IITRI

FIRE/LIFE SAFETY RESEARCH

A STUDY

EARLY WARNING FIRE DETECTION PERFORMANCE IN THE HOSPITAL PATIENT ROOM

Presented By

RIXSON-FIREMARK, INC.

FRANKLIN PARK, ILLINOIS

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IITRI FIRE/LIFE SAFETY RESEARCH
PROJECT J8176

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EARLY WARNING FIRE DETECTION PERFORMANCE IN THE HOSPITAL PATIENT ROOM

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15 February 1973
Final Report

FOREWORD

This report describes research experiments conducted in the IITRI Fire Research Laboratory, Gary, Indiana, on January 30 and 31, 1973. These experiments were conducted to evaluate whether early warning fire detection in hospital patient occupied areas provides adequate time to rescue a patient.

The response of smoke detectors mounted on the ceiling and top section of the door frame was measured against the conditions of gas and smoke at the "patients" head.

The test criteria was established in cooperation with John G. Degenkolb, Fire Protection Engineer, Glendale California and C. Walter Stickney, Oregon State Fire Marshal. Participating IITRI Personnel were Carl Foxx, John Kopec and T. E. Waterman.

Respectfully submitted,

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Senior Research Eng.
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Approved by

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TABLE OF CONTENTS

I. INTRODUCTION ...5

II. ATTENDEES ...6

III. SCOPE AND OBJECTIVES ...6

IV. FACILITY ...7

A. DETECTORS
B. INSTRUMENTATION

V. EXPERIMENTAL PROCEDURE ...11

A. FIRES AND LOCATIONS

VI. TEST DATA AND RESULTS ...12

A. GENERAL

B. SUMMARY OF TEST CONDITIONS AND COMPARISON OF RESPONSE TIME FOR DETECTORS 4&7

C. COMPARISON OF DETECTOR RESPONSE AND SMOKE OBSCURATION MEASUREMENTS AT THE PATIENTS HEAD AT TIME OF ALARM

D. GAS CONCENTRATION MEASUREMENTS

1. Oxygen Depletion
2. Carbon Monoxide
3. Carbon Dioxide
4. General
5. Physiological effects of Carbon Monoxide

VII. CONCLUSIONS ...27

VIII. CLOSING REMARKS ...27

APPENDIX ...28

FULL SCALE HOSPITAL ROOM SMOKE DETECTOR TESTS

SYNOPSIS

...THESE EXPERIMENTS CLEARLY INDICATE THAT A DOOR FRAME MOUNTED DETECTOR PROVIDES AUTOMATIC POSITIONING AND ONE OF THE BEST LOCATIONS FOR OPTIMUM DETECTOR RESPONSE IN PATIENT SLEEPING ROOMS.

...THE EXPERIMENTS, WHICH REPRESENT FIRE SITUATIONS IN A HOSPITAL PATIENT SLEEPING ROOM, CLEARLY INDICATE THE NEED FOR ADDITIONAL FULL SCALE TESTING OF SMOKE AND IONIZATION DETECTORS UNDER ACTUAL CONDITIONS.

...THEY ALSO SHOW THAT THE DESIGN CONFIGURATION OF THIS COMBINATION DETECTOR/HOLDER/CLOSER UNIT PROVIDES EQUIVALENT PROTECTION OF THE ROOM OCCUPANTS AS COMPARED WITH THE CEILING MOUNTED DETECTOR INSTALLATIONS.

I. INTRODUCTION

Recent fire loss statistics have highlighted the surprisingly large number of fire injuries and fatalities among hospital patients.

Based upon this loss experience there has been a growing recognition by code writing and regulatory officials for early warning fire detection in all hospital patient occupied areas. In addition, both the Uniform Building Code, in its' current edition (1973) and the regulations of the Oregon State Fire Marshal have recognized the life safety value of early warning fire detection in hospital sleeping rooms. The effectiveness of ionization-type smoke detectors in patient rooms was demonstrated in earlier full scale fire tests conducted by Southwest Research Institute at Lutheran Hospital in Des Moines, Iowa. (Southwest Research Institute Project #3-2947-350, June 25, 1971.)

It has been proven far too many times that thermally operated devices such as sprinkler struts and heat detectors operate too slowly to be considered reliable life safety protection in this kind of an environment. Compared to sprinklers, the "lead time" or rescue potential" provided by early warning fire detection is unquestionable.

Additionally with the professional help found in hospitals, as compared to other type health care facilities, this lead time could materially cut down "single death" fires.

Current trends of thought in fire protection indicate; the combination of early warning detection and automatic-closing patient room doors, backed by a modified arrangement of automatic sprinklers, (designed to prevent the spread of fire from point of origin) establishes a far greater level of life safety.

II. ATTENDEES

Various individuals participated in the conduct of the experiments. Others observed one or more of the 31 fires over the two day period.

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III. SCOPE & OBJECTIVES

The purpose of this research was to gather information to evaluate the effectiveness of early warning fire detection in hospital sleeping rooms.

The major concern is not the length of time it takes a fire detector to operate, but that it operates in sufficient time to permit rescue of a non-alert and non-ambulatory patient before smoke injury is incurred.

To accomplish this objective the following criteria were established:

A. Gather data on the generation of products of combustion, (heat, smoke, depletion of oxygen O_2 carbon dioxide CO_2 carbon monoxide CO and their dispersion within a patient room, under varying conditions of air movement (i.e. fan ON-fan OFF.)

B. Compare response time of ceiling mounted smoke and ionization fire detectors versus door frame mounted combination ionization fire detector door-holder release and closer in typical patient room fire situations.

C. Monitor conditions at the patients head before and after detector response for: smoke obscurity and gas concentration of CO, CO_2 and O_2.

IV. FACILITY

IITRI'S reusable fire burnout facility was modified to represent a 10 foot by 15 foot hospital room connected by a 4 foot wide doorway to a corridor as shown in Figure 1.

In tests 25 through 29, the hospital room was enlarged through a six foot wide opening to an adjoining 15 foot by 17 foot room also shown in Figure 1. (Total area of approximately 400 square ft.)

One end of the hospital room had a drop ceiling, typically provided as a utility chase in modern hospital construction. A small washroom with open door was simulated on one corner (under the drop ceiling) and is also shown in Figure 1. The washroom was provided with an exhaust fan in the ceiling capable of moving 51 cfm of air.

A simulated fan-coil heater was mounted on the wall opposite the room to corridor door opening. (Also typical of modern hospital construction.) This heater was capable of supplying 51 cfm of outside air (make-up air) to the room. It could also recirculate room air, drawn in near the floor level and discharge the combined air upward through a variable opening 4" wide by 45" long. This upward combined flow could be adjusted to either 100 cfm or 182 cfm. These air flow rates are in conformance with the minimum ventilating requirements defined by the U. S. Public Health Service in "General Standards of Construction and Equipment for Hospitals and Medical Facilities" (1969 Revision.)

The room was furnished with a hospital bed and patient table/cabinet, placed as shown in Figure 2. A cubical curtain (used for patient privacy) was installed, when required, as shown in Figure 4. This curtain hung 6 inches from the ceiling and ended 8 inches above the floor.

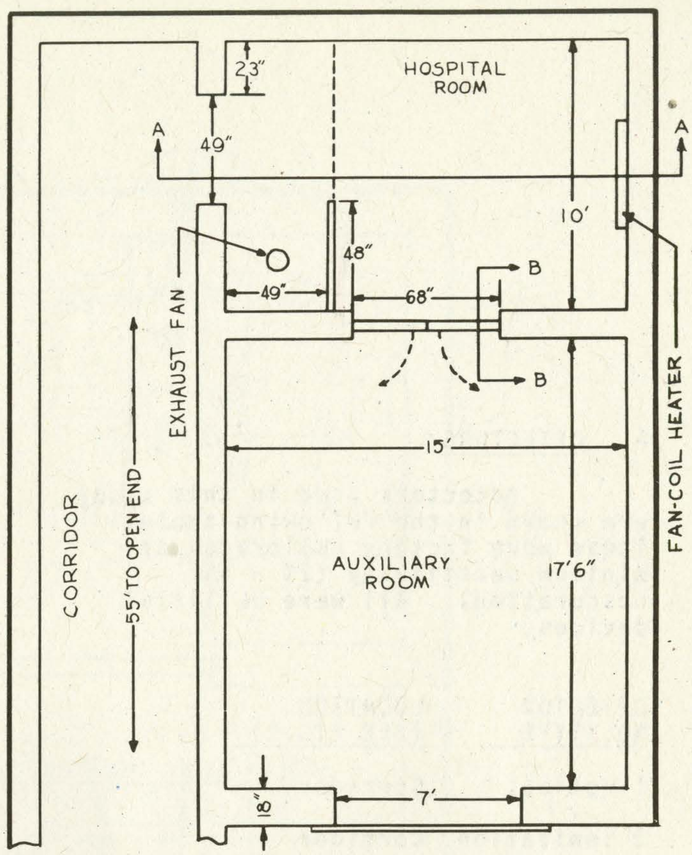


FIGURE 1
EXPERIMENTAL FACILITY

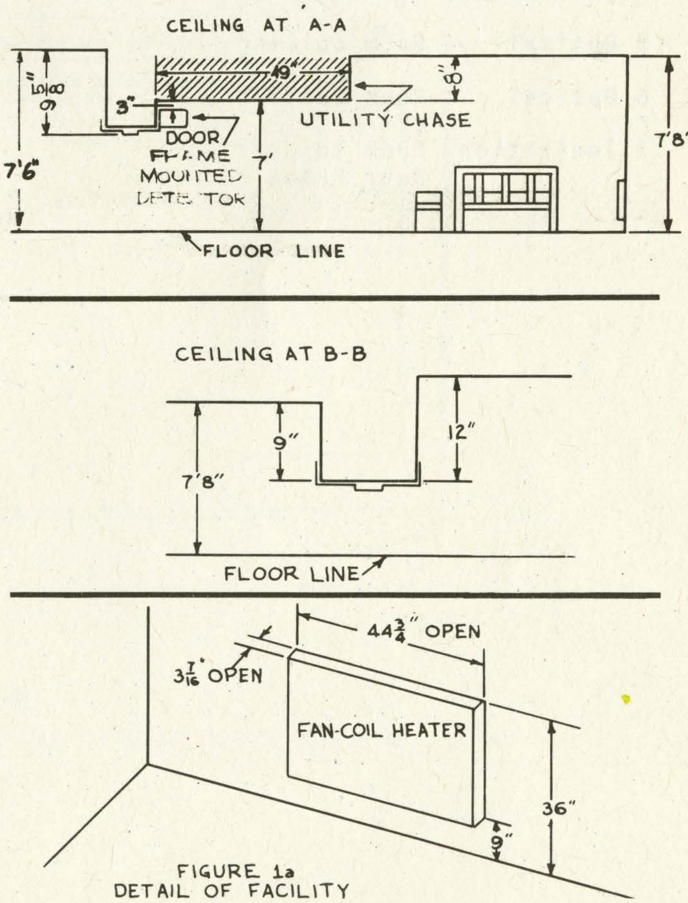


FIGURE 1a
DETAIL OF FACILITY

A. DETECTORS

Detectors used in this study are shown in the following table. These were factory calibrated at minimum sensitivity (2% - 4% obscuration). All were UL listed devices.

