Wind speed m/s		Wind direction
					Vane anemometer	Cup anemometer	
	1	2	3	4	5	6	7
N	S	19. 8.65	21	70	3	/*	SW
R	S	5.10.65	14	90	1	1	SE
J	S	7. 4.65	13	75	1	/	W
K	S	2. 6.65	18	50	2	2.5	NE
D	N	16. 2.65	7	60	2	3	N
F	N	10. 5.65	16	50	2	2	NW
E	N	19. 5.65	11	45	2	2	NNW
L	S	29. 3.65	21.5	25	2	/	SSW
P	S	20. 9.65	18	60	2	2	W
W	S	2. 2.66	11	80	2	2	SW
Y	S	9. 2.66	/	/	/	/	E
S	S	14.12.65	5	~ 95	1	1	SW
M	S	26. 8.65	15	85	1	2	SW
Q	S	13.10.65	15	60	1	/	S+
A	N	24. 2.65	4	55	2	/	N.
B	N	3. 3.65	-1	/	1.5	4	SW
G	S	22. 4.65	11	70	3	3	NE
X	S	21. 1.66	1	~ 90	1.5	2.5	NW
H	S	28. 4.65	8	75	1.5	2	NE
I	S	9. 6.65	12	85	2	2	N
C	N	10. 3.65	7	55	3	4	SSE
U	S	3.11.65	7	50	1	1	NNW
O	S	22. 9.65	20	55	1.5	1	WSW
V	S	14. 3.66	9	75	1	0.5	W

*See notes on Table 5

+During test Q the wind changed direction from SW through S to E.

TABLE 5(b)

	Mean moisture content of fuel %	Bare steel members in compartment (see reference(1) and figure 2)	DEVELOPMENT OF FIRE					
			Time for flames to touch ceiling (min)	Time for flames to emerge from window (min)	Time for flash-over* (min)	Time (min) for fuel weight to fall to following percentages of initial weight		
						80	55	30
	8	9	10	11	12	13	14	15
N	12	C13, C22*	3.5	3	~ 8	10.4	16.2	21.3
R	12	C13, C22*	4	4	~ 6	9.2	13.2	19.2
J	11.5	C13	-*	-	-	7.6	11.8	16.6
K	12	C13	-	-	-	8.3	12.9	18.1
D	13	C6, C13	4	-	-	7.4	11.9	17.2
F	12	C7	5.5	5.5	4.5*	8.2	12.8	19.0
E	11.5	C6, C13	3	7.5	3.5*	8.3	13.3	19.6
L	13.5	C13	3	6	~ 6	10.1	16.2	24.0
P	11.5	C13, C22*	-	-	-	8.1	13.1	18.7
W	-	C13, C22*	~ 0.7	~ 0.7	~ 0.7	~ 1.13	/	~ 3.33
Y	-	All except C21*	1.5	1.8	~ 2	~ 2	/	~ 7
S	13	C13, C22*	/	1.2	1.5	~ 2	/	~ 5
M	12	C13, C22*	2.5	~ 7.5	~ 8.7	12.0	17.7	23.9
Q	13.5	C13, C22*	/	4.2	~ 5.5	13.1	17.9	23.9
A	12	C6, C13	-	-	-	7.4	12.0	17.3
B	12	C7, C13	-	-	-	6.5	10.6	15.2
G	12	C13	6	9	7*	8.2	12.8	18.8
X	/	All except 2*	5.2	-	-	9.6	15.0	21.8
H	13	C13	~ 4	~ 6	6	9.7	15.0	21.3
I	12.5	C13	2.2	~ 5.7	~ 6	8.1	13.6	19.7
C	12	C7, C13	4.5	8	9.7	/	/	/
U	11.5	C13, C22*	3.5	5.5	6.2	15.8	24.6	34.8
O	11	C13, C22*	-	-	-	9.0	14.5	20.7
V	12.5	C13, C22*	2.8	14	~ 14	24.6	36.8	51.3

*See notes on Table 5.

TABLE 5(c)

	DEVELOPMENT OF FIRE							
	Mean burning rate 80/30* kg/min	Mean burning rate (kg/s)			Peak flame height above window++ (m)	Period of longest flames (min from ignition)	Mean duration of flaming* (min)	Equivalent fire duration* (min)
		80/30*	80/55*	55/30*				
	16	17	18	19	20	21	22	23
N	40	0.67	0.63	0.71	2+	12.5-17.5	45	22
R	44	0.73	0.91	0.60	3+	6.5-17	40	20
J	12	0.20	0.22	0.19	-	4-7	33	18
K	11	0.19	0.20	0.17	-	2-5	36	19
D	22	0.37	0.40	0.34	-	/	35	20
F	40	0.67	0.79	0.58	2+	10-14	44	22
E	39	0.64	0.73	0.58	2+	10-16	40	23
L	63	1.05	1.19	0.93	3■	12.5-19	46	28
P	10	0.17	0.18	0.16	-	2-4	31	21
W	20	0.33	/	/	5+	0.75-3	4.7	4.4
Y	9	0.15	/	/	4+	2-5.5	10	9.9
S	36	0.60	/	/	4	1.75-5	6.5[x]	6.1
M	37	0.61	0.64	0.59	3	10-17.5	45	24
Q	40	0.67	0.76	0.60	3	9-13.5	46	22
A	11	0.18	0.20	0.17	-	6-10	35	20
B	12.5	0.21	0.22	0.20	-	3-8	31	17
G	21	0.34	0.39	0.30	0ø	9-14	40	21
X	18	0.30	0.34	0.27	-	8.5-20	43.5	24
H	38	0.63	0.69	0.58	3	10-16	48.5	23
I	38	0.63	0.66	0.59	3	9.5-13	50	23
C	~ 46	~ 0.77	/	/	3	15.5-35	62	38
U	46	0.77	0.83	0.71	3	11.5-24	62	38
O	9	0.16	0.17	0.15	-	3.5-7.5	34.5	23
V	33	0.54	0.60	0.50	2	22-34	95.5	54

*See notes on Table 5.

++Measured from the top of the window opening.

+Flames emerging from one window only.

■Flames emerging continuously from one window and intermittently from the other.

øSmall licks of flame emerging.

[x]Time to end of all flaming.

TABLE 5(d)

	TEMPERATURE RISE								
	Thermocouples in compartment gases. Means over 80/30 period. (deg C)								
	Upper				Lower				Mean of S_1 to S_6
	West S_1	Centre S_3	East S_5	Mean	West S_2	Centre S_4	East S_6	Mean	
	24	25	26	27	28	29	30	31	32
N	755	675	630	685	775	685	665	705	690
R	585	695	820	700	555	640	840	685	690
J	195	230	205	210	235	245	165	215	210
K	180	230	235	215	180	250	240	225	220
D	400	460	485	445	365	460	460	430	440
F	715	770	785	760	735	765	735	745	750
E	750	750	740	745	635	660	680	660	705
L	1070	1045	1045	1050	/	990	1070	1030	1045
P	280	270	250	265	265	305	220	260	265
W	1075	1055	1035	1055	835	1020	630	830	940
Y	/	/	/	/	/	/	/	/	/
S	/	885	825	855	760*	725	/	745	800
M	1005	940	970	970	915	865	900	895	930
Q	1055	1030	1045	1045	975	945	995	970	1010
A	280	345	345	325	245	295	295	280	300
B	295	320	320	310	260	270	295	275	290
G	615	665	700	660	675	665	675	670	665
X	570	570	555	565	580	555	510	550	555
H	815	1020	1045	960	1020	965	1020	1000	985
I	1060	1025	1050	1045	1045	895	1025	990	1015
C	/	1070	1045	/	/	/	/	/	/
U	1190	/	1120	1155	1170	1030	1090	1095	1120
O	430	415	380	405	375	370	345	360	385
V	/	1145	1110	1125	950	970	1105	1010	1055

*Single reading.

TABLE 5(e)

	TEMPERATURE RISE					Height of suction pyrometer above floor	Height of crib under suction pyrometer
	Thermocouples in compartment gases. Means over 80/30 period						
	7.5 cm below ceiling (deg C)	Suction pyrometer (deg C)	Unshielded thermocouple near suction pyrometer (deg C)	Peak value of mean of S_1 to S_6 (deg C)	Time to peak (min)	(cm)	(cm)
	33	34	35	36	37	38	39
N	635	⌿	⌿	755	16	⌿	21
R	715	850	985	825	9	80	21
J	185	⌿	290	255	4	50	13
K	210	⌿	220	230	5	75	13
D	445	⌿	720	445	9	67	22
F	770	⌿	980	810	11	70	42
E	775	⌿	860	745	14	120	42
L	1040	⌿	1045	1070	14	115	83
P	275	210	255	290	4	80	13
W	880	⌿	935	1045	2.4	⌿	-
Y	600	⌿	⌿	⌿	⌿	⌿	-
S	825	⌿	780	805	2.5	⌿	0
M	980	⌿	1040	1005	16	⌿	21
Q	1065	1010	1035	1070	11	80	21
A	310	⌿	⌿	325	6	⌿	13
B	320	⌿	390	325	6	⌿	13
G	700	⌿	865	685	10	50	22
X	570	565	565	580	14	50	20
H	1000	1030	1070	1025	14	75	42
I	1000	1100	1055	1050	12.5	145	42
C	1000	⌿	1045	1045	22	135	83
U	1100	985	1085	1170	27.5	145	81
O	420	400	355	450	5	80	13
V	1070	970	1110	1100	40	120	81

TABLE 5(f)

	TEMPERATURE RISE						
	Thermocouples in exit gases. Mean over 80/30 period (deg C)						
	Upper			Lower			Mean of W_1 to W_4
	West W_1	East W_3	Mean	West W_2	East W_4	Mean	
	40	41	42	43	44	45	46
N	640	540	590	600	485	545	565
R	515	635	575	410	540	475	525
J	205	145	175	160	100	130	155
K	120	210	165	90	175	130	145
D	390	460	425	365	440	405	415
F	650	680	665	575	620	595	630
E	665	645	655	590	580	585	620
L	915	840	880	840	720	780	830
P	245	215	230	215	180	195	215
W	1035	915	975	925	670	795	885
Y	≠	≠	≠	≠	≠	≠	≠
S	825	900	860	810	830	820	840
M	900	815	855	865	770	820	840
Q	880	970	925	825	930	880	900
A	295	320	305	285	295	290	300
B	270	260	265	270	170	220	240
G	565	590	580	370	525	450	520
X	515	535	525	435	485	460	490
H	840	865	855	720	770	745	800
I	830	885	860	640	765	700	780
C	530	≠	≠	390	940	≠	≠
U	1035	1020	1030	940	945	945	985
O	390	370	380	360	340	350	365
V	935	950	945	825	915	870	905

TABLE 5(g)

	TEMPERATURE RISE							
	Thermocouples on surfaces. Mean over 80/30 period (deg C)							
	Plaster block			Ceiling (concrete)	Mineral wool insulation			
	Rear wall	Side wall	Ceiling		Rear wall	Side wall	Ceiling	Column
	47	48	49	50	51	52	53	54
N	605	720	600	625	–	–	–	⌿
R	725	585	660	–	720	650	780	920
J	160	205	180	225	–	–	–	360
K	150	135	250	220	–	–	–	305
D	⌿	290	380	310	–	–	–	525
F	630	630	⌿	690	–	–	–	915
E	710	690	675	675	–	–	–	930
L	⌿	850	935	980	–	–	–	⌿
P	185	250	235	–	⌿	335	335	⌿
W	835	715	765	700	–	–	–	⌿
Y	⌿	⌿	⌿	⌿	–	–	–	⌿
S	545	625	620	785	–	–	–	805
M	900	825	760	⌿	–	–	–	1020
Q	980	810	925	–	⌿	920	975	940
A	220	200	250	200	–	–	–	330
B	195	210	245	200	–	–	–	345
G	545	660	545	575	–	–	–	745
X	450	505	480	530	–	–	–	–
H	820	985	905	975	–	–	–	⌿
I	990	870	930	905	–	–	–	1030
C	⌿	⌿	⌿	⌿	–	–	–	⌿
U	⌿	⌿	⌿	1010	–	–	–	⌿
O	290	370	320	–	⌿	⌿	390	⌿
V	945	875	945	1030	–	–	–	⌿

TABLE 5(h)

