Fire Research Note No.889

SMOKE TESTS IN NEW LAW COURTS BUILDING

by

E. G. BUTCHER Fire Research Station

and

MAURICE HALL Directorate of Building Development
Department of the Environment

September 1971

FIRE RESEARCH STATION

F.R.Note No. 889
September 1971

SMOKE TESTS IN NEW LAW COURTS BUILDING

by

E. G. Butcher Fire Research Station

and

Maurice Hall Directorate of Building Development
Department of the Environment

SUMMARY

The system of pressurization which forms part of the smoke control arrangements in the New Law Courts Building is described. The results of smoke tests carried out in the building show that the pressurization not only prevents smoke penetrating to the two staircases but also acts to clear smoke which has been allowed to penetrate into the lobbies.

KEY WORDS: Building, pressurization, smoke, test

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

F.R.Note No. 889
September 1971

SMOKE TESTS IN NEW LAW COURTS BUILDING

by

E. G. Butcher Fire Research Station

and

Maurice Hall Directorate of Building Development
Department of the Environment

(a) The Building
(b) The Pressurization
(c) The Smoke Tests
(d) The Test Results
(e) Discussion

INTRODUCTION

This new building has been erected on a very small site which called for special requirements, namely, to build to a height of about 120 ft and to use the whole perimeter for useful accommodation, with stairs and services in a core. The stairs could not therefore be fenestrated.

This paper is concerned with the measures adopted by the D.O.E. design team to keep the escape routes, particularly the stairs and lobbies, useable at all times in the event of fire by the exclusion of smoke and products of combustion.

(a) The Building

A floor plan of the building is shown in Fig.1. It is built of reinforced concrete with twelve floors above the ground. Floors 1-10 are offices, 11 is a restaurant and the top floor is occupied by the plant which supplies the services to the building. In plan the building is 75 ft square. The central core, which is approximately 30 ft square and contains two staircases and three lifts, is surrounded by a corridor (5 ft wide) on each floor and the office accommodation opens on to this. The part of the corridor which leads to each staircase is formed into a lobby by suitably placed double swing doors.

(b) The Pressurizing System

The two staircases are of the scissor variety so that each stair opens to the east and to the west alternately from floor to floor.

A single duct is therefore able to serve both staircases at alternate landings. As explained below, twin ducts are in fact provided adjacent to each other, one supplying "normal air" (marked 7 on Plan) and one

"fire air" (marked 6 on Plan).

Smoke from a fire would be excluded from the stair so long as its atmosphere were maintained at a higher pressure than that in adjoining circulation spaces and accommodation. The degree of protection would depend on the excess pressure provided.

The pressurization is in two stages. A low excess pressure maintained on the staircase continuously forms part of the total ventilation system for the building and also gives a limited degree of protection. When a fire alarm is given this excess is boosted to a higher level by bringing to operation emergency fans.

The design requirement was for air to be introduced into each staircase on alternate landings from the structural ducts marked 'Air' (7 on plan) and 'Fire Air' (6 on plan). During office hours under normal conditions the staircase would be maintained at an excess pressure of 0.75 mm (0.03 inch) water gauge by a warm air supply from a fan (rated at 71 m^3/min 2500 ft^3/min) in the basement plant room. In case of fire the excess pressure would be increased to 2.5 mm (0.1 inch) water gauge by a cold air supply from an additional fan which has a duty rating of 850 m^3/min (30,000 ft^3/min). This rate of air supply was designed to be sufficient to maintain the 2.5 mm w.g. excess pressure in each stairwell even if one door were held open.

The corridor and lobby system surrounding the centre core which are shown on the plan applies to all floors above the ground floor. Under normal conditions the offices or other rooms which open out of this corridor are heated or cooled by air supplied from a high velocity system which gives a slight excess pressure. The air inlets are round the perimeter of the building. In the event of fire the air supply is cut off but because of the small diameter of the duct work it was thought to be unlikely that smoke would spread through the building by this means,

Excess air leaves by grilles in ceiling voids over the corridors and ultimately through a duct (5 on plan) which is part of the normal system of toilet ventilation. This arrangement is not intended to provide specifically for smoke removal (which would require very high capacity ducts and fans) but, in conjunction with the pressurized stair it should ensure that the drift will be away from the corridor and staircases so that smoke will not seep past the doors of the rooms.