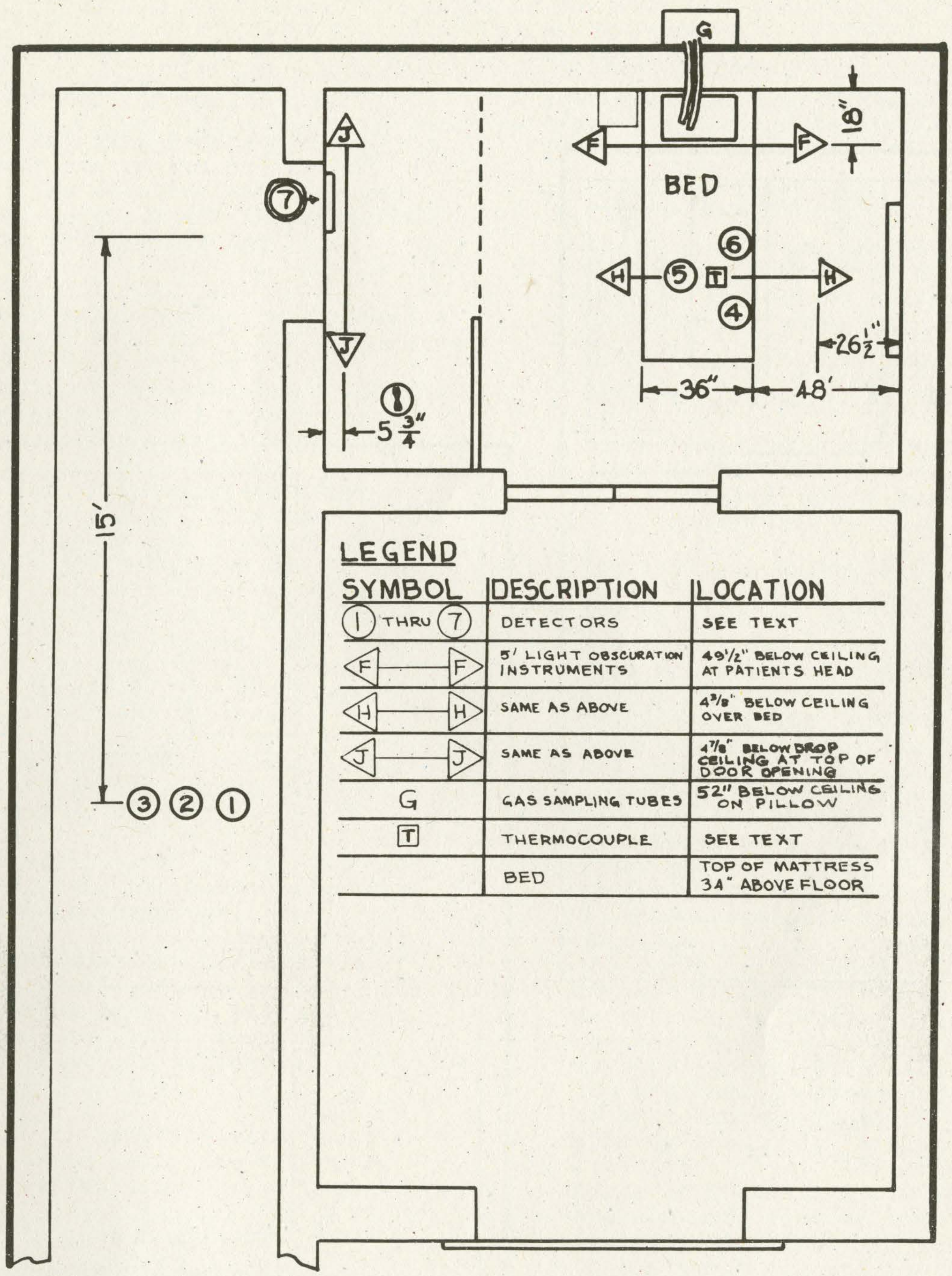
DETECTOR NO./TYPE	LOCATION (SEE FIG.2)
1 Optical	Corridor
2 Ionization	Corridor
3 Optical	Corridor
4 Ionization	Room Ceiling
5 Optical	Room Ceiling
6 Optical	Room Ceiling
7 Ionization	Room to Corridor Door Frame Mounted

B. INSTRUMENTATION

1. Light Obscurity - was measured by three standard ADT light sources and detectors, which were modified to provide output signals proportional to the light received across a 5 foot beam. These instruments were located as shown in Fig. 2.

2. Gas Analysis - Room gases were drawn through a small polyethelene sampling tube to equipment placed outside the experimental facility, (see Figure 2) where they were continuously analyzed for CO, CO_2 and O_2 concentrations. The amount of gases withdrawn was small so as not to upset the experiments. The open end of the tube was placed near the head of the bed, 52" below the ceiling (7" above the mattress).

3. Thermocouple - No temperatures were monitored in tests 1 through 16 because of the small fire size. A 28 gauge chromel-alumel thermocouple was installed after test 16 and centered between detectors 4,5 and 6. It was located just below the room ceiling (see figure 2). Ceiling air temperature was recorded for test 17 through 31.



LEGEND

SYMBOL	DESCRIPTION	LOCATION
1 THRU 7	DETECTORS	SEE TEXT
F — F	5' LIGHT OBSCURATION INSTRUMENTS	49 1/2" BELOW CEILING AT PATIENTS HEAD
H — H	SAME AS ABOVE	4 3/8" BELOW CEILING OVER BED
J — J	SAME AS ABOVE	4 7/8" BELOW DROP CEILING AT TOP OF DOOR OPENING
G	GAS SAMPLING TUBES	52" BELOW CEILING ON PILLOW
T	THERMOCOUPLE	SEE TEXT
	BED	TOP OF MATTRESS 34" ABOVE FLOOR

FIGURE 2
LOCATION OF BED, DETECTORS AND OTHER INSTRUMENTATION

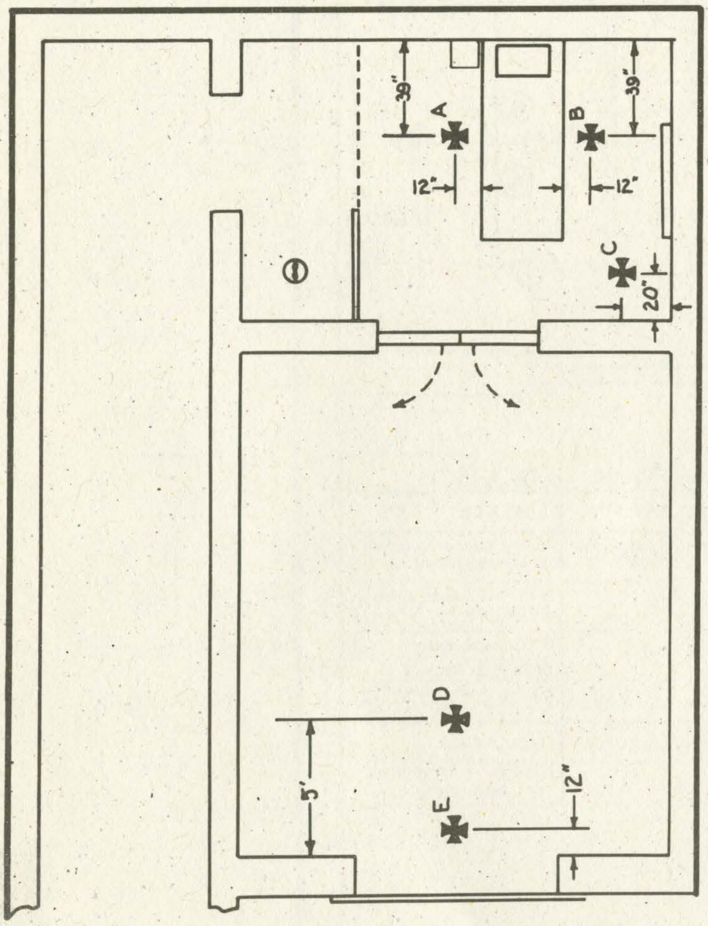


FIGURE 3
✚ FIRE LOCATIONS

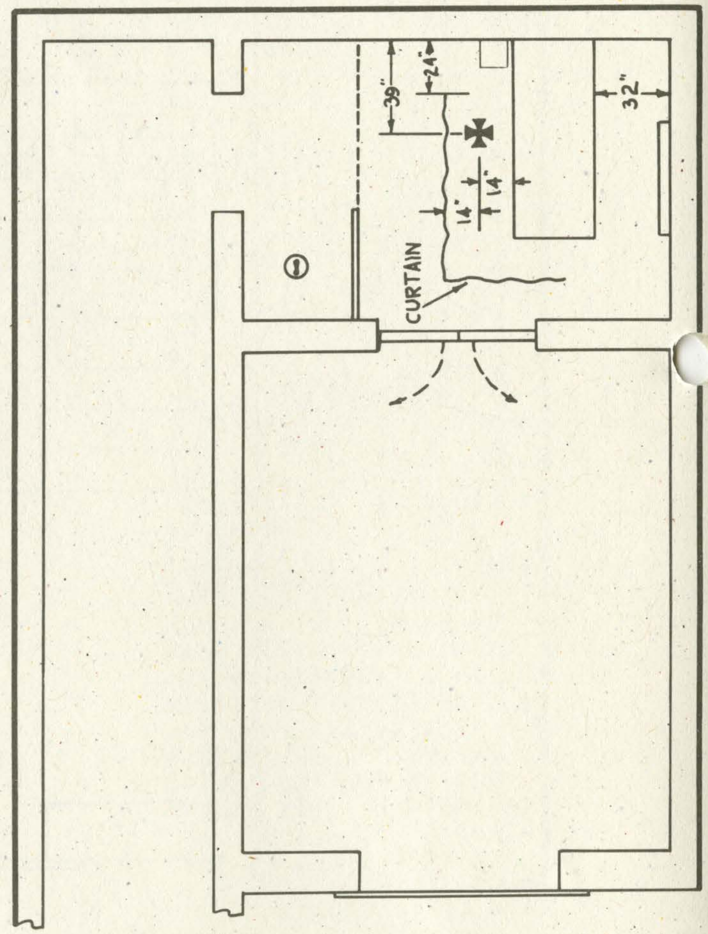


FIGURE 4
BED WITH CUBICLE CURTAIN

V. EXPERIMENTAL PROCEDURE

The starting temperature of each experiment was in the 60° to 70° region. The relative humidity was near 47%. Outside air temperatures held near 30°F. throughout the tests.

A 5 second scan/recorder sequentially entered data from the 3 ADT obscuration monitors, the 6 ceiling mounted detectors, and the door frame mounted detector once every 5 seconds on a punched paper tape.

NOTE: The alarm response times reported for detector 1, 2, 3, 5, and 6 are accurate to + or - 2.5 seconds due to the 5 second recording interval. Response of detectors 4 and 7 were continuously monitored by a two-pen recorder, and therefore, the exact alarm points are reported.

The two-pen recorder was simultaneously time marked by the 5 second scan/recorder.