	TEMPERATURE RISE							
	Means over 80/55 and 55/30 periods (deg C)							
	Compartment (Mean of S_1 to S_6)		Suction pyrometer		Near suction pyrometer		Exit gas (Mean of W_1 to W_4)	
	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30
	55	56	57	58	59	60	61	62
N	650	730	⌿	⌿	⌿	⌿	545	585
R	720	675	870	840	970	995	490	545
J	230	190	⌿	260	410	165	165	135
K	215	220	150	⌿	220	220	145	150
D	450	430	⌿	⌿	795	675	440	400
F	775	735	1025	⌿	995	975	635	625
E	710	695	⌿	⌿	875	850	610	630
L	1045	1045	⌿	⌿	990	1095	805	855
P	280	250	230	190	285	230	230	200
W	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
Y	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
S	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
M	980	885	⌿	⌿	1135	945	875	800
Q	1040	980	1000	1015	995	1070	935	870
A	295	295	⌿	⌿	⌿	⌿	305	295
B	295	285	⌿	⌿	345	415	245	235
G	690	670	⌿	⌿	840	880	530	510
X	560	550	600	530	580	550	500	485
H	1020	955	1045	1015	1070	1045	765	820
I	1020	1010	1095	1110	1045	1060	765	795
C	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
U	1100	1140	950	1015	1025	1140	970	1000
O	405	365	430	370	325	390	385	345
V	1035	1075	945	990	1065	1150	870	935

TABLE 5(i)

	TEMPERATURE RISE							
	Thermocouples on surfaces. Means over 80/55 and 55/30 periods (deg C)							
	Rear wall		Side wall		Ceiling		Ceiling temperature (concrete)	
	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30
	63	64	65	66	67	68	69	70
N	510	675	585	830	560	625	575	665
R	745	715	595	575	655	665	–	–
J	160	165	205	205	170	195	220	230
K	135	160	125	145	240	260	210	235
D	≠	≠	280	300	370	390	300	325
F	620	640	585	665	≠	≠	690	695
E	690	730	680	700	655	690	655	690
L	≠	≠	845	855	915	950	940	1005
P	180	195	250	245	220	245	–	–
W	≠	≠	≠	≠	≠	≠	≠	≠
Y	≠	≠	≠	≠	≠	≠	≠	≠
S	≠	≠	≠	≠	≠	≠	≠	≠
M	965	835	760	890	770	750	≠	≠
Q	1025	950	785	830	945	915	–	–
A	210	225	190	205	240	255	185	210
B	190	200	200	220	240	250	185	210
G	535	555	630	680	535	545	555	595
X	445	455	460	545	475	485	530	525
H	905	730	985	985	900	910	990	955
I	1005	975	855	880	915	940	900	915
C	≠	≠	≠	≠	≠	≠	≠	≠
U	850	≠	765	≠	995	≠	1000	≠
O	295	290	380	360	320	325	–	–
V	990	905	835	905	930	955	1005	1050

TABLE 5(j)

	TEMPERATURE RISE							
	Thermocouples on surface of mineral wool insulation. Means over 80/55 and 55/30 periods (deg C)							
	Rear wall		Side wall		Ceiling		Column	
	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30
	71	72	73	74	75	76	77	78
N	-	-	-	-	-	-	655	⌿
R	685*	730	660	645	785	775	940	910
J	-	-	-	-	-	-	410	315
K	-	-	-	-	-	-	315	295
D	-	-	-	-	-	-	550	500
F	-	-	-	-	-	-	930	905
E	-	-	-	-	-	-	920	935
L	-	-	-	-	-	-	⌿	⌿
P	⌿	⌿	355	325	335	340	⌿	⌿
W	-	-	-	-	-	-	⌿	⌿
Y	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
S	-	-	-	-	-	-	⌿	⌿
M	-	-	-	-	-	-	1080	960
Q	⌿	⌿	975	875	1010	945	880	985
A	-	-	-	-	-	-	350	310
B	-	-	-	-	-	-	360	335
G	-	-	-	-	-	-	740	745
X	-	-	-	-	-	-	-	-
H	-	-	-	-	-	-	⌿	⌿
I	-	-	-	-	-	-	1030	1035
C	-	-	-	-	-	-	⌿	⌿
U	-	-	-	-	-	-	955	⌿
O	⌿	⌿	⌿	⌿	405	375	⌿	⌿
V	-	-	-	-	-	-	1020	⌿

*One reading only

TABLE 5(k)

	HEAT TRANSFER (EXTERNAL)								
	Intensity of radiation from window opening. Mean over 80/30, 80/55 or 55/30 periods. (Cal $cm^{-2}s^{-1}$)							Configuration factor* $\emptyset$	Total radn. pyrometer 80/30 mean cal cm^{-2} s^{-1}
	Unshielded radiometer			Shielded radiometer (I_o)			$I_o/\emptyset$# 80/30 mean		
	80/30	80/55	55/30	80/30	80/55	55/30			
	79	80	81	82	83	84	85	86	87
N	0.101	0.091	0.110	0.094	0.078	0.109	1.40	0.067	1.46
R	0.126	0.132	0.122	0.117	0.124	0.113	1.75	0.067	0.99
J	0.005+	0.004+	0.007+	0.005+	0.003+	0.007+	0.07+	0.067	0.70
K	0.008+	0.009+	0.007+	0.009+	0.009+	0.008+	0.13+	0.067	0.50
D	0.049	0.052	0.046	0.042	0.044	0.040	0.40	0.105	0.95
F	0.186	0.194	0.182	0.186	0.184	0.187	1.77	0.105	2.58
E	0.191	0.192	0.191	0.184	0.180	0.187	1.75	0.105	2.18
L	0.285	0.257	0.307	0.259	0.220	0.292	3.9	0.067	3.60
P	0.01	0.01	0.01	0.01	0.01	0.01	0.15	0.067	0.55
W	⌿	⌿	⌿	⌿	⌿	⌿	⌿	0.064	⌿
Y	⌿	⌿	⌿	⌿	⌿	⌿	⌿	-	⌿
S	0.12	⌿	⌿	0.09	⌿	⌿	2.4	0.038	1.46
M	0.128	0.144	0.113	0.113	0.126	0.100	2.8	0.040	1.66
Q	0.137	0.143	0.133	0.124	0.133	0.117	3.3	0.038	2.45
A	0.012	0.014	0.012	0.012	0.013	0.011	0.17	0.069	0.18
B	0.009	0.009	0.009	0.008	0.007	0.008	0.12	0.069	0.33
G	0.036	0.036	0.036	0.031	0.031	0.031	0.77	0.040	1.40
X	0.020	0.019	0.021	0.021	0.020	0.022	0.55	0.038	0.76
H	0.166	0.151	0.181	0.148	0.127	0.170	3.7	0.040	3.63
I	0.142	0.121	0.160	0.125	0.105	0.142	3.1	0.040	2.72
C	0.239	⌿	⌿	0.186	⌿	⌿	2.7	0.069	2.10
U	0.194	0.194	0.194	0.139	0.121	0.154	3.7	0.038	2.66
O	0.011	0.012	0.010	0.011	0.012	0.010	0.29	0.038	0.60
V	0.087	0.083	0.091	0.066	0.059	0.072	3.3	0.020	1.62

*See notes on Table 5.

+Radiometers obstructed by spectators.

#This is virtually the intensity of radiation at the window opening. $\emptyset$ is the configuration factor (column 86).

TABLE 5(1)

	HEAT TRANSFER (EXTERNAL) Heat flow to wall above window opening. Means over 80/30, 80/55 and 55/30 periods (Cal $cm^{-2}s^{-1}$)		
	80/30	80/55	55/30
	88	89	90
N	$\sim$ 0.3	$\sim$ 0.3	0.29
R	0.28	0.28	0.28
J			
K			
D	0.09	0.09	0.09
F	0.26	0.29	0.23
E	0.25	0.25	0.24
L	0.8	0.6	0.9
P			
W	$\not-$	$\not-$	$\not-$
Y	$\not-$	$\not-$	$\not-$
S	$\not-$	$\not-$	$\not-$
M	$\sim$ 0.3	0.24	$\sim$ 0.3
Q	0.4	0.5	0.3
A	0.05	0.04	0.06
B	0.03	0.03	0.03
G	0.07	0.07	0.07
X	0.14	0.17	0.12
H	0.5	0.6	0.4
I	$>$ 0.3	0.25	$>$ 0.37
C	$\not-$	$\not-$	$\not-$
U	$\sim$ 0.7	1.0	$\sim$ 0.4
O			
V			

TABLE 5(m)

	Height of crib under tube (cm)	HEAT TRANSFER (INTERNAL): Heat flow to receivers on water-filled tube. Mean heat flow (cal $cm^{-2}s^{-1}$) over 80/30 period to receiver:- A (Hor.)	B (Vert.)	C (Hor.)	D (Hor.)	E (Hor.)	F (Vert.)	Peak heat flow (cal $cm^{-2}s^{-1}$) A (Hor.)	B (Vert.)
	91	92	93	94	95	96	97	98	99
N	21	0.9	1.7	2.3	1.8	1.8	1.5	1.1	1.8
R	21	2.2	3.2	4.5	⌿	2.5	1.6	2.3	3.7
J	13	0.6	0.4*	0.4	0.4	0.8	1.4*	0.7	0.4*
K	13	0.4	0.7	0.5	0.4	0.9	1.5	0.4	0.7
D	22	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
F	42	2.1	1.9	3.5	0.5	0.6	0.5	2.5	3.0
E	42	2.1	1.9	3.1	0.8	0.5	0.5	2.3	2.3
L	83	5.0	3.7*	3.9	1.9	1.2	1.2*	6.3	4.4*
P	13	0.2	0.4	0.5	0.5	0.6	1.3	0.3	0.5
W	-	2.2	3.8	5.1	3.1	2.3	1.3	3.5	4.3
Y	-	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
S	-	2.3	2.3	2.8	1.9	2.0	1.8	2.7	2.3
M	21	3.5	4.5	5.6	3.0	2.7	2.6	4.2	5.2
Q	21	3.9	4.7	5.1	2.9	2.0	1.8	4.3	5.2
A	13	0.6	0.4	0.4	0.6	0.8	1.1	0.8	0.7
B	13	1.1	0.7	0.8	0.8	0.9	1.2	1.3	0.9
G	22	2.1	1.6*	⌿	1.9	1.4	1.2*	2.3	1.8*
X	20	0.8	1.3	1.8	1.3	1.4	1.0	0.9	1.5
H	42	3.7	3.2*	4.5	1.1	0.6	0.6*	3.8	3.4*
I	42	3.0	3.5	4.7	1.1	0.4	0.7	3.2	3.8
C	83	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
U	81	3.4	4.7	1.1	0.5	0.4	0.5	4.5	5.5
O	13	0.6	0.8	0.9	0.8	0.9	1.3	0.6	0.8
V	81	3.5	4.5	1.8	0.7	0.5	0.5	4.2	5.0
	Height above floor (cm)								
	Tests C & L	200	200	97	69	54	54	200	
	Other tests	160	160	57	28	14	14	160	

*Vertical receivers facing to side of compartment. In all other tests vertical receivers facing to centre of compartment.