In the lift corridor, adjacent to the lift doors smoke extract grilles in the ceiling connect by independent horizontal metal ducting (in the ceiling void) to vertical structural ducts (1 and 2 on plan). These have extract fans rated at 613 m^3/min (6,600 ft^3/min) situated at roof level. The other leg of the corridor and the two lobbies which lead to the staircases have no mechanical extract system. The kitchen ventilation on the eleventh floor is by a separate mechanical system.

The goods-firemans lift serves alternate landings, which are the same landings as those supplied by the air ducts. Thus fresh air is available near each lift door on all floors above the ground floor.

The staircase doors open inwards and close against rebated frames except at the base of the stairs where the normal double swing type doors are fitted.

(c) The Smoke Tests

In order to assess the effectiveness of the pressurization system as a smoke control measure a series of tests were carried out in the building.

For this purpose smoke was produced from a smoke generator in one of the office rooms on the third floor. This room, marked on the plan, opened onto the corridor which did not contain the lifts and therefore had no extract system. The smoke was produced by burning cellulosic (wood shavings, fibre board cuttings) materials with some pieces of polystyrene foam in a container in which the air supply is restricted. The resultant smoke is therefore hot, but not as hot as that which comes from a fully developed fire. The temperature of the smoke at one point inside the smoke room and at another outside was measured. The density of the smoke was measured by six smoke meters. These were situated as follows:

(1) Inside the smoke room
(2) In corridor immediately outside smoke room door
(3) Inside lobby nearest to smoke room
(4) Inside staircase on landing immediately adjacent to lobby mentioned in (3) above
(5) Inside lobby remote from smoke room
(6) Inside staircase adjacent to lobby of (5) above

All of these smoke meters were placed at head height, ie approximately 2 metres (6 ft) from the floor, and the two thermocouples for measuring the smoke temperature were fixed to meters 1 and 2. Visibility observations were

also made using black letters (C) 100 mm (4 in) high on white card placed in position indicated on Fig.1. In addition air flow measurements were made at each supply grille in the two staircases and pressure differential measurements were made across the staircase and lobby doors in selected positions.

Three smoke tests were carried out. These were:

Test 1. No fans operating, ie no 'normal air' or 'fire air' supplied to the staircases, no air input or extraction in the office accommodation. All doors to the staircases and lobbies were closed on all floors, initially the door between the smoke room and corridor was closed but was opened 5 minutes after starting the test.

Test 2. Fans operating for normal conditions, ie 'normal air' supplied to staircases, air input and extraction to office accommodation operating. Initially all doors to the staircases and lobbies on all floors were closed but some were opened during the test as noted. Door between smoke room and corridor open.

Test 3. Fans operating for emergency conditions, ie 'normal air' and 'fire air' supplied to staircases, no air supply or extraction in the office accommodation. All doors to staircases and lobbies on all floors closed during test but some were opened during test as noted. Door between smoke room and corridor open. Smoke level increased at end of test by using a smoke candle.

(d) Test Results

The results of the measurements of air flows and of pressure differentials are given in Tables 1 to 4. Table 1 is for the fans operating normally and Tables 2-4 related to the emergency conditions.

Table 2 shows the pressure differential developed across the staircase door on each floor when all the stair doors were closed. Table 3 shows the differential across the same doors when a door on an adjacent landing was open but all the lobby doors were closed and Table 4 shows the effect on these pressure differentials when a lobby door associated with the open door was also opened.

Table 5, 6 and 7 are records of observations taken during each of the three tests recorded in log form and the readings of the smoke meters in the corridor outside the smoke room, in the lobby and staircase nearest to the

smoke room are shown in Figs 2-4.

(e) Discussion of Test Results

(1) The natural air movement in the building when no part of the ventilating plant was operating was such that there was a small flow of air from the staircase to the rest of the building. This was presumably dictated by the weather conditions prevailing and by the inside/outside temperature conditions. The result of this was that it was not possible to show whether or not, without any fans operating the lobby doors alone afford protection.

Nevertheless it would be wrong to assume that this condition would always obtain, since certain natural conditions could apply which might result in smoke logging of the staircases and the lobbies if no ventilating fans were operating.

(2) The measurements of air flow and pressure differential show the extent to which the design criteria have been achieved but it must be realized that accurate measurement of these quantities, particularly of the air flow, is extremely difficult under the conditions which obtain in a test such as that described here.

