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Experimental Fires in Multiroom/Corridor Enclosures

Gunnar Heskestad and
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Notice

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TECHNICAL REPORT

EXPERIMENTAL FIRES IN MULTIROOM/CORRIDOR ENCLOSURES

by

Gunnar Heskestad and John P. Hill
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ABSTRACT

A series of 60 fire tests have been conducted in an enclosure consisting of a corridor and three attached rooms, one of which served as a burn room. The purpose was to establish validation data for theoretical fire models of multi-room fire situations with particular emphasis on health care facilities. Fire sources were propylene gas burners, producing steady fires at 56 and 522 kW as well as fires growing with the square of time at several growth rates up to a maximum output of 2 MW. Measurements were made of gas temperatures; ceiling surface temperatures; optical densities in white light and at three discrete wavelengths; concentrations of CO, CO_2 and O_2; gas velocities; and pressure differentials. In addition, smoke detectors and simulated heat detectors were installed and monitored. In the experiments, various combinations were investigated of fire source, open and closed doors, open or closed window in burn room, and natural or forced ventilation in all rooms. A number of tests were devoted to examining smoke migration via ventilation ducting, and others were designed to examine burning rates of polyurethane slabs installed in the burn room as targets for flashover ignition. The data have been filed with the Center for Fire Research, NBS.

ACKNOWLEDGMENTS

This program was planned in cooperation with the Center for Fire Research, National Bureau of Standards (NBS), with resources made indirectly available by the U.S. Department of Health and Human Services. The work was to a large extent formulated on ideas brought together or generated by Harold E. Nelson of NBS. Other NBS personnel contributing to the program include Leonard Cooper and Edward K. Budnick, successive program monitors, as well as George W. Mulholland, W. Douglas Walton, and Richard W. Bukowski.

Donald E. Charlebois, Manger of the FMRC Test Center where the experiments were performed, assisted with the design of the experimental facility and supervised Test Center staff engaged in the program. Other contributing FMRC personnel include Alan P. Symonds, instrumentation; David W. Crouse and James M. Roche, computer software and data reduction; William R. Brown, Donald S. Mann, Robert L. Monti and Stephen D. Ogden, instrumentation support; as well as Billy Burks and David W. Haberlin, smoke detector calibration support, and Samuel M. Knight, fire door structural integrity, of the FMRC Approvals Division.

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I

INTRODUCTION

Numerous enclosure fire tests have been conducted over the past decade. Some of these have been run primarily for testing enclosure fire models[1-13]. Typically, the fires involved a single room with natural ventilation through open doors and windows to a large laboratory space. With enclosure fire models progressing in capability for the single room[14-17], interest is expanding to modeling a fire room connected to surrounding building space[18,19]. Some data have already been collected for such fire situations[20], but there is need for additional data allowing for variations in fire source, ventilation and geometry, especially situations with closed doors. This report describes a series of 60 fire experiments in multiroom enclosures with variations in these key parameters. The purpose was to furnish validation data for theoretical fire models, to be made available to the Center for Fire Research of the National Bureau of Standards (NBS) and to the fire research community at large.

The broad outlines of the program were established in consultation with the NBS Center for Fire Research. It was agreed that emphasis be placed on fire situations possible in health care facilities. The following fire and related life-safety issues were to be addressed: ceiling jet in burn room; descent of smoke layer in burn room and buildup of pressure gradients; escape of smoke through open and closed door to corridor; propagation of smoke front underneath corridor ceiling and buildup of smoke layer; penetration of smoke and toxic gases into patient rooms communicating with the corridor through open or closed doors; passage of smoke through ventilation ducting; response of sprinklers and fire detectors; and the effect of the flashed-over fire environment on the mass loss rate of a newly ignited item in the burn room relative to a freeburn situation.

This report is complete except for a detailed data record. The data have been filed with the NBS Center for Fire Research (scan-to-scan computer printouts and computer tapes of reduced data). Summary and Conclusions are presented in Section VI.

II
EXPERIMENTAL FACILITY

2.1 OVERVIEW

Figure 1 shows a layout of the basic facility with indications of instrumentation. The facility was built on the floor of FMRC's fire test building in West Glocester, R.I., using a part of the 67 m x 76 m test building where the ceiling height is 18.3 m.

The layout is Figure 1 shows a "burn room" and two so-called "target rooms", each measuring (nominally) 3.65 m square, attached to a 2.44 m wide x 18.9 m long corridor. The burn room had a sealable window opening, measuring 0.85 m square. Each of the three rooms was provided with a vent tube (V) to the outside near the floor level. The vent mass flow rate and temperature were monitored with a metering orifice and thermocouple installed in each vent tube, both in the case of natural ventilation in response to the fire and in the case of forced exhaust with fans attached to the vent tubes. In the case of forced exhaust, make-up air was allowed to enter through an inlet vent in the south end of the corridor (IV).

Gypsum board, 12.7 mm thick, on wood studs was used throughout. In addition, the walls and ceiling of the burn room were overlaid with Marinite I (Johns Manville), also 12.7 mm thick, to harden against repeated fire exposure. The existing concrete floor of the test building was used.

Three access doors to the enclosure were provided originally. Before testing began it was realized that it would be very time-consuming to seal these doors tight prior to each test. Accordingly, the three doors were sealed with caulking for the duration of the program and new means of access provided, i.e., resealable hatches in each of the two target room. The dashed area within Target Room 2 in Figure 1 represents an alcove, accessible from the outside, for observers and cameras. A viewport was provided in the wall to the corridor.

Three types of fire sources were used: 1) steady propylene fires at 56 kW on a 0.30 m diameter ("sandbox") burner and at 522 kW on a 0.91 m diameter burner; 2) propylene fires on the 0.91 m diameter burner programmed under computer control to grow with the square of time, exceeding 1 MW in 1, 2, 4 or 8 min; and 3) a naturally growing fire in a configuration of so-called

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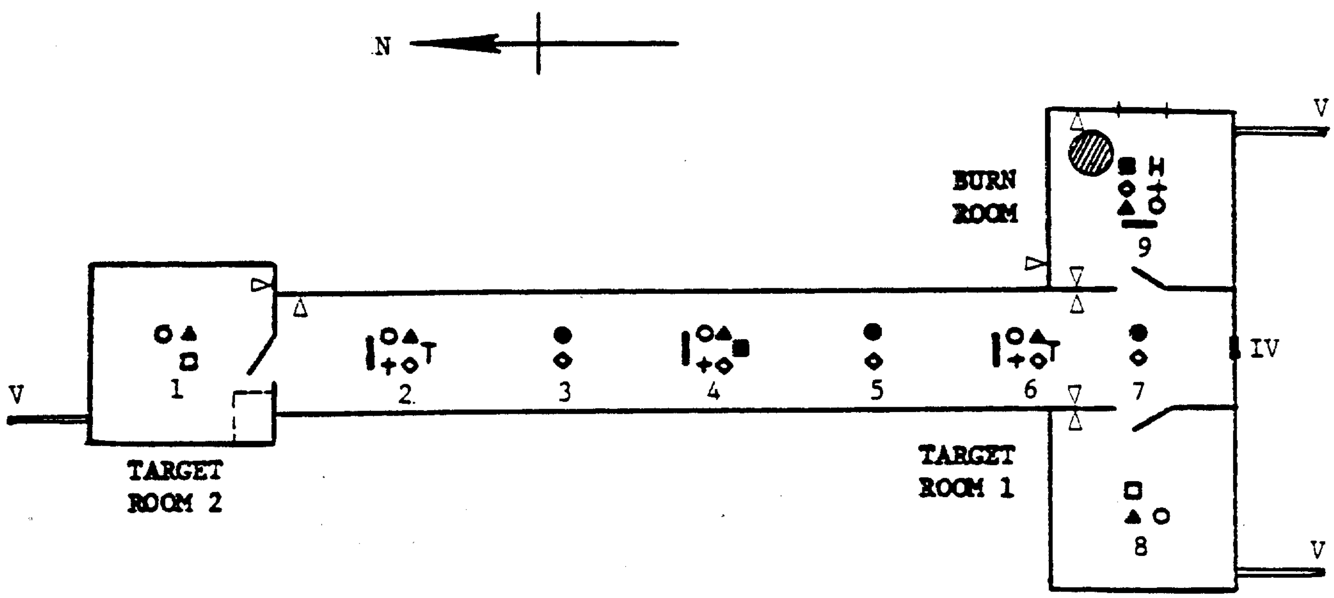


Fire Source (0.30 m or 0.91 m dia. Propylene Burner, 0.58 m above floor)

○ Vertical Thermocouple Array (8 Levels)

▲ Vertical Photometer Array (4 Levels)

+ Ceiling Surface Thermocouple

◇ Brass Disk Under Ceiling (Simulates Heat Detector)

H Bidirectional Flow Probe Under Ceiling

■ Eye-Level Sampling of O_2, CO_2, CO; two add'l CO_2 Levels at Sta. 4

□ Eye-Level Sampling of CO_2, CO

▬ Ionization-Photoel. Pair of Smoke Detectors

● Ceiling Gas Thermocouple

T Turbidimeter Under Ceiling

Δ Wall Pressure Taps (0.39 m From Ceiling)

V Vent tube (102 mm ID) with orifice meter (61 mm dia.) and thermocouple, with option of exhaust fan (tube centered 0.27 m from floor and 0.17 m from near, parallel wall)

IV Inlet vent used with exhaust fans, 0.29 m square, centered 0.43 m above floor

Figure 1 Schematic of facility with instrumentation. Corridor measures 2.44 m x 18.9 m, and each room measures 3.65 m x 3.65 m. Ceiling height is 2.44 m.

"Standard Plastic Commodity", a Factory Mutual test fuel consisting of corrugated boxes with polystyrene tubs in compartments.

Most of the instrumentation indicated in Figure 1 was fairly standard except the "brass disks" and "turbidimeters". The brass discs were provided with thermocouples to measure thermal response, simulating heat detectors and also providing some measure of the gas velocity when coupled with the response of an adjacent thermocouple. The turbidimeters measured the obscuration of light by smoke at three discrete wave lengths. In contrast, the "photometers" measured obscuration of a tungsten filament light source as sensed with a receiver having a spectral response like the human eye. Eight wall pressure taps were provided for measuring six pressure differentials; these included the differentials between each room and the corridor, the differential between the burn room and the outside building space, the differential between the front and the back of the burn room, and the differential between the two ends of the corridor.

In addition to the enclosure and instrumentation indicated in Figure 1, modifications were made for special experimental objectives, as described in Section 2.2.

Depending on the particular test, between 125 and 130 data channels were monitored with a computer-based data acquisition system.

2.2 DETAILS OF ENCLOSURE

Figure 2 identifies a number of vertical sections through the enclosure and presents detailed inside dimensions. A 0.61-m high concealed space was provided above the entire enclosure for possible use in special tests, but this feature was never utilized. Section A-A includes the observation alcove, its height being about the same as the door height. Section C-C includes the window in the burn room, which in many cases was sealed with a wood-framed cover of 12.7-mm thick Marinite I clamped in place from the outside. Section E-E includes the inlet vent opening (IV) identified in Figure 1, which was covered with a steel screen (16 mesh, 0.30 mm dia. wire) and left open in tests with forced ventilation (exhaust) at the vent tubes in the rooms; when not in use, the inlet vent was sealed with a gypsum board cover taped in place.

Details of door geometries in closed positions are presented in Figure 3.

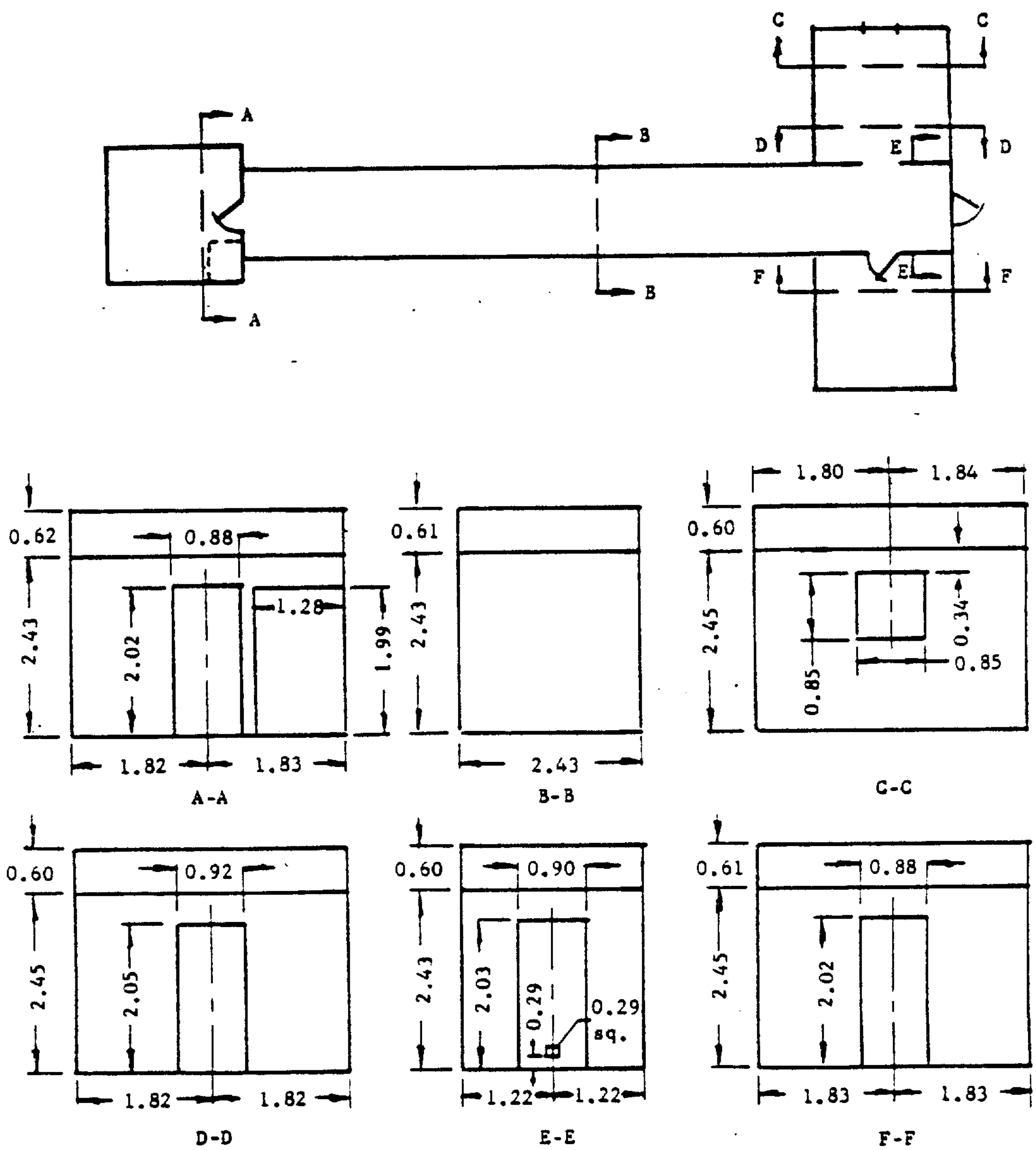
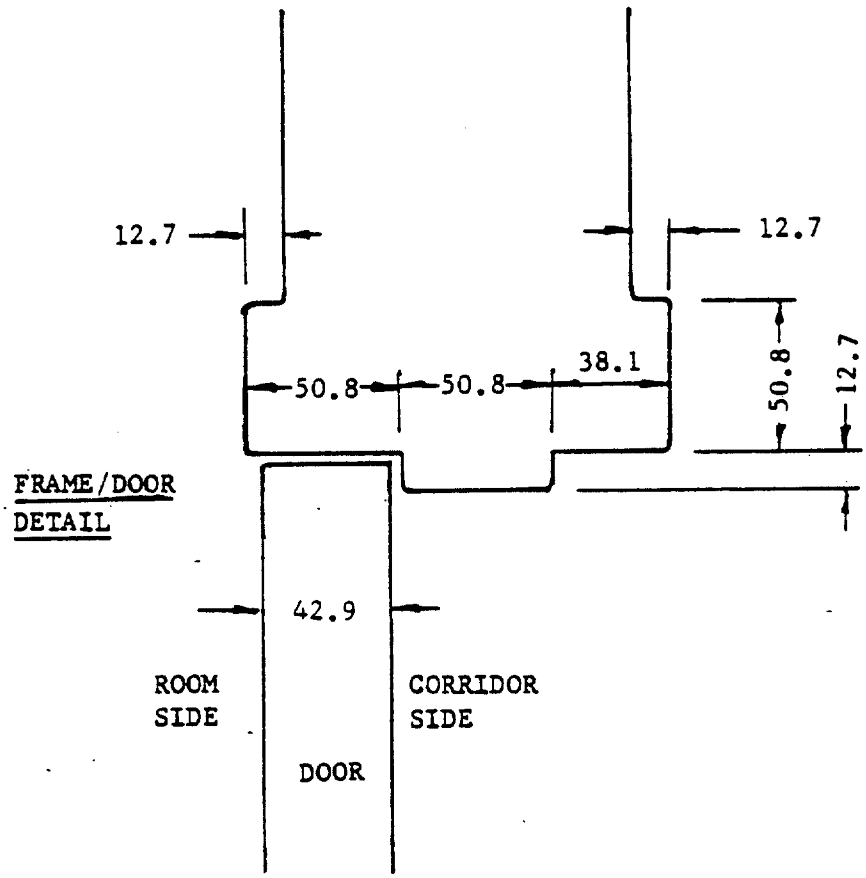


Figure 2 Geometric details of enclosure (dimensions in m)



a) Target rooms (Columbus Door Co. 3068 fire door and frame)

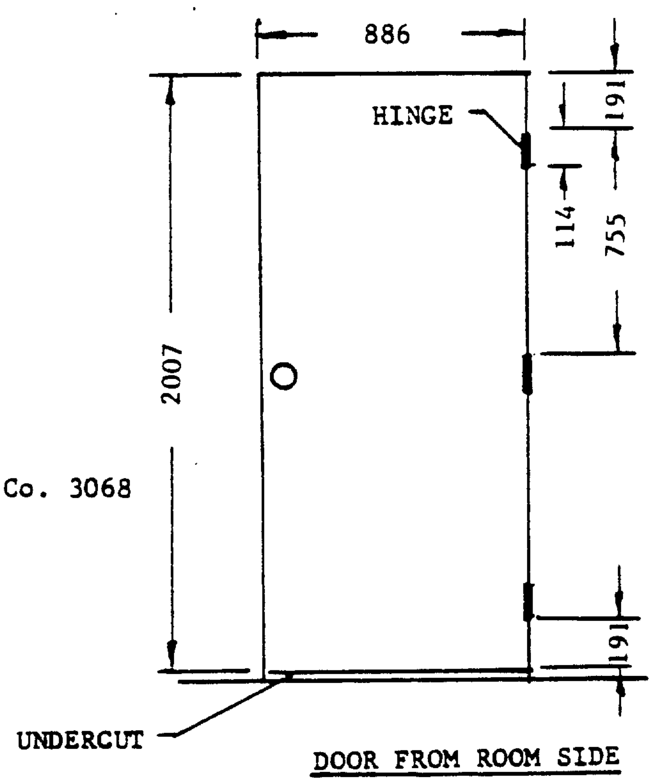
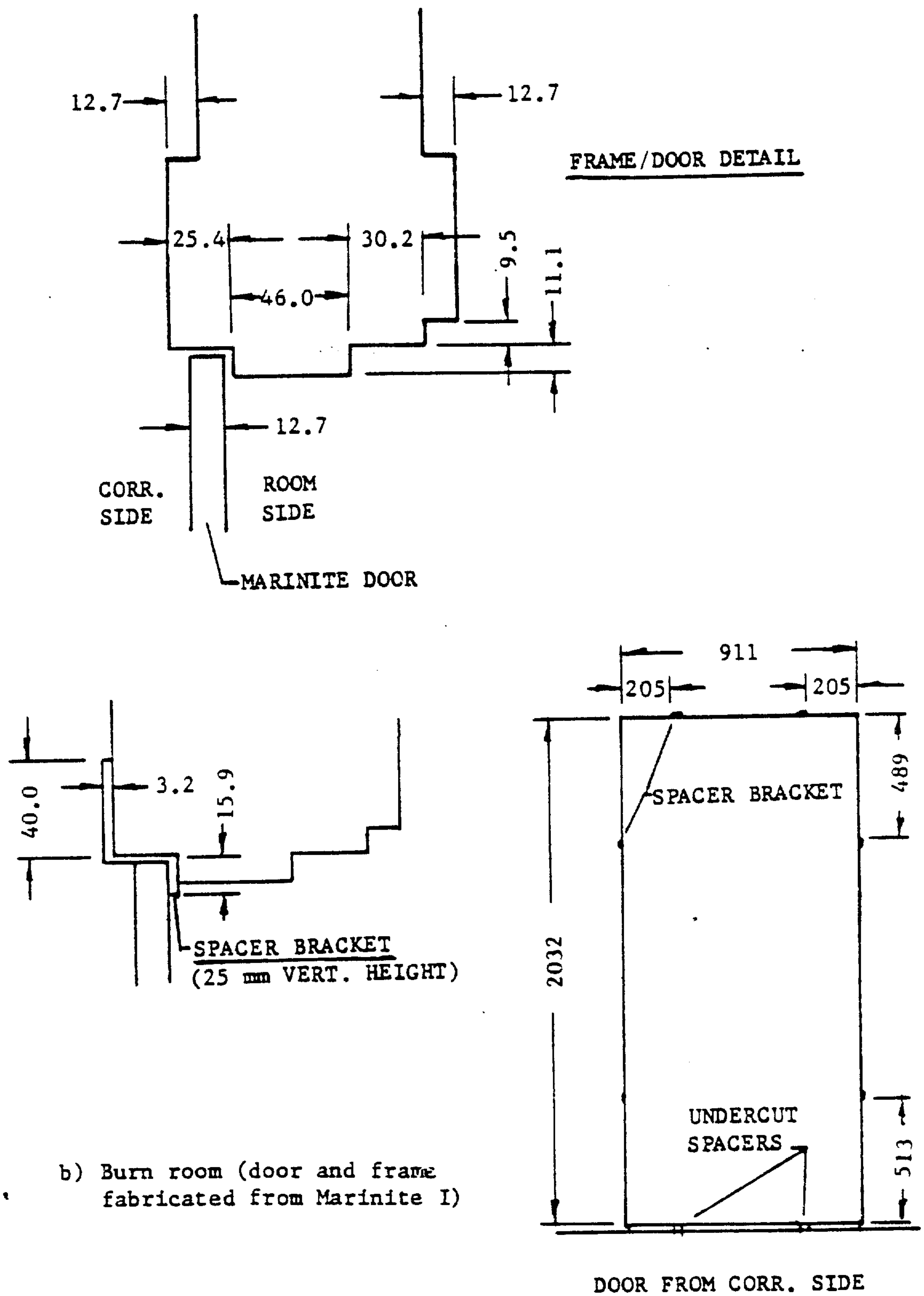


Figure 3 Door geometries (dimensions in mm)



b) Burn room (door and frame fabricated from Marinite I)

Figure 3 (Completed)

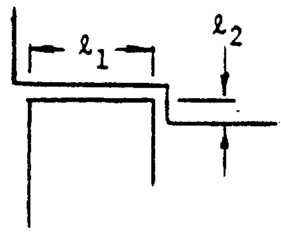
Figure 3a shows dimensions of the door to Target Room 1, including a local cross section in the vicinity of the door crack ("frame/door detail"); the door to Target Room 2 was similar except for being hinged on the opposite side. The target room doors were fire doors manufactured by Columbus Door Co., Model 3068 (wood-faced composite door with calcium silicate core, 1 1/2 hr rated, machined for hinges and latch and with a 16 gage steel frame). Screws were driven into the steel frame at a number of points to act as crack spacers for the purpose of fixing the geometry of the door cracks. In addition, two steel drop bars were provided on the room side through which bolts extended to bearing plates on the door to press the door against the frame. Crack widths were measured with feeler gages for various crack segments: the top crack across the width of the door; the undercut across the width of the door; and the three pairs of cracks ("left" and "right") provided by dividing the height of the door into three equal sections, i.e., the "top 1/3", "middle 1/3" and "bottom 1/3". The crack widths are listed in Table 1.