TABLE 5(n)

	HEAT TRANSFER (INTERNAL)											
	Heat flow to receivers on water-filled tube											
	Mean heat flow (cal $cm^{-2}s^{-1}$) over 80/55 and 55/30 periods to receiver:-											
	A (Hor.)		B (Vert.)		C (Hor.)		D (Hor.)		E (Hor.)		F (Vert.)	
	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30
	100	101	102	103	104	105	106	107	108	109	110	111
N	0.8	1.1	1.4	2.1	1.7	3.0	1.3	2.3	1.2	2.4	1.1	1.9
R	2.2	2.2	2.7	3.7	4.4	4.6	⌿	⌿	2.4	2.8	1.5	1.7
J	0.7	0.5	0.4*	0.4*	0.4	0.3	0.4	0.3	0.9	0.6	1.6*	1.2*
K	0.4	0.4	0.7	0.7	0.5	0.5	0.4	0.4	0.9	0.8	1.5	1.4
D	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
F	2.0	2.3	2.0	1.8	3.6	3.4	0.5	0.6	0.6	0.7	0.5	0.6
E	1.8	2.3	1.7	2.0	3.2	3.0	0.6	0.9	0.5	0.6	0.5	0.5
L	4.5	5.3	3.5*	3.8*	3.7	4.0	1.6	2.1	1.2	1.2	1.1*	1.2*
P	0.2	0.2	0.4	0.4	0.5	0.5	0.4	0.5	0.7	0.6	1.4	1.2
W	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
Y	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
S	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
M	4.1	2.8	5.1	3.9	6.4	4.7	3.4	2.7	2.5	2.9	2.3	2.9
Q	4.1	3.7	4.9	4.6	4.2	6.0	2.2	3.6	1.5	2.4	1.3	2.2
A	0.7	0.5	0.5	0.4	0.4	0.4	0.6	0.5	0.8	0.8	1.0	1.1
B	1.2	1.0	0.8	0.6	0.8	0.7	0.8	0.7	0.9	0.9	1.3	1.1
G	1.9	2.2	1.6*	1.6*	⌿	⌿	1.9	2.0	1.3	1.5	1.1*	1.4*
X	0.8	0.8	1.2	1.4	1.8	1.8	1.3	1.3	1.3	1.5	0.9	1.0
H	3.8	3.6	3.3*	3.2*	5.1	4.2	1.1	1.2	0.5	0.6	0.6*	0.6*
I	2.8	3.2	3.3	3.7	4.6	4.9	1.1	1.2	0.4	0.5	0.6	0.9
C	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿	⌿
U	2.8	3.9	4.0	5.2	1.0	1.2	0.5	0.6	0.4	0.5	0.5	0.6
O	0.6	0.5	0.8	0.8	0.9	0.8	0.8	0.7	0.9	0.8	1.3	1.4
V	3.0	3.9	4.0	4.9	1.1	2.3	0.6	0.8	0.4	0.6	0.5	0.6

*Vertical receivers facing to side of compartment. In all other tests vertical receivers facing to centre of compartment.

TABLE 5(o)

	HEAT TRANSFER (INTERNAL)					
	Heat flow into walls and ceiling					
	Mean heat flow (cal $cm^{-2}s^{-1}$) over 80/30 period to plaster block in:-			Peak heat flow (cal $cm^{-2}s^{-1}$) to plaster block in:-		
	Rear wall	Side Wall	Ceiling	Rear wall	Side wall	Ceiling
	112	113	114	115	116	117
N	0.23	0.31	0.25	0.40	0.52	0.31
R	0.22	0.19	0.15	0.58	0.59	0.47
J	0.08	0.12	0.11	0.10	0.16	0.12
K	0.07	0.06	0.11	0.10	0.08	0.15
D	⌿	0.15	⌿	⌿	0.17	⌿
F	⌿	0.24	⌿	0.40	0.45	⌿
E	0.27	0.28	0.23	0.38	0.43	0.48
L	⌿	⌿	0.36	0.89	⌿	0.98
P	0.05	0.09	0.08	0.08	0.15	0.10
W	0.80	0.49	0.74	0.96	0.55	0.83
Y	⌿	⌿	⌿	⌿	⌿	⌿
S	0.50	0.42	0.61	0.53	0.47	0.61
M	0.18	0.27	0.26	0.53	0.42	0.39
Q	0.19	⌿	0.16	0.53	0.59	0.39
A	0.10	⌿	⌿	0.12	⌿	⌿
B	0.09	⌿	0.10	0.12	⌿	0.16
G	0.27	0.34	0.27	0.39	0.44	0.42
X	0.19	0.15	0.20	0.27	0.19	0.28
H	0.28	0.32	0.36	0.61	0.53	0.54
I	0.33	⌿	0.40	0.49	0.64	0.53
C	⌿	⌿	⌿	0.52	0.33	0.48
U	⌿	⌿	⌿	0.57	0.56	0.46
O	0.08	0.11	0.09	0.14	0.34	0.18
V	⌿	0.09	⌿	0.83	0.18	0.49

TABLE 5(p)

	HEAT TRANSFER (INTERNAL)					
	Heat flow into walls and ceiling					
	Mean heat flow (cal $cm^{-2}s^{-1}$) over 80/55 and 55/30 periods to plaster blocks in:-					
	Rear wall		Side wall		Ceiling	
	80/55	55/30	80/55	55/30	80/55	55/30
	118	119	120	121	122	123
N	0.25	0.20	0.31	0.31	0.26	0.24
R	0.26	0.19	0.22	0.17	0.16	0.15
J	0.09	0.07	0.15	0.10	0.11	0.11
K	0.08	0.09	0.06	0.06	0.11	0.10
D	⌿	⌿	0.16	0.13	⌿	⌿
F	0.39	⌿	0.26	0.21	⌿	⌿
E	0.29	0.25	0.30	0.26	0.26	0.21
L	⌿	⌿	⌿	⌿	0.46	0.26
P	0.05	0.05	0.12	0.08	0.08	0.08
W	⌿	⌿	⌿	⌿	⌿	⌿
Y	⌿	⌿	⌿	⌿	⌿	⌿
S	⌿	⌿	⌿	⌿	⌿	⌿
M	0.24	0.12	0.28	0.26	0.30	0.21
Q	0.23	0.15	⌿	⌿	0.18	0.14
A	0.10	0.09	⌿	⌿	⌿	⌿
B	0.10	0.09	⌿	⌿	0.11	0.09
G	0.32	0.22	0.40	0.28	0.34	0.22
X	0.23	0.15	0.16	0.13	0.23	0.17
H	0.38	0.15	0.38	0.24	0.41	0.29
I	0.39	0.27	0.30	⌿	0.45	0.36
C	⌿	⌿	⌿	⌿	⌿	⌿
U	⌿	⌿	⌿	⌿	⌿	⌿
O	0.09	0.06	0.13	0.09	0.10	0.08
V	⌿	⌿	0.12	0.07	⌿	⌿

TABLE 5(q)

	COMPOSITION OF COMPARTMENT GASES Percentage by volume (dry basis)											
	Oxygen				Carbon dioxide				Carbon monoxide			
	Mean over 80/30 period		Minimum		Mean over 80/30 period		Maximum		Mean over 80/30 period		Maximum	
	B*	W*	B	W	B	W	B	W	B	W	B	W
	124	125	126	127	128	129	130	131	132	133	134	135
N R												
J K D F E L	6	6.5	3.5	5.5	15.5	15	19.5	17.5	0.1	0.1	0.3	0.3
P												
W Y												
S	≠	13	≠	7	≠	7	≠	13	≠	1	≠	2
M Q												
A B G X	≠	18	≠	17	≠	3.5	≠	4.5	≠	0	≠	0
H	7.5	8	5	7	14	13.5	16.5	14	<0.1	0.3	0.1	0.5
I	7.5	6.5	6.5	4	14.5	14	15.5	15.5	≠	0.6	0	0.9
C	3.5	5	2.5	3	16.5	15.5	18	17.5	4	3	4.5	4.5
U	6.5	3	3.5	2.5	13	17.5	16	20	2.5	5	3.5	5
O												
V	5	1.6	0.4	1.5	15.5	18.5	19.2	19.5	1.5	2	3.5	3.5

*B = Sampling point 12 cm from beam

*W = Sampling point 60 cm from beam

TABLE 5(r)

	COMPOSITION OF COMPARTMENT GASES Percentage by volume (dry basis)							
	Hydrogen				Methane			
	Mean over 80/30 period		Maximum		Mean over 80/30 period		Maximum	
	B	W	B	W	B	W	B	W
	136	137	138	139	140	141	142	143
N R								
J K D F E L	 0	 0	 0	 0	 0	 0	 0.1	 0.1
P								
W Y								
S	⌿	0.9	⌿	1.7	⌿	0.3	⌿	0.6
M Q								
A B G X H I C U	⌿ 0 0 3 2	0 0 0 1.5 1.5	⌿ 0 0 4.5 3.5	0 0 0 3 3.5	⌿ 0 0 0.8 0.3	0 0 0 0.7 0.2	⌿ 0 0 1.0 0.6	0 0.1 0.2 1.0 0.7
O								
V	0.2	1.2	0.6	2.5	0.2	0.3	0.8	0.6

KEY TO EXPERIMENTAL CONDITIONS

Test code	Fire load density (wood equivalent) (kg/m²)	Fire load (wood equivalent) (kg)	Compartment lining	Fuel	Ventilation opening area (m²)
N 14	30	872	None	18 wood cribs	11.1
R 18	30	872	Mineral wool		
J 7	7.5	218	None	8 wood cribs	
K 12	7.5	218			
D 2	15	436			
F 10	30	872			
E 11	30	872			
L 6	60	1744			
P 16	7.5	218	Mineral wool		
W 23	7.5	218	None	Petrol	
Y 24	7.5	218		Kerosene	
S 21	7.5	218	Fibre insulation board		5.6
M 15	30	872	None	18 wood cribs	
Q 19	30	872	Mineral wool		
A 3	7.5	218	None	8 wood cribs	
B 4	7.5	218			
G 8	15	436			
X 22	15	436			
H 9	30	872			
I 13	30	872			
C 5	60	1744			
U 20	60	1744			
O 17	7.5	218	Mineral wool		
V 25	60	1744	None		2.6

Table 6

Flame conditions during the tests

Fire load density kg/m²	Fuel	Window opening	Test	Approximate period of largest flames min	Flame conditions during period of largest flames
7.5	8 wood cribs	¼	A B	6 - 10 3 - 8	Flames from each crib separated. Flame height 1-1½ m above floor.
			O	3½ - 7½	
		½	J	4 - 7	
			K P	2 - 5 2 - 4	
	Fibre insulation board lining	¼	S	1¾ - 5	Massive merged flame in compartment flowing out of one or other or both window openings to a height usually of 1-3m above the top of the opening. At 4½ min a burst of flame at least 4 m above the top of the opening was produced.
	Petrol	½	W	¾ - 3	Massive merged flame in compartment flowing out of west window (and not east) to a height of about 3 m above the top of window opening. A height of 4-5 m was reached for a short period at 1½ min.
	Kerosene	½	Y	2 - 5½	Massive merged flame in compartment flowing out of east window (and not west) to a height of 2-4 m above the top of the window opening.
15	8 wood cribs	¼	G	9 - 14	Some merging between flames from cribs. Flames from side and rear cribs reaching ceiling. Small flames occasionally licking out of window.
			X	8½ - 20	Little merging between flames from cribs. Flame height up to 2-2½ m above floor.
	8 wood cribs	½	D	-	Some merging between flames from cribs. Flames from rear cribs just reaching ceiling. No flame emerging from window.

Table 6 (cont'd)

Fire load density kg/m^2	Fuel	Window opening	Test	Approximate period of largest flames min	Flame conditions during period of largest flames
30	8 wood cribs	$\frac{1}{4}$	H I	10 - 16 $9\frac{1}{2}$ - 13	Massive merged flame in compartment, flowing out of both window openings to a height of 1-3 m above the top of the window opening.
	18 wood cribs	$\frac{1}{4}$	M	10 - $17\frac{1}{2}$	
			Q	9 - $13\frac{1}{2}$	As tests H, I and M but flames reaching a height of 2-3m above the top of both window openings.
	8 wood cribs	$\frac{1}{2}$	F E	10 - 14 10 - 16	Massive merged flame in compartment flowing out of one or other (but usually not both) window openings to a height of 1-2 m above the top of the window opening.
	18 wood cribs	$\frac{1}{2}$	N	$12\frac{1}{2}$ - $17\frac{1}{2}$	
			R	$6\frac{1}{2}$ - 17	As tests F, E and N but flames reaching a height of 1-3 m above the top of one window opening.
60	8 wood cribs	$\frac{1}{8}$	V	22 - 34	Large flames inside compartment confined to region near window. Flame emerging from both window openings to heights of $1\frac{1}{2}$-2 m above the top of the window opening.
		$\frac{1}{4}$	C U	$15\frac{1}{2}$ - 35 $11\frac{1}{2}$ - 24	Massive merged flame in compartment flowing out of both window openings to heights of 2-3 m above top of window opening
		$\frac{1}{2}$	L	$12\frac{1}{2}$ - 19	Massive merged flame in compartment flowing continuously out of the east window opening and intermittently out of the west window opening to a height of 2-3 m above the top of the window opening.

Table 7

Observations during test S

Time from first ignition min	s	Observation
1	8	Ceiling ignited.
1	13	Flames out of window.
1	33	Flashover.
2	45	Flames dying down.
3	30	Flames still thinning.
4	00	Fire increasing in intensity.
4	15	Sudden increase in flaming.
4	45	Small pieces of fibre insulation board lining falling.
5	00	Dying down.
5	30	Flaming only in very small areas.
6	15	Most of remains of fuel still in position and glowing. A few flashes of flame round the edges of the sheets.