Ignition was relayed by radio to the instrument room and manually entered on the two-pen recorder.

The patient room to corridor door closed automatically at the time the frame mounted detector unit #7 went into alarm; except in tests 25-31, when the closing function was eliminated.

A total of 31 separate experiments were performed using the following items as variables:

a. type of fuel

b. air circulation within the room (fan ON-fan OFF)

c. fire location

d. position of room-to-corridor door (open/closed)

A summary of initial conditions is shown in Table 1.

All tests, with the exception of 16 and 31, were terminated, when the fire fuel was totally consumed. The room was then ventilated by large auxiliary blowers and all detectors reset prior to starting the next fire.

A. FIRES AND LOCATIONS

These fires were designed to simulate a variety of circumstances typical of a fire in a hospital patient room. Fires were built in locations shown in Figs 3 and 4 using three different types of fuel:

a. shredded newspaper
b. cotton cloth
c. hospital waste-basket materials.

The shredded newspaper fires were built in a wire screen basket 10" in diameter and 23" high. The basket had a conical inner base which was 6" above the floor at the perimeter and 7 1/2" above the floor at the center. The paper was placed in the basket and compacted to produce a significant amount of smoke before bursting into live flame. These test fires were ignited from below the fuel stack near the tip of the cone. This fuel produced a dense white-grey smoke.

The cotton cloth used in tests 13 through 15 and 26 through 30 was draped over a stool. This material produced a rather fast developing fire with medium to low heat and a moderate quantity of grey smoke. Tests 16 (sweatshirt), and 31 (pile of rags) were smoldering fires, arranged on a piece of sheetrock, placed on top and near the foot of the bed. Ignition was accomplished by means of a glowing (no active flame) cotton wick inserted in the bottom of the pile. These two fires produced a gradually increasing amount of darker grey smoke.

The hospital waste basket material fires consisted of actual samples collected from individual patient rooms in a nearby hospital. The material was accumulated over a 24 hour period and supplied in paper waste-basket liners, treated with a flame retardant. Due to the nature of the content and the flame retardant treatment of the bag, these fires burned very slowly, with little heat content and did not produce a significant amount of smoke.

VI. DATA AND RESULTS

A. General

The information presented in this section is based entirely on the data print-outs included in Appendix A. The raw data has been organized in order to present a complete and meaningful display of the results.

Table 1 (Section VI-B) summarizes the various initial conditions for each experiment and offers a performance comparison between the ionization-type ceiling mounted detector and the ionization-type detector used in the door frame mounted device.

Section VI-C compares the performance of all detectors (photo electric and ionization type) used in the experiments to the smoke obscuration at the patients' head at the time of alarm.

Section VI-D contains information on the gas concentration at the patients' head.

A complete time history of light transmission for each experiment is contained in Appendix A. Obscuration measurements were made at 5-second intervals, at three room locations: (1) the patients' head, (2) at the ceiling over center of bed, and (3) on the room-to-corridor door frame.

The results of tests #6 and 7 are shown below as representative examples only.

While conditions of each experiment produced distinct smoke obscuration at these three locations, the general shape of the response curve remained the same:

a. Smoke accumulation at the ceiling and door opening increased rapidly

b. Total volume of smoke at the door opening was generally greater than at the ceiling.

c. The percentage of light transmission curves recorded for both the ceiling location and the door frame location showed almost identical response differing only a few seconds in time.

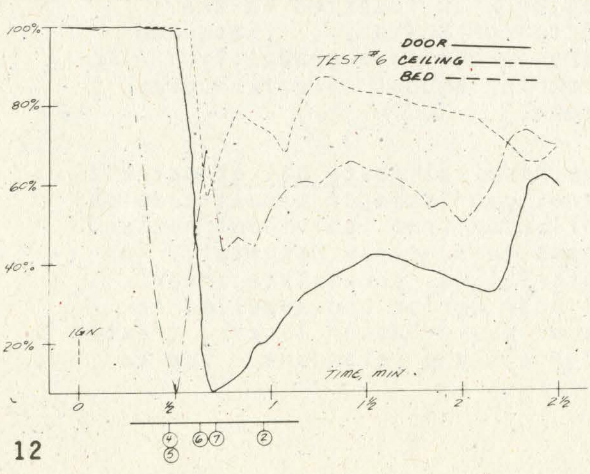
Percentage of light obscuration per foot can be calculated from the percentage of light transmission using the following equation: *

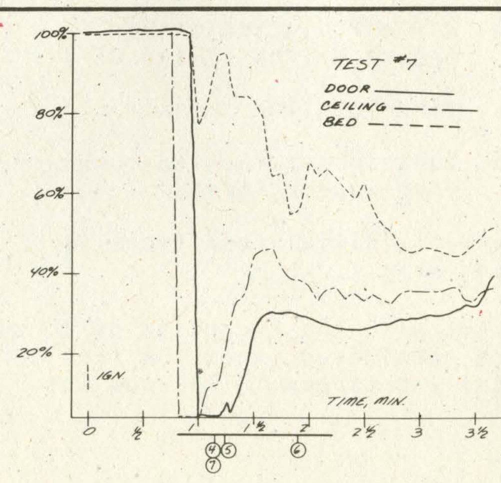
At any distance, the percent obscuration per foot will be:

$$O_u = \left[1 - \left(\frac{T_s}{T_c}\right)^{\frac{1}{d}}\right] 100$$

where O_u = Percent obscuration per foot.
T_s = Smoke density meter reading with smoke.
T_c = Smoke density meter reading with clear air.
d = Distance in feet.

* Underwriters' Lab: UL 168, 1971





B. SUMMARY OF TEST CONDITIONS AND COMPARISON OF RESPONSE TIME FOR DETECTORS 4 AND 7 (TAKEN FROM PEN RECORDS)

TABLE NO. 1

TEST	AIR FLOW (CFM) UNIT HEATER	AIR FLOW (CFM) EXHAUST	RESPONSE TIME (seconds) DET#4 CEILING	RESPONSE TIME (seconds) DET#7 DOOR FRAME	FUEL (ounces) SHREDDED NEWSPRINT	FUEL (ounces) CLOTH★	FUEL (ounces) HOSPITAL WASTEBASKET MATERIAL	ROOM-TO-CORRIDOR DOOR	LOCATION	REMARKS
1*	182	51	13	15.5	2			OPEN	A	
2	DATA NOT RECORDED									
3*	182	51	42	-	2			OPEN	A	
4	182	51	57.1	59.5	4			OPEN	A	
5	182	51	21.4	36.7	4			OPEN	B	
6	182	51	31	45.4	4			OPEN	C	
7	0	0	67.2	71	4			OPEN	A	
8	0	0	75.6	86.5	4			OPEN	B	
9	0	0	50	63.5	4			OPEN	C	
10	0	0	70	90	4			CLOSED	C	
11	0	0	49	69	4			CLOSED	A	
12	0	0	32	71.2	4			CLOSED	B	
13	182	51	30	34.5		8		OPEN	A	
14	182	51	24.5	44.5		8½		OPEN	B	
15	182	51	41	60.5		9		OPEN	C	
16	182	51	973	752		sweat-shirt		CLOSED	Top of bed on incombustible pad	
17	100	51	17	52			2	CLOSED	A	
18	100	51	7.4	737.5			2	CLOSED	B	
19	100	51	215.5	56			2	OPEN	A	
20	100	51	62.5	-			2	OPEN	B	
21	0	51	41.2	-			2	OPEN	A	
22	0	51	23.5	41			2	OPEN	B	
23	0	51	14.5	78.2			1½	OPEN	Foot of bed mat'l in flameproof bag	
24	100	51	76.5	45.5			2	CLOSED	A	Cubicle curtain up
25Δ†	100	51	125	101	8			OPEN	D	Cubicle curtain down
26Δ†	100	51	60	58.5		8		OPEN	D	
27Δ†	100	51	70	78.5		8		OPEN	E	
28Δ†	100	51	33.5	40.6		8		OPEN	E	Cubicle curtain up
29Δ†	0	0	40	47.2		8		OPEN	E	" " "
30Δ	0	0	30	155			2	½OPEN	A	" " "
31Δ	0	0	28'35"	31'28"		rag pile		½OPEN	Top of bed on incombustible pad	" "

* Sticking pen may have added a few seconds error to these records.

Δ Automatic closing function disconnected for these tests. For all other tests, room-to-corridor closed when detector #7 alarmed.

★ Cloth samples draped over chair in tests 13, 14 & 15; and draped over bench in tests 26, 27, 28 & 29.

† Doors to auxillary room open for tests 25 thru 29 only.

FIRE AND ROOM CONDITIONS
TESTS 1, 2 and 3

AIR FLOW: 182 CFM SUPPLY
51 CFM EXHAUST

FUEL: 2 OZ SHREDDED NEWSPRINT

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 1 *LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	7.5	⑦	0.6
	12.5	4,5	0.6
Test end	80		2.1

TEST 2

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START			
IGNITION			

DATA NOT RECORDED

TEST 3 *LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	42	4	0.1
Test end	140		0.1

*Sticking pen may have added a few seconds error to these records.

C. COMPARISON OF DETECTOR RESPONSE AND SMOKE OBSCURATION MEASUREMENTS AT THE PATIENT'S HEAD AT TIME OF ALARM

FIRE AND ROOM CONDITIONS
TESTS 4, 5 and 6

AIR FLOW: 182 CFM SUPPLY
51 CFM EXHAUST

FUEL: 4 OZ SHREDDED NEWSPRINT

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 4 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	57.1	4	2.3
	59.5	⑦	2.3
	67.5	5	4.3
Test end	240		4.3

TEST 5 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	21.4	4	0.1
	27.5	5	1.4
	32.5	6	1.6
(6 Resets)	36.7	⑦	2.5
	47.5	6	4.3
(6 Resets)	55		5.8
Test end	155		3.4

TEST 6 LOCATION C

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	27.5	5	0.1
	31	4	0.1
	37.5	6	5.1
	45.4	⑦	8.6
	57.5	2	5.6
Test end	155		6.4

FIRE AND ROOM CONDITIONS
TESTS 7, 8 and 9

AIR FLOW: 0 CFM
FUEL: 4 OZ SHREDDED NEWSPRINT
ROOM-TO-CORRIDOR DOOR: OPEN

TEST 7 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	67.2	4	3.9
	71	(7)	3.9
	72.5	5	1
	112.5	6	11.2
Test end	225		12.6

TEST 8 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	75.6	4	0
	77.5	5,6	6.9
	86.5	(7)	1.6
	105	2	1.6
Test end	290		4.8

TEST 9 LOCATION C

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	50	4	0.1
	57.5	5	0.8
	63.5	(7)	0.8
	90	6	3.9
(6 Resets)	155		6.4
	162.5	6	5.8
(6 Resets)	167.5		6.4
Test end	270		3.2

FIRE AND ROOM CONDITIONS
TESTS 10, 11 and 12

AIR FLOW: 0 CFM
FUEL: 4 OZ SHREDDED NEWSPRINT
ROOM-TO-CORRIDOR DOOR: CLOSED

TEST 10 LOCATION C

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	70	4	0
	77.5	5,6	0
	90	(7)	0.1
Test end	240		8