(3) A comparison between the smoke meter records for Tests 1 and 2 show that there is only a very small difference between the smoke penetration to the lobby and staircase in the two tests until the office supply and extract system was switched on in Test 2 fifteen and half minutes after the start, (in Test 1 the office air supply was 'off' for the whole test). It must however be realized in comparing the smoke records for the two tests that in Test 2 the door to staircase and lobby was opened very frequently as part of a demonstration and this condition did not apply to Test 1.

(4) The degree of protection provided by the small excess pressure due to the 'normal air' supplied to the staircases was not properly demonstrated, because of the ambient conditions which prevailed at the time of the test.

(5) The smoke meter records for Test 3 show clearly that the 'fire air' supply to the stairs,which exceeded design requirements,was very effective in removing the smoke which had been deliberately allowed to enter the lobby and stair during the period 9 to 18 minutes after the start of the test. The large obscuration at 25 minutes on the staircase smoke meter is attributed to a spectator standing in the meter light beam.

(6) The penetration of smoke from the smoke room to the further corridor (Test No 3) was due mainly to the fact that the smoke room door was open throughout the test and to the constant opening of lobby doors by the fifty

or so visitors. It may also have been aggravated by a failure to maintain pressure differentials between smoke room and corridor. This could have been due to:-

(i) too low a pressure in the corridor and lobbies which were fed only by leaks from the pressurized stairs.

(ii) pressure build up in the smoke room because air could not escape fast enough from it; during the test the windows were closed so that the only leakage path available was through the extract ducts while the fans were not operating.

(7) The slight spread of smoke from the third floor to the second (Test No 3) is not so readily explained. It is possible that the smoke was blown through the high velocity air handling pipe-work when the system was silent. Again had a larger leakage path to open air been available in the smoke room this slight spread of smoke would presumably not have occurred.

(8) The penetrations mentioned in (6) and (7) above is a shortcoming from the theoretical objective of the total control of smoke by confining it to the room of origin. However such spread of smoke which did occur was undoubtedly less than it would have been in a conventional building, and with the fire conditions to be expected for an office building would not have interfered with the escape of the occupants.

Table 1
Air Flows and Pressure differentials
Fans for normal condition
All doors between stair and lobbies closed

Floor	Air supply to staircase		Pressure differential across staircase door(W.G.)			
			East door		West door	
	m^3/min	ft^3/min	mm	in	mm	in
Basement	4.24	150	0.75	0.03	-	-
Ground	6.08	205	0.75	0.03	0.50	0.02
Upper ground	4.24	150	0.62	0.025	0.62	0.025
1st	1.98	70	0.50	0.02	0.50	0.02
2nd	1.84	65	0.50	0.02	0.50	0.02
3rd	1.415	50	0.50	0.02	0.50	0.02
4th	2.69	95	0.62	0.025	0.62	0.025
5th	1.415	50	0.50	0.02	0.50	0.02
6th	3.11	110	0.62	0.025	0.50	0.02
7th	2.41	85	0.62	0.025	0.62	0.025
8th	3.68	130	0.75	0.03	0.50	0.02
9th	1.84	65	0.50	0.02	0.50	0.02
10th	3.82	135	0.62	0.025	0.50	0.02
11th	2.41	85	0.50	0.02	0.62	0.025

The air supply ducts on the staircase are adjacent to the east door.

Table 2
Air flows and Pressure differentials
Fans for Emergency operation
All doors between stair and lobbies closed
and all lobby doors closed

Floor	Air supply to staircase		Pressure differential across staircase door (W.G.)			
			East door		West door	
	m^3/min	ft^3/min	mm	in	mm	in
Basement	15.6	550	10.00	0.40	-	-
Ground	15.6	550	5.00	0.20	5.00	0.20
Upper ground	17.0	600	7.50	0.30	7.00	0.28
1st	22.6	800	8.00	0.32	9.25	0.37
2nd	24.1	850	7.75	0.31	9.25	0.37
3rd	28.3	1000	8.75	0.35	7.50	0.3
4th	24.1	850	8.50	0.34	8.50	0.34
5th	35.4	1250	7.00	0.28	7.00	0.40
6th	26.9	950	10.00	0.40	9.00	0.36
7th	41.0	1450	10.00	0.40	10.25	0.41
8th	29.7	1050	9.75	0.39	9.50	0.38
9th	39.6	1400	7.00	0.28	9.75	0.39
10th	35.4	1250	9.75	0.39	9.75	0.39
11th	41.0	1450	10.00	0.40	10.25	0.41

On the third floor the pressure difference across the lobby/lift corridor door was 0.75 mm (0.03 in) W.G. at both east and west end. That across the lobby/smoke corridor door was 0.675 mm (0.027 in) W.G. at both east and west ends. For the measurements recorded in this footnote all doors to stairs were closed.