Table 8

Temperature rises recorded by suction pyrometer and unshielded thermocouples

Test	Time from ignition (min)	Temperature rise (deg C)							Height of suction pyrometer above top of crib (cm)
		Thermocouples in gases				Wall or ceiling surface			
		Suction pyrometer	Unshielded thermo-couple near suction pyrometer	Mean of upper and lower unshielded thermo-couples on east side (S_5 and S_6)	Mean of all 6 internal unshielded thermo-couples (S_1 to S_6)	Rear wall	Side wall	Ceiling (Surface of plaster block)	
R	10	1025	1055	905	800			840	60
	15	885	1020	805	660			760	
	20	530	795	725	605			735	
	25	235	580	555	475			620	
	30	–	460	430	375			540	
	35	75	320	355	305			490	
J	12.5	415	295	190	225	170	215	190	35
	15	170	120	130	175	160	200	195	
K	10	197	245	240	220	135	130	245	60
	12.5	140	235	215	215	145	130	255	
D	7.5	915	815	485	450				~ 40
	10	940	780	470	445				
F	10	1025	1045	800	785	610	595	–	30
	15	1025	965	765	745	650	665	–	
E	10.5	1070	855	740	730	680	605	640	80
	19.2	885	815	625	640	700	625	675	

Table 8 (cont'd)

L	13	830	965	1030	1030	610	855	905	30
P	10 15 20 25 30	195 275 110 60 30	220 295 170 120 100	235 260 195 165 125	290 270 220 170 140			335 340 325 300 270	65
Q	10 15 20 25 30 35	1025 980 1115 740 440 95	930 980 1135 940 720 555	990 985 1060 935 750 600	1040 1030 1010 870 700 575		1070 990 890 815 685 665	1035 1005 965 905 785 655	60
G	10 12.5	860 920	840 890	700 680	685 670	545 545	625 680	535 530	30
X	10 15 20 25 30	650 575 525 340 225	625 580 650 415 330	490 555 515 460 400	535 575 545 470 400	405 445 450 410 380	390 540 550 480 430	430 480 485 445 420	30
H	10 15 20 25 30	935 1115 935 740 375	1070 1070 990 720 530	1025 1050 990 795 645	1000 1010 925 755 610	945 810 720 710 750	965 1010 980 810 670	885 930 905 775 670	35
I	10 15 20 25 30 35 40	1105 1170 1025 675 530 400 225	1045 1110 930 755 625 485 390	1025 1065 980 790 630 515 410	1010 1035 950 780 630 510 430				100

Table 8 (cont'd)

C	18.5 20 30	940 1010 1010	915 1045 1135	1020 1020 1095	885 1010 920	830 895 $\not{-}$	540 645 $\not{-}$	$\not{-}$ $\not{-}$ $\not{-}$	50
U	10 15 20 25 30 40 50 60	840 840 1025 $\not{-}$ 1070 640 360 385	855 965 1095 1150 1175 965 720 520	925 990 1075 1115 1135 970 765 565	965 1040 1095 1145 1140 955 725 545	825 800 $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$	710 870 $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$	780 855 990 $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$ $\not{-}$	65
O	10 15 20 25 30	485 425 330 205 85	475 400 390 260 195	380 345 330 265 215	415 375 350 270 215			405 385 365 325 280	65
V	10 20 30 40 50 60 70 80 90	660 775 905 1110 770 715 475 430 215	825 905 1010 1230 1025 960 790 745 520	840 970 1075 1155 1060 990 865 745 605	820 765 920 1040 1060 1000 900 735 605	820 985 980 $\not{-}$ 820 770 725 655 575	530 700 850 890 915 970 820 705 625	695 870 925 955 940 930 865 775 660	40

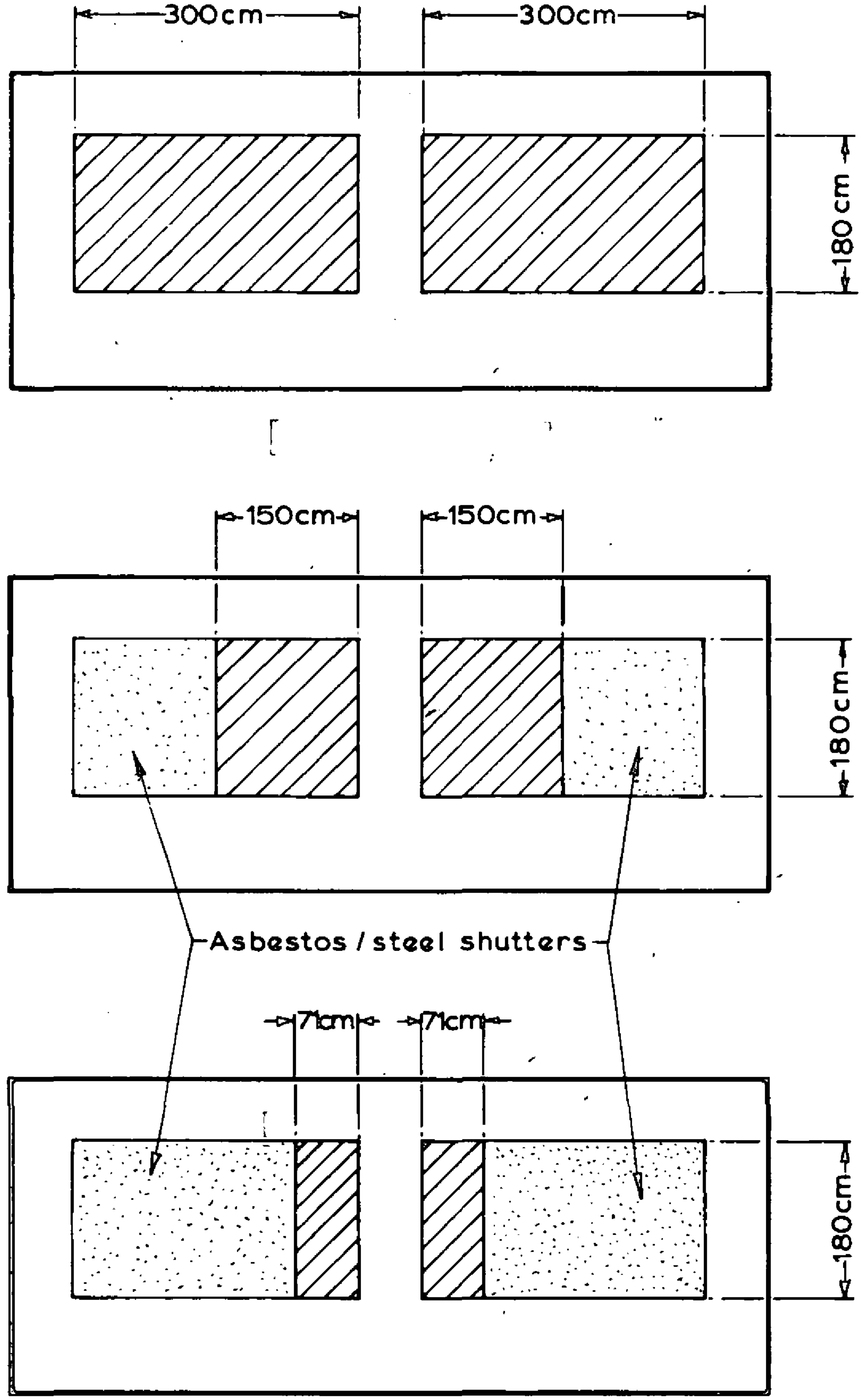
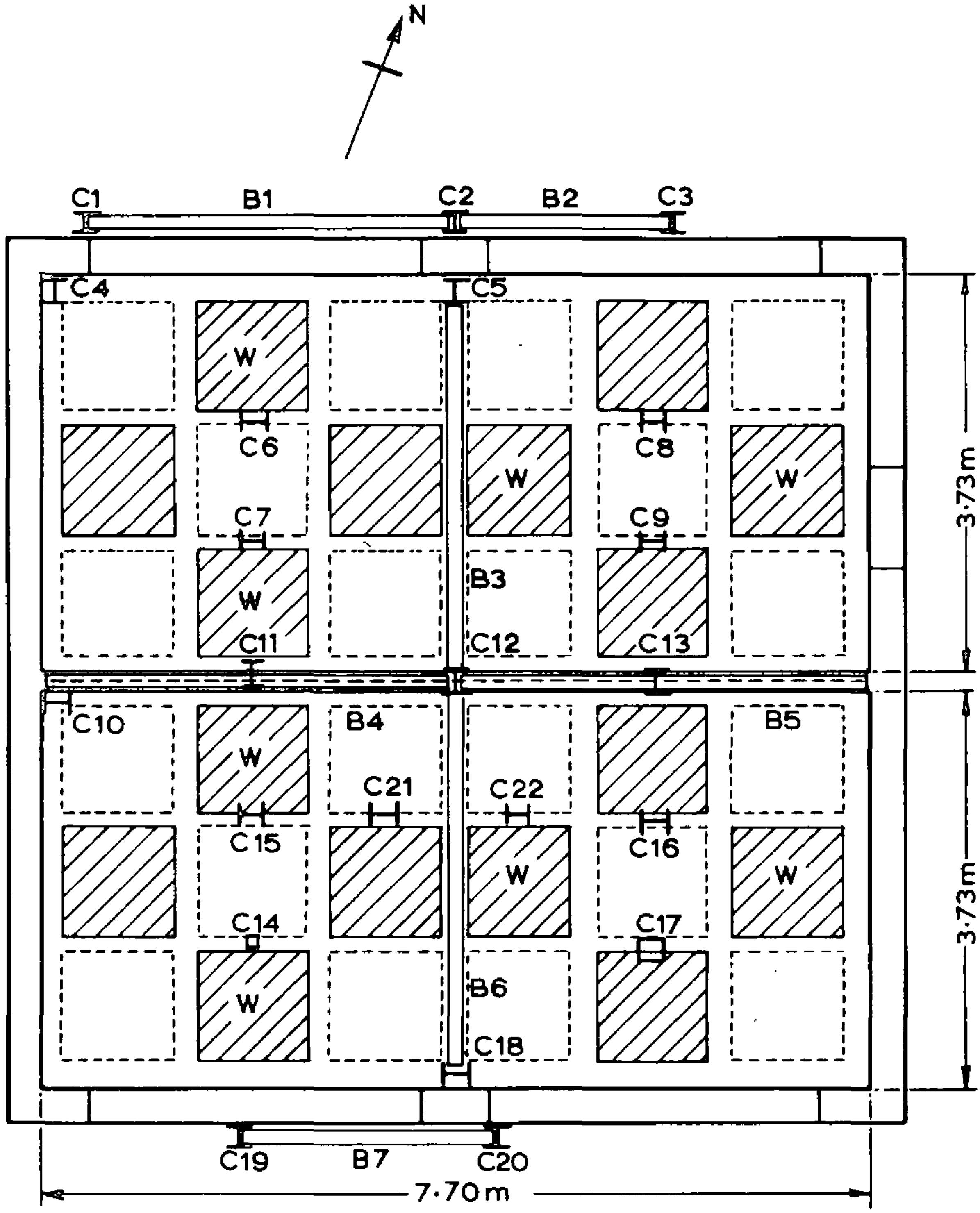