TEST 11 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	49	4	49.1
	69	(7)	9.9
	72.5	5	12.6
	87.5	6	19.7
Test end	180		12.6

TEST 12 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	32	4	0
	57.5	5	29.3
	62.5	6	38.1
	71.2	(7)	41.2
Test end	200		12.6

FIRE AND ROOM CONDITIONS
TESTS 13, 14 and 15

AIR FLOW: 182 CFM SUPPLY
51 CFM EXHAUST

FUEL: CLOTH (8 OZ -13)
($8\frac{1}{2}$ OZ-14) (9 OZ-15)

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 13 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	30	4	0
	34.5	⑦	0
	52.5	2	0.8
	57.5	5	1.6
(5 Resets)	82.5		2.3
	87.5	5	2.3
Test end	95		1.2

TEST 14 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	24.5	4	0
	42.5	5,6	0.1
	44.5	⑦	0.1
(6 Resets)	67.5		4.3
Test end	175		6.9

TEST 15 LOCATION C

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	41	4	0
	60.5	⑦	0.1
	82.5	5	0.4
	122.5	6	4.3
(6 Resets)	167.5		5.8
Test end	170		5.8

FIRE AND ROOM CONDITIONS
TESTS 16

AIR FLOW: 182 CFM SUPPLY
51 CFM EXHAUST

FUEL: CTTON SWEAT SHIRT

ROOM-TO-CORRIDOR DOOR: CLOSED

TEST 16

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	697.5	5	1.8
(5 Resets)	707.5		1.8
	712.5	5	1.8
(5 Resets)	732.5		2.3
	752	⑦	2.3
	897.5	6	15.4
	937	4	20.9
Test end	1035		26

FIRE AND ROOM CONDITIONS
TESTS 17 and 18

AIR FLOW: 100 CFM SUPPLY
51 CFM EXHAUST

FUEL: 2 OZ HOSPITAL WASTEBASKET MATERIAL

ROOM-TO-CORRIDOR DOOR: CLOSED

TEST 17 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	17	4	0
	52	⑦	0.1
Test end	70		0.4

Note: 12 pieces of Kleenex added 0-45 seconds, only 1½ oz consumed total

TEST 18 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	7.4	4	not recorded
	272.5	5	2.3
	737.5	⑦	3.6
Test end	755		3.6

FIRE AND ROOM CONDITIONS
TEST 19 and 20

AIR FLOW: 100 CFM SUPPLY
51 CFM EXHAUST

FUEL: 2 OZ HOSPITAL WASTEBASKET MATERIAL

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 19 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	56	⑦	1
	215.5	4	0.8
Test end	230		0.8

Note: Fireproof bag inadvertantly in fuel, 8 kleenex added to compensate.

TEST 20 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	62.5	4	0
Test end	250		0.1

FIRE AND ROOM CONDITIONS
TESTS 21, 22 and 23

AIR FLOW: 0 CFM SUPPLY
51 CFM EXHAUST

FUEL: 2 HOSPITAL WASTEBASKET
EXCEPT TEST 23, 1½ OZ IN
FLAMEPROOF BAG

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 21 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	41.2	4	0.1
Test end	115		0.1

TEST 22 LOCATION B

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	23.5	4	0
	41	⑦	0.4
Test end	55		0.6

TEST 23 LOCATION foot of bed

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	14.5	4	0.1
	62.5	5	1.6
	78.2	⑦	3.4
Test end	90		2.3

FIRE AND ROOM CONDITIONS
TEST 24

AIR FLOW: 100 CFM SUPPLY
51 CFM EXHAUST

FUEL: 2 OZ HOSPITAL WASTEBASKET
MATERIAL

ROOM-TO-CORRIDOR DOOR: CLOSED

TEST 24 LOCATION between cubicle curtain and bed

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	45.5	⑦	0.6
	76.5	4	1.6
Test end	85		1.6

Note: Cubicle curtain up.

FIRE AND ROOM CONDITIONS
TEST 25

AIR FLOW: 100 CFM SUPPLY
51 CFM EXHAUST

FUEL: 8 OZ SHREDDED NEWSPRINT

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 25 LOCATION D

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	101	⑦	0.1
	125	4	0.6
Test end	150		0.8

Note: Cubicle curtain down

FIRE AND ROOM CONDITIONS
TEST 26, 27 and 28

AIR FLOW: 100 CFM SUPPLY
51 CFM EXHAUST

FUEL: 8 OZ CLOTH

ROOM-TO-CORRIDOR DOOR: OPEN

TEST 26 LOCATION D

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	58.5	⑦	3.6
	60	4	3.6
	72.5	5	5.6
Test end	75		5.6

Note: Cubicle curtain down

TEST 27 LOCATION E

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	70	4	5.3
	78.5	⑦	7.5
	82.5	5	7.5
Test end	115		7.5

Note: Cubicle curtain down

TEST 28 LOCATION E

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	33.5	4	0
	40.6	⑦	0
Test end	70		0

Note: Cubicle curtain up

FIRE AND ROOM CONDITIONS
TEST 29 and 30

AIR FLOW: 0 CFM
FUEL: 8 OZ CLOTH
ROOM-TO-CORRIDOR DOOR: OPEN

TEST 29 LOCATION E

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	40	4	0.4
	47.2	⑦	1.6
Test end	65		0.8

Note: Cubicle curtain up

AIR FLOW: 0 CFM
FUEL: 2 OZ HOSPITAL WASTEBASKET MATERIAL
ROOM-TO-CORRIDOR DOOR: ½ OPEN

TEST 30 LOCATION A

	TIME (SECONDS)	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START	0		0
IGNITION	2.5		0
	30	4	0
	155	⑦	0
Test end	165		0

Note: Cubicle curtain up

FIRE AND ROOM CONDITIONS
TEST 31

AIR FLOW: 0 CFM
FUEL: PILE OF RAGS - SMOLDERING
ROOM-TO-CORRIDOR DOOR: ½ OPEN

TEST 31 LOCATION on incombustible pad on top of bed

	TIME min	TIME sec	DETECTOR NUMBER	OBS/FT @BED (%)
TEST START		0		0
IGNITION		2.5		0
	10	56	5	0.6
(5 Resets)	16	32		0.1
	25	08	5	0
	28	35	4	0.1
	31	28	⑦	0.6
	32	32	6	9.9
	33	16	1	15.8
	33	43	3	22
(1 Resets)	34	44		33
(3 Resets)	35	42		41.2
	39	52	3	57.8
(3 Resets)	40	38		62.4
Test end	45	32		62.4

Note: Cubicle curtain up

D. GAS CONCENTRATION MEASUREMENTS

The following information will be helpful in evaluating the gas concentration data.

1. Oxygen depletion - about 20% of normal air is oxygen. If this concentration falls below 17%, clear thinking and muscular co-ordination start to become difficult.

2. Carbon dioxide ... at low concentration, an increase in the level of CO_2, causes an increased breathing rate; with a subsequent increase in the amount of contaminants inhaled.

3. Carbon Monoxide poisoning - the effect this gas will have on an individual is a function of both time and concentration (i.e. high concentrations for short periods can have the same effect as low concentration over a longer interval), which is shown in the *table following:

4. Throughout all the experiments the gas concentration measurements were small, except for experiment 31. In this experiment, CO and CO_2 concentration was high for a relatively short duration. This condition should not produce any harmful physiological effects.

*The table is taken from Claudy, W. D. Carbon Monoxide in Fire Fighting, NFPA Report F21-1, 11 pp, 1954. It is included for reference purposes only.

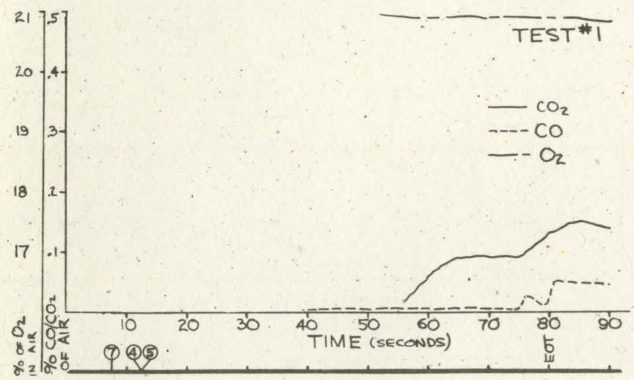
5. PHYSIOLOGICAL EFFECTS OF CARBON MONOXIDE*

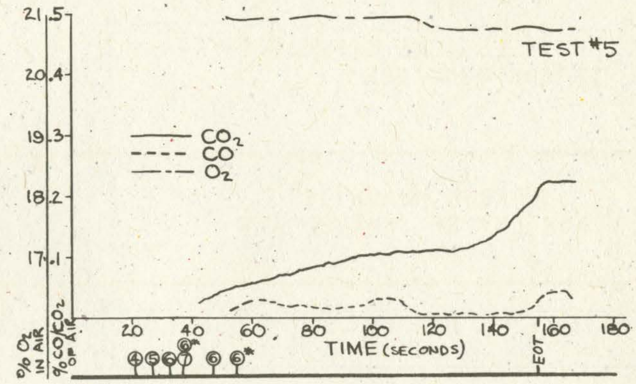
TABLE NO. 2

CARBON MONOXIDE CONTENT OF INHALED AIR %	PPM	EFFECT	AFTER
.02 %	200	Possible mild frontal headache	3 hrs.
.04	400	Frontal headache and nausea	1 to 2 hrs.
		Occipital (rear of head) headache	2½ to 3½ hrs.
.08	800	Headache, dizziness and nausea	45 min.
		Collapse and possible unconsciousness	2 hrs.
.16	1600	Headache, dizziness, nausea	20 min.
		Collapse, unconsciousness, possible death	2 hrs.
.32	3200	Headache and dizziness	5 to 10 min.
		Unconsciousness and danger of death	30 min.
.64	6400	Headache and dizziness	1 to 2 min.
		Unconsciousness and danger of death	10 to 15 min.
1.28	12,800	Immediate effect; unconsciousness and danger of death	1 to 3 min.

*For an average person under normal activity.
Increased activity may shorten time.
Decreased activity may lengthen time.

Claudy, W. D. Carbon Monoxide in Fire Fighting, NFPA Report F21-1, 11 pp, 1954.