For the burn room, with its very hot gases and potential for driving off combustible vapors from the door and distorting door cracks, it was decided to fabricate a well defined, noncombustible door rather than use a commercial product. Figure 3b illustrates the (unhinged) door to the burn room, fabricated from 12.7 mm thick Marinite I (Johns-Manville); the door frame is also lined with Marinite I. As indicated, a number of Z-shaped "spacer brackets" and "undercut spacers" were provided around the door perimeter to aid in defining the dimensions of the door cracks and the undercut. Drop bars were provided across the top and bottom halves of the door on the corridor side, with bolts bearing against steel plates on the door, pressing the door against the frame. The shorter leg of the crack matched the thickness of the spacer bracket, 3.2 mm. The longer leg was somewhat wider because of an imperfect door fit to the frame, approximately 3.6 mm. The undercut was 13.8 mm high. When the door was not in use (door to burn room "open"), it was stored outside the enclosure.

For test conditions requiring open doors to the target rooms, it was at first considered appropriate to unhinge the doors and store them outside the enclosure in order to provide well defined apertures consistent with the usual assumptions in fire modeling. However, this procedure seemed too cumbersome

TABLE 1

SUMMARY OF CRACK WIDTH MEASUREMENTS FOR TARGET ROOM (TR) DOORS



Door	Segment	Crack Width* (mm) Left ℓ_1	Left ℓ_2	Right ℓ_1	Right ℓ_2
TR1	Undercut	17.6			
	Top	3.1	4.4		
	Top 1/3	3.5	3.7	1.8	4.2
	Mid 1/3	2.8	2.6	0.9	4.2
	Bot 1/3	3.1	2.9	0.5	3.9
TR2	Undercut	10.7			
	Top	4.3	2.8		
	Top 1/3	1.1	2.5	2.5	3.4
	Mid 1/3	1.1	2.5	2.2	3.6
	Bot 1/3	0.9	2.3	2.8	3.0

*Average of three readings along each (left or right) crack segment. Left and Right refer to view from room side and do not apply to Undercut and Top.

and it was decided instead to open up the doors wide with the door knob touching the wall. Geometric details of the open target room door are represented in Figure 4.

The geometry of an open window is illustrated in Figure 5, as viewed from inside the burn room. Section A-A is a typical cross section of the window frame, showing the inner steel frame, which defined a window opening of 0.851 m square, and 12.7 mm thick Marinite I liners protecting the wood framing. For closed window operation, the wood-framed Marinite I window cover was pressed against a bead of caulking around the steel frame and held by drop bars positioned into slots on the outside wall.

The enclosure was provided with ten viewports, all furnished with wire glass, Figure 6 (triangles). All viewports, except the one in the observation alcove in Target Room 2, were 0.33 m wide by 0.28 m high and centered 1.41 m above the floor. The alcove viewport measured 0.28 m wide by 0.33 m high and was centered 1.22 m above the floor. Figure 6 also shows the locations of the original access doors, which were sealed before testing began, and the substitute, resealable hatches in the target rooms. The hatch covers (0.71 m wide x 1.47 m high) were of the same materials as the surrounding walls. Figure 7a is a photo of a hatch cover and viewport.

Light for observing smoke movement was provided by fluorescent light fixtures at certain locations of intersecting walls and floor, Figure 8. These light fixtures can also be seen photographically in Figure 7b.

2.3 FIRE SOURCES

The 0.91 m dia., 0.58 m high propylene burner was used for most of the tests. Its design was adopted from D'Souza and McGuire[21] and consisted of a 12 gage steel container with a gas distributor near the bottom, filled with gravel to the 67 percent height, where there was a wire mesh screen, and coarse sand to the full height of the burner. Figure 9a is a photographic view of the burner. The 0.30 m diameter burner was a scaled down version of similar design. When in use, this burner was placed in a central cavity scooped out of the sand above the screen of the larger burner so that its top was level with the top of the larger burner; the sand was back filled and screeded to present a smooth, unbroken top surface level with the burner rims. Ignition was by a propane pilot flame established by spark at the

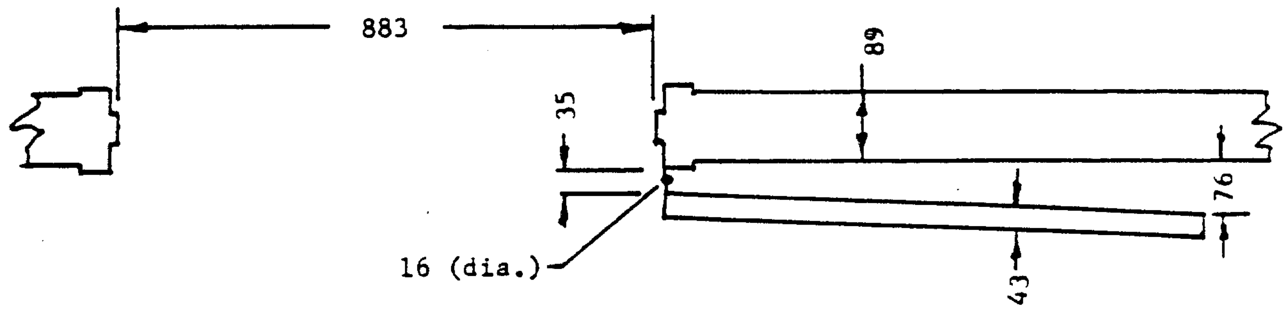


Figure 4 Open target room door (dimensions in mm)

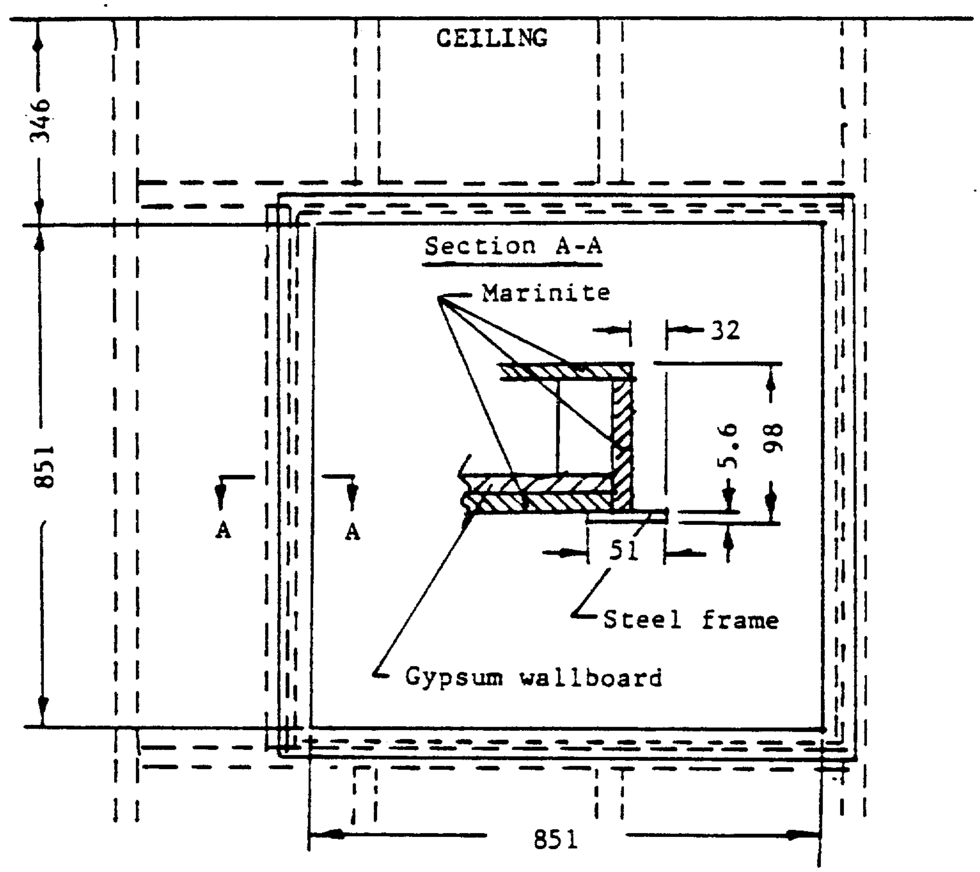


Figure 5 Window in burn room viewed from inside (dimensions in mm)

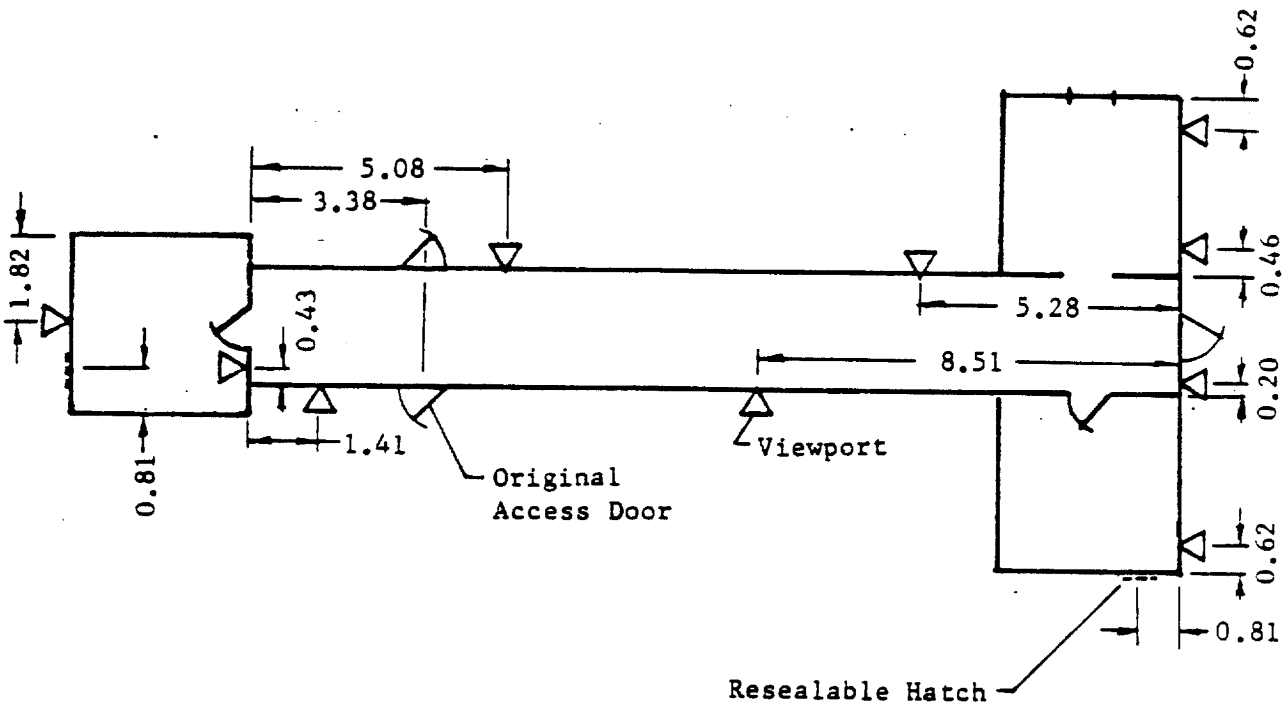
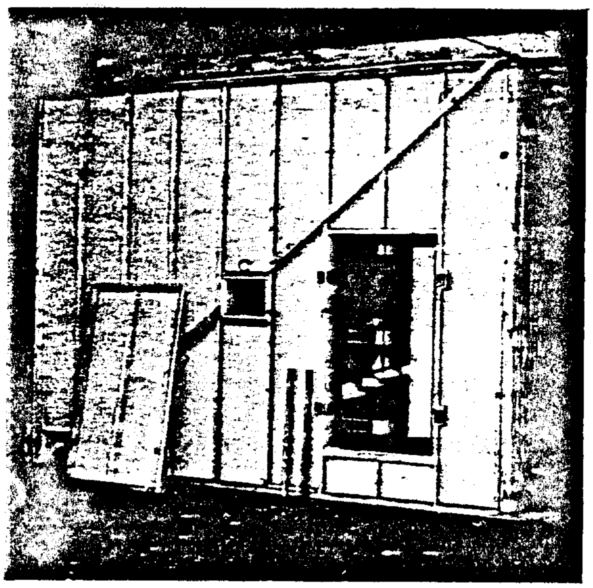


Figure 6 Viewports, original access doors and resealable hatches for access (dimensions in m)



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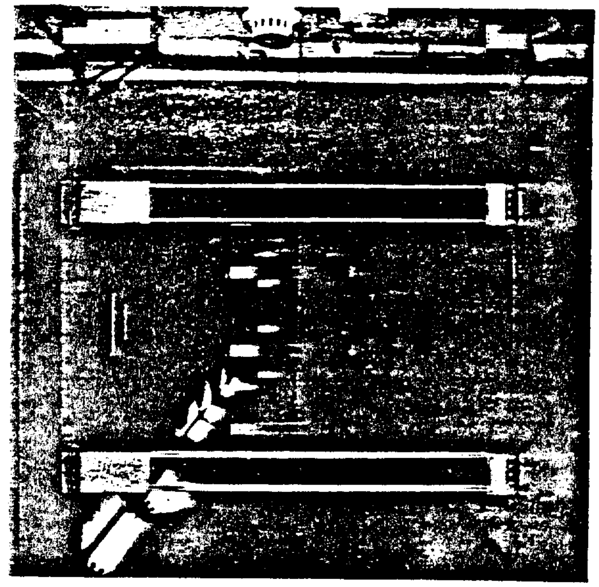
a) Exterior view of TR2 with access hatch and viewport

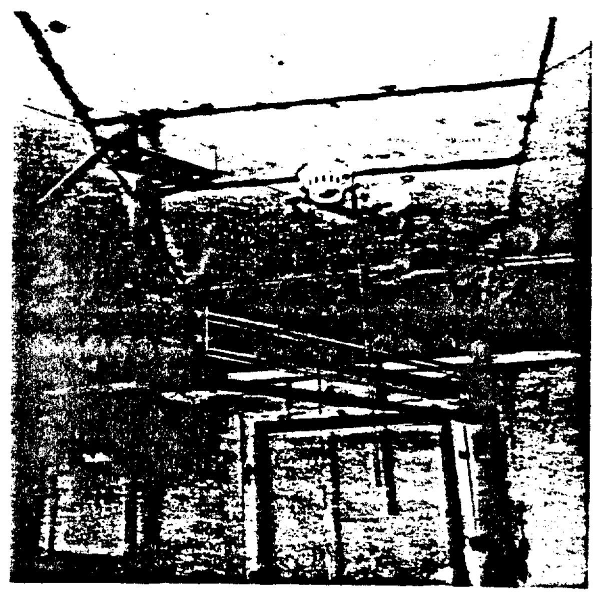


3957-8

b) View along corridor toward burn room

3957-10

c) Instrument station 2



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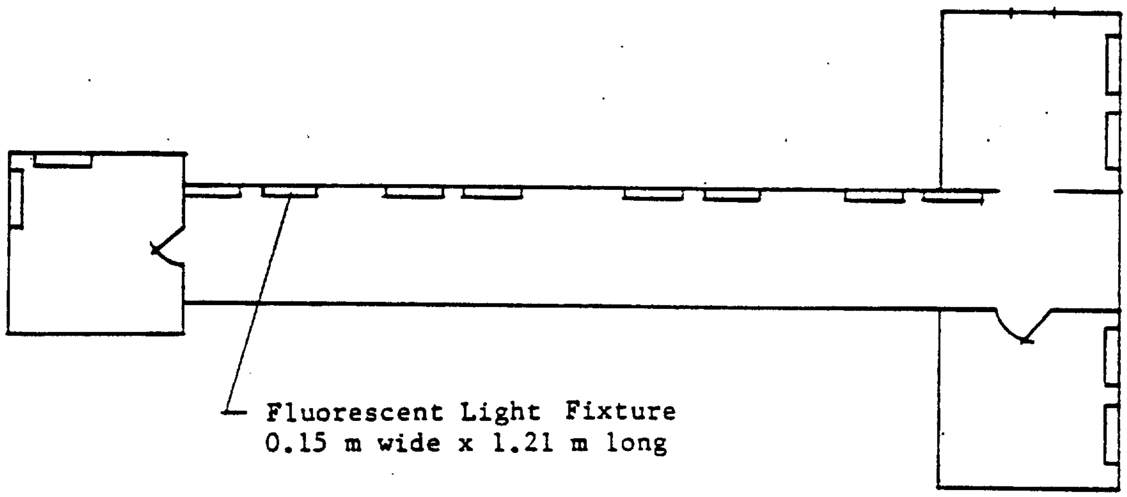
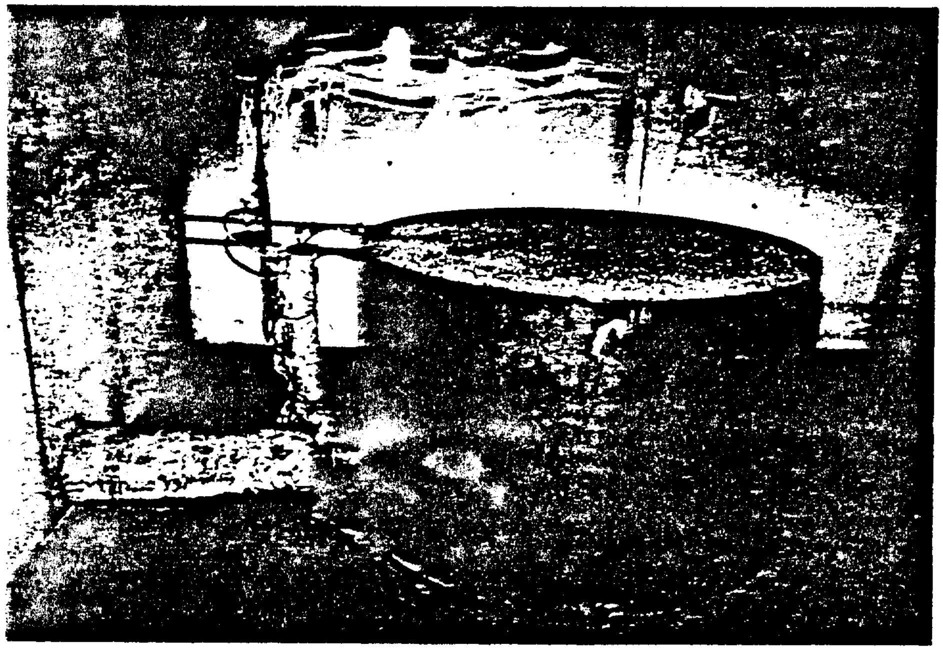
d) Burn room

Figure 7 Views of enclosure with instrumentation

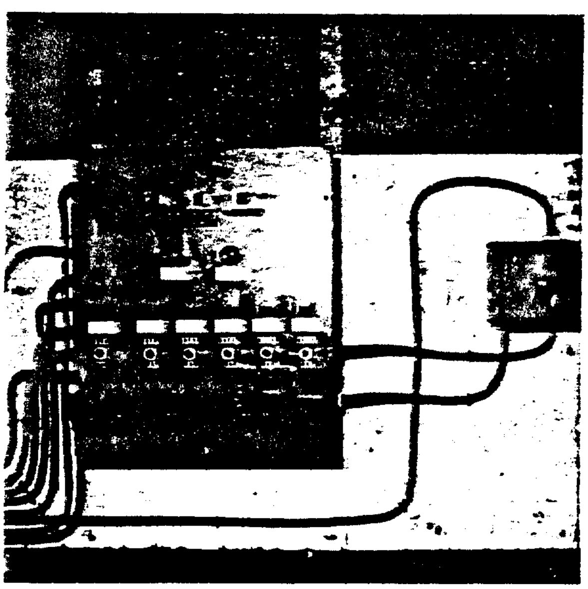


Fixture: American Fluorescent Co.
Light: Two GE F40D Daylight Mainlighter Bulbs (40W)

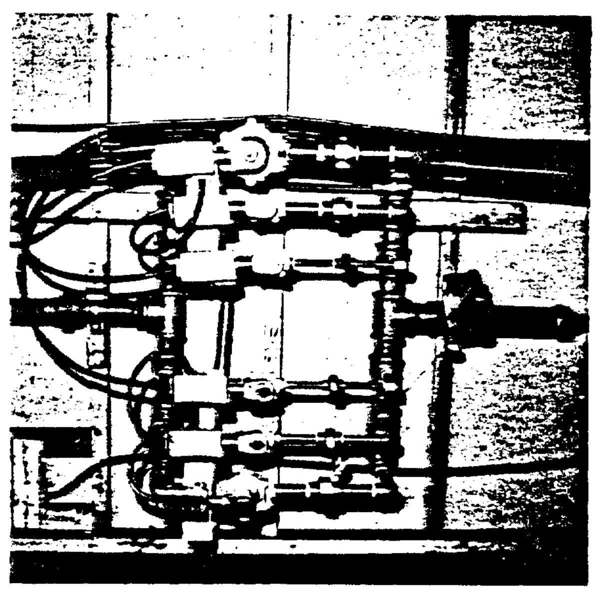
Figure 8 Fluorescent light fixtures along floor-wall intersections (located to scale)



a) 0.91-m diameter burner 4048-1



b) Master control panel 3957-2



c) Fuel control 3957-1

Figure 9 Photographic views of fuel supply components burner periphery well before the start of a test; ignition occurred when propylene gas was admitted to the burner.

The pilot flame and spark igniter were part of a combustion safeguard system which also incorporated a UV (ultraviolet light) sensor viewing the pilot flame, a pilot gas solenoid shut-off valve and a master solenoid valve for the propylene supply to the burner. Without the UV sensor seeing sufficient ultraviolet radiation from either the pilot or the burner, the master solenoid valve would not remain open.

Propylene was selected as a fuel because of its high yield of smoke, which would make the fire gases easily traceable by the eye and the optical devices (photometers).

Fuel supply elements are illustrated in Figure 10. In Figure 10a the propylene gas can be traced from its source at six manifolded cylinders, via a pressure regulator and master solenoid valve (Figure 10b) to a fuel control (Figure 10d) which controls the flow rate of fuel, and then alongside the pilot fuel supply (Figure 10c) to the burner. All manual controls were accomplished at the master control panel mounted on the outside wall of Target Room 2 (photo in Figure 9b). Provisions were made for purging the gas line of fuel gas, using nitrogen (Figure 10b).