FIG.1. VENTILATION OPENINGS USED IN TEST SERIES

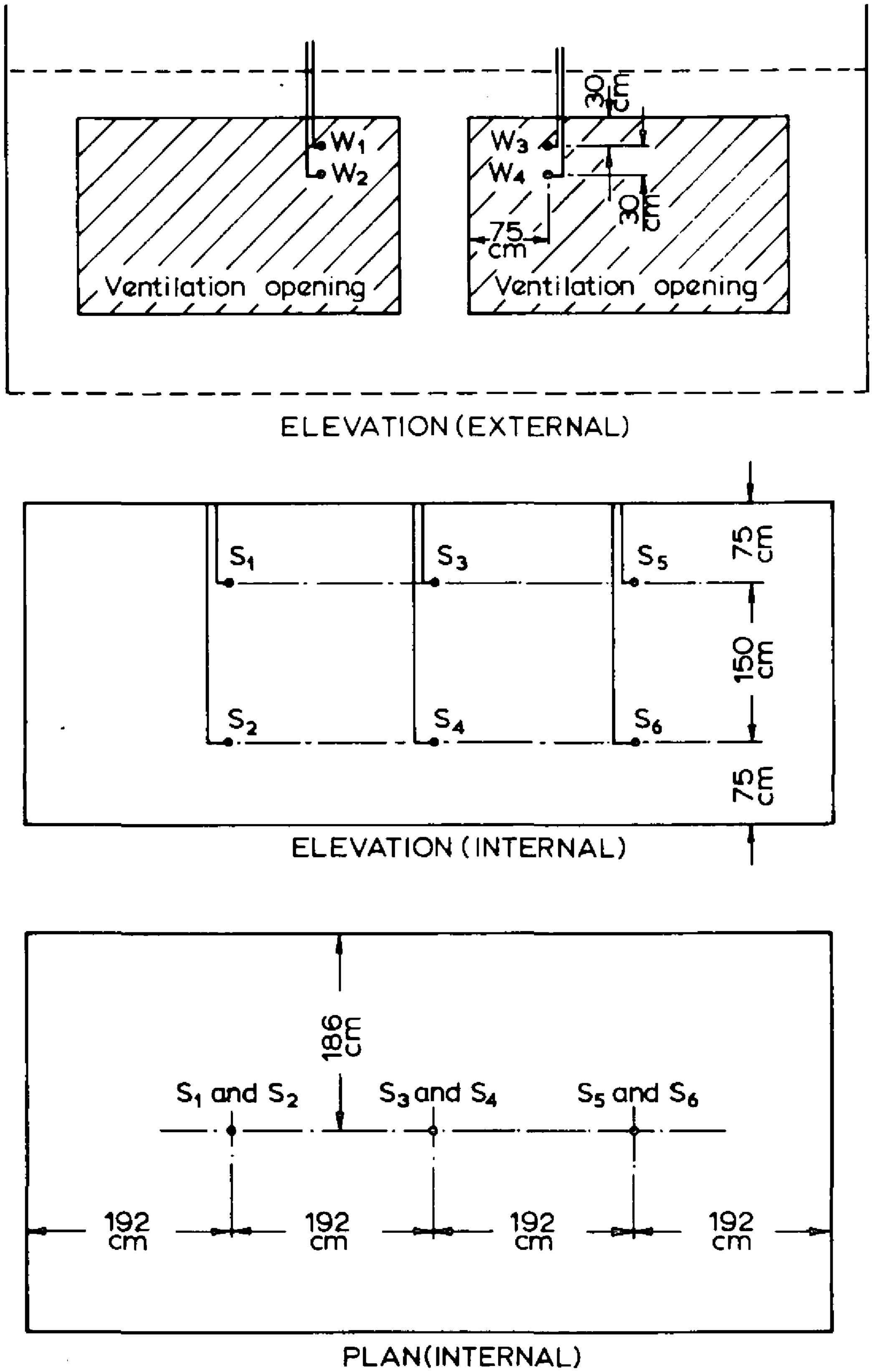
1/7439 F.R. 646



PLAN

Hatched areas indicate position of cribs in tests using 8 cribs
Dotted lines indicate positions of extra cribs in tests using 18 cribs
W indicates crib on weighing platform

FIG.2. ARRANGEMENT OF CRIBS AND STEELWORK



W_1 to W_4 — Thermocouples in plane of ventilation opening
In test V they were at the same height but were moved to one side to bring them into the centre of the ventilation openings