Table 3

Pressure differentials with fans on emergency operations

Pressure measurements made across stair door closed at floor indicated but with a stair door on the next landing held open, and with all lobby doors closed

Floor	Pressure differential across staircase door (W.G.)			
	East door		West door	
	mm	in	mm	in
Basement	-	-	-	-
Ground	-	-	-	-
Upper ground	-	-	-	-
1st	6.00	0.24	6.50	0.26
2nd	5.00	0.20	7.25	0.29
3rd	7.00	0.28	6.00	0.24
4th	7.00	0.28	7.00	0.28
5th	6.50	0.26	6.00	0.24
6th	6.75	0.27	6.25	0.25
7th	7.25	0.29	7.50	0.30
8th	7.25	0.29	7.50	0.30
9th	5.50	0.22	8.00	0.32
10th	5.00	0.20	6.25	0.25
11th		-		-

Table 4

Pressure Differential with fans on emergency operation

Pressure measurements made across stair door closed at floor indicated but with a stair door on the next landing held open and with the lobby door associated with the held open door also open.

Floor	Pressure differential across staircase door (W.G.)			
	East door		West door	
	mm	in	mm	in
Basement	-	-	-	-
Ground	-	-	-	-
Upper ground	-	-	-	-
1st	3.00	0.12	3.75	0.15
2nd	2.75	0.11	4.50	0.18
3rd	4.25	0.17	3.75	0.15
4th	4.25	0.17	4.00	0.16
5th	4.00	0.16	3.75	0.15
6th	4.50	0.18	3.00	0.12
7th	4.00	0.16	4.25	0.17
8th	4.00	0.16	4.50	0.18
9th	3.00	0.12	5.00	0.20
10th	2.75	0.11	2.75	0.11
11th	-	-	-	-

Table 5

RECORD OF TEST 1

No fans operating - door between smoke room and corridor open after 5 minutes

Time of test - 10.20 hrs on 24th March 1971

Time (mins)	Observations
0	Smoke generator started
1	(Adjustments made to
5	(Smoke generator
5	Smoke disappointingly light
10	Slight smoke encroachment into lobby A due to door B being opened to allow passage of observers and spectators
15	Letter C (C_6) not visible from Door B
19	Second smoke generator started
19	Letter C (C_5) appears indistinct when viewed from Lobby B
15-25	Tests with smoke tracer showed that there was a small but definite air flow under and around staircase door and lobby door - The direction of air movement was from the staircase into the lobby and then into corridor adjacent to smoke room. Even so during this period when door B to lobby A was opened smoke entered the lobby from the corridor
24	Letter C (C_5) when viewed from Lobby B was not visible
31	Test ended

Table 6

RECORD OF TEST 2

Staircase fans operating normally. Test started with no air supply or extract from office accommodation - Door between smoke room and corridor open.

Time of test - 11.30 hrs on 24th March 1971

Time (mins)	Observations
0	Two smoke generators started
5	Generators going well and producing large volume of smoke
9	Smoke density in corridor increasing Letter C (C_6) viewed from Lobby A becoming indistinct
9½	Door to smoke room closed
10	Letter C (C_5) viewed from Lobby B becoming indistinct
10½	Door to smoke room opened
11½	Letter C (C_5) viewed from Lobby disappeared
12½	With one leaf of door B to Lobby A open 45° smoke pours into lobby but with one leaf of door D (lobby to staircase) opened as well smoke is prevented from flowing into Lobby A
15½	Office supply and extract fans switched on
17	Now with Door B half opened and Door D also opened smoke is not prevented from entering A. Conditions in Lobby A become unpleasant after a few demonstrations
21	Doors closed
25	Test ended.

Table 7

RECORD OF TEST 3

Staircase fans operating as for emergency as indicated. Door between smoke room and corridor open.