The fuel control shown schematically in Figure 10d and in the photo of Figure 9c consisted of two headers, one supply (left) and one exhaust (right), between which ran six branch lines. Each branch line incorporated a solenoid valve and a sharp-edged critical-flow orifice designed to meter a specific propylene flow equal to 1, 2, 4, 8, 16 or 32 so-called "flow units". At the supply pressure selected 274 kPa (39.7 psia), a flow unit corresponded nominally to a heat-release rate of 32 kW, assuming complete combustion (lower heat of combustion of 45,800 kJ/kg). By activating the branch lines in various combinations using the solenoid valves, any integer number of flow units could be supplied to the burner within the range 1-63 (32-2016 kW, nominally). For steady fires, solenoids were activated manually from the master control panel to give the desired burning rate. For simulation of fires growing with the square of time, control was switched to the data-acquisition computer which was programmed to sequence combinations of solenoid valves to approximate the desired fire growth in stepwise increments of $1000/31 \approx 32$ kW. The increments occurred at times t_n, where $n=1$ corresponded

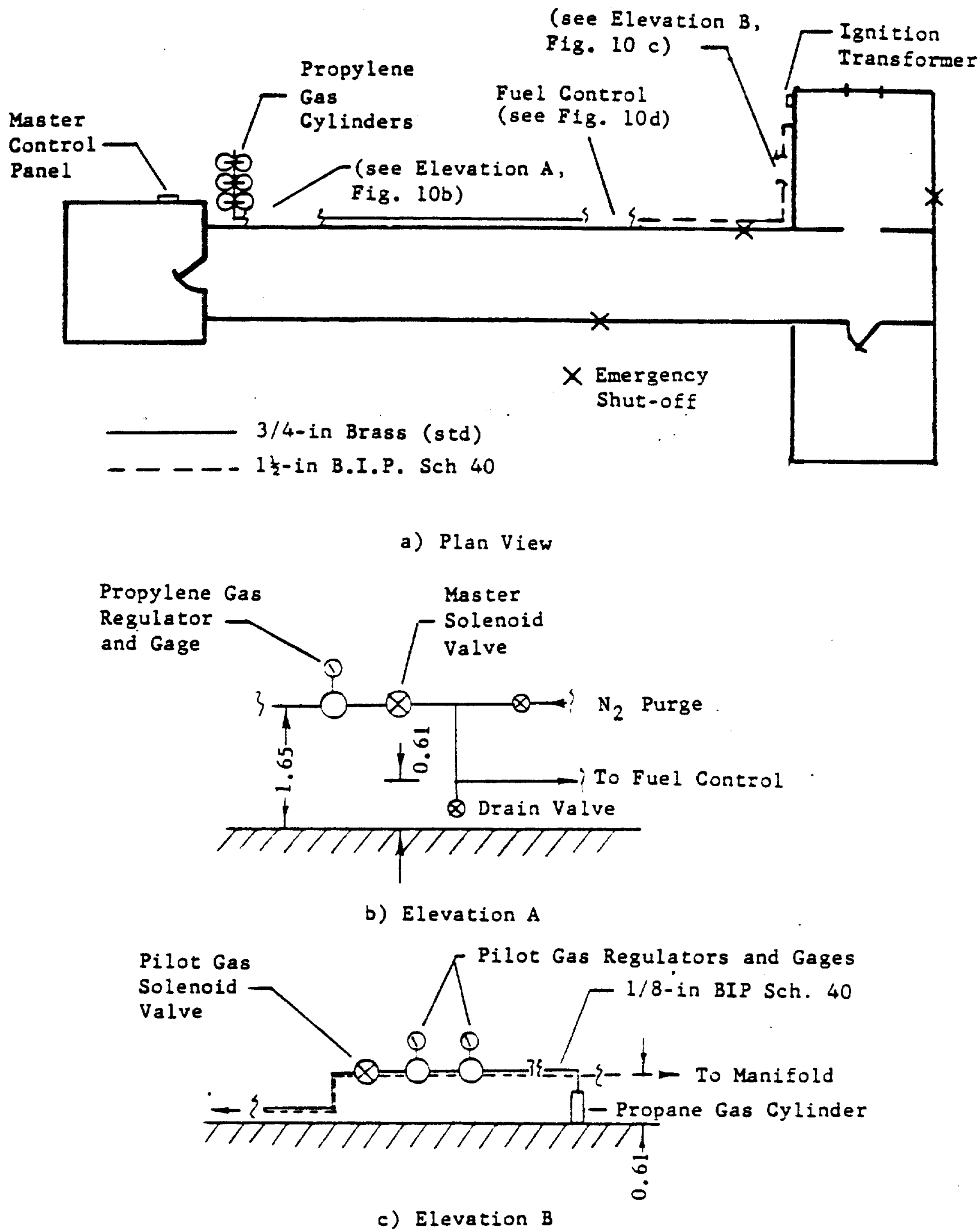
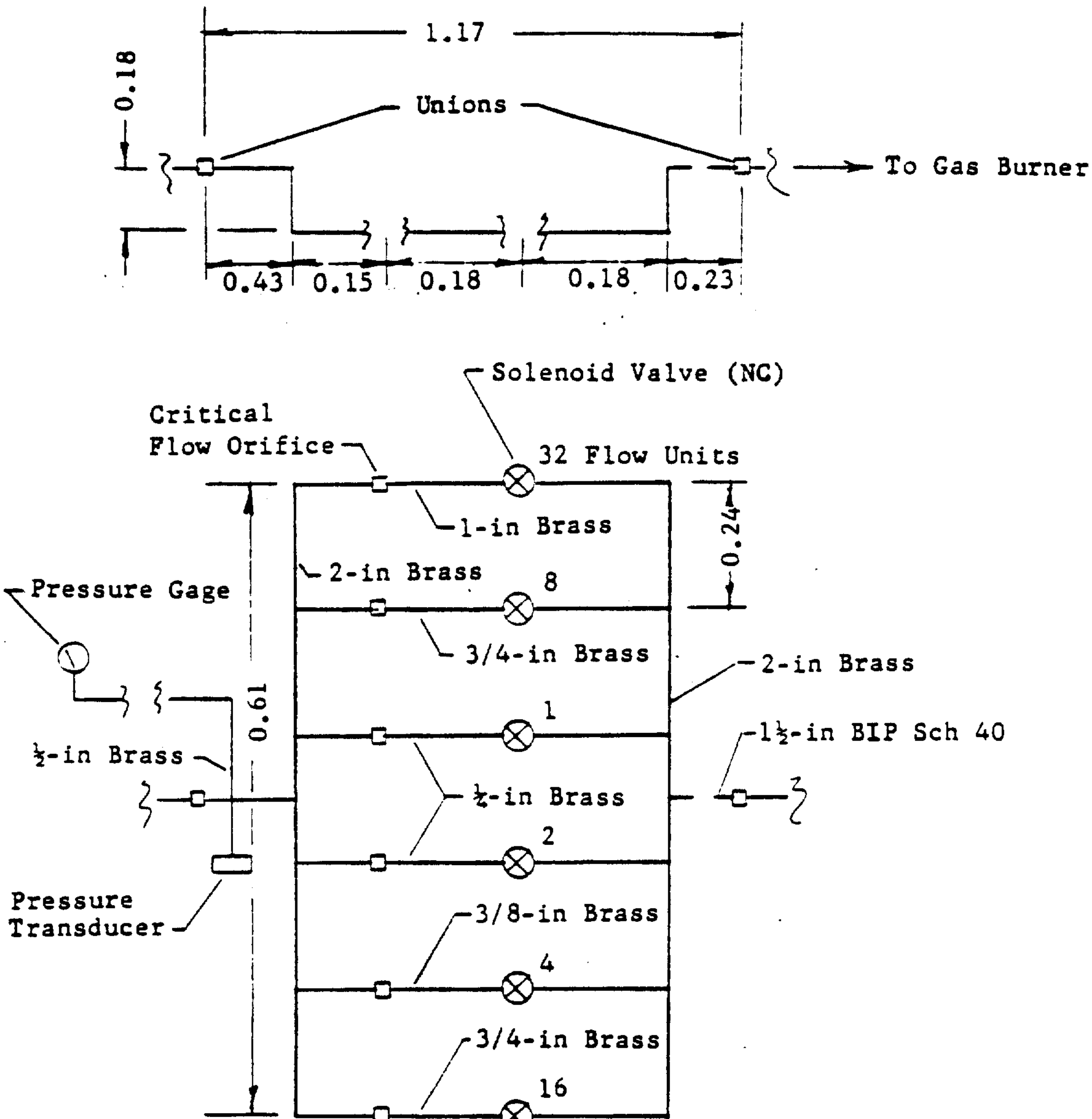


Figure 10 Fuel supply (dimensions in m except as indicated)



d) Fuel Control

Figure 10 (Completed)

to the first increment in the heat release rate, $\dot{Q}$, Figure 11. Representing the smoothly growing fire as

$$\dot{Q}\ (\text{kW}) = 1000\ (t/t_g)^2, \qquad (1)$$

where t is time and t_g is the "growth time" until the heat-release rate exceeds 1000 kW, the times t_n follow from the equation included in Figure 11.

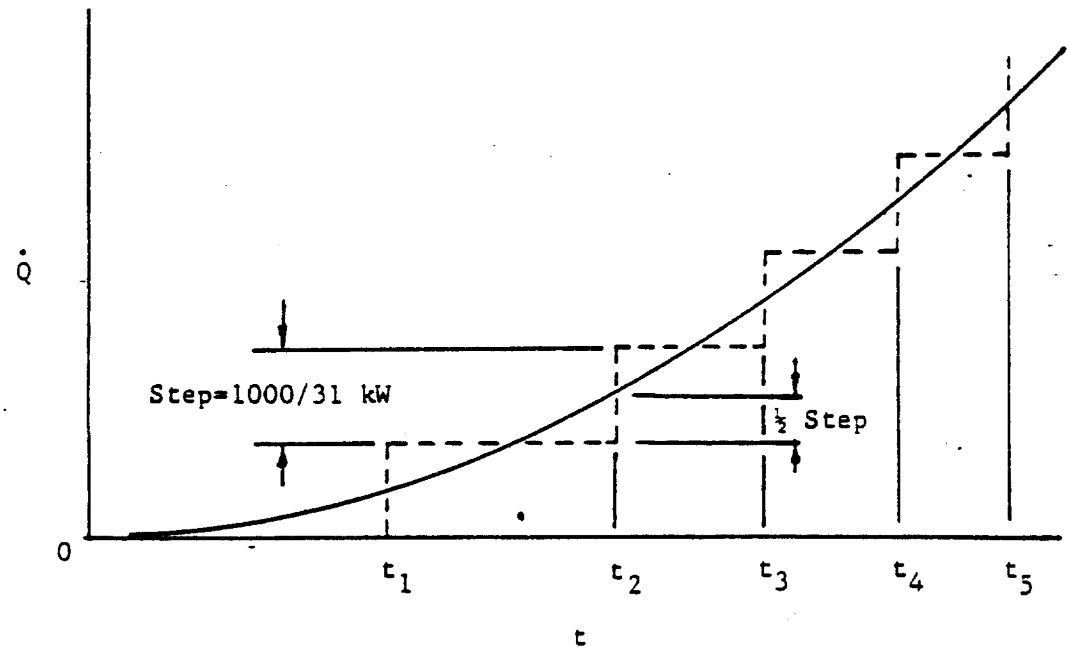
The design of the critical-flow orifices of the fuel control was based on a discharge coefficient of 0.80, as determined from Grace and Lapple[22] for the pressure ratio used in the present application. The actual diameters of the fabricated orifices, as measured on an optical comparator, deviated slightly from the design diameters. The two diameters are compared in Table 2 for the various flow capacities in terms of nominal number of flow units. The ratio of diameters squared indicated in the table is proportional to the ratio of actual to design flow rates (for a given supply pressure). When multiplied by the nominal number of flow units, this ratio gives the actual number of flow units indicated in the last column of Table 2.

2.4 INSTRUMENTATION

2.4.1 Locations

In Figure 1 the instrument clusters, or instrument stations, are numbered 1 through 9. Figure 12 shows the locations of the instrument stations along with detailed interior dimensions and placement of the fire source. The instrument locations indicated corresponded to the vertical thermocouple array of each instrument cluster; locations in the rooms were at the geometric center and, in the corridor, half way between the side walls.

Figure 13 is a layout of the largest possible instrument cluster at an instrument station as seen from above, representing all stations if appropriate instruments are deleted (Figure 1). The cross represents the locations indicated in Figure 12, coincident with the beads of the vertical array of thermocouples or ceiling gas thermocouple (circles) as well as the ceiling surface thermocouple. In the notation of Figure 1, the brass disk was to the right, the bidirectional flow probe to the left, the photometer beam just behind, and the gas sampling tube further behind. The individual smoke detectors are shown to scale rather than symbolically and so is the turbidimeter up



$$t_n/t_g = ((n-\tfrac{1}{2})/31)^{\frac{1}{2}}$$

Figure 11 Approximation of fire growing with the square of time by discrete increments in heat release rate

TABLE 2

CRITICAL-ORIFICE DIAMETERS

Nom No. of Flow Units	Design Dia. (mm)	Actual Dia.(mm)	$\left[\frac{\text{Act. Dia.}}{\text{Des. Dia.}}\right]^2$	Act. No. of Flow Units
1	1.199	1.178	0.965	0.97
2	1.694	1.737	1.051	2.10
4	2.400	2.372	0.977	3.91
8	3.391	3.439	1.029	8.23
16	4.796	4.790	0.997	15.97
32	6.782	6.750	0.991	31.71

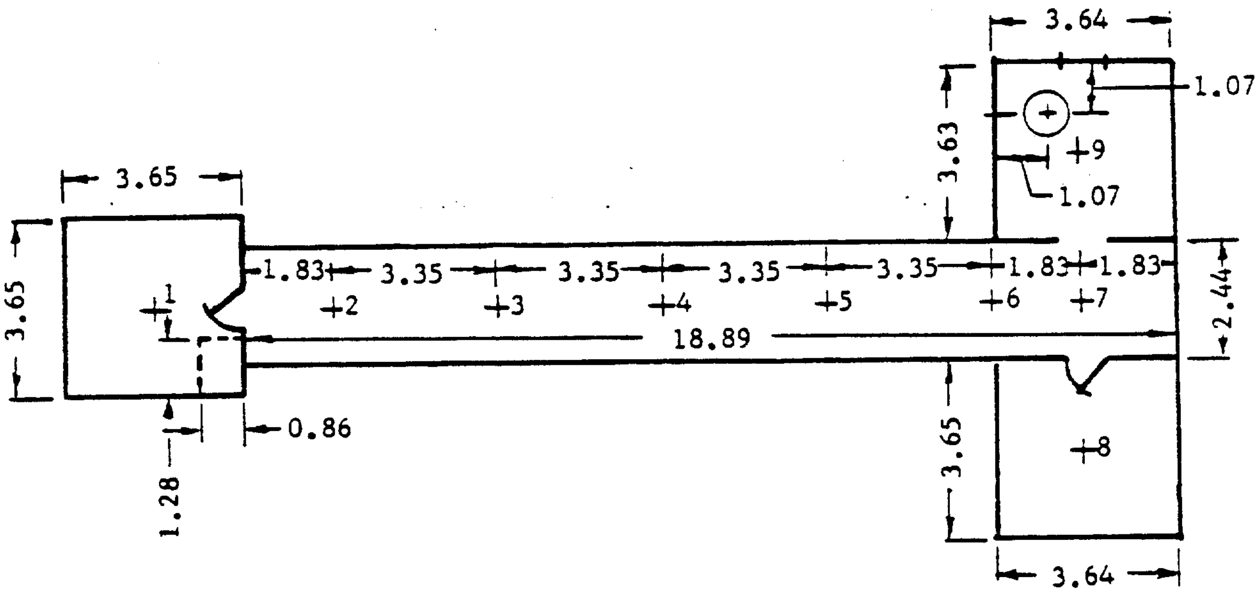


Figure 12 Locations of instrument stations and fire source (dimensions in m)

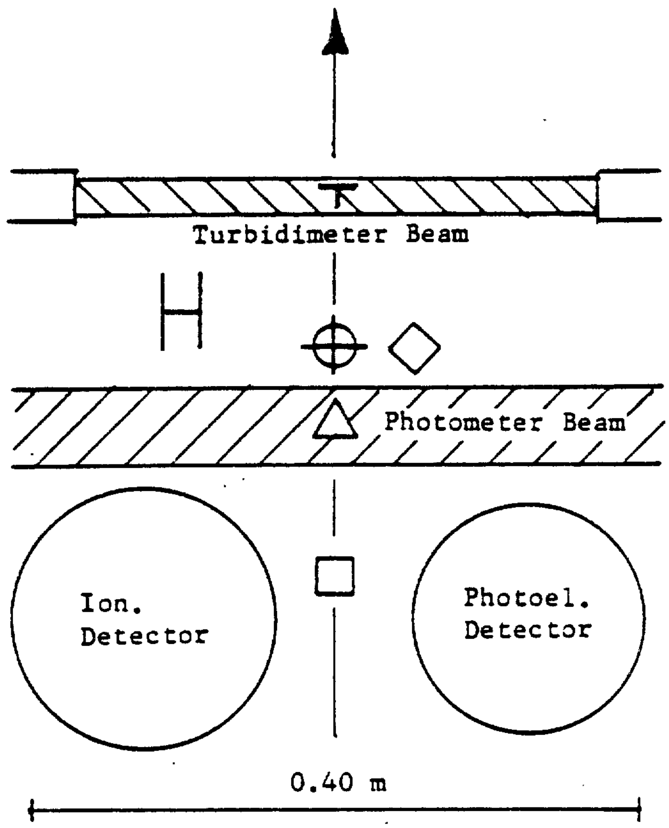


Figure 13 Layout, to scale, of largest possible instrument cluster. See Figure 1 for symbols.

front. (The diameters of the turbidimeter and photometer beams are shown to scale.) For Stations 1 and 2, the arrow in Figure 13 pointed perpendicularly toward the plane of the doorway; for Stations 2-7, the arrow pointed south along the axis of the corridor; and for Station 9 in the burn room, the arrow was aligned with the SW to NE diagonal of the room, pointing toward the NE corner. Figures 7b-7d present photographic views of the installed instruments.

Figure 14 illustrates the placement of the wall pressure taps, 0.39 m below ceiling level. Lines connecting taps indicate which pressure differentials were measured; i.e.: 1-2 (back of burn room to front of burn room), 2-4 (burn room to exterior of the enclosure), 2-3 (across doorway, burn room to corridor), 3-5 (one end of corridor to the other), 5-6 (across doorway, corridor to Target Room 2), and 7-8 (across doorway, corridor to Target Room 1). The first tap in each pair was connected for positive polarity. Tubing for the pressure measurements was 6.4 mm (1/4 in.) O.D. stainless steel tubing carried to the exterior of the enclosure from flush pressure taps, connected to 6.4 mm (1/4 in.) O.D. nylon tubing which carried the signals to the pressure transducers. All tubing was routed to the pressure transducers in the horizontal plane of the pressure taps, 0.39 m below ceiling level.

Elevations of all instruments except the pressure taps are summarized in Table 3.

2.4.2 Descriptions

Gas phase thermocouples were chromel-alumel, 28 gage, insulated with glass braid except in the burn room where magnesium oxide insulation in 1.6 mm diameter inconel sheathing was used. The wire bundles of the vertical thermocouple arrays entered through the ceiling and were kept taut with the aid of steel springs anchored in the concrete floor; the beads extended on horizontal wire a distance of 50 mm to the side of the wire bundles.

Chromel-alumel, "cement on" thermocouples (Style II, manufactured by Omega Engineering, Inc., Stamford, Conn.) were used to measure ceiling surface temperatures.

The brass disks were 0.50 mm thick and 25 mm in diameter, mounted with their plane normal to the assumed local flow direction (normal to direction of arrow, Figure 13). Chromel-alumel thermocouples were attached to the disks (with flattened wire ends separately spot welded to the disk).

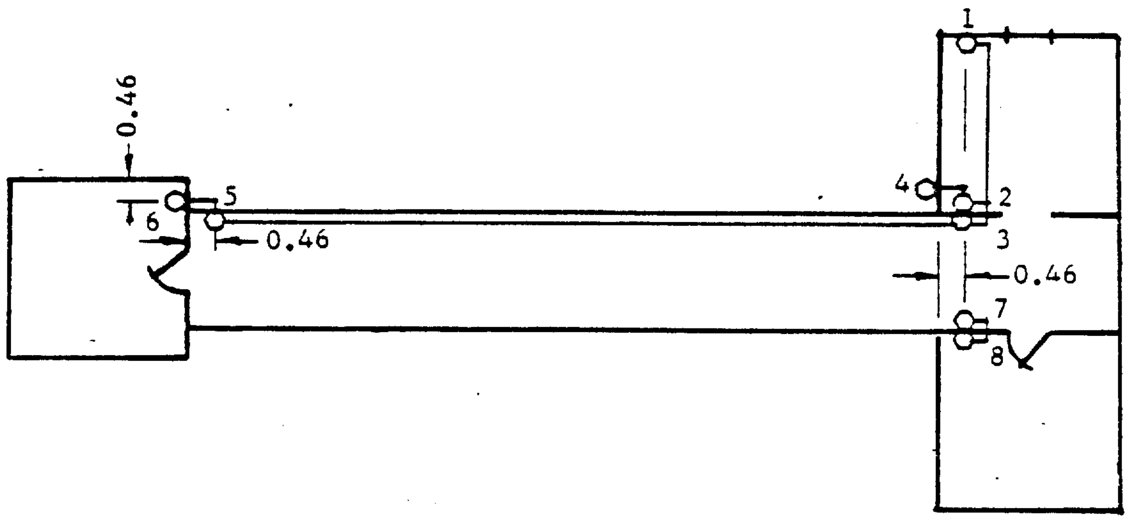


Figure 14 Locations of wall pressure taps, 0.39 m below ceiling (dimensions in m)

TABLE 3

ELEVATIONS OF INSTRUMENTS

Dist. Below Ceiling (m)	Vert. TC Array	Vert. Phot. Array	Ceil. TC	Brass Disk	B-D Flow Probe	O_2 CO_2 CO	CO_2 CO	Smoke Detect.	Ceil. Gas TC	Turb. Meter
0			X							
0.051	X	X		X	X	(X)*		X	X	X
0.102	X									
0.254	X									
0.559	X	X								
0.965	X					X	X			
1.372	X	X								
1.778	X									
2.184	X	X				(X)*				

*CO_2 at Station 4 only.

Values of the "response time index"*, RTI, for this size disk with thermocouple attached was measured as 28.0 $(m \cdot s)^{1/2}$ with the plane of the disk facing the flow in the FMRC Plunge Test Tunnel[23].

All thermocouple wires were connected to 20 gage extension wire immediately outside the enclosure for connections to building signal stations.

The photometers were fabricated according to NBS design.[24,25] The lamp was operated at an estimated color temperature of 2425 K. The light receiver was a 1P39 phototube with a filter to correct its spectral response approximately to that of the human eye. A one-meter beam length was used and the units in a vertical array were mounted in a rack made from slotted angle framing. The phototube output was transmitted unamplified across a 167 kΩ load resistor to the data acquisition computer. The system response time to sudden blocking of the light beam was about 4 s (to 63 percent attenuation of output).

The turbidimeter measured obscuration of light by smoke at three discrete wave lengths, 0.4579 µm ("red"), 0.6328 µm ("blue") and 1.060 µm ("infrared"). These meters were designed and built by J.S. Newman of FMRC[26] and were operated with a beam length of 0.346 m. Response times to sudden obscuration have been estimated at less than 1 ms. The three-wavelength technique can be used to determine smoke particle size and concentration, as first described by Cashdollar et al.[27].

Responses of photometers and turbidimeters were reduced to optical densities per unit length, D_u, according to:

$$D_u = \ell^{-1} \ln(I_o/I) \tag{2}$$

where ℓ is the beam length and I_o, I are the photometer signals without and with smoke, respectively.