S_1 to S_6 — Thermocouples suspended within compartment

1/7441 F.R. 646

FIG. 3. POSITIONING OF THERMOCOUPLES WITHIN COMPARTMENT

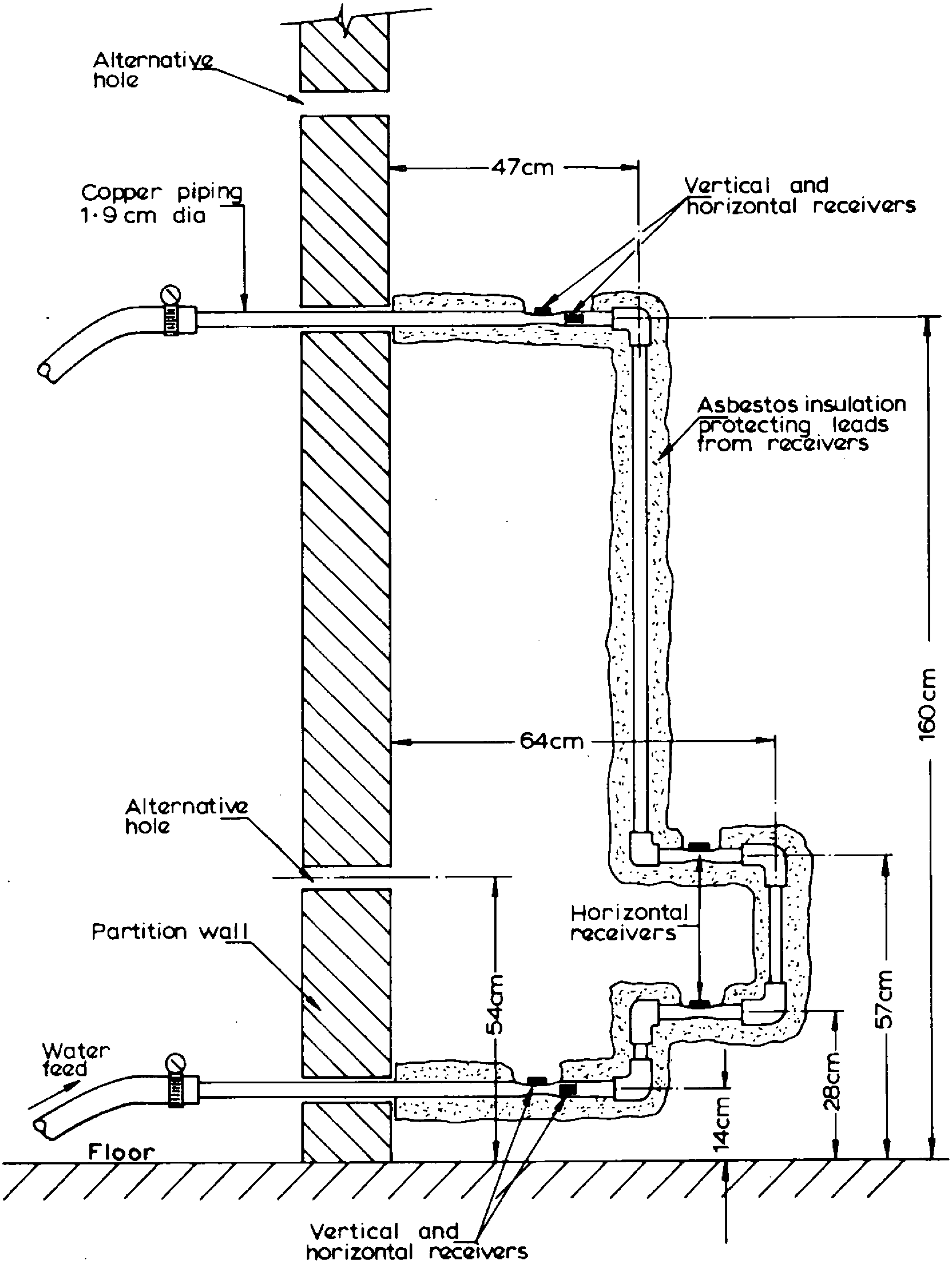


FIG. 4. STEPPED PIPE SHOWING POSITIONS OF HEAT-FLUX RECEIVERS

1/7443 F.R. 646

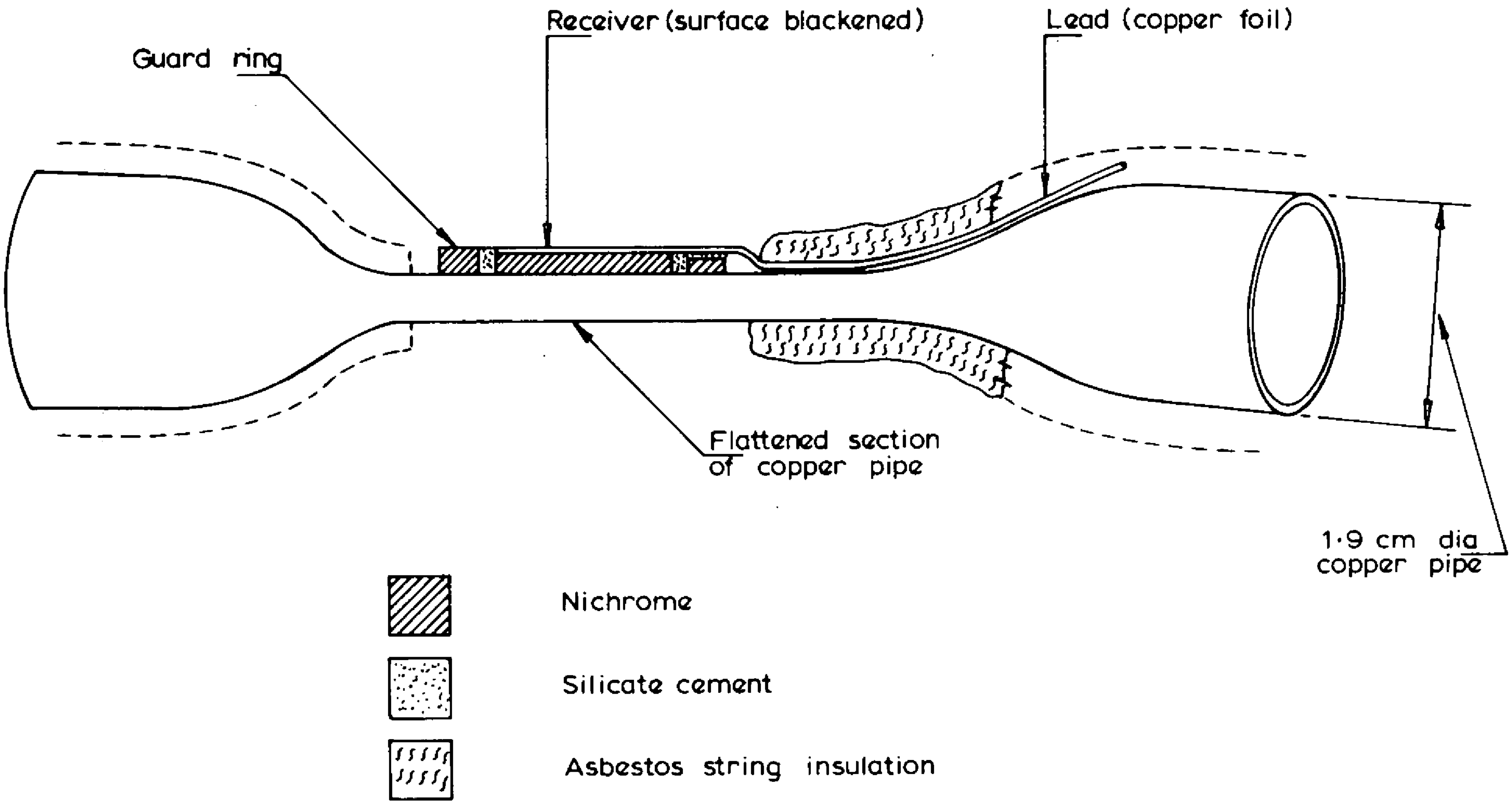


FIG. 5. SCHEMATIC DIAGRAM OF RECEIVER MEASURING HEAT FLOW TO WATER-FILLED TUBE

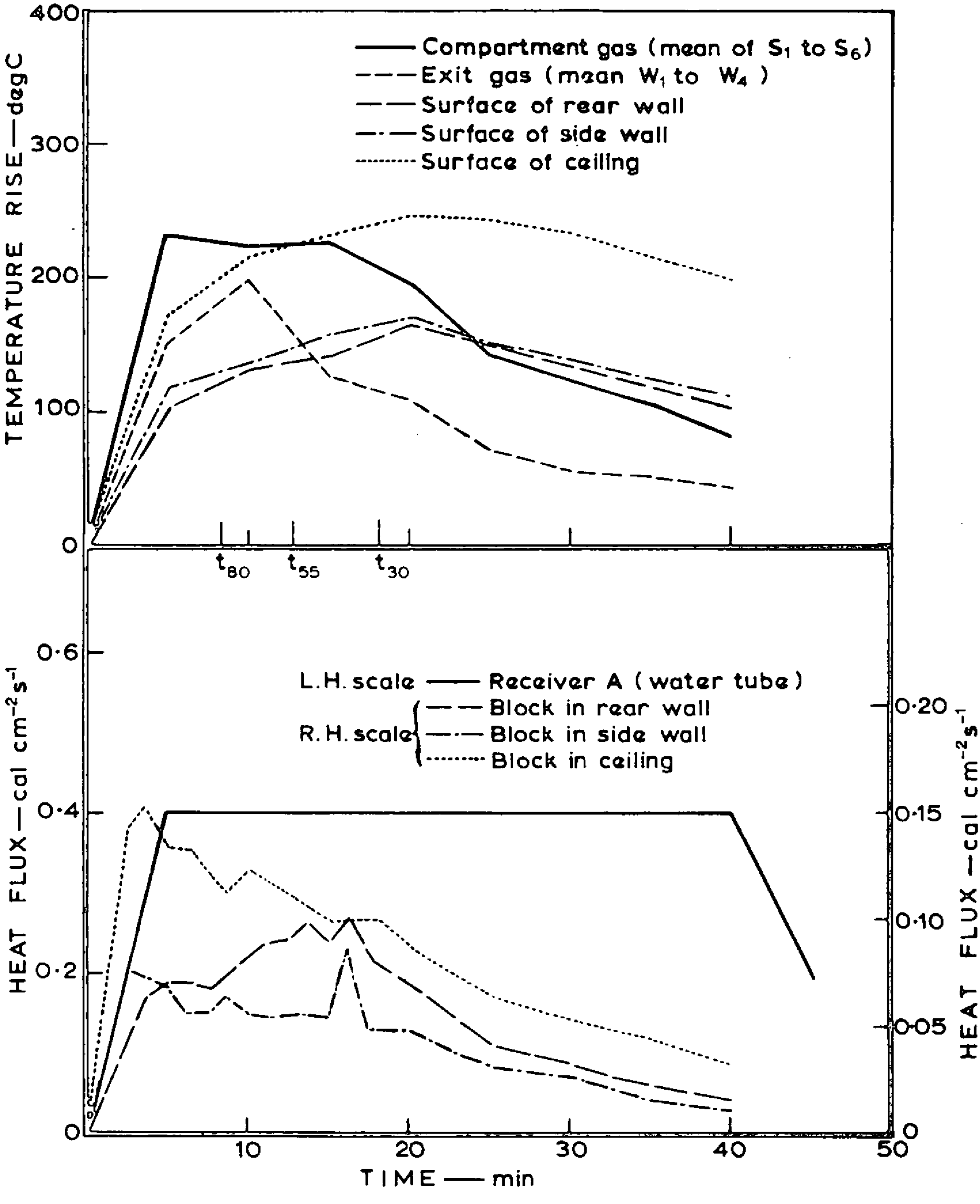


FIG. 6a. SELECTED DATA FOR TEST K (7·5kg/m^2; ½WINDOW)

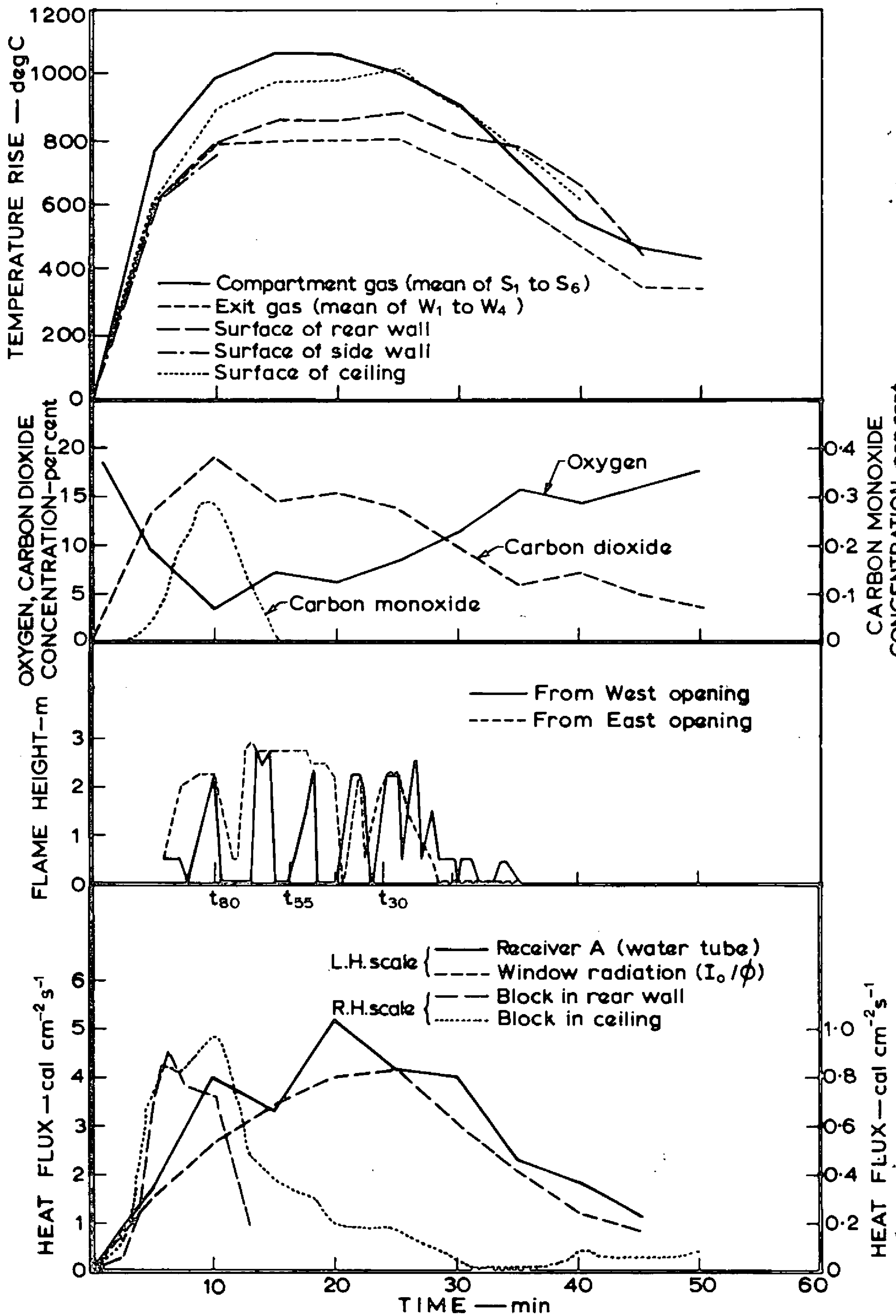


FIG. 6 b. SELECTED DATA FOR TEST L (60 kg/m², ½ WINDOW)

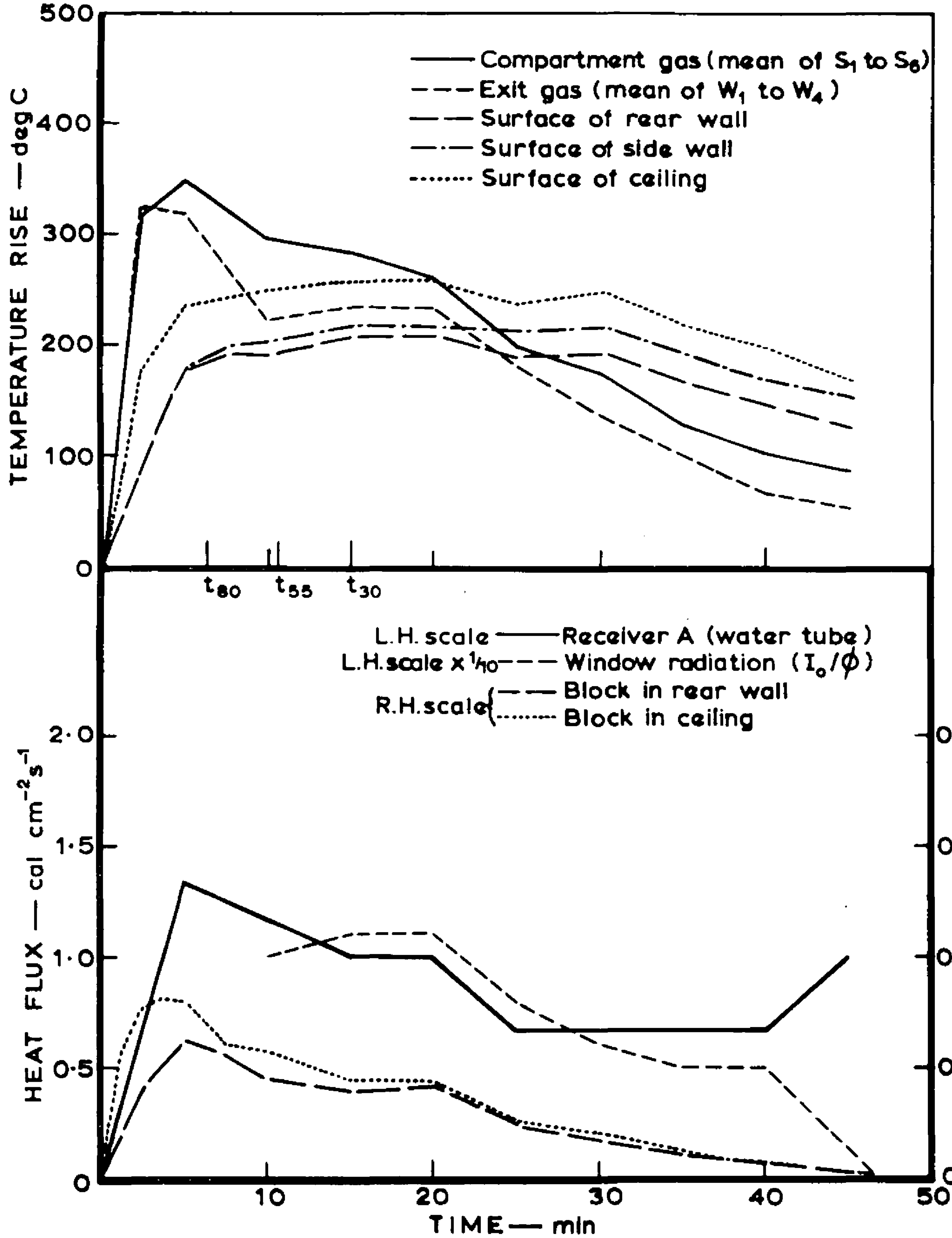


FIG. 6c. SELECTED DATA FOR TEST B (7·5 kg/m^2, ¼ WINDOW)