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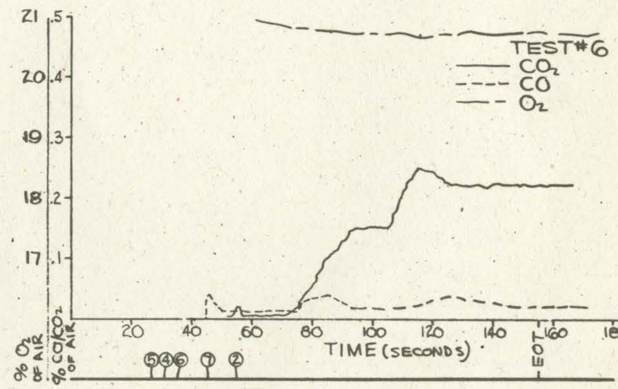
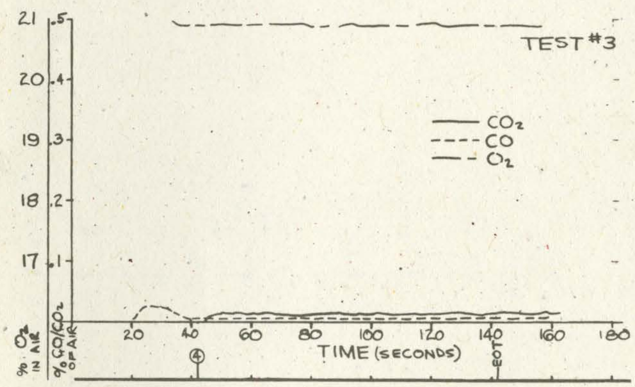
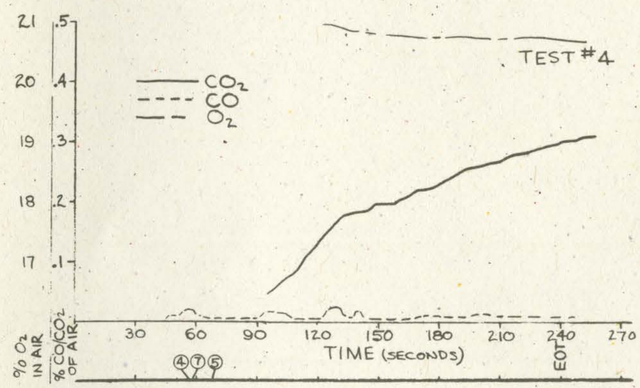
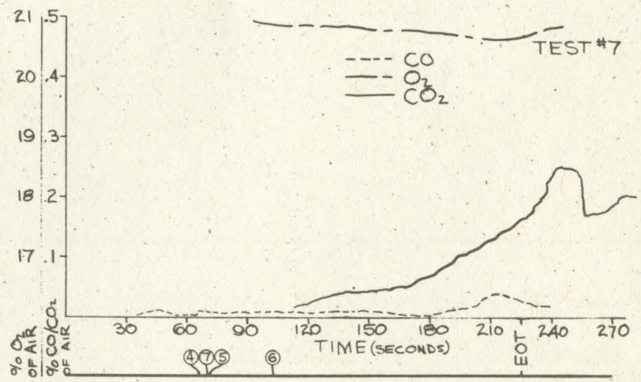
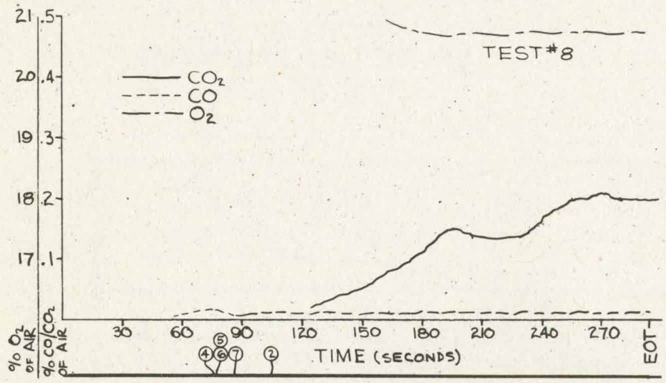
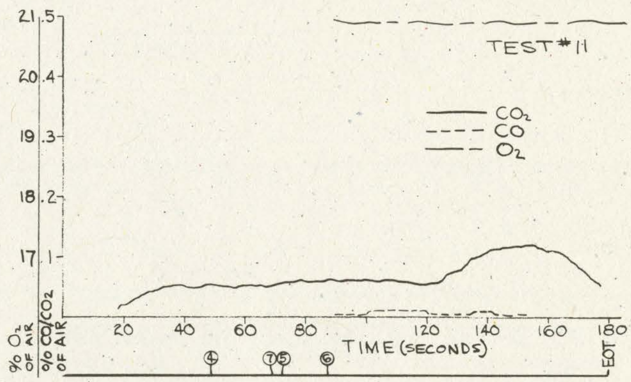