---

* The "response time index", RTI, is terminology developed for automatic sprinkler applications,[23] RTI being defined as:

$$RTI = \tau u^{1/2} \tag{1}$$

where τ is the time constant of thermal response of the heat-sensitive element to convective heating and u is the gas velocity. The RTI value is, in principle, insensitive to gas temperature and velocity.

The bidirectional flow probe was of standard design(28,29) with a diameter of 22 mm. It was connected to a Datametrics electronic manometer (Barocel Model 1023, transducer Model 523).

Gases were sampled through vertical, 12.7 mm O.D. and 9.4 mm I.D. stainless steel tubing, coupled to 12.7 mm O.D. and 9.7 mm I.D. polyethylene tubing above the roof of the enclosure. Some 63 m of the polyethylene tubing led from each of the steel sampling tubes to a manifold in the overhead space of the test building, near the gas analyzers, the manifold being exhausted to the atmosphere at a total estimated rate of 4 ℓ/s. Ahead of the manifold, individual nylon sampling lines were tee'ed into the polyethylene sampling tubes for delivering gas samples to respective gas analyzers via glass wool particulate filters, moisture condensers (ice bath), dryers, pumps and flow meters. Beckman analyzers were employed for oxygen (Model 755 paramagnetic), carbon dioxide, and carbon monoxide (Model 315A infrared). Analyzers were calibrated at the beginning of each test day. Delay times from the instant of exposure to a constant gas concentration at the open end of a sampling tube to 63% of full response of an analyzer were measured at the beginning of the test program and checked at certain intervals thereafter.

Smoke detectors selected for the program included an ionization type (BRK Electronics, Model 1751) and a photoelectric type (Pyrotector Model 3040 RC). Both types mounted into separate base units in quick-connect or disconnect fashion. Both the ionization and photoelectric units were designed to alarm when smoke in the detection chamber reached a threshold density. Additionally, the photoelectric unit supposedly had a feature which would lower the threshold for fast rates of rise in the smoke density, but this feature may not have been important in this test program (see Section 3.5 on smoke detector calibrations).

All pressure differentials from wall pressure taps were recorded on Datametrics electronic manometers (Barocel Model 1023, transducer Model 523).

The 102 mm I.D. vent tubes (Sch. 40 BIP) described in conjunction with Figure 1 and attached to each room were 1.63 m long and were provided with an orifice meter and a thermocouple. Pressure differentials across the 61 mm diameter orifice meter, which was positioned at mid length and provided with flange connections, were measured with pressure transducers manufactured by Setra Systems Inc. (selected from among Model 239, ± 0.2 psid; Model 261,

± 0.5 in water; and Model 261, ± 5 in water). The thermocouple in each tube was positioned on the tube axis, 0.51 m from the orifice away from the room. Where needed, a Dayton fan (Granger Stock No. 7C650) was coupled to the open end of each vent tube to provide forced exhaust; throttling to desired flow rate was achieved with adhesive tape across the discharge of each fan.

2.5 DATA ACQUISITION

The data were recorded at a rate of one scan per second on the building data acquisition system (Hewlett-Packard 1000, 21 MX F Series Processor with a 2313 measurement subsystem). The data acquisition computer also controlled the fuel control system where required, i.e., in the automatic, growing-fire mode. Except for thermocouple signals, which were reduced directly to temperatures by the building data acquisition system, all other data reductions were made on computer facilities in FMRC's Norwood laboratories from raw data tapes.

2.6 SPECIAL PROVISIONS

2.6.1 Corridor Ventilation

Starting with Test 38, a number of tests were performed to investigate smoke migration in certain ventilation situations. A sealed partition (Figure 15) was provided midway between instrument stations 3 and 4 (as identified in Figure 12). Figure 15a is a plan view of the region, showing the instrument stations, the partition (gypsum board on a frame of wood studs with silicone caulking around the perimeter), and the location of ceiling diffusers (American Metal Products Co., RA2502 W 6 x 6). As evident in Figures 15b and c, the diffusers were ducted together into a common horizontal duct, continued as a vertical, round tube (aluminum) with an orifice meter ($\beta = 0.6$) and thermocouple, followed by horizontal and vertical round ducts (steel) into the wall of a plenum. Figure 15d is a side view of the plenum (steel pipe), showing the entering duct and the inlet of a blower attached to one end of the plenum, the other end of the blower being open to the building space. The blower connection just described (bottom of Figure 15d) was employed when the venting system was in the "return mode", i.e., with air being drawn into the ceiling diffusers in the corridor. Suction was provided by subatmospheric pressures in the plenum developed as a venturi effect by air drawn into the

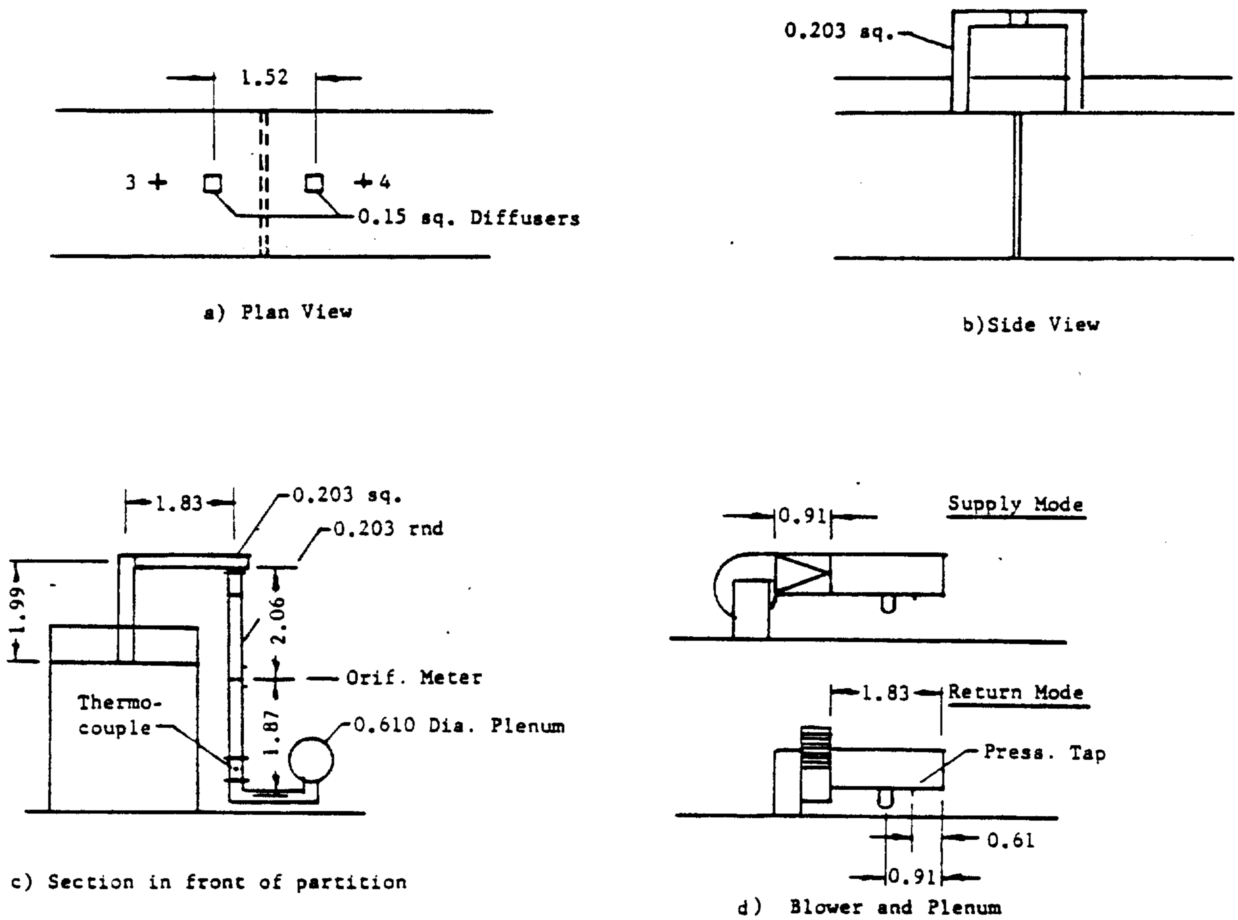


Figure 15 Corridor partition with ventilation ducting (dimensions in m)

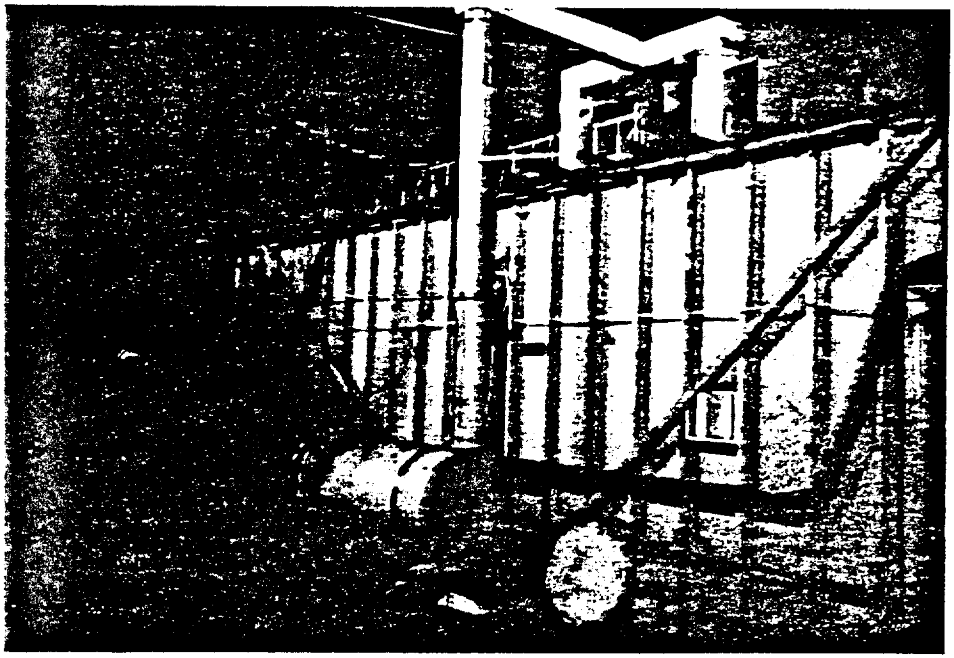
plenum from the building space by the blower; the air flow, suction pressure, and hence the vent flow, were controlled with a louvered damper at the exit of the blower. The blower connection shown at the top of Figure 15d, with the blower discharge connected (via a rectangular-to-round transition) to the plenum, was used when the venting system was in the "supply mode", i.e., with air being discharged through the ceiling diffusers into the corridor*. In this case, a positive plenum pressure and the desired vent flow were generated by partially obstructing the open end of the plenum with a plate. Because the blower had to be elevated in this mode, the top section of the vertical round duct in Figure 15c had to be replaced with a shorter section.

Figure 16 presents photographic views of the ducting and the corridor ceiling vents.

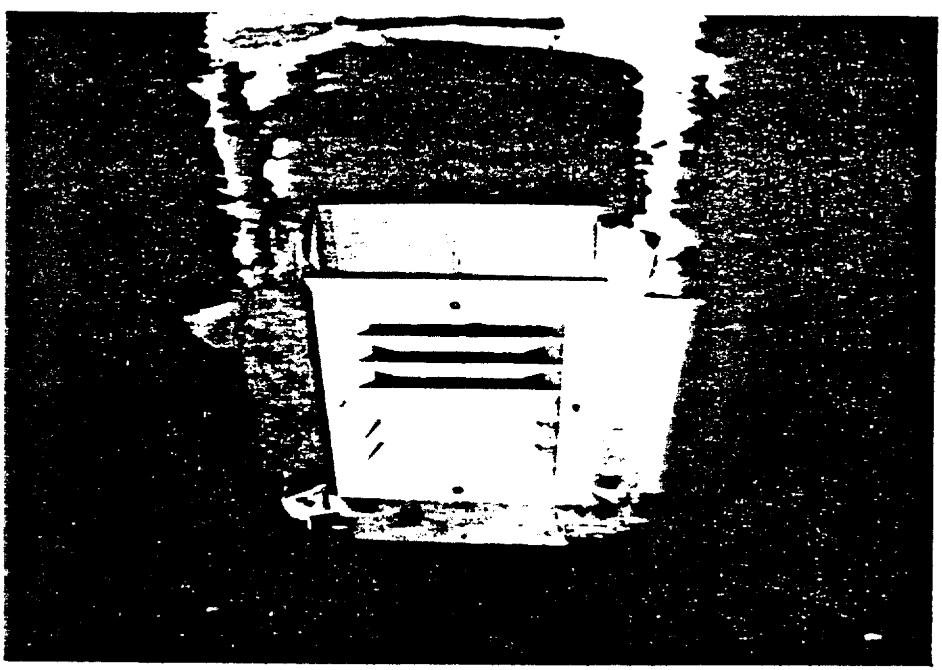
The blower capacity and plenum were so large that the plenum pressure was practically independent of any flow to or from the corridor ceiling vents. In other words, the plenum may be considered to have been a constant pressure plenum in both the return and supply modes, regardless of any fire activity. Total mass venting rates were determined from the pressure differential across the orifice meter, using a Setra Systems transducer, together with the flow temperature indicated by the thermocouple. Plenum pressures relative to the atmosphere were determined with a Setra Systems transducer connected to the plenum tap indicated in Figure 15d.

When the vents were operated in a return mode at approximately 170 g/s total flow with no fire, the plenum pressure was 249 Pa below atmospheric pressure (82 Pa pressure drop in each of the vent ducts before joining and 167 Pa pressure drop in remaining ducting to the plenum, according to experiments). When the vents were operated in a supply mode at approximately 170 g/s total flow with no fire, the plenum pressure was 284 Pa above atmospheric pressure (184 Pa pressure drop from plenum through common ducting and 100 Pa pressure drop in individual ducts to vents, according to experiments).

*The discharge was observed to occur in two oppositely directed ceiling jets, away from the vent, generally aligned with the length of the corridor. At 0.20 m from the vent, the ceiling jets had a maximum depth of about 0.10 m and a width of about 0.4 m.



a) Ducting leading to plenum 4048-2



b) Diffuser in corridor ceiling, viewing along length of corridor 4048-3

Figure 16 Ducting for ceiling vents in corridor

2.6.2 Target Slabs

Test 48 began a series of tests to obtain flashed-over mass loss rates in the burn room of horizontal and vertical, foamed polyurethane slabs. These mass loss rates were to be compared to mass loss rates of similar slabs in freeburn.

The foamed polyurethane slabs measured 0.610 m x 0.610 m x 0.102 m thick and had a density of 32.04 kg/m^3. A sample was submitted to a testing laboratory for elemental analysis with the following results: Carbon - 57.25 percent; Hydrogen - 6.66 percent; Oxygen - 30.09 percent; Nitrogen - 5.29 percent. An FM laboratory measured the heat of combustion with an oxygen bomb calorimeter: 25,150 kJ/kg (no measurable inert residue).

The slabs were mounted either in a vertical or horizontal orientation, and their weights were continuously monitored with load cells. The load cell systems were housed in specially provided enclosures open to the outside of the burn room to keep them cool, one enclosure near the SE corner of the burn room designed for vertical slabs and one enclosure in the NW corner designed for horizontal slabs, Figure 17a. Both enclosures were 0.457 m high. Installation of a vertical slab above the SE load cell enclosure is illustrated in Figure 17b (photo in Figure 18a); the slab was attached to an L-shaped aluminum backing plate and platform with adhesive, the platform transferring the combined weight via a water-sealed shaft to a load cell system in the enclosure. An aluminum foil drip tray was fashioned under the slab on top of the platform to catch melt running off the slab. The sides of the slab were inhibited from burning by aluminum foil attached with high temperature adhesive. The bottom of the slab was positioned 0.584 m from the floor, the same height as the burner. Installation of the horizontal slab in the NW corner of the fire room is illustrated in Figure 17c (photo in Figure 18b). The slab, inhibited from burning around the sides with aluminum foil as in the case of the vertical slabs, rested on a platform provided with a drip tray for the melt, with the combined weight transferred to a load cell system in the enclosure underneath. The top of the slab, 0.584 m from the floor, was level with the top of the burner. In one case, a vertical slab was installed in the NW corner, Figure 18c. Only one slab was installed in any one experiment.

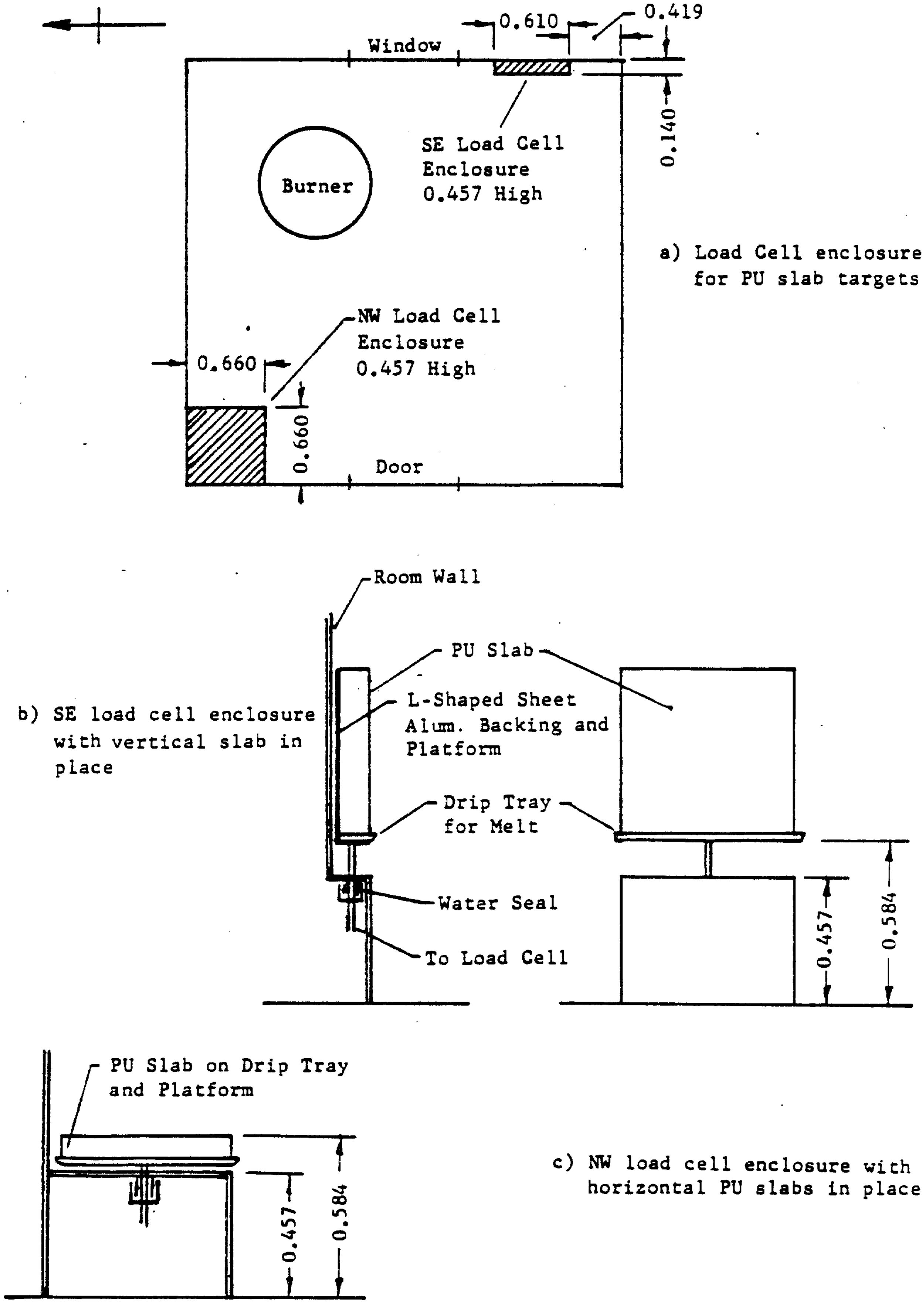
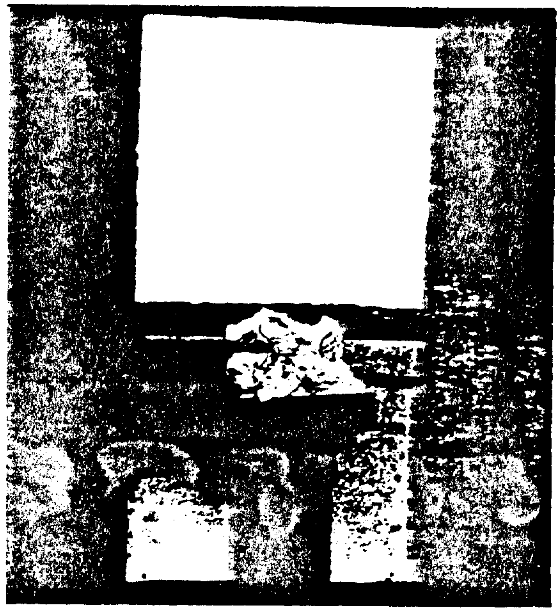
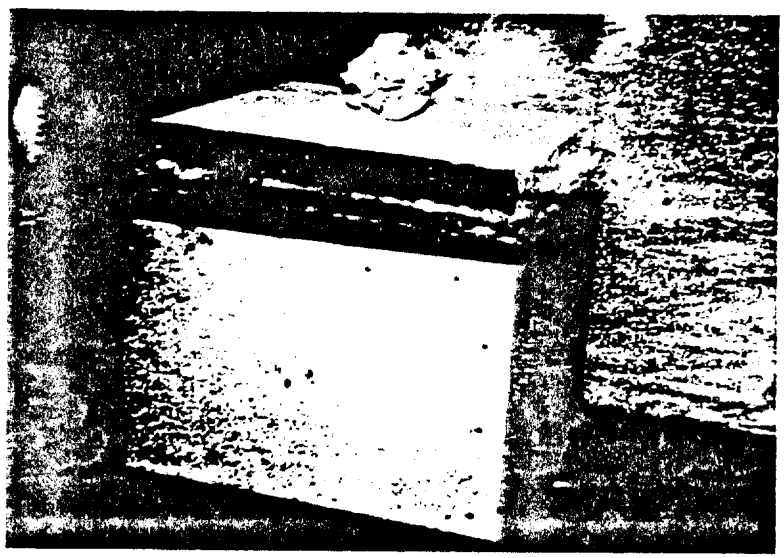


Figure 17 Installation of PU target slabs, Tests 48-55 and 60 (dimensions in m)



a) Vertical slab in SE corner

4048-4



b) Horizontal slab in NW corner

4048-5

c) Vertical slab in NW corner

4048-6

Figure 18 Photos of PU target slabs

2.6.3 Pyrolyzing Fire

A single fire, the final test of the program, was conducted with FM's Standard Plastic Commodity(30), primarily to explore generation and dispersion across open and closed doors of carbon monoxide in a pyrolyzing enclosure fire.

The Standard Plastic Commodity unit is a corrugated carton measuring 0.533 m x 0.533 m x 0.508 m high. Its interior is divided into 5 x 5 x 5 = 125 compartments formed by vertical and horizontal corrugated partitions. Each compartment contains a "16-oz" polystyrene tub with the open end down. The weight of the polystyrene tubs in a carton is 3.66 kg and that of the empty carton with partitions is 2.73 kg, the total weight being 6.39 kg.