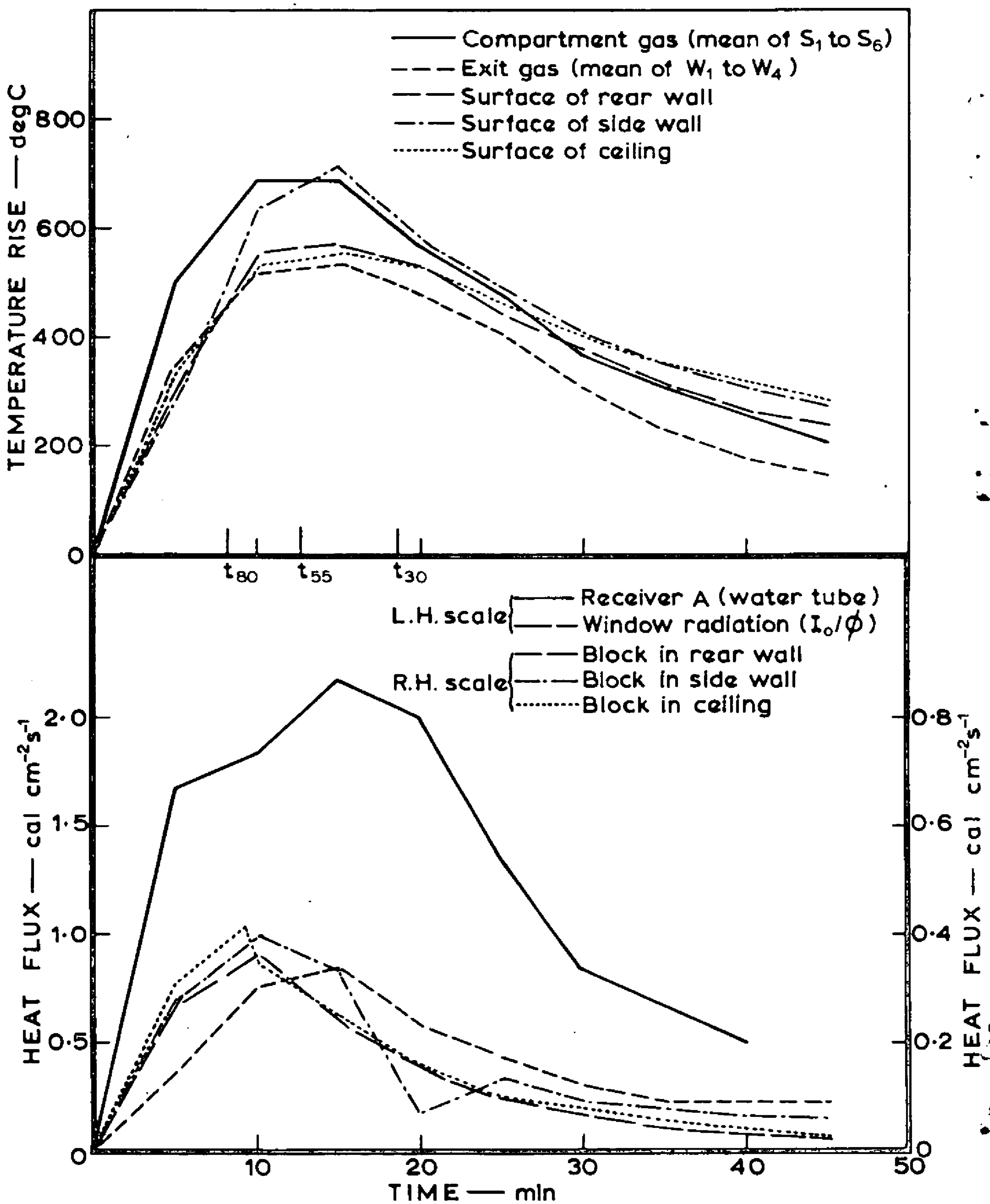


FIG. 6d. SELECTED DATA FOR TEST G (15 kg/m², ¼ WINDOW)

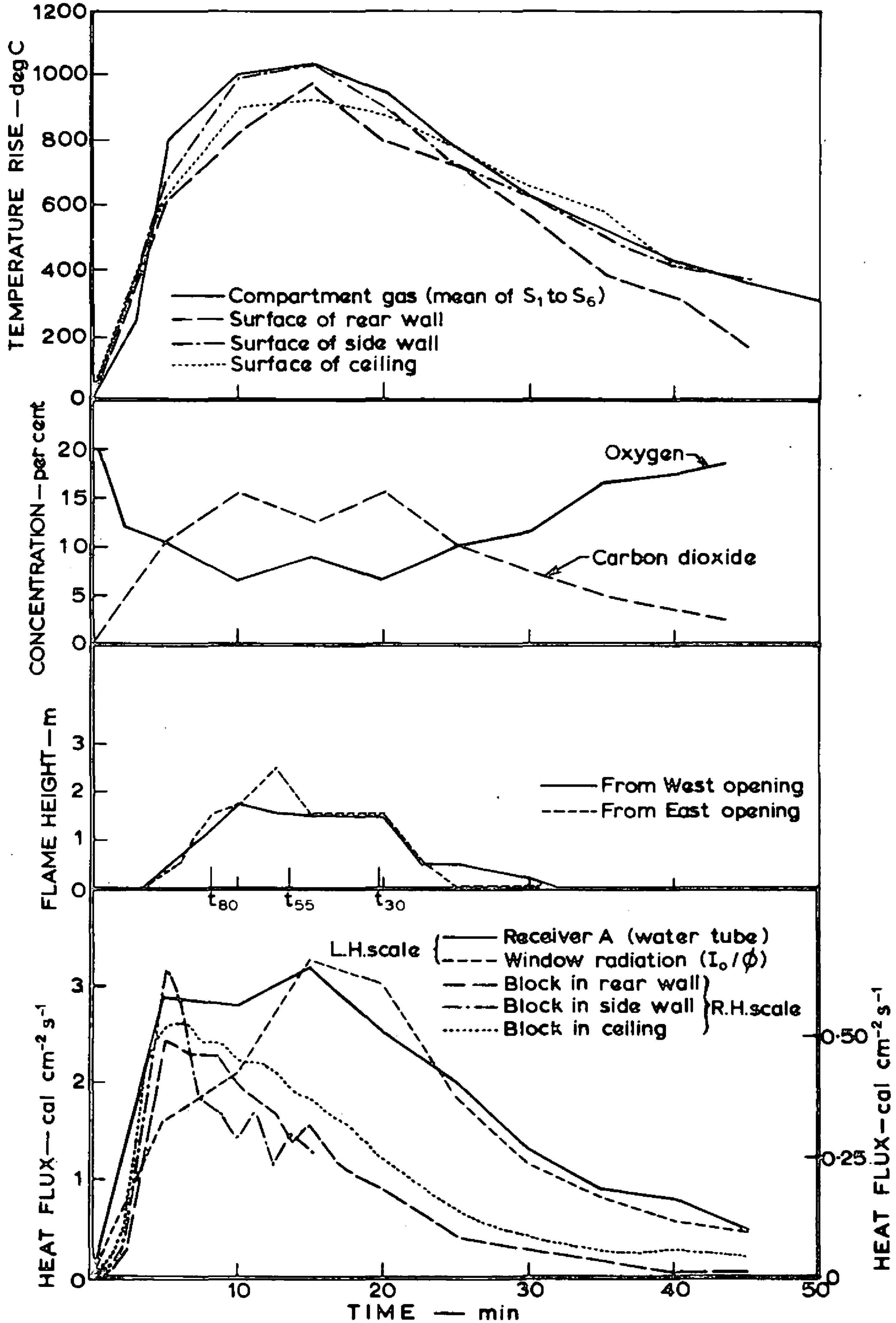


FIG.6e. SELECTED DATA FOR TEST I (30kg/m^2, ¼ WINDOW)

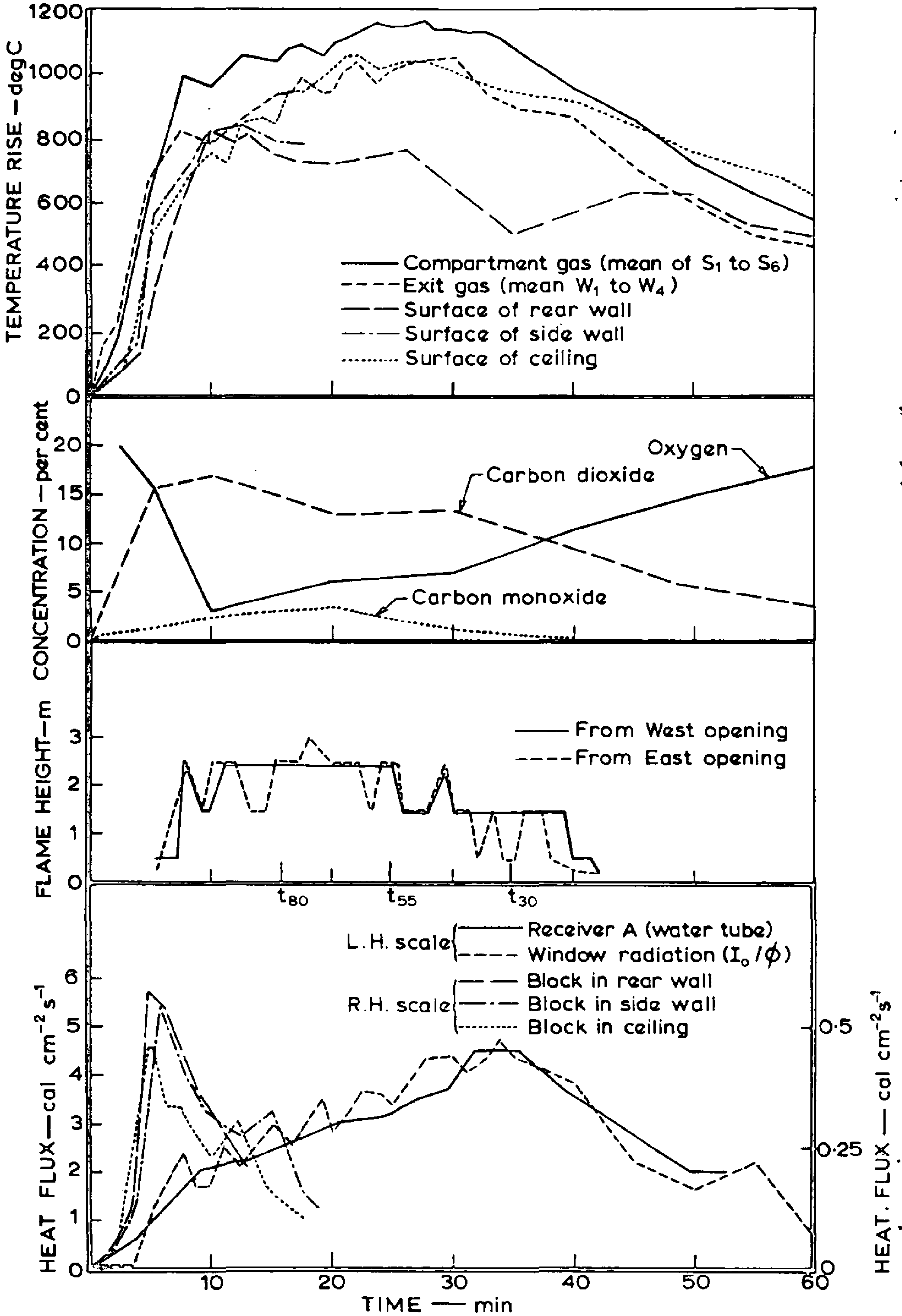


FIG.6f. SELECTED DATA FOR TEST U (60 kg/m², ¼ WINDOW)

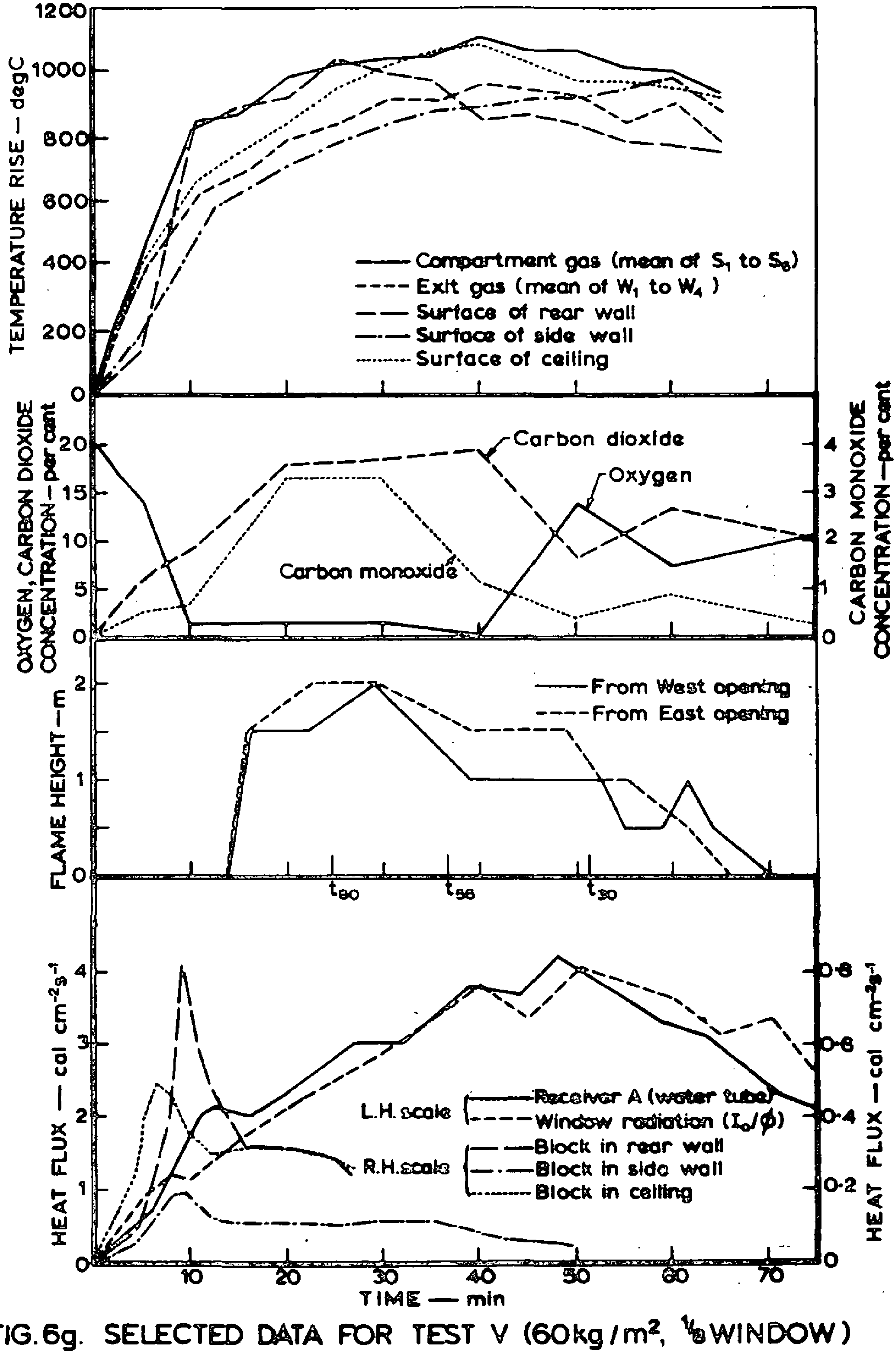


FIG. 6g. SELECTED DATA FOR TEST V (60 kg/m², 1/8 WINDOW)