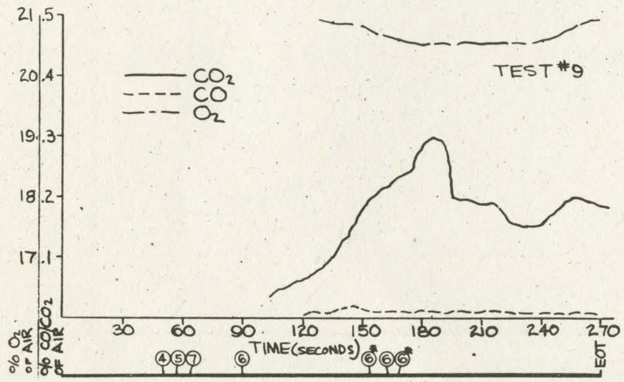


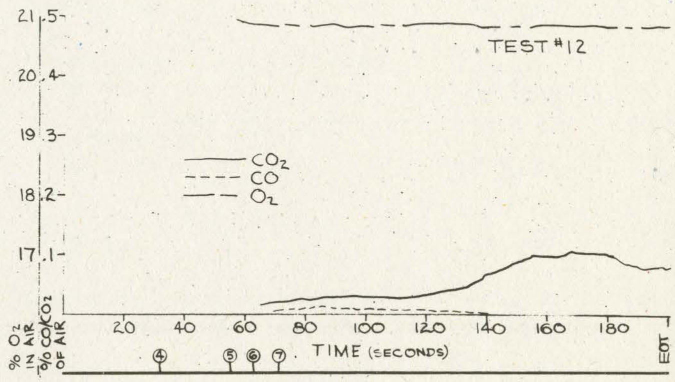


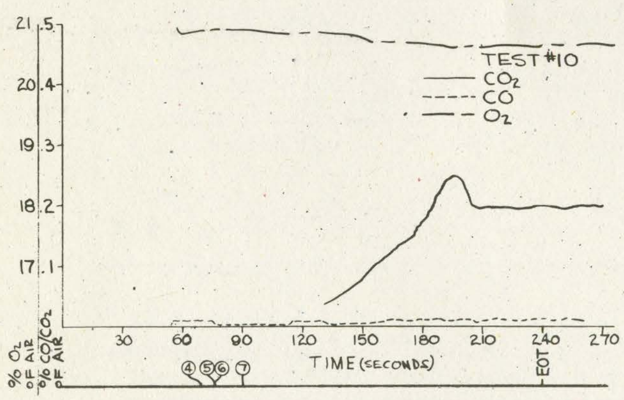


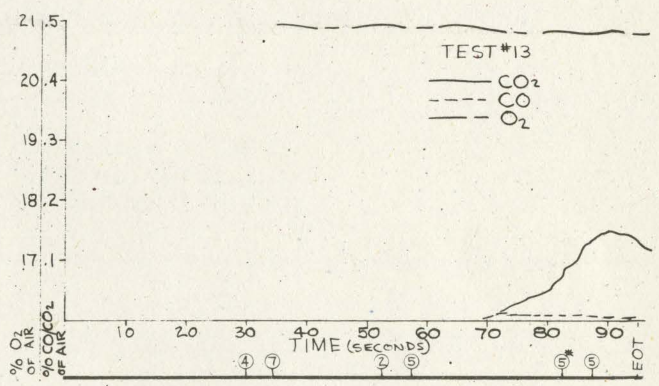

TEST #8
CO2
CO
O2
% O2 OF AIR
% CO/CO2 OF AIR
TIME (SECONDS)
EOT

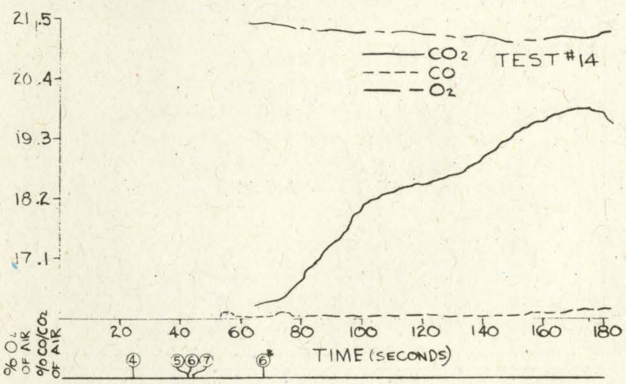

TEST #11
CO2
CO
O2
% O2 OF AIR
% CO/CO2 OF AIR
TIME (SECONDS)
EOT

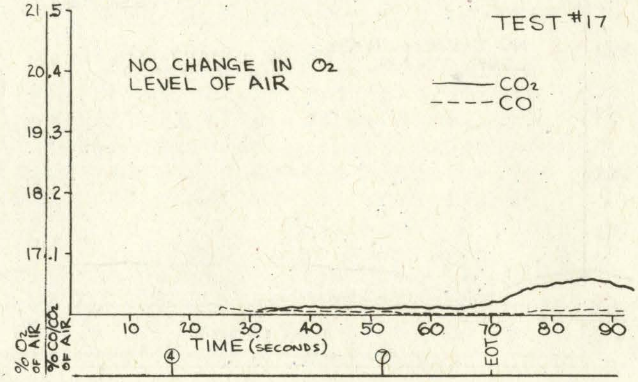

TEST #9
CO2
CO
O2
% O2 OF AIR
% CO/CO2 OF AIR
TIME (SECONDS)
EOT

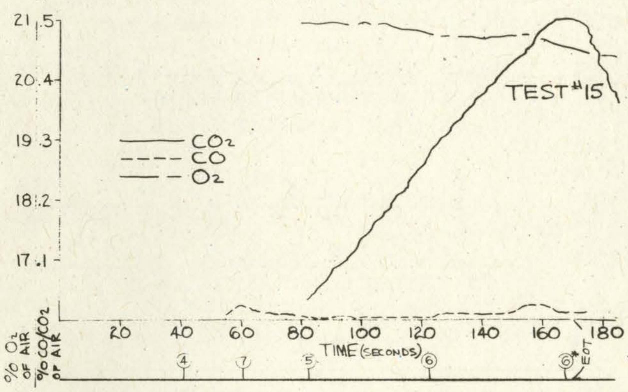

TEST #12
CO2
CO
O2
% O2 IN AIR
% CO/CO2 OF AIR
TIME (SECONDS)
EOT

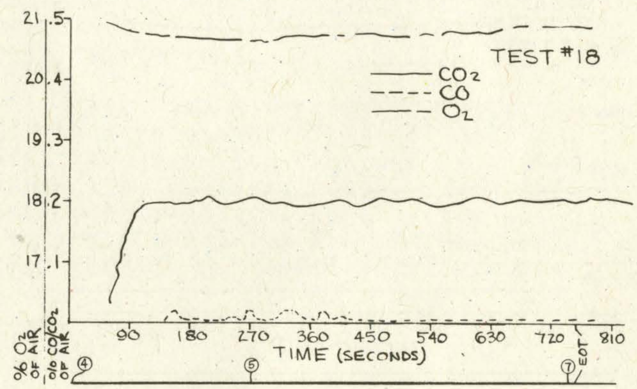

TEST #10
CO2
CO
O2
% O2 OF AIR
% CO/CO2 OF AIR
TIME (SECONDS)
EOT

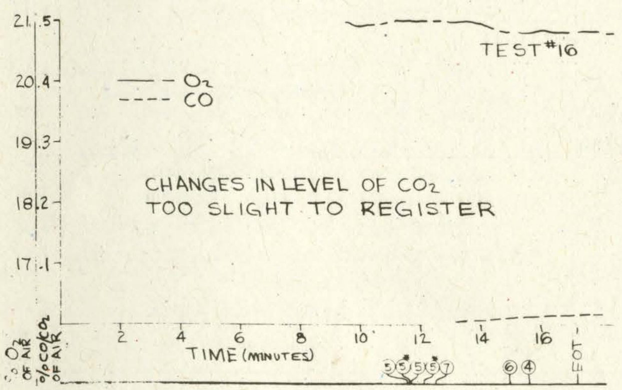

TEST #13
CO2
CO
O2
% O2 OF AIR
% CO/CO2 OF AIR
TIME (SECONDS)
EOT

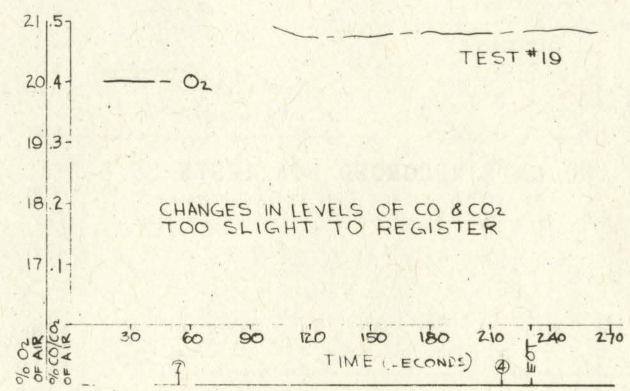

TEST #14
CO2
CO
O2
21.5
20.4
19.3
18.2
17.1
20 40 60 80 100 120 140 160 180
TIME (SECONDS)
% O2 OF AIR
% CO/CO2 OF AIR

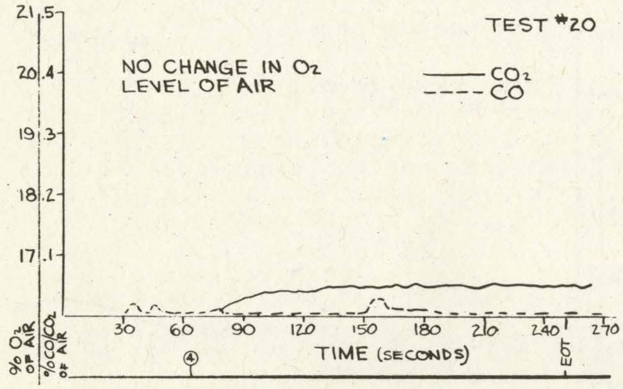

TEST #17
NO CHANGE IN O2 LEVEL OF AIR
CO2
CO
21.5
20.4
19.3
18.2
17.1
10 20 30 40 50 60 70 80 90
TIME (SECONDS)
EOT
% O2 OF AIR
% CO/CO2 OF AIR


TEST #15
CO2
CO
O2
21.5
20.4
19.3
18.2
17.1
20 40 60 80 100 120 140 160 180
TIME (SECONDS)
EOT
% O2 OF AIR
% CO/CO2 OF AIR

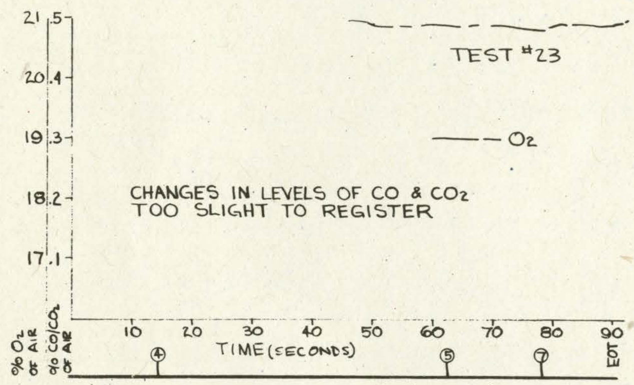

TEST #18
CO2
CO
O2
21.5
20.4
19.3
18.2
17.1
90 180 270 360 450 540 630 720 810
TIME (SECONDS)
EOT
% O2 OF AIR
% CO/CO2 OF AIR

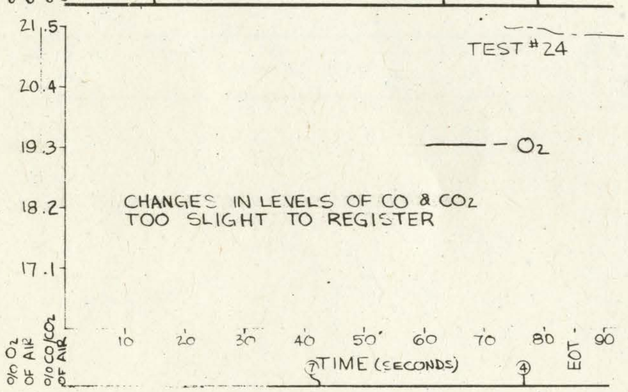

TEST #16
O2
CO
CHANGES IN LEVEL OF CO2 TOO SLIGHT TO REGISTER
21.5
20.4
19.3
18.2
17.1
2 4 6 8 10 12 14 16
TIME (MINUTES)
EOT
% O2 OF AIR
% CO/CO2 OF AIR


TEST #19
O2
CHANGES IN LEVELS OF CO & CO2 TOO SLIGHT TO REGISTER
21.5
20.4
19.3
18.2
17.1
30 60 90 120 150 180 210 240 270
EOT
% O2 OF AIR
% CO/CO2 OF AIR



NO DATA RECORDED FOR TESTS 21 & 22





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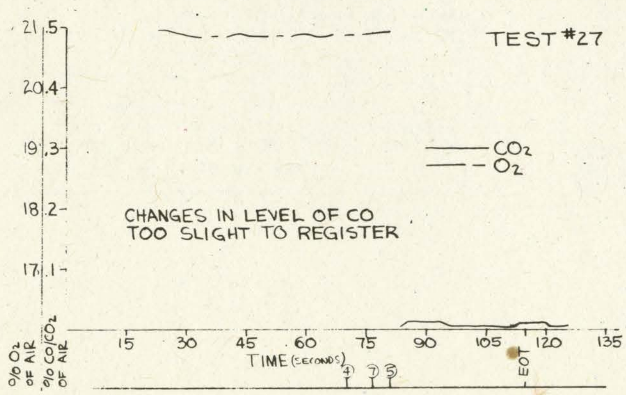
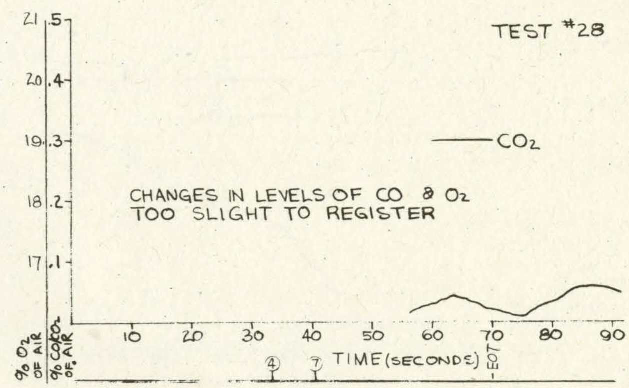
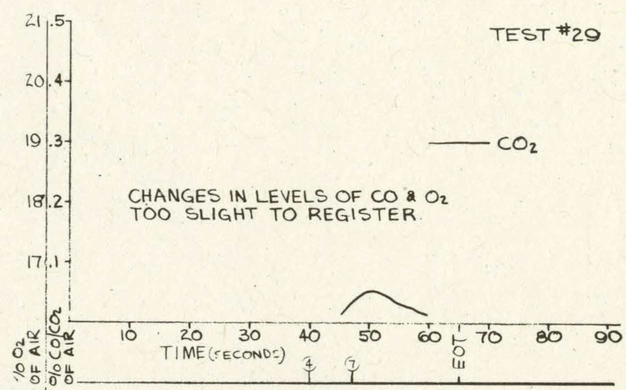
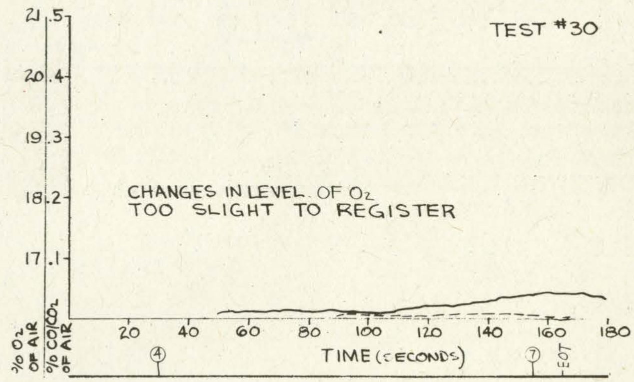
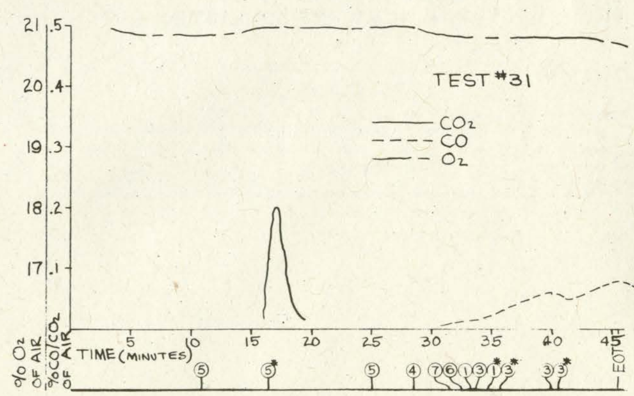










VII. CONCLUSIONS

1. Air movement is the single most important factor influencing reaction time of early warning detection devices within a patient room.

2. In all experiments the early warning detectors operated before dangerous concentrations of smoke occured.

3. Compared to sprinklers (none of which would have operated during any of these tests) the "lead time" or "rescue potential" provided by early warning detection is unquestionable. Coupled with the professional help found in hospitals, this time factor could materially cut down on the single death fires.

4. The time difference in response of ceiling mounted versus door frame mounted combination detector/holder/closers is of no great significance; (Fan ON-Fan OFF)

5. A door frame mounted detector provides automatic positioning, and one of the best locations for optimum detector response in patient sleeping rooms.

6. These experiments clearly show that the design configuration of this combination early warning fire detector, door holder release and closer provided equivalent protection of the room occupants as compared with the ceiling mounted detector installations.

VIII. CLOSING REMARKS

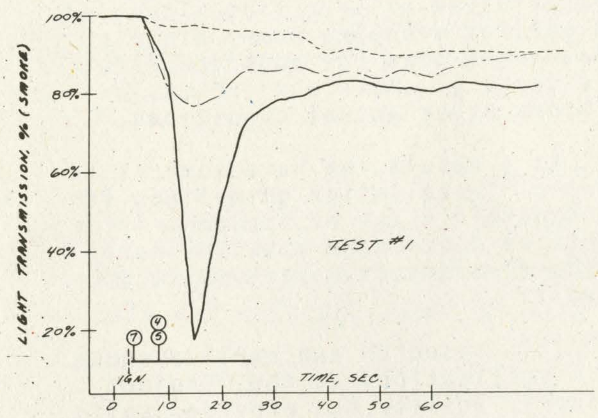
These experiments, which are representative of true fire situations in a patient sleeping room, clearly indicate the need for additional full scale tests of smoke and ionization detectors under actual conditions.