Referring to Figure 19, which represents the burn room with load cell enclosures still in place (Section 2.6.2), the propylene burner was removed and replaced with four cartons of Standard Plastic Commodity, an array two cartons wide by two cartons high having a central flue for ignition. Ignition was achieved with a cellucotton roll (75 mm dia x 75 mm long) saturated with 0.12 ℓ of gasoline, touched off with a small propane flame manipulated from the exterior of the enclosure.

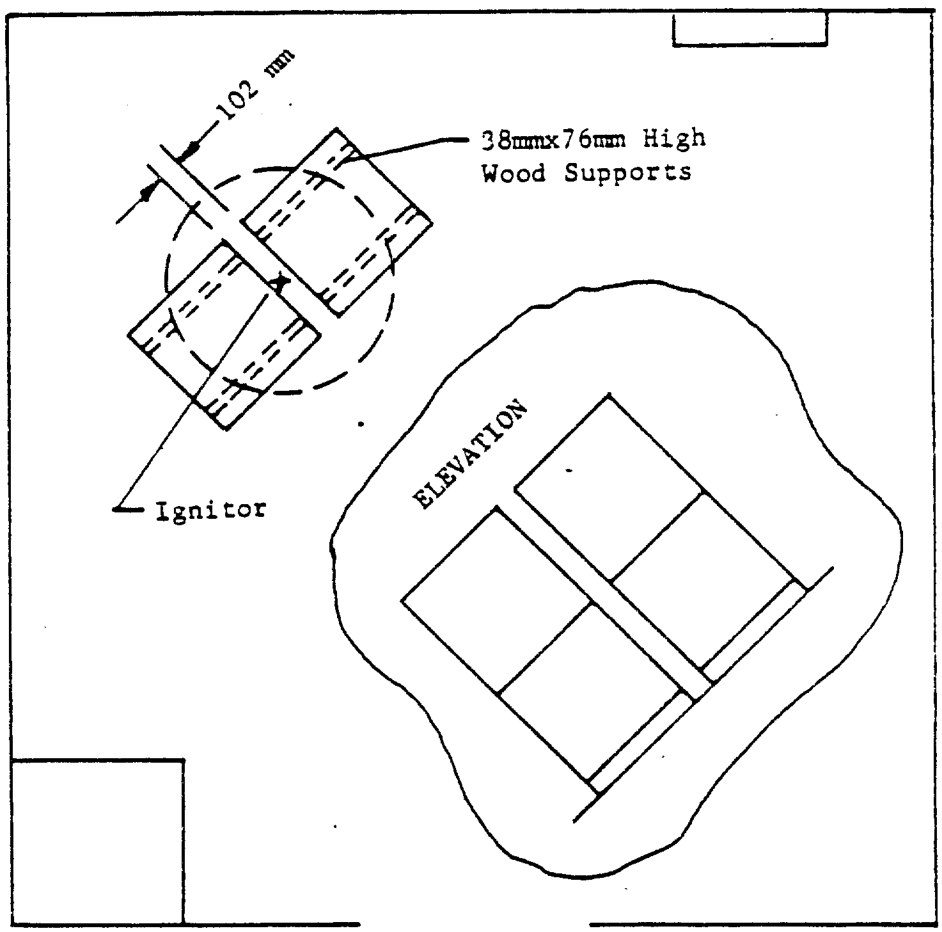


Figure 19 Installation of "Standard Plastic Commodity" in burn room for Test 60 relative to the site of the 0.91 m burner (dashed)

III
CALIBRATIONS

3.1 LEAKAGE-ENCLOSURE

It had been the intent to confine the leakage of the enclosure primarily to the paths provided by the vent tubes in the three rooms, i.e., to reduce leakage through all other paths (cracks, fissures and small holes) to a small fraction of the vent-tube leakage.

First, the leakage rate for a given enclosure pressure through a vent tube/orifice combination was calculated and found to be equivalent to the leakage flow rate through a 90 mm diameter hole in the wall.

Leakage through other paths than the vent tubes was determined by blocking two of the vent tubes (target rooms) and pressurizing the enclosure with a fan through the remaining vent tube (burn room) with all interior doors open. Simultaneous readings were taken of enclosure pressure and flow rate through the pressurizing vent tube. The initial trial indicated very large leakage rates, twice the estimated rates through open vent tubes. After several attempts at reducing leakage, the single most effective step being to caulk with a silicone bead around the entire wall-floor perimeter from the inside, the crack leakage was reduced to about 1/4 of the estimated leakage through open vents for enclosure pressures in the range 1.7 - 6.5 Pa. Further attempts to reduce leakage were without result.

3.2 LEAKAGE THROUGH CLOSED DOORS

The doors to the three rooms in the enclosures were characterized for leakage in their closed positions in special tests.

The leakage was considered to occur along door cracks of a certain width, length, and internal geometry. The mass leakage rate over a certain crack length can be represented by:

$$\dot{m} = C A_c (2\rho\Delta p)^{1/2} \qquad (3)$$

where C is a discharge coefficient dependent on the internal crack geometry and the Reynolds number; A_c is the throughflow area of the crack; ρ is fluid density; and Δp is the pressure difference across the door. Per unit crack length, eq (3), becomes:

$$\dot{m}' = C\, w\, (2\rho\Delta p)^{1/2} \qquad (4)$$

where $\dot{m}'$ is mass flow rate per unit crack length and w is the crack width. For a given crack, the discharge coefficient, C, depends on the Reynolds number, $\rho uw/\mu$, where u is a characteristic crack velocity and μ is the dynamic viscosity. The Reynolds number can be written:

$$\frac{\rho uw}{\mu} = \frac{\rho uA_c}{L_c\mu} = \frac{\dot{m}'}{\mu} \qquad (5)$$

where L_c is the crack length. Hence in eq (4):

$$C = C\,(\dot{m}'/\mu) \quad . \qquad (6)$$

The combination C w in eq (4) can be considered to be a characteristic crack width, w_c:

$$w_c = \dot{m}'/(2\rho\Delta p)^{1/2}. \qquad (7)$$

The objective of the leakage measurements was to determine w_c as a function of the Reynolds number, $\dot{m}'/\mu$.

Figure 20 illustrates how one side of a door was pressurized at a known flow rate through the door cracks. A polyethylene bag was taped over the door and supplied with a metered air flow from a fan and orifice meter. The pressure differential across the door was sensed by a pressure tap provided in the wall on the high-pressure side, away from the local flow of the fan discharge and the local flow entry into the crack, as compared to the ambient pressure on the low-pressure side of the door.

For the measurements of widths of door cracks reported in Section 2.2, it is recalled that the crack perimeter of each door was divided into five segments: the top crack; the undercut; and three crack pairs ("left" and "right") provided by dividing the height of the door into three equal sections, i.e., the "top 1/3", "middle 1/3", and "bottom 1/3". It was decided to

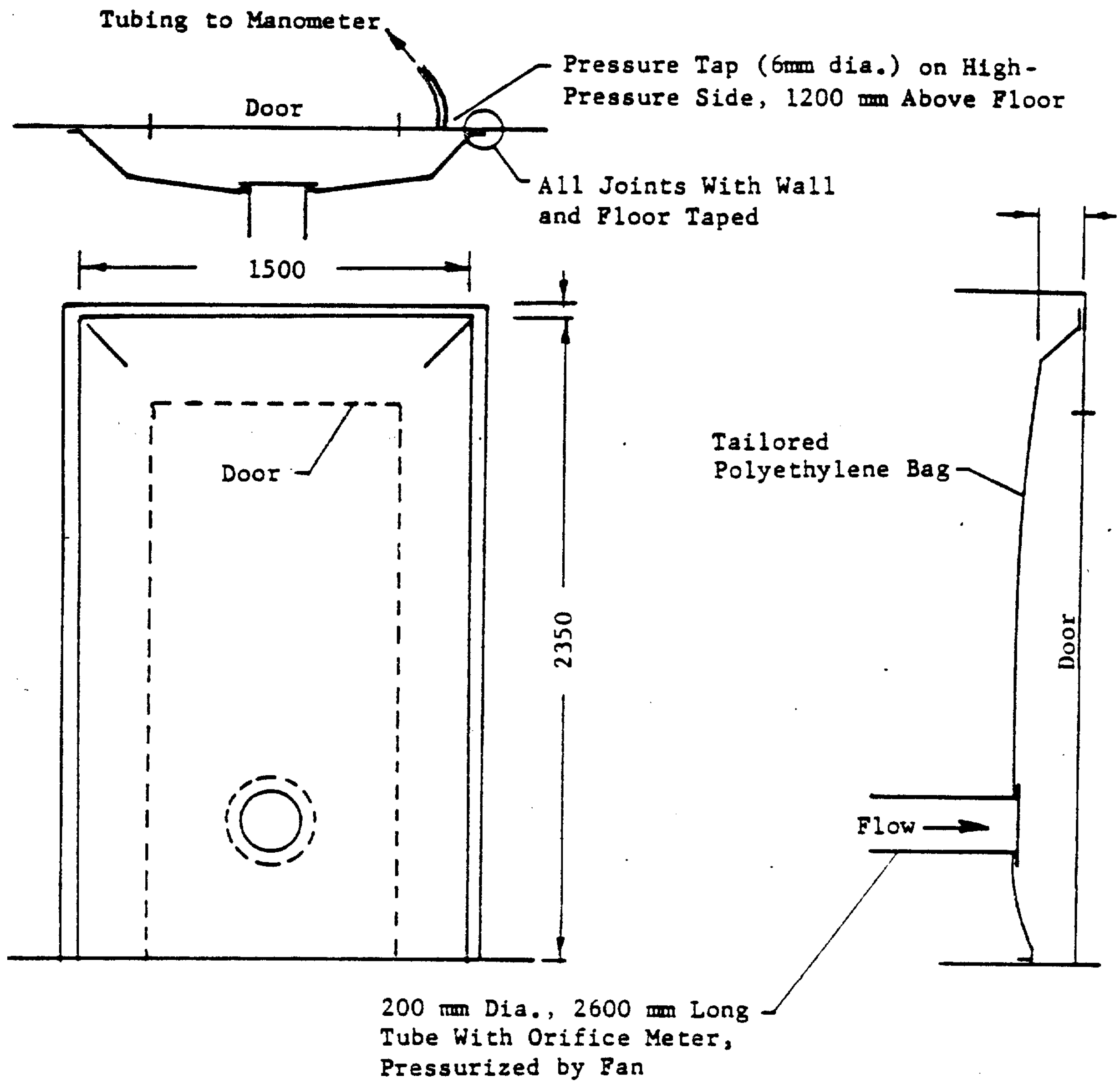


Figure 20 Pressurized polyethylene bag plenum for measuring door leakage characteristics (dimensions in mm)

measure the leakage characteristics for each of the crack segments defined in this manner. One segment was measured at a time, accomplished either by taping the remaining segments shut on the low-pressure side or, in cases where segments on the low-pressure side of the door had exposed hinges, by taping a sheet of polyethylene across the segment.

The first leakage measurements were performed on the door to TR1 (Target Room 1). In Figure 21, results for effective crack width, w_c [eq (7)], are shown as a function of the Reynolds number for this door, using pressurization from both the room side and the corridor side. There appears to be no consistent effect of the side of pressurization. For the door cracks (Figure 21a), the effective widths are on the order of 0.003 m = 3 mm, which seems reasonable in view of the physical crack widths listed in Table 1. The undercut (Figure 21e) gave an effective width of about 0.015 m = 15 mm.

Results for corridor-side pressurization of the TR1 door are replotted in Figure 22 using logarithmic coordinates. Results for corridor-side pressurization of the TR2 door are plotted in Figure 23. Finally, results for room-side pressurization of the BR (burn room) door are presented in Figure 24.

Excepting the undercuts, the effective crack widths in Figures 22-24 vary closely as the 1/4 power of Reynolds number. As a consequence, the following proportionality is evident (with the aid of the definition of w_c, eq (7)):

$$\dot{m}' \propto (2\rho\Delta p)^{2/3}/\mu^{1/3}. \tag{8}$$

The volumetric flow rate per unit crack length, $\dot{v}' = \dot{m}'/\rho$, follows the proportionality:

$$\dot{v}' \propto (2\Delta p)^{2/3}/(\rho\mu)^{1/3}. \tag{9}$$

It may be verified that the quantity $(\rho\mu)^{1/3}$ is quite insensitive to temperature.

The results for the undercuts in Figures 22-24 do not show a clear effect of Reynolds number. Averaging all the results for each undercut, as if there is negligible effect of Reynolds number, and dividing by the measured height of the undercut, values of the discharge coefficient, C [eq (4)], can be

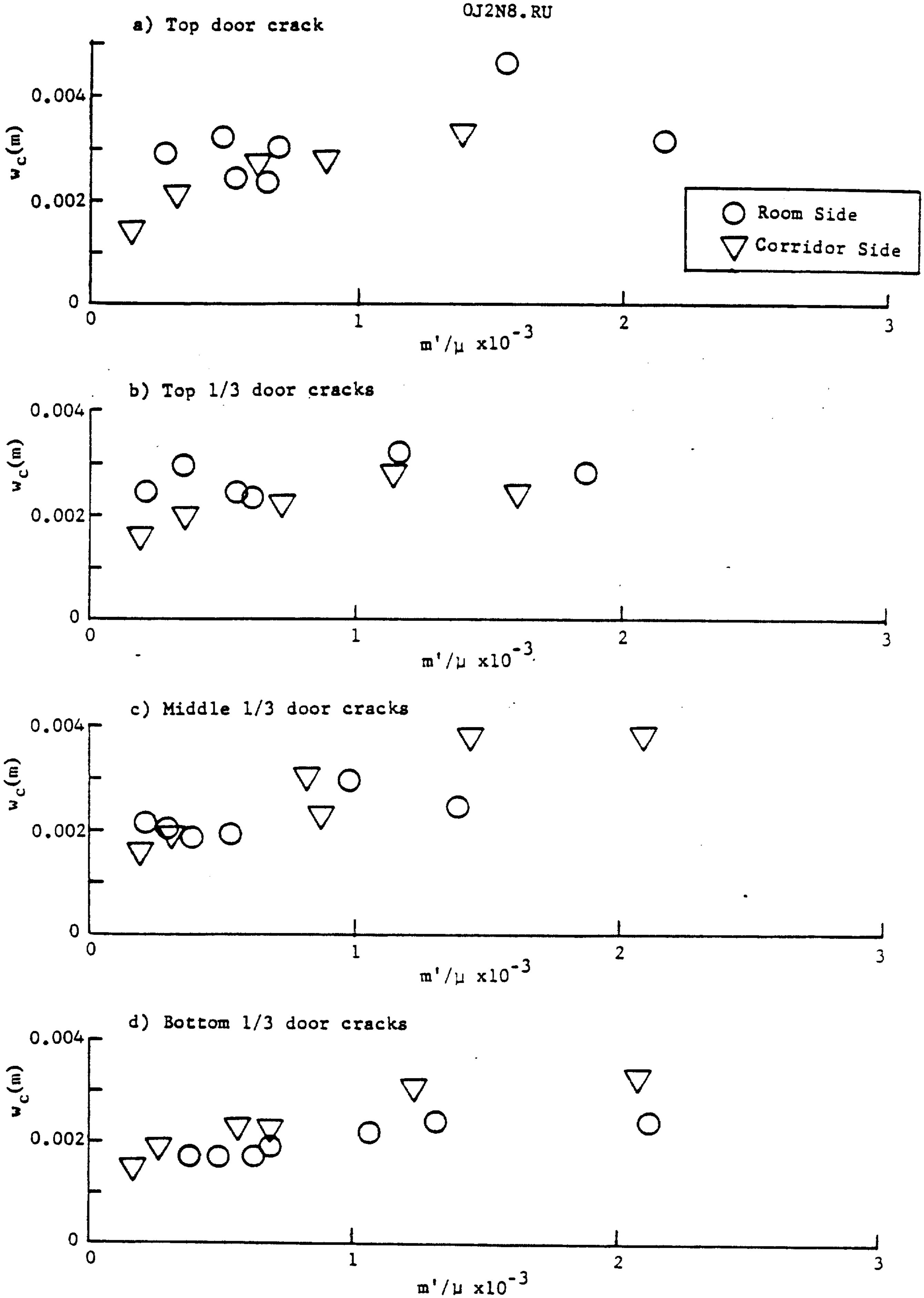


Figure 21 Effective crack widths as measured from both room side and corridor side of TR1 door

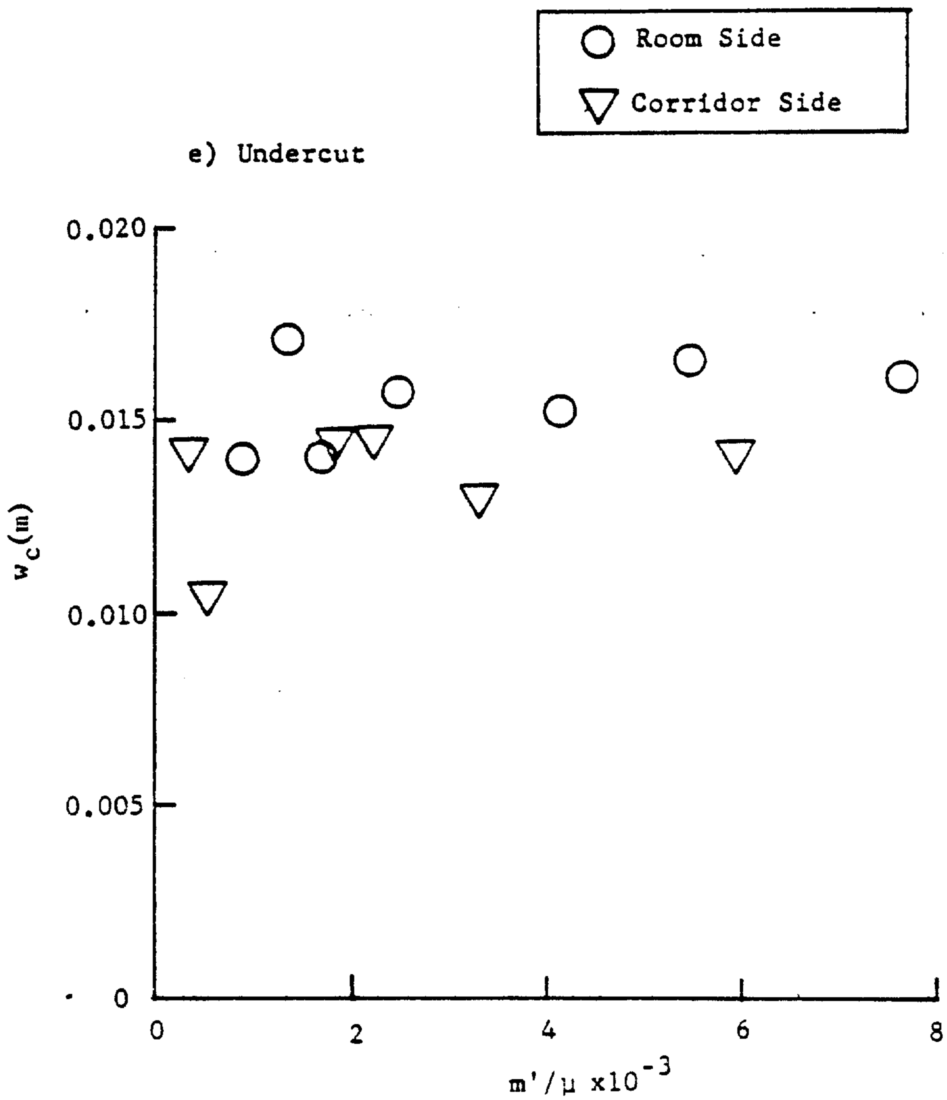


Figure 21 (Completed)