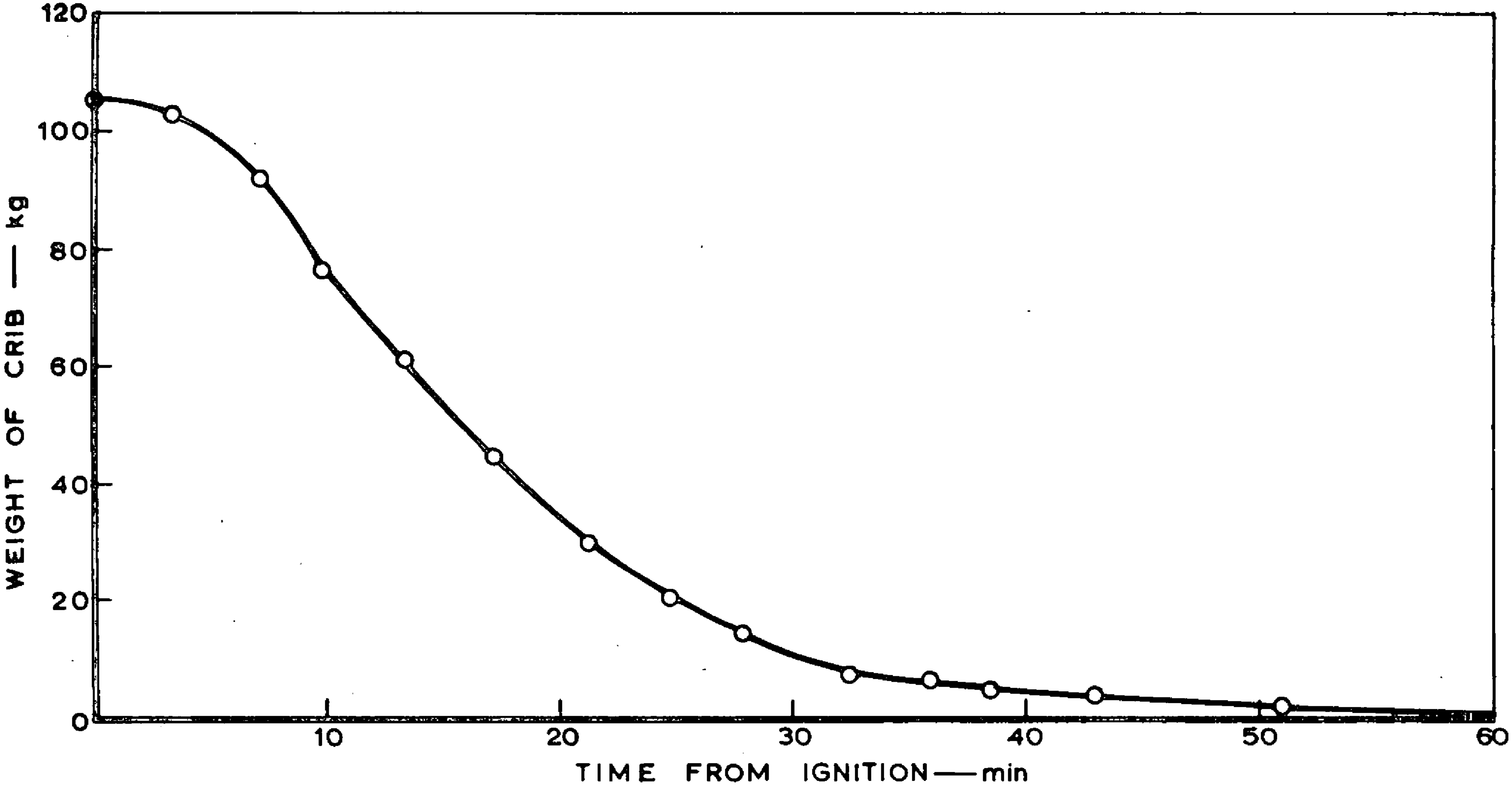
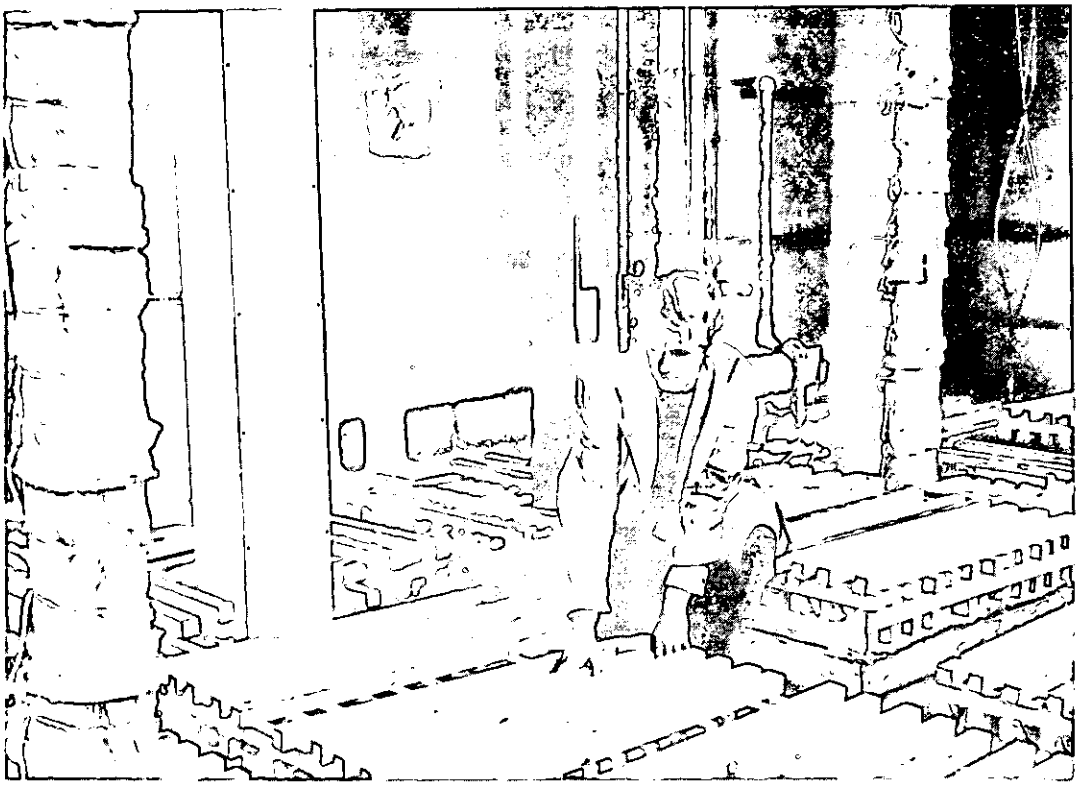


FIG. 7. VARIATION WITH TIME OF WEIGHT OF ONE CRIB (TEST F)

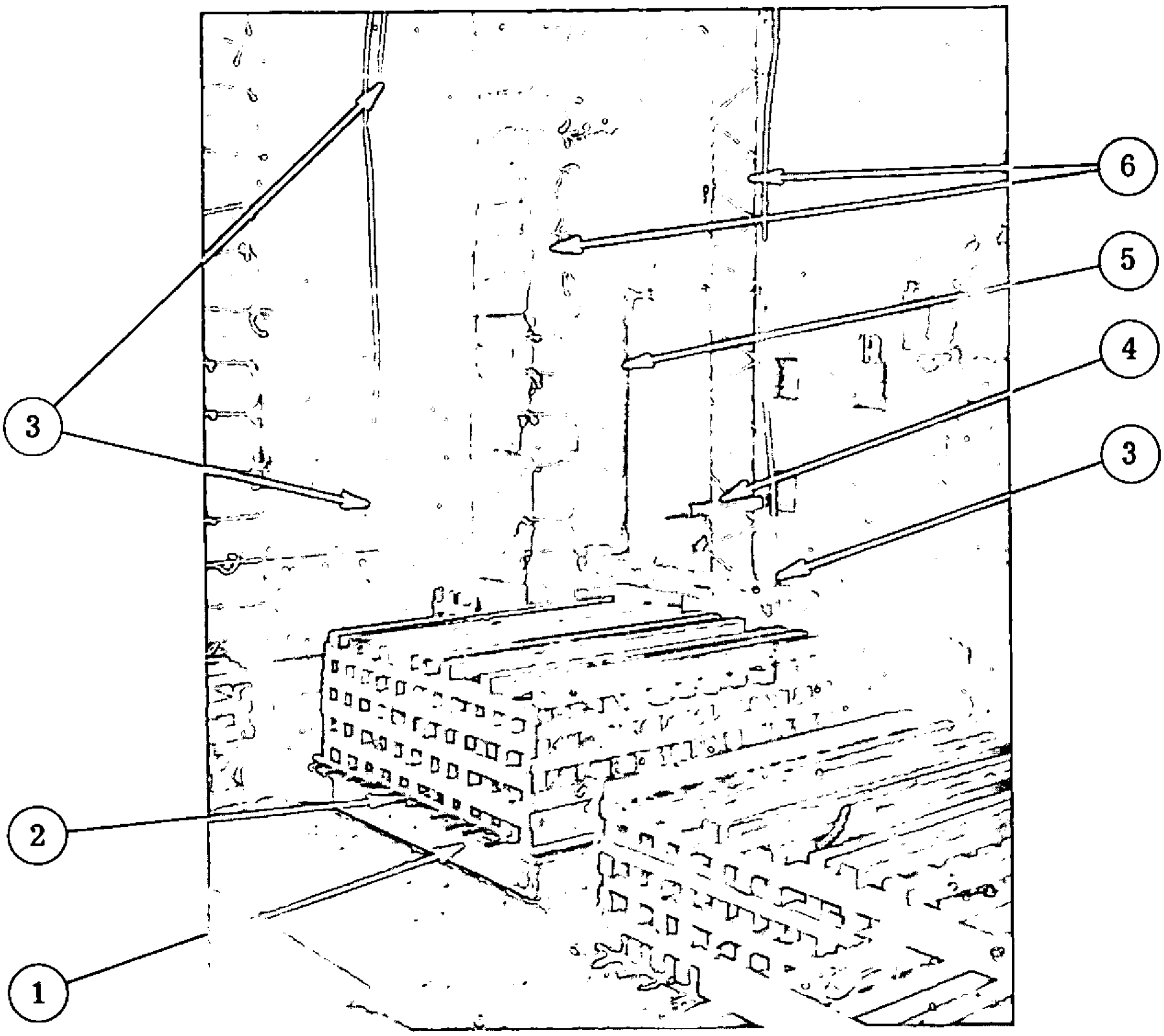


SOUTH COMPARTMENT BEFORE TEST R
(Fire Load Density 30 kg/m^2)

Note: (1) Mineral Fibre insulation on walls (Tests O, P, Q, R)

(2) Layout of 18 cribs (Tests M, N, Q, R.)

PLATE I



NORTH COMPARTMENT BEFORE TEST F
(Fire Load Density 30 kg/m^2)

1. Weighing platform
2. Strips for igniting fire load
3. Thermocouples for measuring gas temperature
4. Suction pyrometer
5. Pipe with heat flow receivers
6. Protected steelwork

PLATE II