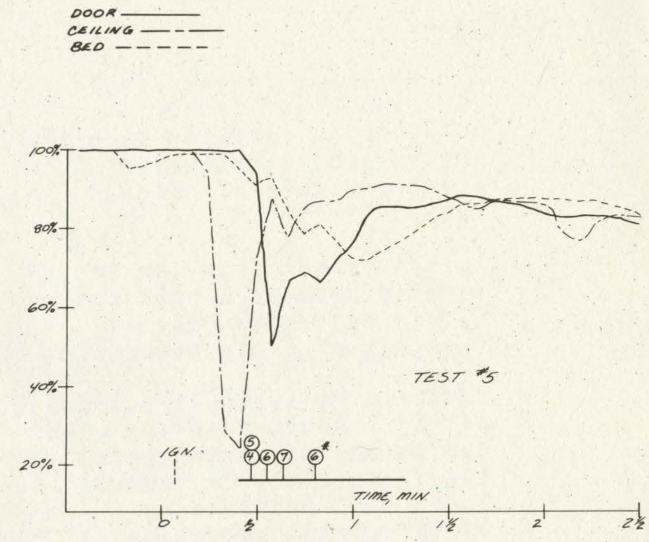
As a result, we have some of the essential installation guidelines (in this specific class of occupancy) for the use of door-frame mounted, early warning fire detection/automatic door control.

This research and earlier smoke flow investigations at the "Project Corridor" facility has provided solid information upon which to verify basic detection principles and building code regulations.

Full scale testing is essential to the development of performance/effectiveness data required by performance type building codes. Such information provides the best system to continually improve life safety protection through our model building codes.

APPENDIX





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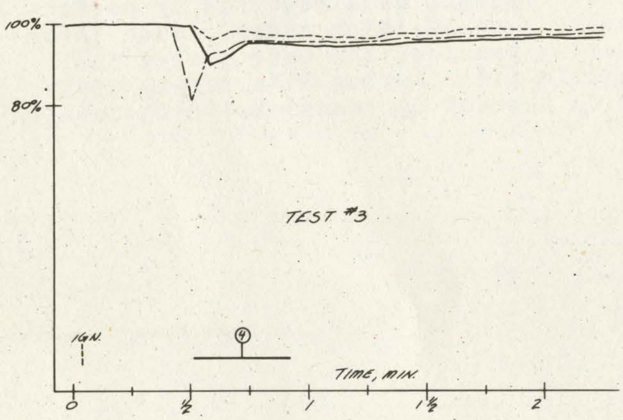
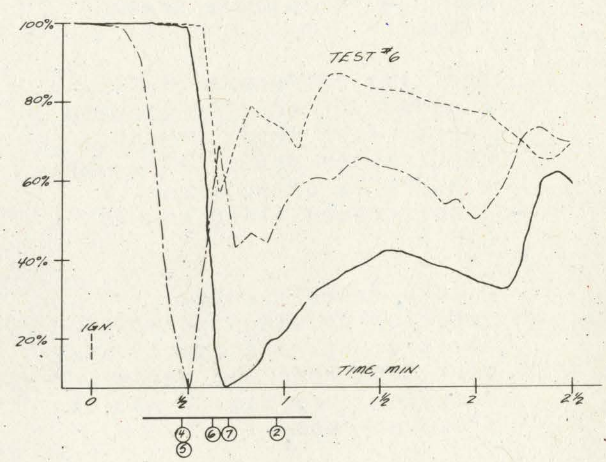
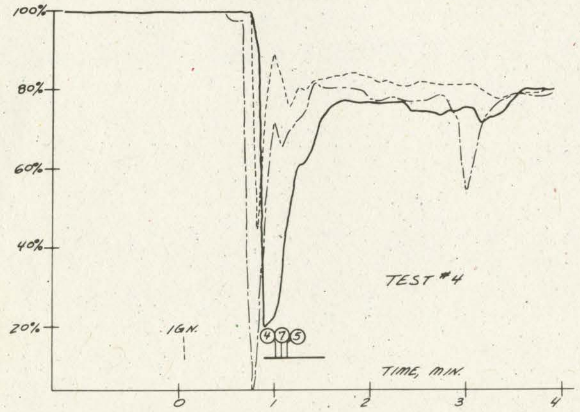
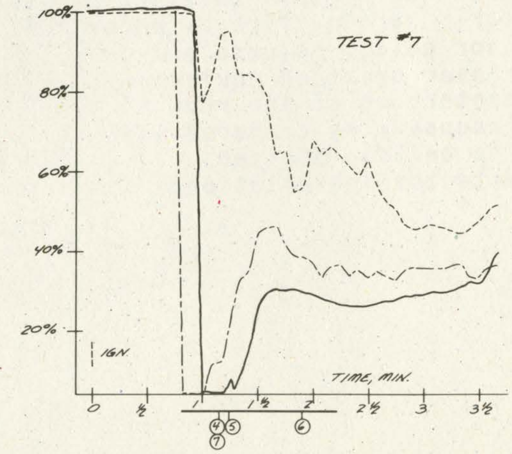
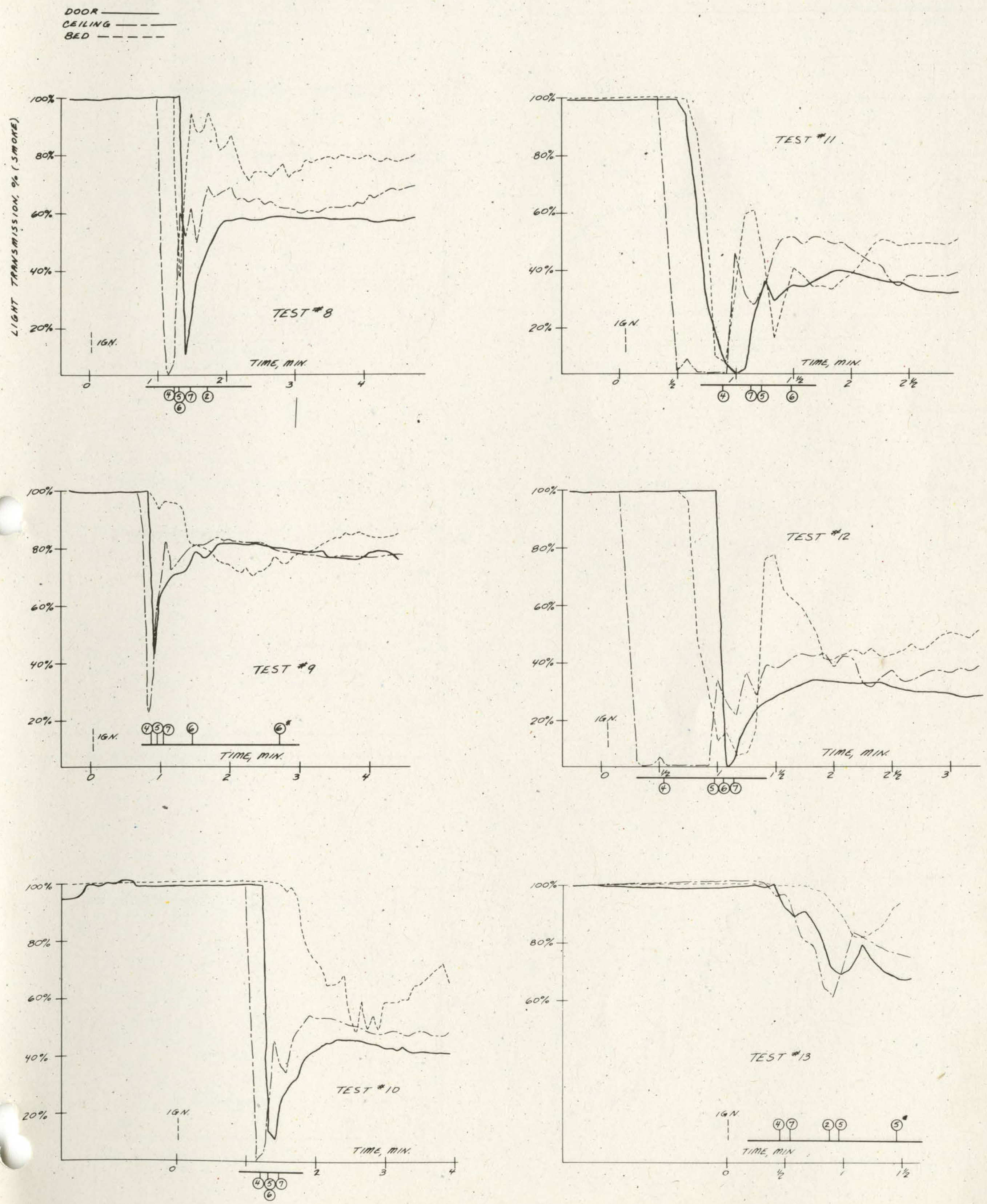
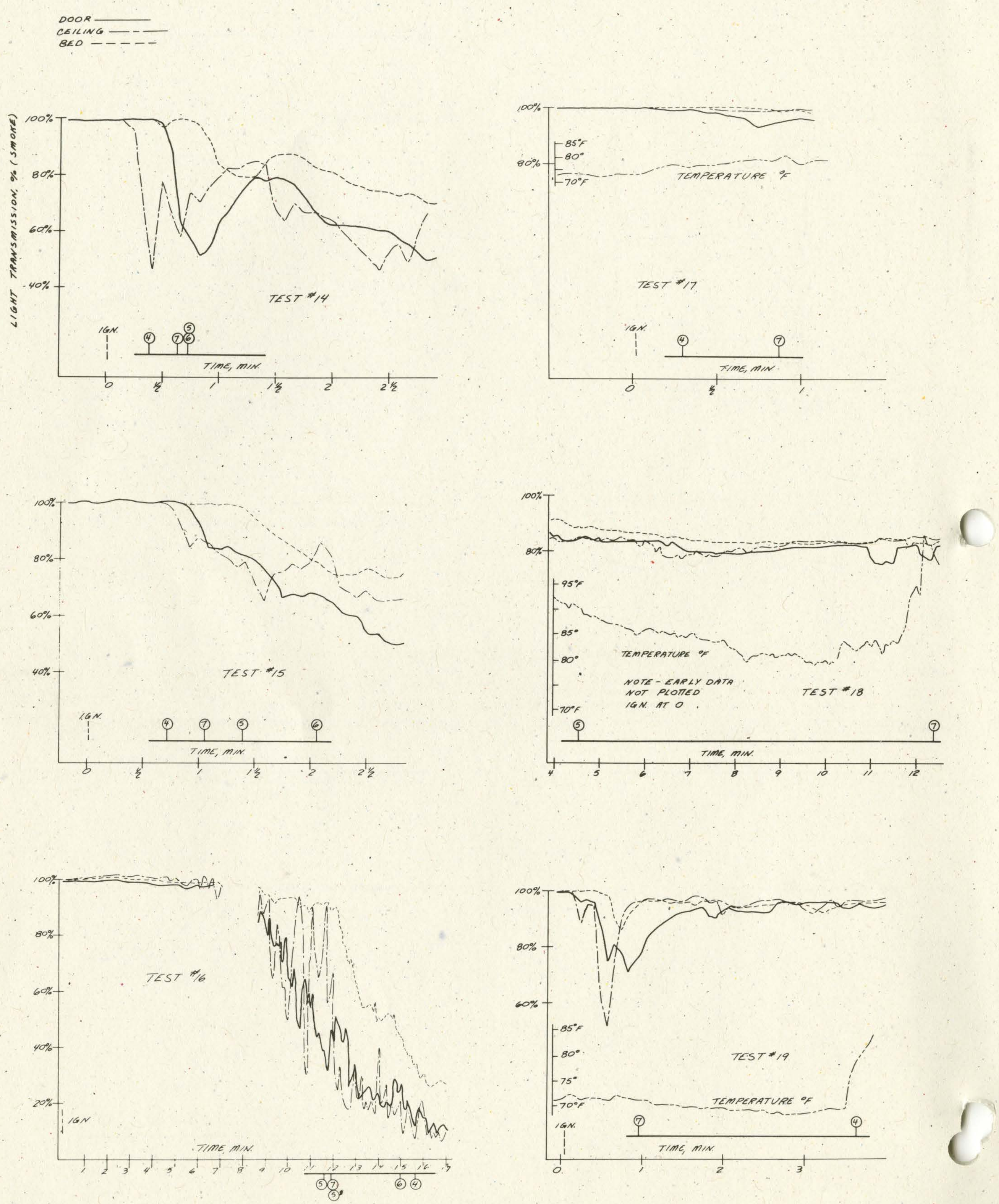