Time of test - 1400 hrs on 24th March 1971

Time (mins)	Observations
0	Smoke generator started Emergency fans operating
4½	Emergency fans switched off
5¾	Letter C (C_6) invisible from Lobby A
6½	Letter C (C_5) invisible from Lobby B
9	Considerable smoke accumulated in Lobby A as a result of opening Door B
9½	Emergency fans switched on
10	Smoke in Lobby A noticeably clearing
15 - 25	The following observations were made and demonstrated several times: 1) Small opening of one leaf of door B gives an air flow of lobby to corridor 2) Half opening one leaf of door B allows smoke to penetrate into Lobby A 3) Opening Door A in addition to half opening one leaf of Door B gives a large air flow out of staircase and completely cleared smoke.
20	From 20 minutes onwards presumably as a result of repeated demonstrations of above effect smoke began to penetrate into other half of corridor on 3rd floor and very slightly into some rooms on 2nd floor
30	Test ended

Table 8

Temperature Rise due to Smoke

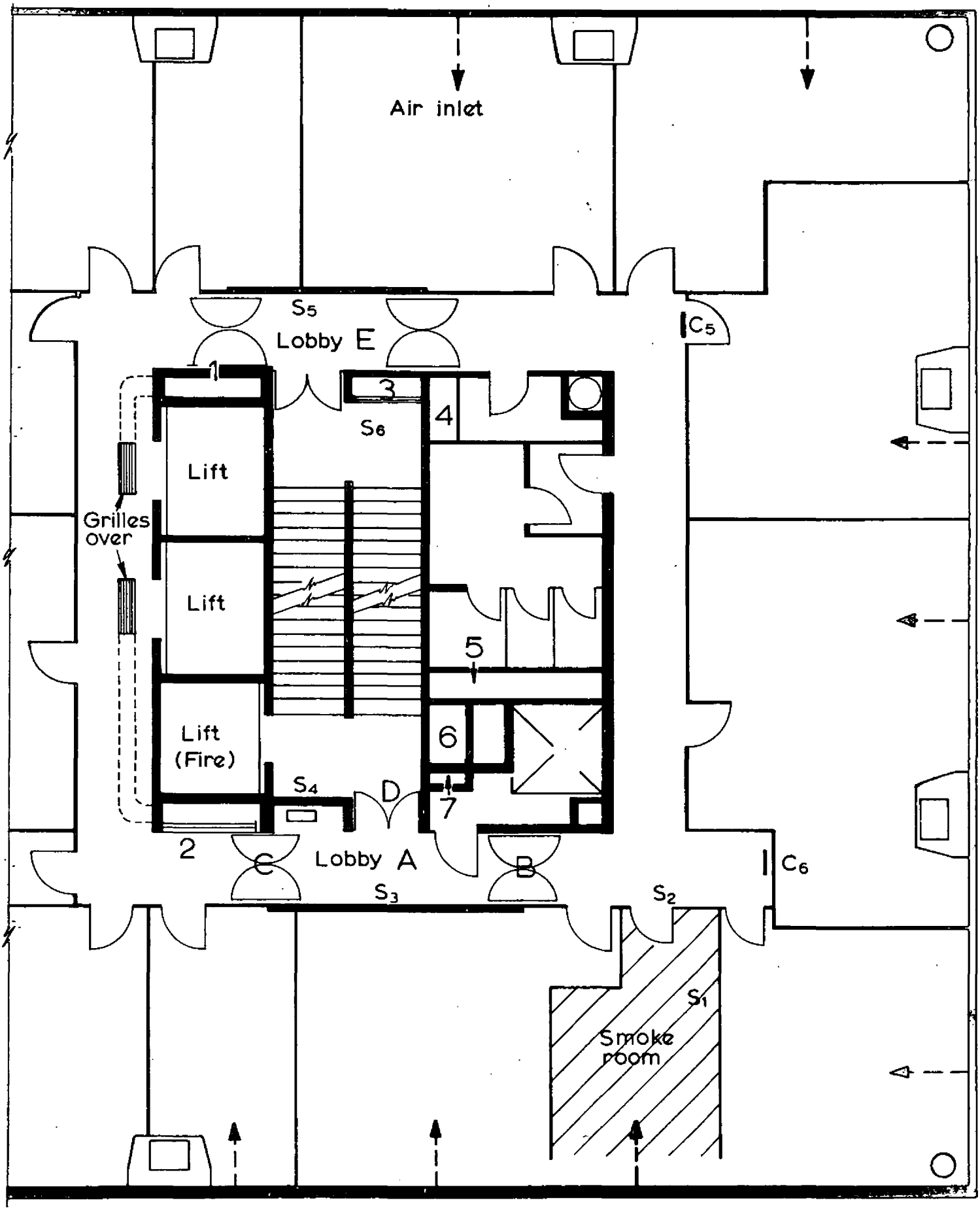
Thermocouple 1 on s/m frame inside smoke room
Thermocouple 2 on s/m frame outside smoke room