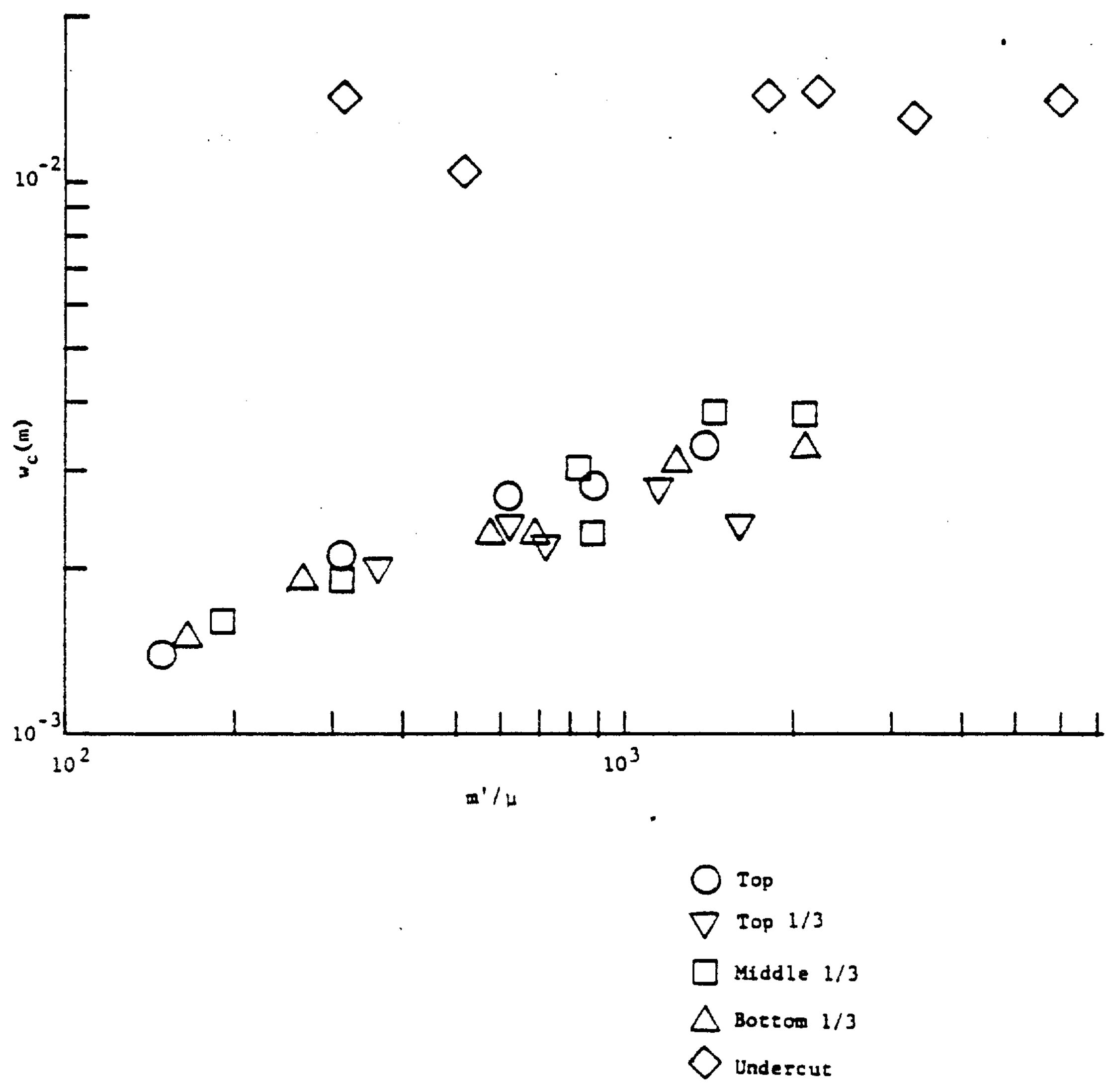


Figure 22 TR1 door: Effective crack widths from corridor side

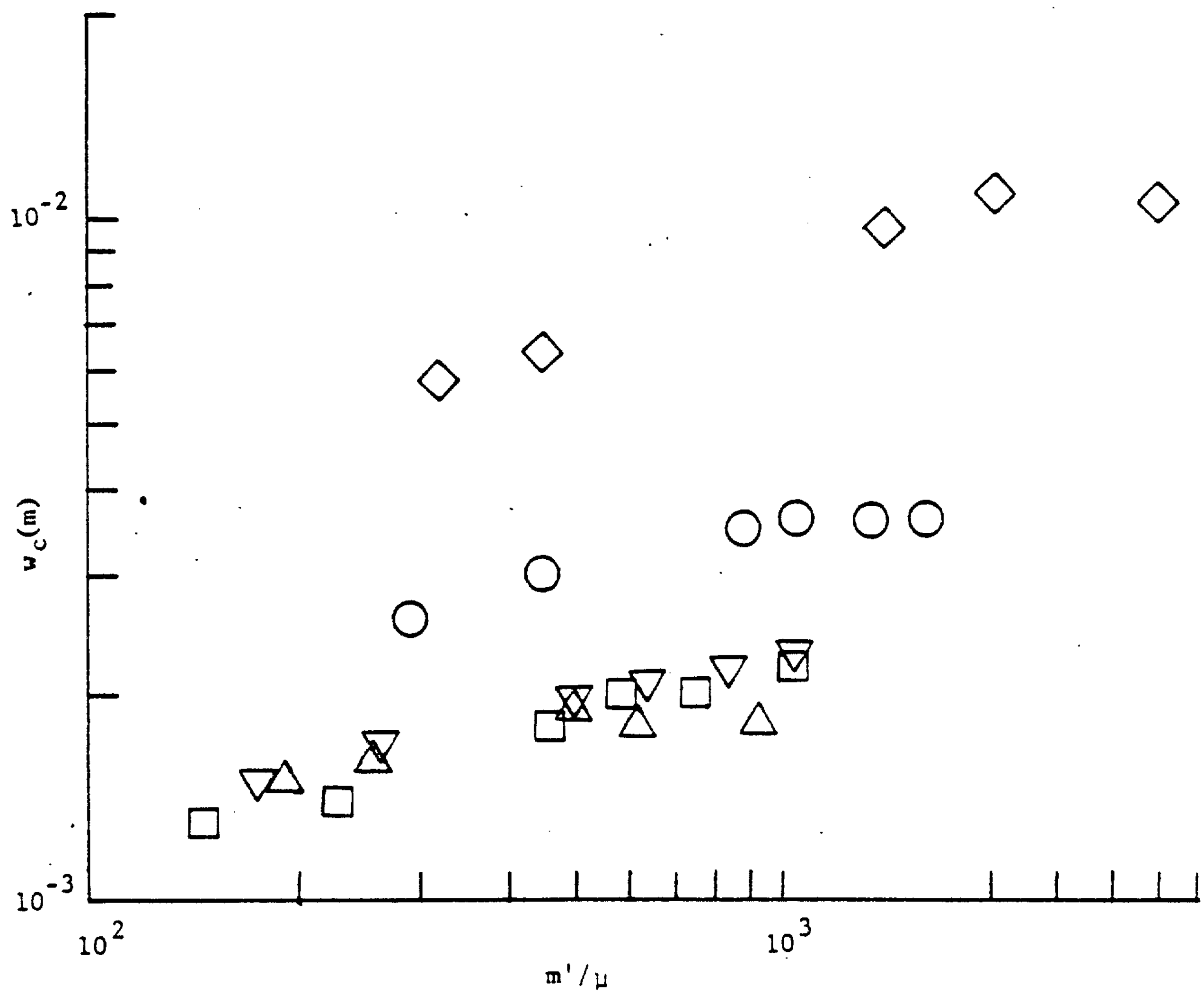


Figure 23 TR2 door: Effective crack widths from corridor side (symbols as in Figure 22)

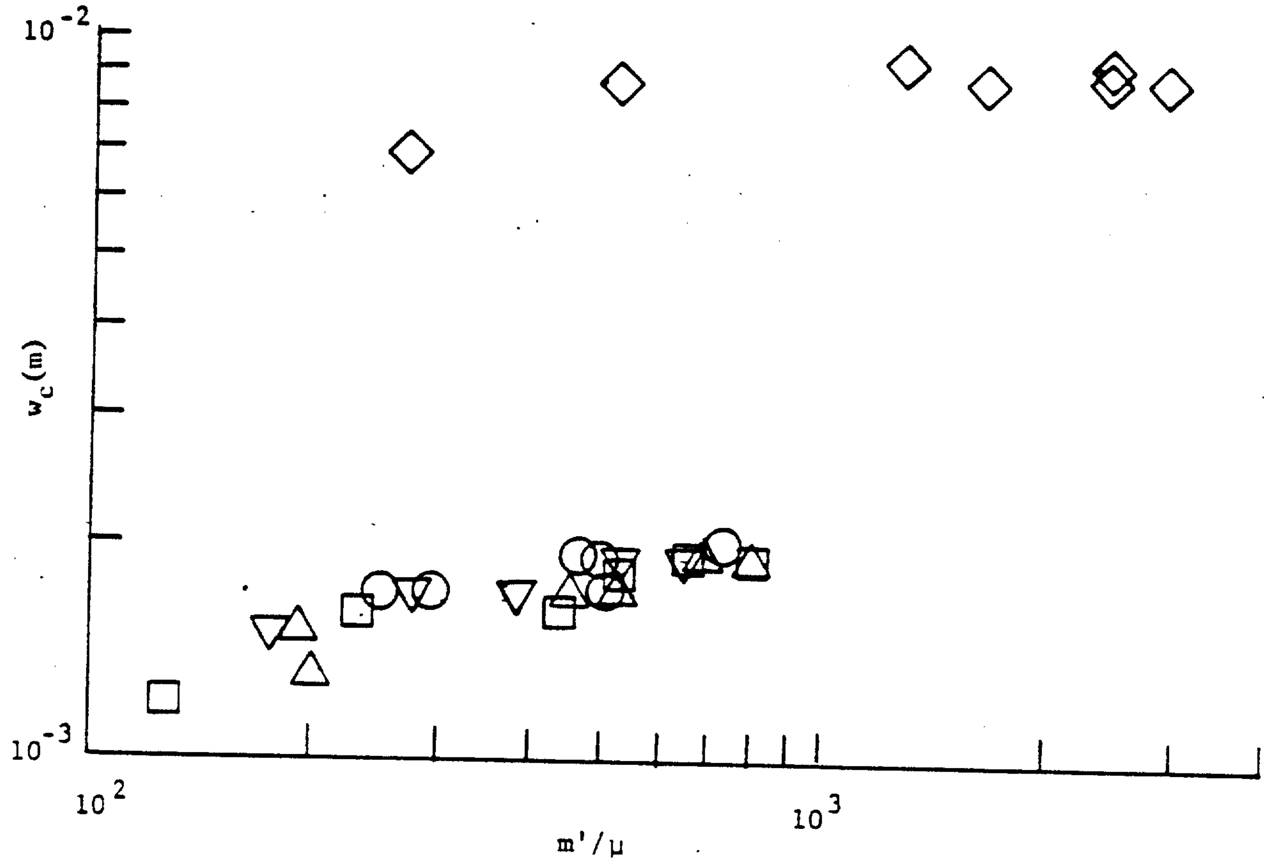


Figure 24 Burn room door: Effective crack widths from room side (symbols as in Figure 22)

determined. The following values are obtained as a function of the ratio of door thickness (t_d) to undercut height (h):

Room	t_d/h	C
BR	0.9	0.63
TR1	2.4	0.76
TR2	4.0	0.81

The variation of C with t_d/h is orderly and reasonable.

Room pressures covered in these calibrations ranged from less than 1 Pa to over 30 Pa.

3.3 YIELDS OF FIRE SOURCES

The larger, 0.91 m diameter propylene burner was calibrated first, using the FMRC Fire Products Collector[31] located in the test building. This device gathers fire gases from a test fire below an inlet cone and then conditions the flow to one of uniform velocity, temperature and species concentrations. Single-point measurements of temperature and species concentrations, together with the known flow rate, lead to determinations of heat release rates and species generation rates. In the present application, measurements were made of total heat release rate, convective heat release rate, yields of CO and CO_2, yields of particulates, and flux of optical density.

Total heat release rate ($\dot{Q}_t$) was determined from mass flow rate and generation rates of CO_2 ($\dot{m}_{CO2}$) and CO ($\dot{m}_{CO}$). Convective heat-release rate ($\dot{Q}_c$) was determined from mass flow rate and temperature rise. Particulate yield rates ($\dot{m}_p$) were established using particle mass concentrations (C_p) measured with a TEOM Particulate Mass Monitor (Rupprecht & Patashnick Co., Inc.), together with the mass flow rate. Flux of optical density in the Collector was defined as $D_u \cdot \dot{v}$, where D_u is the optical density (per unit length) defined in eq (2) and $\dot{v}$ is the volumetric flow rate in the Collector duct. Optical density was determined from a photometer of the kind installed in the multi-room enclosure and mounted across the Collector duct at the instrument section (beam length = duct diameter = 1.52 m).

It is recalled that the fuel control for the burners was designed to provide any gas flow in units of approximately 32 kW, up to a total of 63 units. Combinations were provided manually with electrical switches, or controlled automatically with the data acquisition computer to generate parabolically growing fires ($\dot{Q}_t \propto t^2$) . The calibrations were performed in the automatic mode. Two different automatic modes were employed, one with a design "growth time" t_g = 240 s and one with t_g = 480 s. ("Growth time" is the time for a parabolically growing fire to exceed 1 MW.) For t_g = 240 s, measurements were also made at a reduced mass flow rate in the Collector, $\dot{m}$ = 10 kg/s (versus 33.5 kg/s) in order to enhance sensitivity of the measurements to low heat outputs.

Calibration results are presented in Figure 25. Figure 25a presents the total heat release rate per flow unit as a function of the number of flow units actuated as the fires developed. (Nominal number of flow units was used). The value 32.6 kW per flow unit represents well the entire range and is close to the design value of 32 kW per flow unit. Figure 25b indicates that the convective fraction of the total heat-release rate can be taken as 0.59. In Figure 25c, the flux of optical density is expressed in ratio to the fuel mass rate,* $\dot{m}_f$; the ratio is seen to vary somewhat with the size of the fire (number of flow units). Figure 25d presents the mass generation rate of particulates in ratio to the fuel mass rate; again, there is a variation with the size of the fire. Figure 25e shows the ratio of generation rates of CO to CO_2, clearly indicating an effect of fire size. Finally, Figure 25f indicates the ratio of mass concentration of particulates to optical density.

Figure 26 depicts the growth of heat-release rate during the calibration run for t_g = 480 s. The arrow at 1263 seconds corresponds to zero time. Small drops in gas supply pressure occurred during the run as additional orifices were actuated, resulting in somewhat lower growth rates than would have been the case otherwise. The calibration results discussed in the preceding paragraph have been referenced to a constant gas supply pressure of 274 kPa (39.7 psia). During fire tests, deviations of the gas supply pressure from the reference value were minimized by manual adjustments of the pressure regulator for the gas supply.

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*Determined on the assumption of 32.6 kW per flow unit, using the lower heat of combustion for propylene of 45,800 kJ/kg.

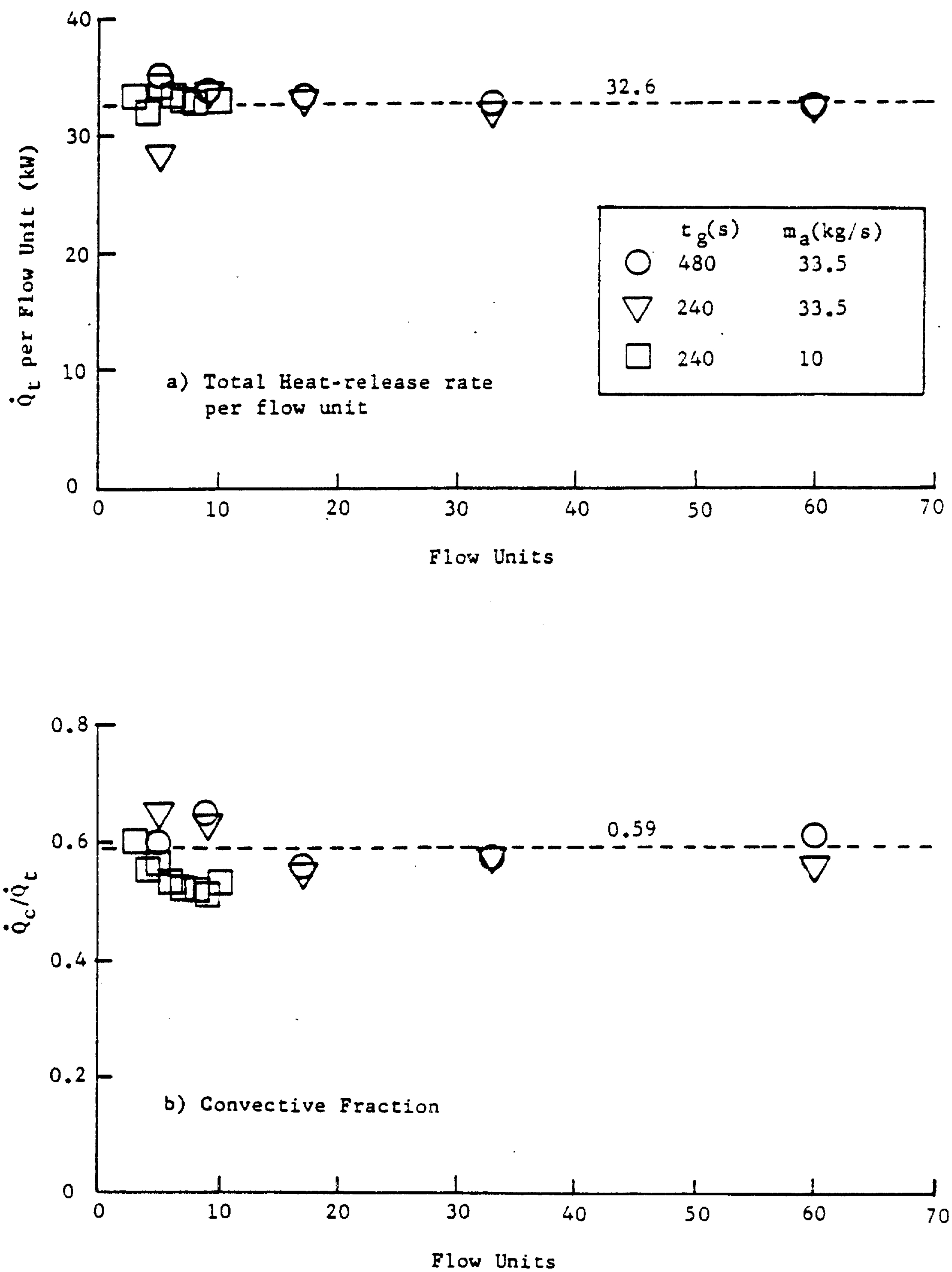
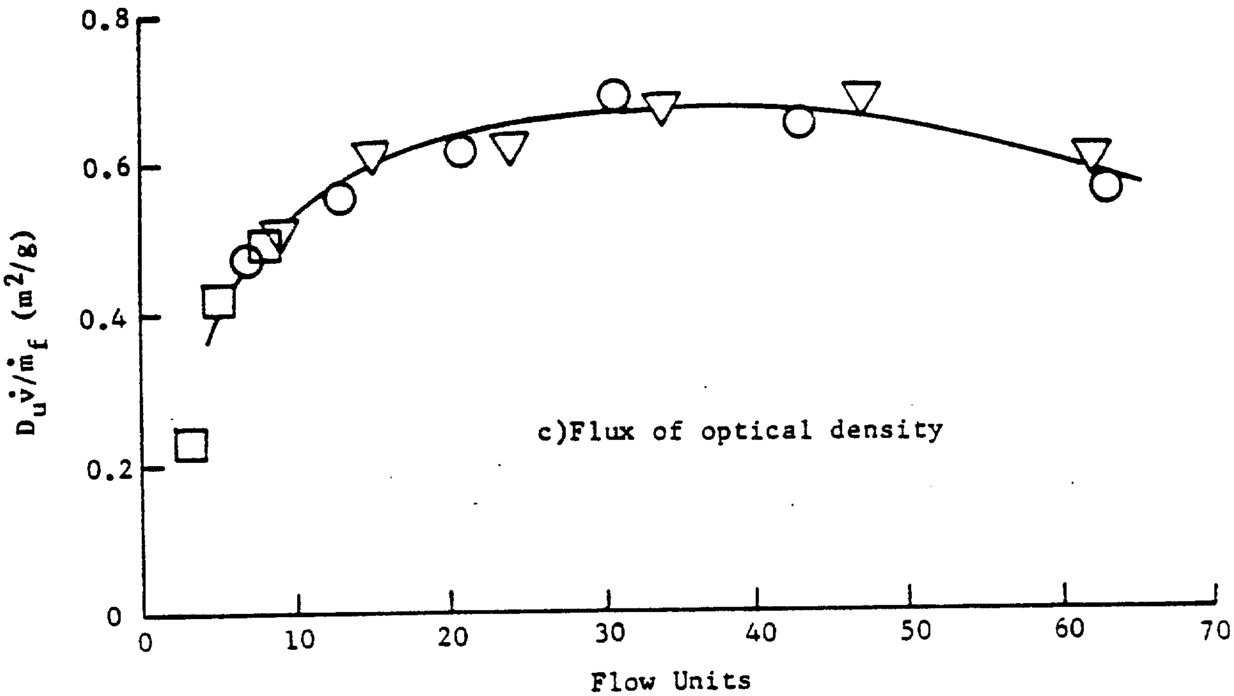


Figure 25 Calibration of 0.91-m diameter propylene burner (gas supply pressure of 274 kPa and temperature of 293 K)



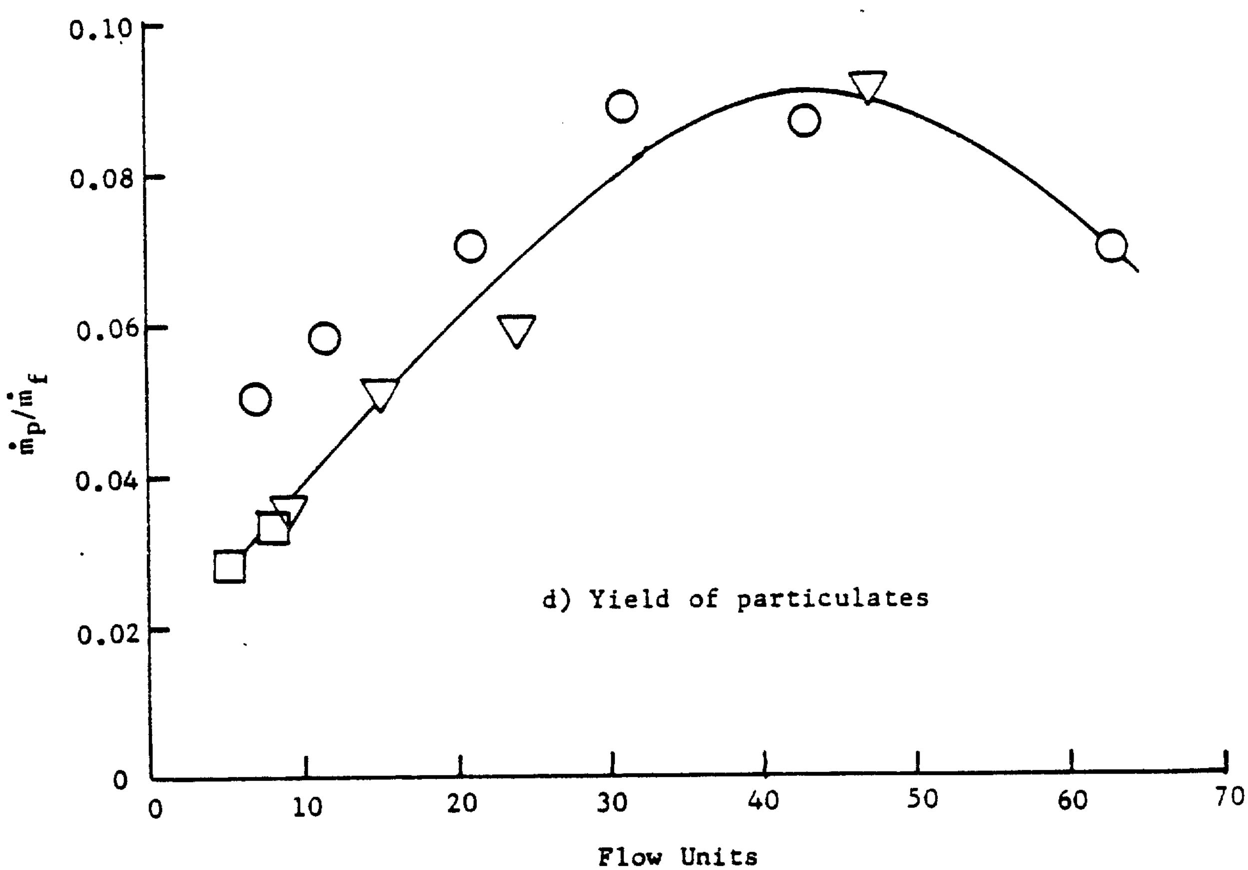
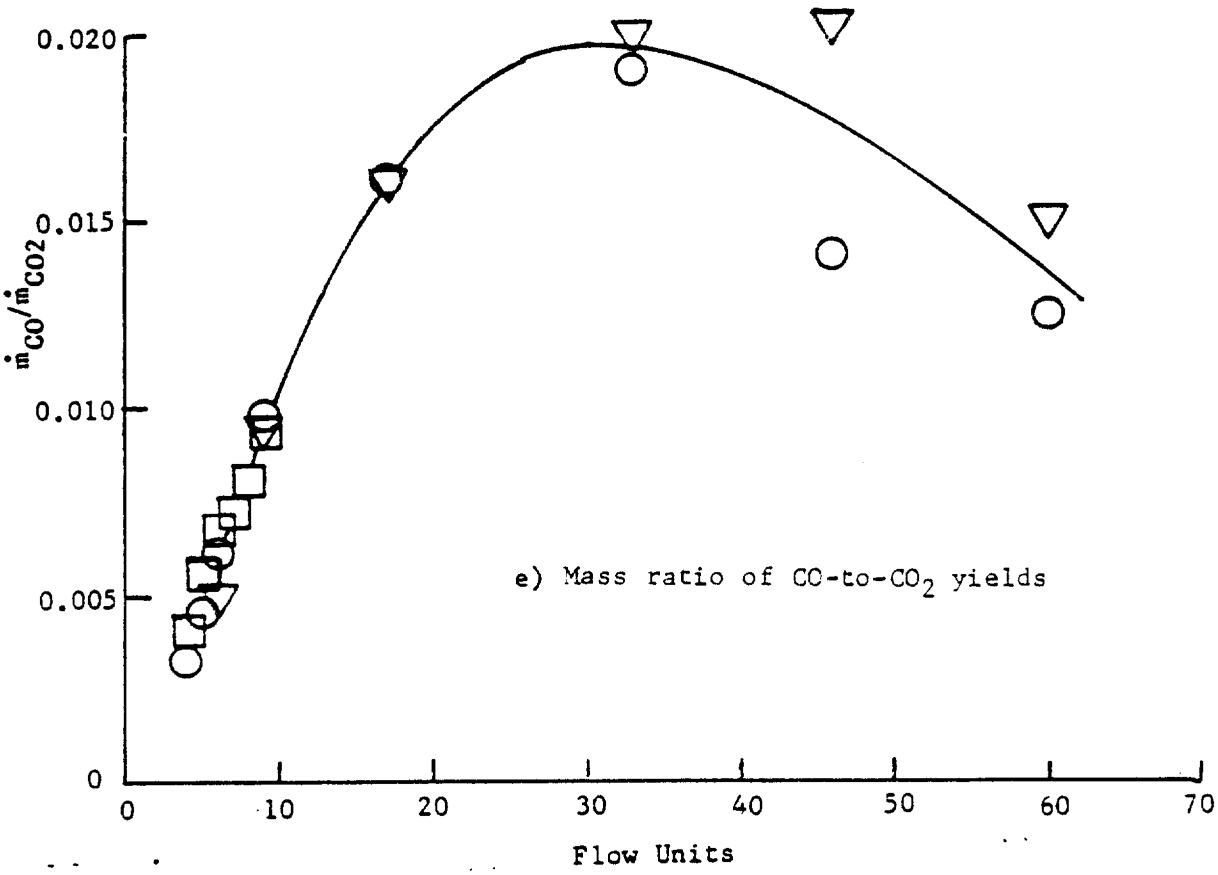