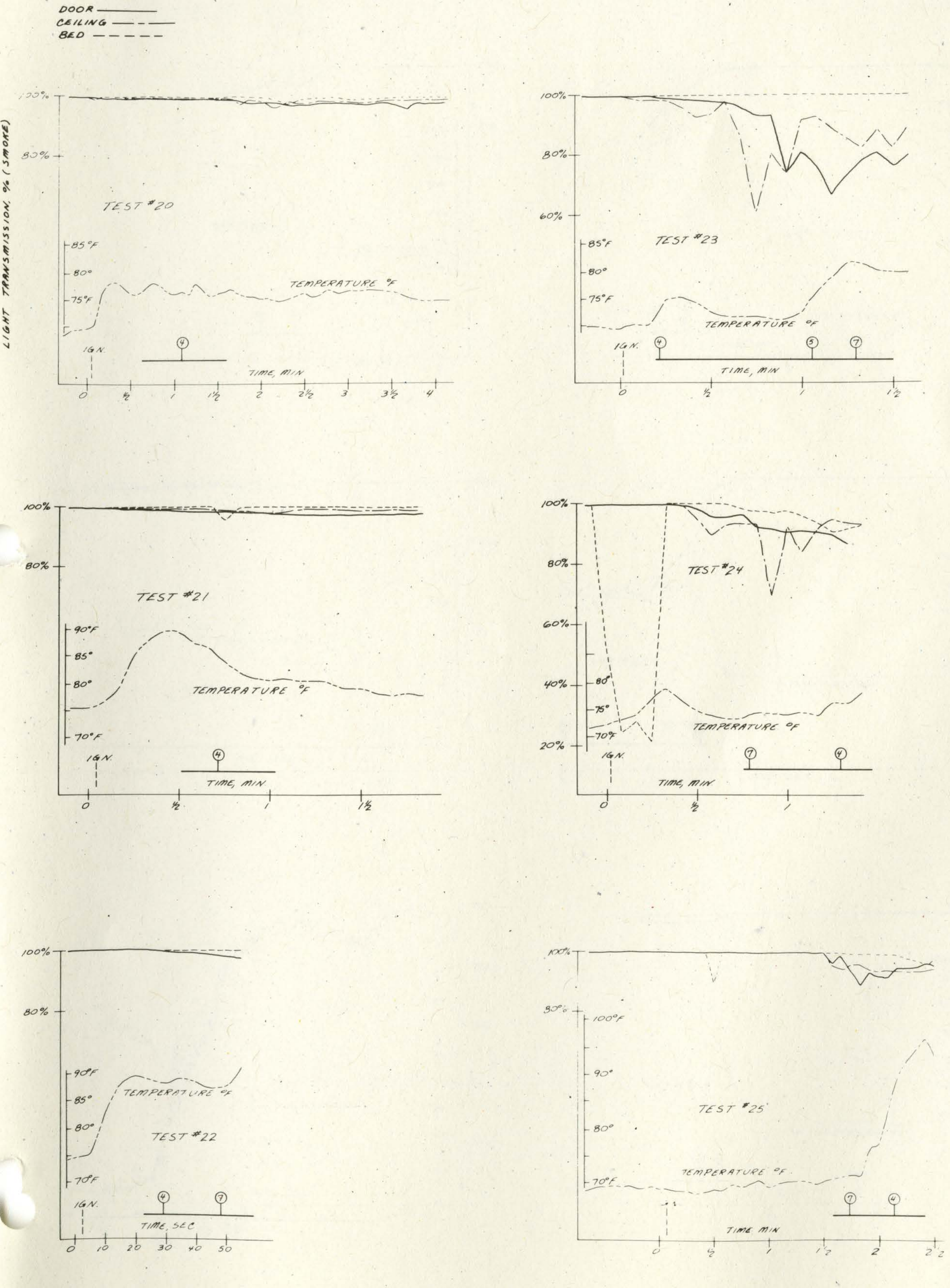


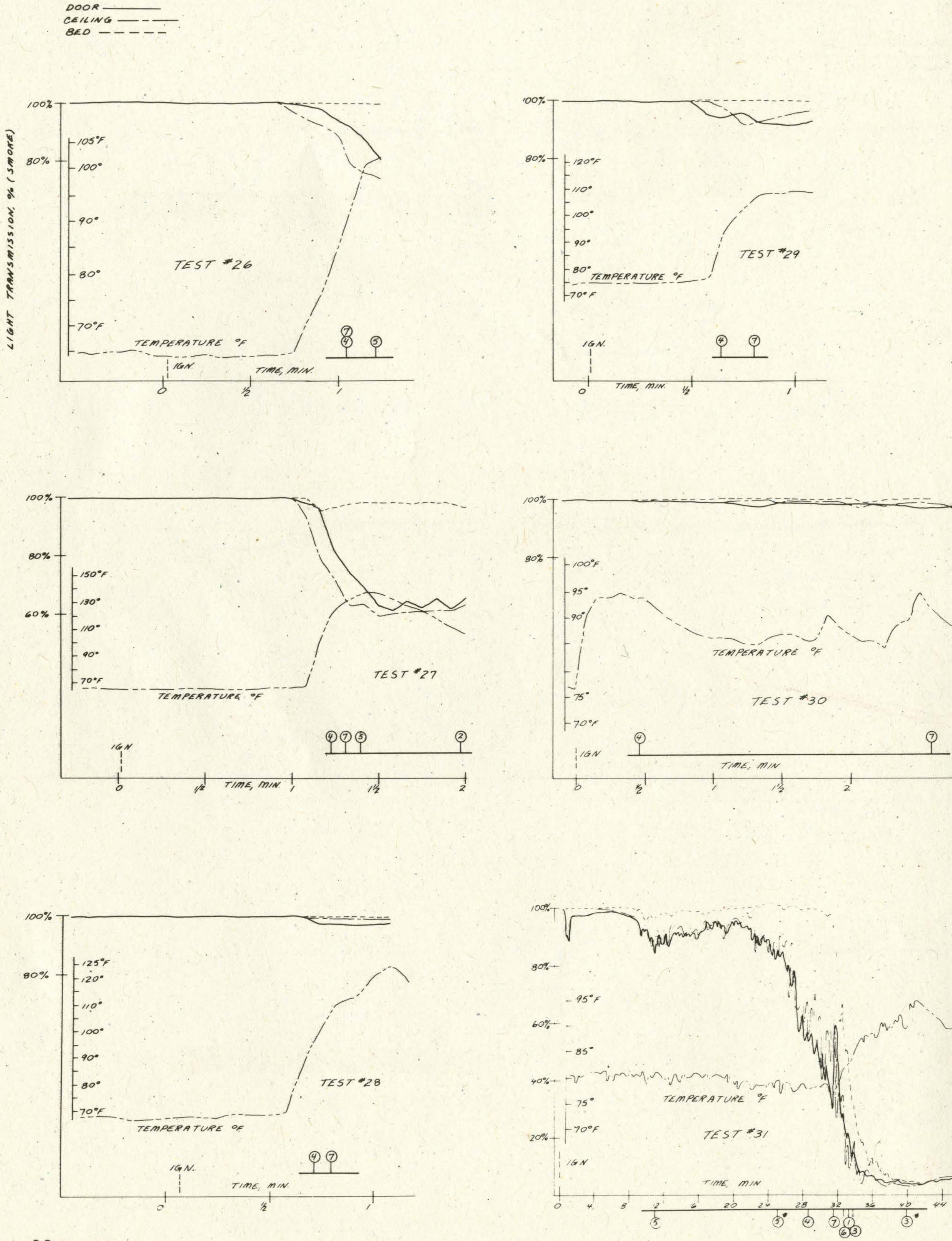





DOOR
CEILING
BED
LIGHT TRANSMISSION, % (SMOKE)
100%
80%
60%
40%
20%
IGN.
TIME, MIN.
TEST #8
TEST #9
TEST #10
TEST #11
TEST #12
TEST #13


DOOR
CEILING
BED
LIGHT TRANSMISSION, % (SMOKE)
TEST #14
IGN.
TIME, MIN.
TEST #17
TEMPERATURE °F
TEST #15
TEST #18
NOTE - EARLY DATA NOT PLOTTED IGN. AT 0
TEST #16
TEST #19


DOOR
CEILING
BED
LIGHT TRANSMISSION, % (SMOKE)
TEST #20
TEMPERATURE °F
TIME, MIN
IGN.
TEST #23
TEMPERATURE °F
TIME, MIN
IGN.
TEST #21
TEMPERATURE °F
TIME, MIN.
IGN.
TEST #24
TEMPERATURE °F
TIME, MIN
IGN.
TEST #22
TEMPERATURE °F
TIME, SEC
IGN.
TEST #25
TEMPERATURE °F
TIME MIN


DOOR
CEILING
BED
LIGHT TRANSMISSION, % (SMOKE)
TEST #26
TEMPERATURE °F
IGN.
TIME, MIN.
TEST #29
TEMPERATURE °F
IGN.
TIME, MIN.
TEST #27
TEMPERATURE °F
IGN
TIME, MIN
TEST #30
TEMPERATURE °F
IGN
TIME, MIN
TEST #28
TEMPERATURE °F
IGN.
TIME, MIN.
TEST #31
TEMPERATURE °F
IGN
TIME, MIN