Maximum rise in temperature over ambient during a test

	Rise in temperature
TEST 1.	
Thermocouple 1	4.9°C
2	2.5°C
TEST 2.	
Thermocouple 1	36.5°C
2	18.0°C
TEST 3.	
Thermocouple 1	22°C
2	4.9°C

Ambient temperature - measured in corridors and offices on 3rd Floor - 19°C

External Weather conditions - Temperature 13.7°C
Wind - moderate 13.5 - 18 miles per hour but gusty.
Strong gust at 16.50 BST - 32 miles per hour
Direction - west to south west.



S Smoke meters

N

1 2 3 4 5 Ducts 6 Fire air 7 Air

FIG. 1. FLOOR PLAN (3rd)

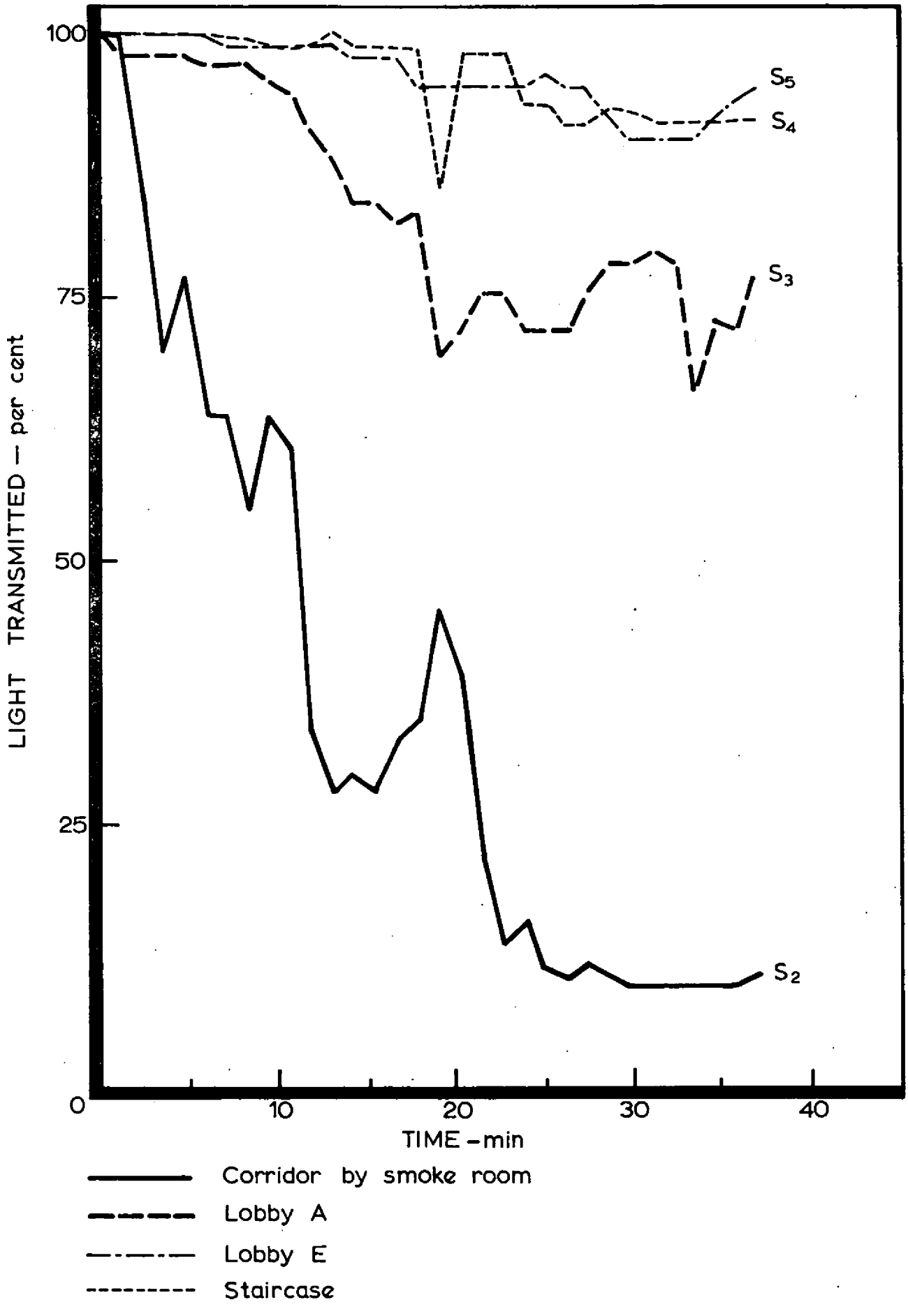


FIG. 2. SMOKE MEASUREMENTS FOR TEST 1

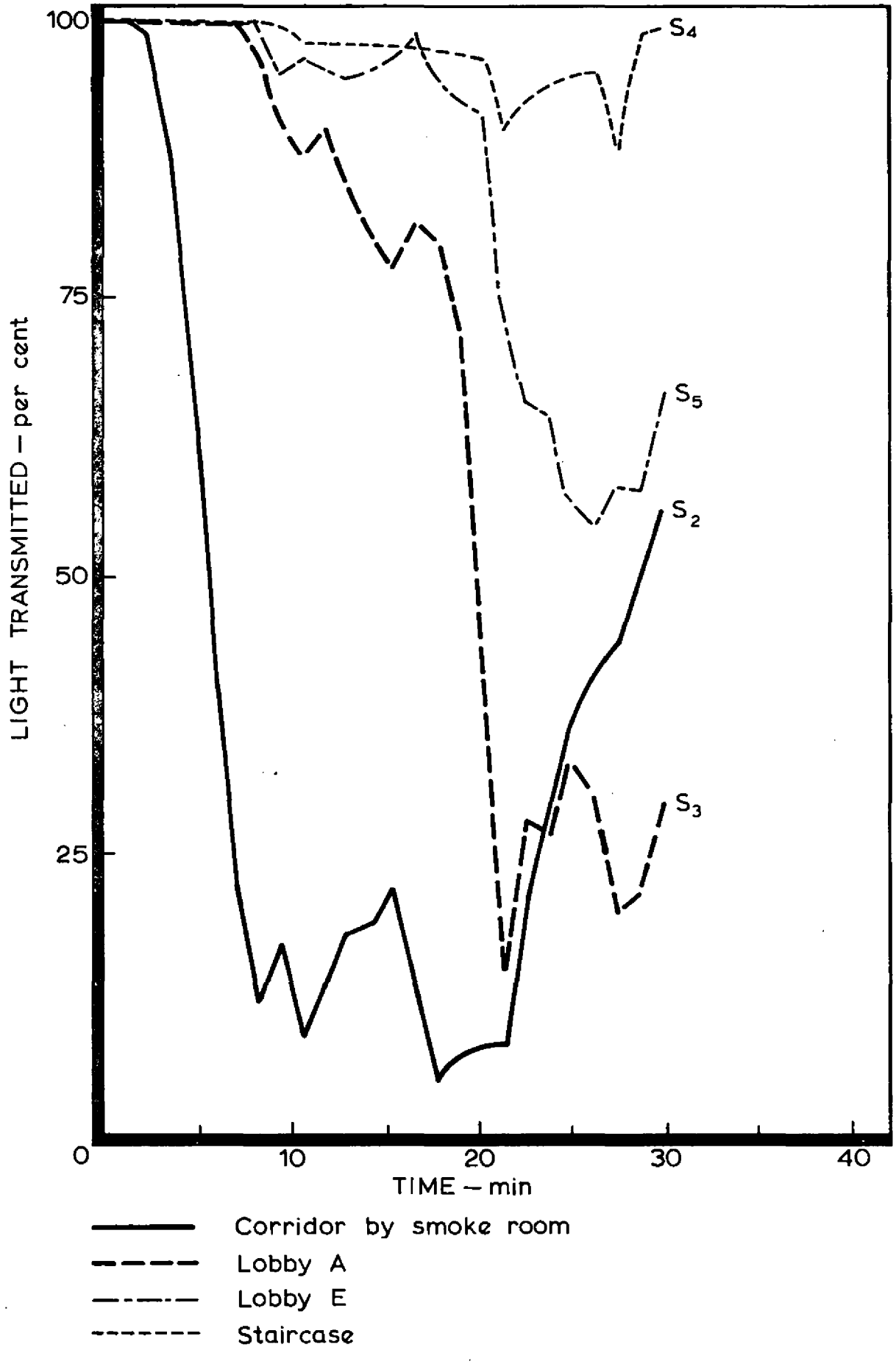


FIG. 3. SMOKE MEASUREMENTS FOR TEST 2

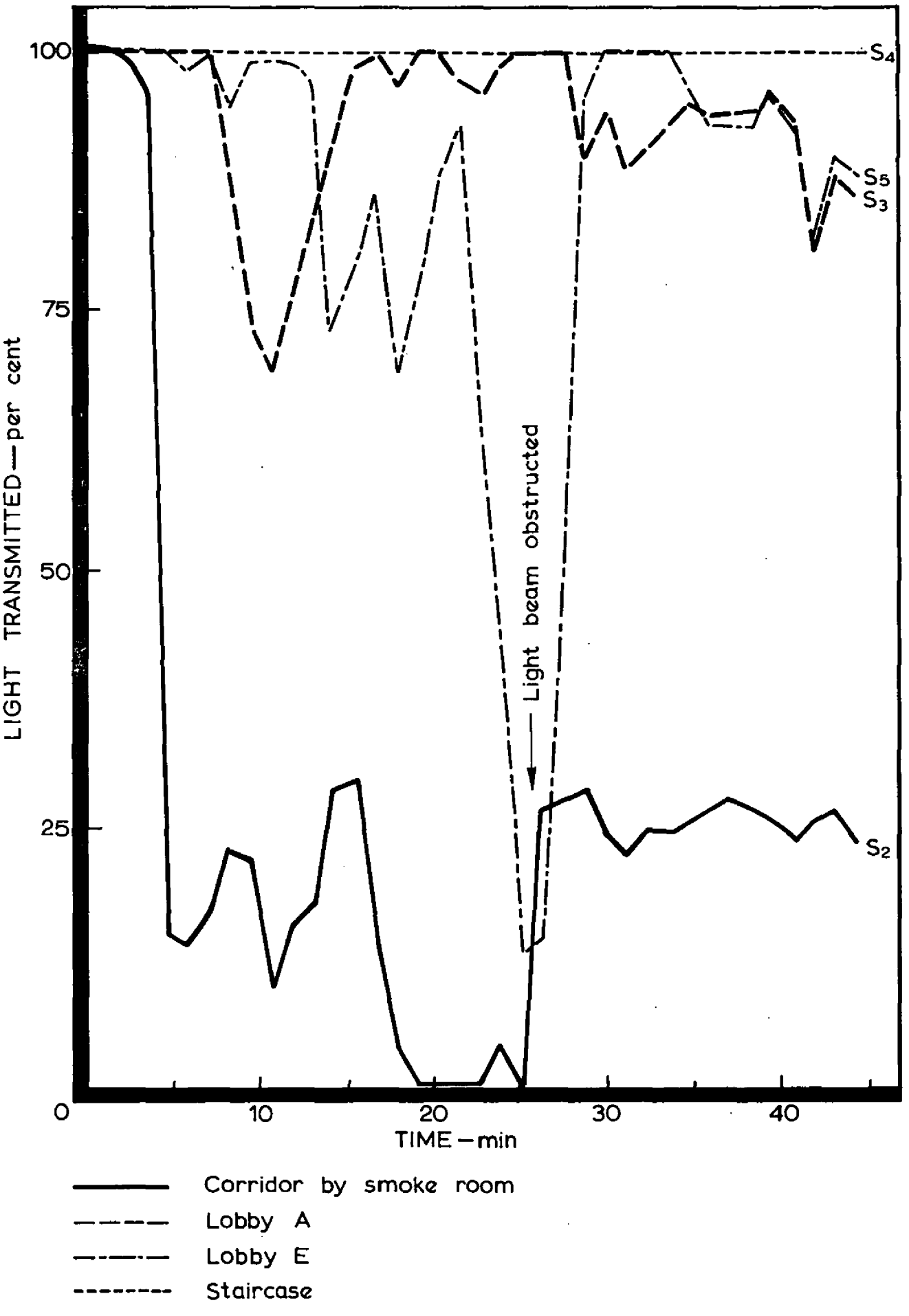


FIG. 4. SMOKE MEASUREMENTS FOR TEST 3