Figure 25 (Continued)



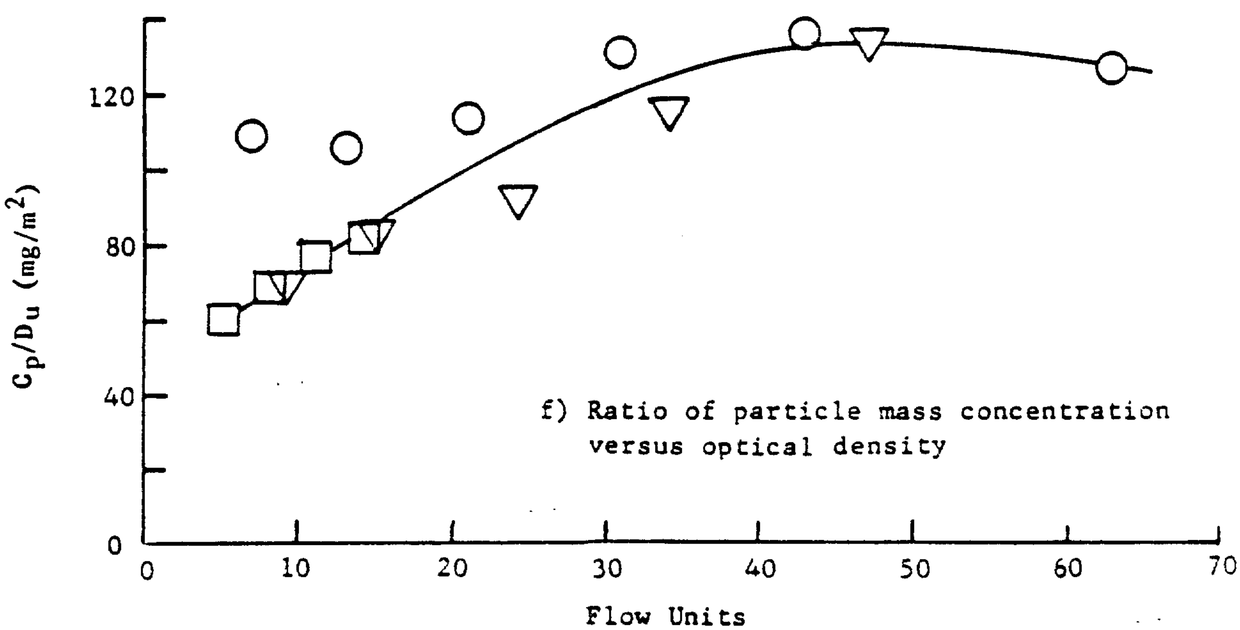


Figure 25 (Concluded)

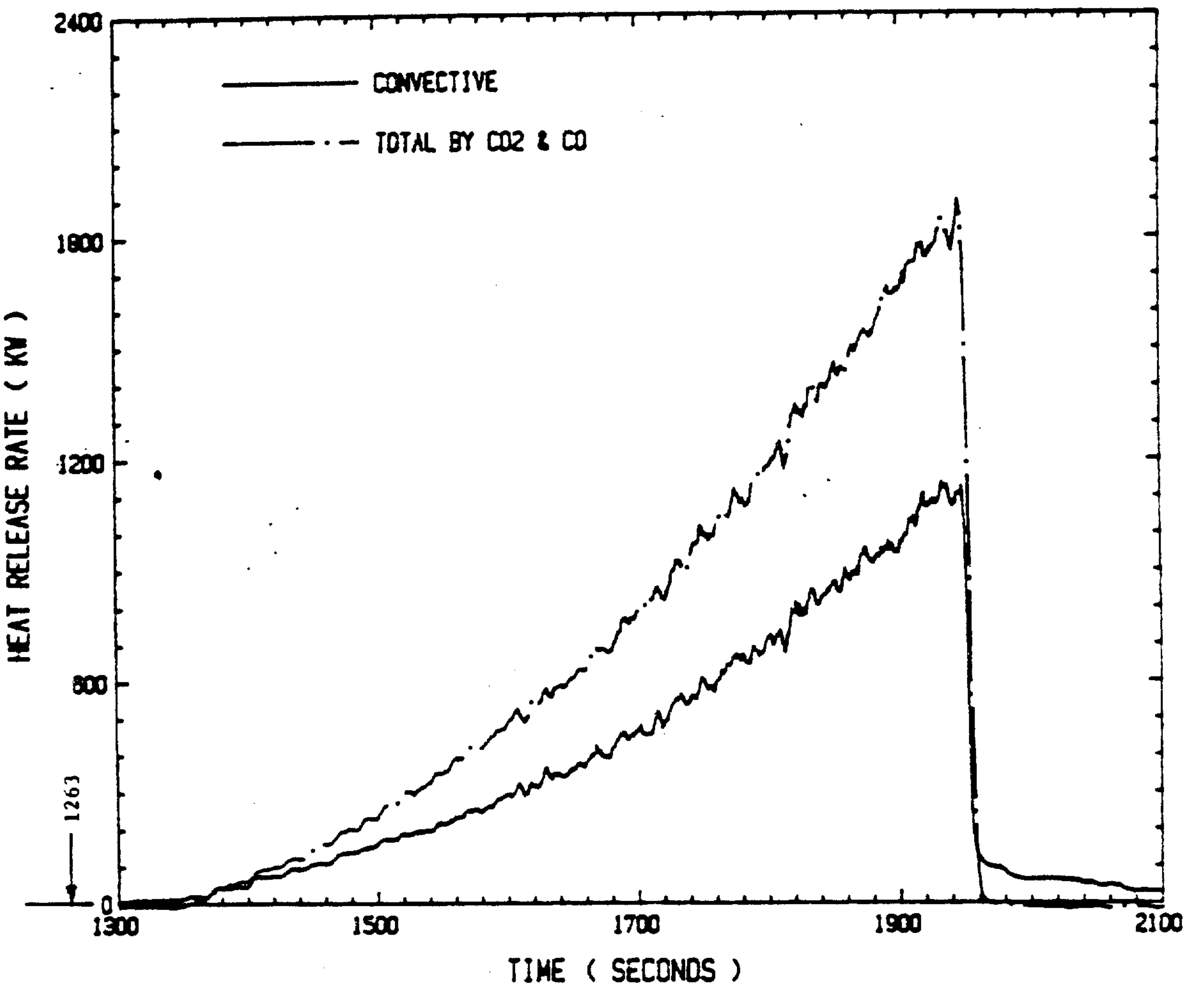


Figure 26 Parabolic fire growth during calibration of 0.91-m diameter propylene burner, t_g = 480 s (1263 s corresponding to zero time)

The smaller, 0.31 m diameter propylene burner did not provide enough heat output for accurate measurements in the large Fire Products Collector. Instead, a smaller, but similar device located at FMRC's Norwood laboratories[32] was used. Fuel supplies incorporating the three smallest critical-flow orifices were fabricated. Measurements of yields were made for 1,2,3 (1 and 2 flow units in parallel) and 4 nominal flow units. The results are summarized in Table 4. It is seen that the total heat-release rates per flow unit* (FU) average around 27 kW, versus 32.6 kW observed for the larger burner. The convective fraction, $\dot{Q}_c/\dot{Q}_t$, averages to 0.59, consistent with the result for the larger burner (Figure 22b). The mass yield ratios, $\dot{m}_{CO}/\dot{m}_{CO2}$, and particulate yields, $\dot{m}_p/\dot{m}_f$, may be compared to the results for the larger burner, Figures 25c and 25d. Only the two-flow-unit orifice was used with the smaller burner in the fire tests. An output of 26.9 kW per flow unit is indicated in Table 4 for this orifice, and hence, the output for the nominal two-flow unit burner will be indicated as 2.10 x 26.9 = 56 kW.

The final test employed the so-called "Standard Plastic Commodity". There was no time to calibrate this fire source in rigorous fashion. However, a freeburn of the array, previously shown in Figure 19, was conducted to establish the rough burning behavior. The fire intensity appeared to peak between 5-7 min from ignition with copious production of black smoke and flame heights extending about 2 1/2 m above the array, although flames hidden by smoke may have extended even higher. From flame-height correlations[33] it was estimated that maximum heat release of at least 1 MW was achieved in the freeburn.

3.4 FREEBURN OF TARGET SLABS

Freeburn tests were conducted on the polyurethane target slabs in one of FMRC's Norwood laboratories. The slabs were burned in both horizontal and vertical orientations, as in the enclosure tests. Measurements were confined to mass loss rates as deduced from a load cell record of the slab weight. In addition, observations were made of burning behavior.

*Actual flow units were used explicitly here because of the more marked deviations, actual versus nominal, for the smaller critical-flow orifices than the larger ones (Table 2).

TABLE 4

CALIBRATION OF 0.31 m DIAMETER PROPYLENE BURNER
(Gas Supply Pressure of 274 kPa and Temperature of 293 K)

Orifice Nom. No. Flow Units	Orifice Act. No. Flow Units (FU)	$\dot{Q}_t / FU$ (kW)	$\dot{Q}_c / \dot{Q}_t$	$\dot{m}_{CO} / \dot{m}_{CO2}$	$\dot{m}_p / \dot{m}_f$
1	0.97	26.4	0.58	0.0126	0.081
2	2.10	26.9	0.60	0.0105	0.083
3	3.07	28.1	0.60	0.0095	0.076
4	3.91	26.9	0.57	0.0094	0.071

Two types of ignition were investigated, area ignition and point ignition. In area ignition, approximately 70 mℓ of heptane were brushed over the exposed surface of the slab before ignition by a small propane flame. In point ignition, a 0.25 g cotton ball was soaked with 1 mℓ of heptane and placed in the center of a horizontal slab or at the bottom-center of a vertical slab, touched off with a small propane flame.

Horizontal slabs with area ignition would momentarily burn with a flame height approaching 2 m as the heptane burned off, quickly decaying to a steady height attributed to slab burning of about 0.23 m. With point ignition, the flame circles on horizontal slabs would expand slowly to cover the entire exposed surface in about 3 1/2 min. Area ignition of vertical slabs generated an initial flame height of about 3/4 m above the top of the slab, diminishing to about 0.18 m above the top after the heptane had burned off. In point ignition of vertical slabs, the flame propagated to the top center of the slab in about 20 s and covered the entire slab in less than 2 1/2 min.

With area ignition for both the horizontal and vertical slabs, the mass loss rates became steady as soon as the heptane appeared to have burned off. These were the mass loss rates which were assigned for freeburn. With point ignition for both horizontal and vertical slabs, mass loss rates increased monotonically; values assigned were those achieved as soon as the flames had covered the entire exposed surface of the slab. The results are summarized in Table 5.

3.5 SMOKE DETECTORS

All the detector units used were identified either by the letter I, for ionization, or the letter P, for photoelectric, preceded by a numeral assigned at the time it was placed in use, e.g., 2I and 4P. About two thirds of all the smoke detectors employed were characterized for sensitivity in the FMRC smoke box (normally used for approval work). In its standard mode of operation, the FMRC smoke box employs a test stream air speed of 0.15 m/s and smoke from a cotton lamp wick. The optical density at the test section builds up at a typical rate $dD_u/dt = 0.016\ m^{-1}\ min^{-1}$. Table 6 summarizes the optical density at response for the units tested, each value representing the average of three trials.

TABLE 5

FULLY-INVOLVED BURNING RATES
OF POLYURETHANE SLABS (FREEBURN)

Test	Slab Orientation	Ignition Type	Mass Burning Rate (g/s)
1H	Horizontal	Area	2.62
2H	"	"	2.22
6H	"	"	1.92
3H	Horizontal	Point	3.40
4H	"	"	2.72
5H	"	"	3.72
1V	Vertical	Area	1.40
2V	"	"	1.43
3V	"	"	1.39
4V	Vertical	Point	2.61
5V	"	"	2.70
6V	"	"	2.46

TABLE 6

SMOKE DETECTOR SENSITIVITIES

IN FM SMOKE BOX

(Cotton wick smoke; u=0.15 m/s; $dD_u/dt \approx 0.016\ m^{-1}\ min^{-1}$)

Detector Type	Unit	Ave. D_u at response (m^{-1})
Ionization	2I	0.042
"	4I	0.033
"	6I	0.042
"	9I	0.036
"	10I	0.033
"	12I	0.052
"	13I	0.049
"	14I	0.042
"	15I	0.049
"	16I	0.030
"	17I	0.033
Photoelectric	2P	0.039
"	4P	0.042
"	6P	0.033
"	9P	0.042
"	10P	0.039
"	12P	0.030
"	13P	0.046
"	14P	0.039
"	15P	0.030
"	16P	0.033
"	17P	0.046

According to a response model for smoke detectors[34] (of a type which actuates when the particle concentration within a sensing chamber reaches a threshold level, the sensing chamber communicating with the surrounding gas via simple apertures in the detector housing), the surrounding optical density at response, D_{ur}, can be represented:

$$D_{ur} = D_{uo} + L \langle dD_u/dt \rangle / \langle u \rangle. \qquad (10)$$

Here, D_{uo} is the optical density at response within the detector sensing chamber and depends on the particular detector and fire source; $\langle dD_u/dt \rangle$ is the average rate-of-rise in optical density until detection; and $\langle u \rangle$ is the average gas velocity until detection. The parameter, L, has the dimension of length and is a characteristic of the geometry of the particular detector relative to the direction of the oncoming smoke flow. D_{uo} is referred to as characteristic optical density, dependent on both detector and fire source, and L is referred to as characteristic length, dependent only on the detector and possibly its orientation.

In order to measure L, the FM smoke box, which normally recirculates the smoke, was configured in an alternative mode wherein the smoke does not recirculate, incorporating a so-called "extender box". It was expected that absence of recirculation would help minimize aging effects in the smoke and hence help maintain constant particulate properties (constant D_{uo}) from one test run to the next. In order to produce significant effects of L [eq (10)], it was necessary to generate rather high rates of change in optical density, $\langle dD_u/dt \rangle$, which was accomplished by smoldering several panels of cotton cloth stapled together and letting smoldering spread from a local ignition. Figure 27 shows plots of D_{ur} versus $\langle dD_u/d_t \rangle / \langle u \rangle$ for a photoelectric unit (17P) and an ionization unit (unnumbered), both units oriented relative to the smoke flow as in the enclosure fires. All data points were obtained at a stream air speed of 0.10 m/s, except the point at the lowest abscissa value in Figure 23a for which the air speed was 0.46 m/s. According to eq (10), the slopes of these plots correspond to the characteristic lengths, L, being L = 3.3 m for the photoelectric unit and L = 2.1 m for the ionization unit.

The standard mode of the FM smoke box used for the results in Table 6 corresponds to a value $\langle dD_u/dt \rangle / \langle u \rangle = 0.0018\ m^{-2}$. Reference to Figure 27

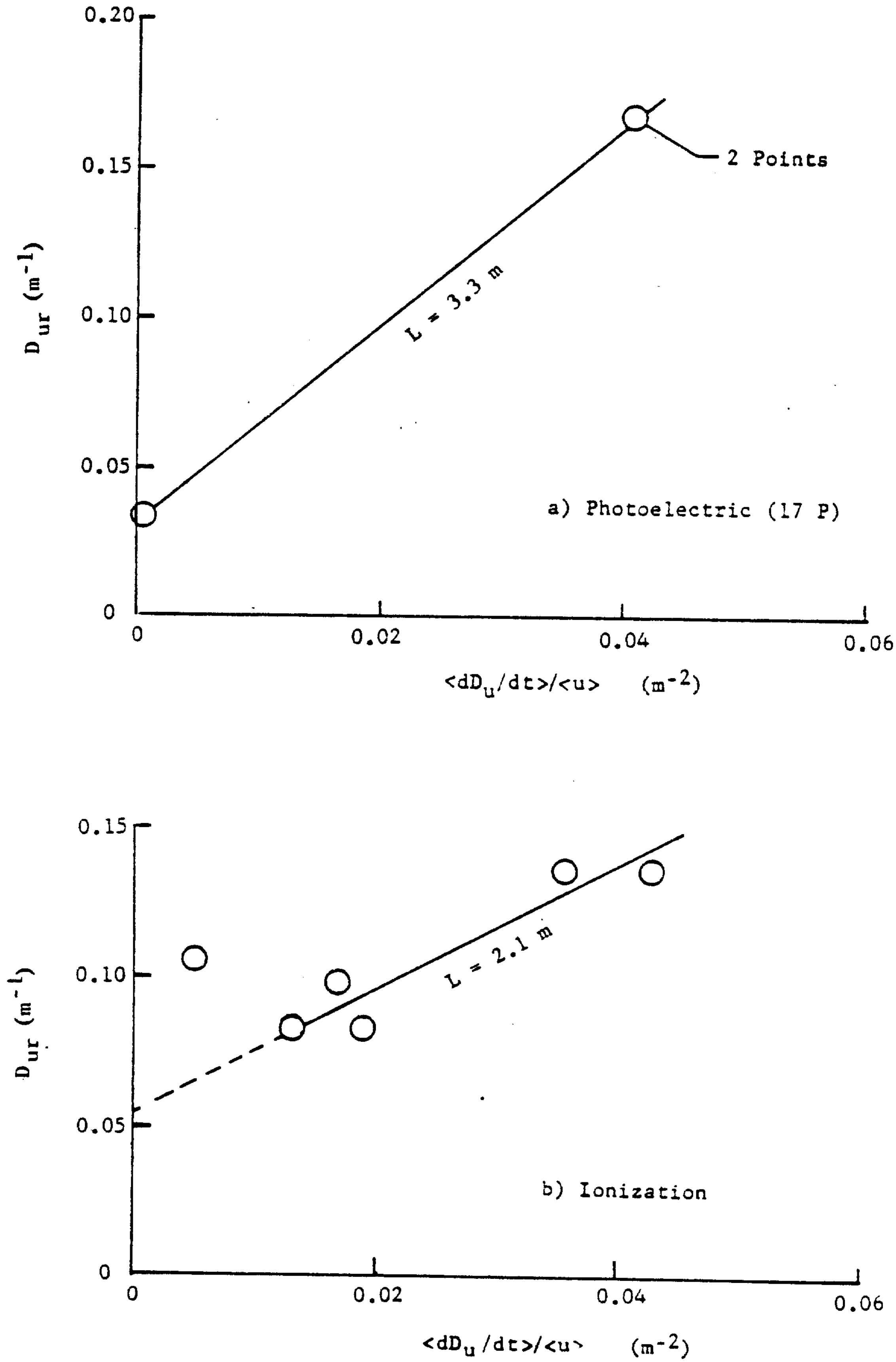


Figure 27 Calibration of smoke detectors for characteristic length, L

indicates that this value is so small that the optical densities in Table 6 can be considered equivalent to the characteristic optical densities of the smoke detectors examined and the smoke source employed (smoldering cotton wick).

IV

EXPERIMENTAL CONDITIONS

A total of 60 tests were conducted over a period of 4 1/2 months. Table 7 lists the conditions.

The column "HRR" (heat release rate) in Table 7 indicates the heat release characteristics of the source fires. The entries 56 kW and 522 kW refer to steady total heat release rates at the levels indicated in the 0.30 m diameter and 0.91 m diameter burners, respectively. The entries 60 s, 120 s, 240 s and 480 s refer to fires growing with the square of time (0.91 m diameter burner), exceeding 1000 kW total heat release rate in the indicated growth times. For the last test, Test 60, "PS Tubs in Cartons" is indicated, corresponding to the Standard Plastic Commodity described in Section 2.6.3, consisting of compartmented corrugated boxes with polystyrene tubs.

The column "TR doors" refers to the disposition of the target room doors, which were either both open or both closed, except in Test 60 where the west target room (TR1) door was closed and the north target room (TR2) door was open.

"Forced Vent" in Table 7 indicates whether forced ventilation (exhaust) was provided for the vent tube attached to each of the three rooms. An entry of a number in units of g/s refers to the approximate mass exhaust rate set in each vent tube prior to each experiment.

The columns "BR Door" and "BR Window" refer to the dispositions of the door to the burn room and the burn room window, respectively, i.e., open or closed.

Tests 38-47 incorporated the corridor partition. Two columns in Table 7 indicate whether a partition was in place and the mode which the ceiling vents on either side of the partition were in: "None" (ceiling vents blocked); "Natural" (enclosure free to vent through venting system in response to fire pressures); "170 g/s Ret." (venting in return mode and set at 170 g/s prior to experiment); and "170 g/s Sup." (venting in supply mode and set at 170 g/s prior to experiment).

Starting with Test 48, the corridor partition was removed, the ceiling vents blocked, and the modifications made for accommodating the polyurethane slabs as flashover targets. The column "Flashover Target" in Table 7 indi-

TABLE 7

EXPERIMENTAL CONDITIONS

Test	Date	Burn Dia.	HRR*	TR Doors	Forced Vent	BR Door	BR Window	Corridor Parti- tion	Corridor Ceiling Vent	Flashover Target
1	11-16-84	0.30 m	56 kW	Closed	None	Open	Closed	No	None	None
2	"	"	"	"	"	"	"	"	"	"
3	"	"	"	"	"	"	Open	"	"	"
4	"	"	"	"	"	Closed	Closed	"	"	"
5	"	"	"	"	"	"	Open	"	"	"
6	"	"	"	"	"	Open	Closed	"	"	"
7	12-14-84	"	"	Open	"	"	"	"	"	"
8	"	"	"	"	"	"	"	"	"	"
9	"	"	"	"	"	Closed	"	"	"	"
10	"	"	"	"	"	"	Open	"	"	"
11	"	"	"	"	"	Open	"	"	"	"
12	12-17-84	"	"	Closed	18 g/s	"	Closed	"	"	"
13	"	"	"	"	9 g/s	"	"	"	"	"
14	"	"	"	"	"	Closed	"	"	"	"
15	12-18-84	"	"	"	18 g/s	"	"	"	"	"
16	"	0.91 m	522 kW	"	None	Open	"	"	"	"
17	12-20-84	"	"	"	"	"	"	"	"	"
18	"	"	"	"	"	"	Open	"	"	"
19	"	"	"	Open	"	"	"	"	"	"
20	01-23-85	"	"	Closed	"	Closed	"	"	"	"
21	"	"	"	Open	"	Open	Closed	"	"	"
22	01-24-85	"	"	"	"	Closed	"	"	"	"
23	"	"	"	Closed	36 g/s	Open	"	"	"	"
24	"	"	"	"	72 g/s	"	"	"	"	"
25	"	"	"	"	144 g/s	"	"	"	"	"
26	01-25-85	"	240 s	"	None	Closed	Open	"	"	"
27	"	"	"	"	"	Open	Closed	"	"	"
28	01-28-85	"	120 s	"	"	"	"	"	"	"
29	"	"	"	"	"	Closed	Open	"	"	"
30	"	"	"	Open	"	Open	Closed	"	"	"
31	01-29-85	"	240 s	"	"	"	"	"	"	"
32	02-26-85	"	"	Closed	"	"	Open	"	"	"
33	"	"	"	Open	"	"	"	"	"	"
34	"	"	120 s	Open	"	"	"	"	"	"
35	"	"	240 s	"	"	Closed	Closed	"	"	"
36	02-27-85	"	120 s	Closed	"	Open	Open	"	"	"
37	"	"	"	Open	"	Closed	Closed	"	"	"
38	"	"	240 s	"	"	Open	"	Yes	"	"
39	02-28-85	"	"	"	"	"	"	"	Natural	"
40	"	"	120 s	"	"	"	"	"	"	"

TABLE 7 (Concluded)

Test	Date	Burn Dia.	HRR[a]	TR Doors	Forced Vent	BR Door	BR Window	Corridor Parti-tion	Corridor Ceiling Vent	Flashover Target
41	02-28-85	0.91 m	240 s	Open	None	Open	Closed	Yes	170 g/s Ret.	None
42	"	"	240 s	"	"	"	Open	"	Natural	"
43	"	"	"	"	"	"	"	"	170 g/s Ret.	"
44	03-01-85	"	120 s	"	"	"	"	"	Natural	"
45	"	"	240 s	"	"	"	Closed	"	170 g/s Sup.	"
46	"	"	"	"	"	"	Open	"	"	"
47	"	"	"	"	"	"	"	"	None	"
48	03-26-85	"	"	"	"	"	Closed	No	"	Vert.PU slab, SE
49	"	"	"	"	"	"	"	"	"	Vert.PU slab[b], SE
50	03-27-85	"	"	Closed	"	Closed	Open	"	"	Vert.PU slab, SE
51	"	"	"	Open	"	Open	Closed	"	"	Vert.PU slab[c], SE
52	"	"	"	Closed	"	Closed	Open	"	"	"
53	"	"	"	"	"	"	"	"	"	"
54	03-28-85	"	"	"	"	"	"	"	"	"
55	"	"	"	Open	"	Open	Closed	"	"	Horiz.PU slab[c], NW
56	"	"	"	"	"	"	"	"	"	Vert.PU slab[c], NW
57	03-29-85	"	120 s	"	"	"	"	"	"	None
58	"	"	60 s	"	"	"	"	"	"	"
59	"	"	480 s	"	"	"	"	"	"	"
60	"	PS Tubs in Cartons		TR1 Closed TR2 Open	"	"	"	"	"	Horiz. PU slab[c] NW

----

[a]HRR = Heat release rate. Units "kW" indicate steady fires. Units "s" indicate parabolically growing fires of the listed "growth time" to 1000 kW.

[b] With propane pilot flame.

[c] With newsprint pilot.

cates the orientation of the slab (vertical or horizontal) and its location in the burn room (south-east corner or north-west corner); furthermore, footnotes refer to the use of pilots, if any, for igniting the slab.

The smoke detectors were always cleaned with a vacuum cleaner before each test or replaced with a new unit if the preceding test or a pretest check with a smoke source (smoldering or flaming paper towel) indicated malfunctions. Table 8 provides information on specific detector units used in specific tests, most of these detector units having been calibrated in the FM Smoke Box (Table 6). Starting with the increased heat-release rate fires, Test 16 onwards, the detectors in the burn room (Station 9) were removed in anticipation of certain destruction in each test.

After Test 25, a crack was discovered in the Marinite ceiling over the fire source. The affected ceiling area was reinforced with an overlay of 12.7 mm thick Marinite I, screwed through the existing ceiling into ceiling joists. The overlay measured 1.22 m x 1.65 m and is shown relative to the walls in the burn room and the bidirectional probe in Figure 28.

TABLE 8

SMOKE DETECTOR PLACEMENTS

Test	Station #2		Station #4		Station #6		Station #9	
1-7	2I	2P	4I	4P	6I	6P	9I	9P
8-15	"	"	10I	"	11I	"	"	"
16-19	"	"	"	"	"	"	None	
20-21	13I	"	12I	"	"	"	"	
22-25	"	"	"	"	14I	"	"	
26	"	"	16I	"	15I	10P	"	
27-31	17I	"	"	"	"	"	"	
32-38	"	12P	19I	"	18I	11P	"	
39-47	"	"	"	"	20I	"	"	
48	"	"	22I	13P	21I	"	"	
49	"	"	"	"	23I	"	"	
50-51	"	"	"	"	24I	"	"	
52-55	"	"	"	"	25I	14P	"	
56	"	"	"	"	None		"	
57-59	28I	17P	27I	16P	26I	15P	"	
60	"	"	"	"	29I	"	"	

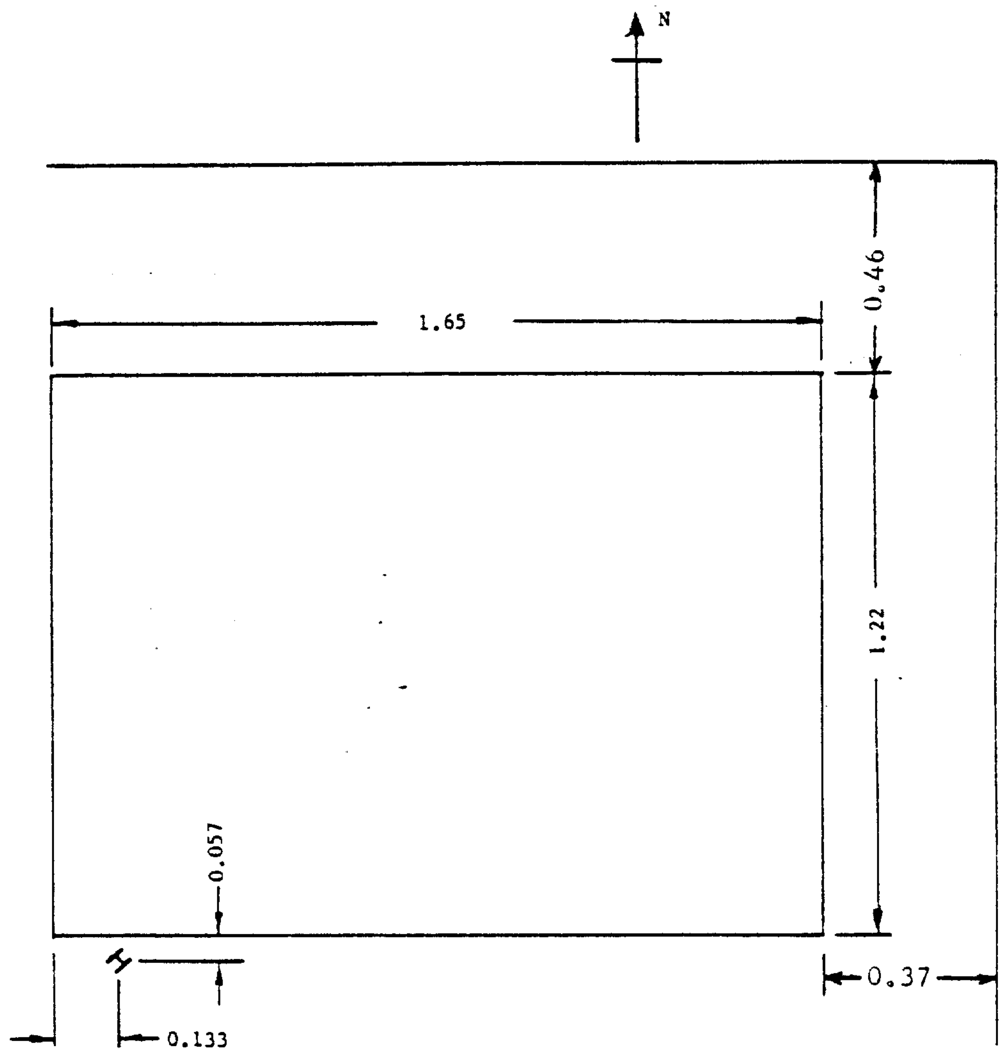


Figure 28 Marinite overlay on burn room ceiling, viewed from above, installed after Test 25. Overlay position is shown relative to bidirectional flow probe (dimensions in m).

V

RESULTS

Computer tapes and a complete printout of reduced data have been filed with the Center for Fire Research, NBS. A parallel set of data has been filed at FMRC, together with raw data tapes.

This section supplements the numerical data with observations, provides a guide to the reduced data, and considers the integrity of the data channels. It also summarizes the response of the smoke detectors, for ease of reference, and presents sample data.

5.1 OBSERVATIONS

The test conditions have been presented previously in Table 7. Notes from the various tests are listed chronologically in the Appendix.

The notes in the Appendix are self-explanatory. However, attention is directed to notes on Test 22, with puffing of smoke through closed door to burn room; Test 23, with puffing of smoke through open vent in south corridor (access) door; Test 34, where the forward smoke front under the corridor ceiling and the return front underneath are first referred to; and Tests 48-56, where it became evident how difficult it was to ignite the polyurethane target slabs by flashover from the source fires.

5.2 GUIDE TO REDUCED DATA

Tables 9A-9D are copies of data channel maps from the reduced data file.

Table 9A pertains to Test 1, but is representative of Tests 1-19. The second and third lines indicate that reductions of channels 67-96 (photometers and turbidimeters) and 107-116 (pressure transducers for room pressure differentials and vent tube orifice meters) are referenced to initial readings averaged from -70 s to -10 s before ignition. Then follows a listing of delay times for the gas concentration measurements, channels 97-106. A few lines further down begins Test Information, consistent with the listing in Table 7. Then follow the sensitivity ranges employed for the Datametrics Barocel pressure transducers, weather conditions (wind direction, wind speed in mph, as well as the barometric pressure in in. Hg), dry and wet bulb temperatures (in °F within the burn room prior to the test). The Channel Map

TABLE 9 A
DATA CHANNEL MAP, TEST 1
~~(Representative of Tests 1-19)~~

```
FEB. 1985       REDUCED       NBS FIRE TEST  #1  ( UNITS APPLY AFTER TIME -10 SECONDS )
-----------------------------------------------------------------------------------------
   AID4 REDUCTIONS OF CHANNELS 67-96  AND 107-116 REFERENCED TO INITIAL
        READINGS AVERAGED FROM -70 SECONDS TO -10 SECONDS (BEFORE IGNITION)

            DELAY TIMES FOR GAS CONCENTRATION MEASURMENTS
                          CHANNEL     SECONDS
                             97    :    33
                             98    :    27
                             99    :    15
                            100    :    18
                            101    :    19
                            102    :    17
                            103    :    21
                            104    :    18
                            105    :    21
                            106    :    31

    FRI029 -- 10/30/76      FILE CREATED: 02/05/85
   NBS-MULTI ROOM TEST # 1    11/16/84
   OJ2N8.RU            119
   11/16/84 START =  8:40:47:700 IGN =  8:43:51:320 END =  8:55:53:670 SCANS =  906

     SPRINKLERS:NONE

     TEST INFORMATION:
    1.  1 FT DIA. PAN
    2.  64 KW PROPYLENE (2 FLOW UNITS)
    3.  GAS PRESSURE 25 PSIG
    4.  NATURAL VENTILATION
    5.  SOUTH CORRIDOR DOOR VENT CLOSED
    6.  TARGET ROOM DOORS CLOSED
    7.  FIRE ROOM DOOR OPEN
    8.  FIRE ROOM WINDOW CLOSED


     BARACEL RANGES:
        BIDIRECTIONAL FLOWPROBE-.3
        ROOM PRESSURE-.03

     WEATHER CONDITIONS: WIND E  @ 12 MPH, B.P. 29.75 INCHES,
                 INSIDE    DRY BULB 56  DEG F  WET BULB  49 DEG F  R.H. =   %
                 OUTSIDE   DRY BULB     DEG F  WET BULB     DEG F  R.H. =   %

     CHANNEL MAP:

   STA.#1  2" BELOW CEILING DEG.C  CO1   1   ST1 2DN
```

FEB. 1985 REDUCED NBS FIRE TEST #1 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#1 4" BELOW CEILING	DEG.C	C02	2	ST1 4DN
STA.#1 10" BELOW CEILING	DEG.C	C03	3	ST110DN
STA.#1 22" BELOW CEILING	DEG.C	C04	4	ST122DN
STA.#1 38" BELOW CEILING	DEG.C	C05	5	ST138DN
STA.#1 54" BELOW CEILING	DEG.C	C06	6	ST154DN
STA.#1 70" BELOW CEILING	DEG.C	C07	7	ST170DN
STA.#1 86" BELOW CEILING	DEG.C	C08	8	ST186DN
STA.#2 2" BELOW CEILING	DEG.C	C09	9	ST2 2DN
STA.#2 4" BELOW CEILING	DEG.C	C10	10	ST2 4DN
STA.#2 10" BELOW CEILING	DEG.C	C11	11	ST210DN
STA.#2 22" BELOW CEILING	DEG.C	C12	12	ST222DN
STA.#2 38" BELOW CEILING	DEG.C	C13	13	ST238DN
STA.#2 54" BELOW CEILING	DEG.C	C14	14	ST254DN
STA.#2 70" BELOW CEILING	DEG.C	C15	15	ST270DN
STA.#2 86" BELOW CEILING	DEG.C	C16	16	ST286DN
STA.#2 DISK 2" DN	DEG.C	C17	17	ST2DISK
STA.#2 CEILING T/C	DEG.C	C18	18	ST2CLTC
STA. 2" BELOW CEILING	DEG.C	C19	19	ST3 2DN
STA.#3 DISK 2" DN	DEG.C	C20	20	ST3DISK
STA.#4 2" BELOW CEILING	DEG.C	C21	21	ST4 2DN
STA.#4 4" BELOW CEILING	DEG.C	C22	22	ST4 4DN
STA.#4 10" BELOW CEILING	DEG.C	C23	23	ST410DN
STA.#4 22" BELOW CEILING	DEG.C	C24	24	ST422DN
STA.#4 38" BELOW CEILING	DEG.C	C25	25	ST438DN
STA.#4 54" BELOW CEILING	DEG.C	C26	26	ST454DN
STA.#4 70" BELOW CEILING	DEG.C	C27	27	ST470DN
STA.#4 86" BELOW CEILING	DEG.C	H01	28	ST486DN
STA.#4 DISK 2" DN	DEG.C	H02	29	ST4DISK
STA.#4 CEILING T/C	DEG.C	H03	30	ST4CLTC
STA. 2" BELOW CEILING	DEG.C	H05	31	ST5 2DN
STA.#5 DISK 2" DN	DEG.C	H06	32	ST5DISK
STA.#6 2" BELOW CEILING	DEG.C	H07	33	ST6 2DN
STA.#6 4" BELOW CEILING	DEG.C	H08	34	ST6 4DN
STA.#6 10" BELOW CEILING	DEG.C	H09	35	ST610DN
STA.#6 22" BELOW CEILING	DEG.C	H10	36	ST622DN
STA.#6 38" BELOW CEILING	DEG.C	H11	37	ST638DN
STA.#6 54" BELOW CEILING	DEG.C	H12	38	ST654DN
STA.#6 70" BELOW CEILING	DEG.C	H13	39	ST670DN
STA.#6 86" BELOW CEILING	DEG.C	H14	40	ST686DN
STA.#6 DISK 2" DN	DEG.C	H15	41	ST6DISK
STA.#6 CEILING T/C	DEG.C	H16	42	ST6CLTC
STA. 2" BELOW CEILING	DEG.C	H17	43	ST7 2DN
STA.#7 DISK 2" DN	DEG.C	H18	44	ST7DISK
STA.#8 2" BELOW CEILING	DEG.C	H19	45	ST8 2DN
STA.#8 4" BELOW CEILING	DEG.C	H20	46	ST8 4DN
STA.#8 10" BELOW CEILING	DEG.C	H21	47	ST810DN
STA.#8 22" BELOW CEILING	DEG.C	H22	48	ST822DN
STA.#8 38" BELOW CEILING	DEG.C	H23	49	ST838DN
STA.#8 54" BELOW CEILING	DEG.C	H24	50	ST854DN
STA.#8 70" BELOW CEILING	DEG.C	H25	51	ST870DN

FEB. 1985 REDUCED NBS FIRE TEST #1 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#8 86" BELOW CEILING	DEG.C	H26	52	ST886DN
STA.#9 2" BELOW CEILING	DEG.C	H27	53	ST9 2DN
STA.#9 4" BELOW CEILING	DEG.C	H28	54	ST9 4DN
STA.#9 10" BELOW CEILING	DEG.C	D01	55	ST910DN
STA.#9 22" BELOW CEILING	DEG.C	D02	56	ST922DN
STA.#9 38" BELOW CEILING	DEG.C	D03	57	ST938DN
STA.#9 54" BELOW CEILING	DEG.C	D04	58	ST954DN
STA.#9 70" BELOW CEILING	DEG.C	D05	59	ST970DN
STA.#9 86" BELOW CEILING	DEG.C	D06	60	ST986DN
STA.#9 DISK 2" DN	DEG.C	D07	61	ST9DISK
STA.#9 CEILING T/C	DEG.C	D08	62	ST9CLTC
NORTH VENT TUBE T/C	DEG.C	D09	63	N-VT-TC
WEST VENT TUBE T/C	DEG.C	D10	64	W-VT-TC
FIRE VENT TUBE T/C	DEG.C	D11	65	F-VT-TC
GAS LINE T/C	DEG.C	D12	66	GASLNTC
STA.#1 PHOTOMETER 2"DN	OD/MV	C01/0267		ST1PH 2
STA.#1 PHOTOMETER 22"DN	OD/MV	C03/0468		ST1PH22
STA.#1 PHOTOMETER 54"DN	OD/MV	C05/0869		ST1PH54
STA.#1 PHOTOMETER 86"DN	OD/MV	C07/0870		ST1PH86
STA.#2 PHOTOMETER 2"DN	OD/MV	C09/1071		ST2PH 2
STA.#2 PHOTOMETER 22"DN	OD/MV	C11/1272		ST2PH22
STA.#2 PHOTOMETER 54"DN	OD/MV	C13/1473		ST2PH54
STA.#2 PHOTOMETER 86"DN	OD/MV	C15/1674		ST2PH86
STA.#4 PHOTOMETER 2"DN	OD/MV	C17/1875		ST4PH 2
STA.#4 PHOTOMETER 22"DN	OD/MV	C19/2076		ST4PH22
STA.#4 PHOTOMETER 54"DN	OD/MV	C21/2277		ST4PH54
STA.#4 PHOTOMETER 86"DN	OD/MV	C23/2478		ST4PH86
STA.#6 PHOTOMETER 2"DN	OD/MV	C25/2679		ST6PH 2
STA.#6 PHOTOMETER 22"DN	OD/MV	C27/2880		ST6PH22
STA.#6 PHOTOMETER 54"DN	OD/MV	C29/3081		ST6PH54
STA.#6 PHOTOMETER 86"DN	OD/MV	C31/3282		ST6PH86
STA.#8 PHOTOMETER 2"DN	OD/MV	C33/3483		ST8PH 2
STA.#8 PHOTOMETER 22"DN	OD/MV	C35/3684		ST8PH22
STA.#8 PHOTOMETER 54"DN	OD/MV	C37/3885		ST8PH54
STA.#8 PHOTOMETER 86"DN	OD/MV	C39/4086		ST8PH86
STA.#9 PHOTOMETER 2"DN	OD/MV	C41/4287		ST9PH 2
STA.#9 PHOTOMETER 22"DN	OD/MV	C43/4488		ST9PH24
STA.#9 PHOTOMETER 54"DN	OD/MV	C45/4689		ST9PH54
STA.#9 PHOTOMETER 86"DN	OD/MV	C47/4890		ST9PH86
STA.#2 TURBIDIMETER RED	MV	C49/5091		ST2TRED
STA.#2 TURBIDIMETER BLUE	MV	C51/5292		ST2TBLU
STA.#2 TURBIDIMETER IR.	MV	H19/2093		ST2T IR
STA.#6 TURBIDIMETER RED	MV	H21/2294		ST6TRED
STA.#6 TURBIDIMETER BLUE	MV	H23/2495		ST6TBLU
STA.#6 TURBIDIMETER IR.	MV	H25/2696		ST6T IR
STA.#1 CO 38" BELOW CLG	MV	I34/3597		ST1 CO
STA.#1 CO2 38" BELOW CLG	MV	I31/3298		ST1 CO2
STA.#4 CO 38" BELOW CLG	MV	I47/4899		ST4 CO
STA.#4 CO2 38" BELOW CLG	MV	I49/50100		ST4 CO2
STA.#4 O2 38" BELOW CLG	MV	I43/44101		ST4 O2

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FEB. 1985        REDUCED        NBS FIRE TEST  #1  ( UNITS APPLY AFTER TIME -10 SECONDS )
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        STA.#8 CO   38" BELOW CLG     MV    I24/25102 ST8 CO
        STA.#8 CO2  38" BELOW CLG     MV    I26/27103 ST8 CO2
        STA.#9 CO   38" BELOW CLG     MV    I22/23104 ST9 CO
        STA.#9 CO2  38" BELOW CLG     MV    I20/21105 ST9 CO2
        STA.#9 O2   38" BELOW CLG     MV    I18/19106 ST9 O2
        STA.#9 BIDIRECTIONAL F/P VOLTS   H49/50801 ST9F/P
        ROOM PRESSURE 1-2        VOLTS   H37/38802 RPR1-2
        ROOM PRESSURE 2-3        VOLTS   H39/40803 RPR2-3
        ROOM PRESSURE 2-4        VOLTS   H41/42804 RPR2-4
        ROOM PRESSURE 3-5        VOLTS   H43/44805 RPR3-5
        ROOM PRESSURE 5-6        VOLTS   H45/46806 RPR5-6
        ROOM PRESSURE 7-8        VOLTS   H47/48807 RPR7-8
        NORTH ROOM VENT TUBE     VOLTS   H51/52808 N VT
         WEST ROOM VENT TUBE     VOLTS   H53/54809 N VT
         FIRE ROOM VENT TUBE     VOLTS   F41/42810 N VT
        NBS PMM                  VOLTS   D13/14811 NBSPMM
        GAS LINE PRESSURE        VOLTS   D01/02812 GASPRS

           EVENT CHANNEL MAP

             1 STA.#2 SMOKE DETECTOR (IONIZATION)      H 27
             2 STA.#2 SMOKE DETECTOR (PHOTOELECTRIC)   H 28
             3 STA.#4 SMOKE DETECTOR (IONIZATION)      H 29
             4 STA.#4 SMOKE DETECTOR (PHOTOELECTRIC)   H 30
             5 STA.#6 SMOKE DETECTOR (IONIZATION)      H 31
             6 STA.#6 SMOKE DETECTOR (PHOTOELECTRIC)   H 32
             7 STA.#9 SMOKE DETECTOR (IONIZATION)      H 33
             8 STA.#9 SMOKE DETECTOR (PHOTOELECTRIC)   H 34
                COMMON GROUND H 36
        ** LOGG  PARAMETERS **
          NO. OF GROUPS =  4          NO. OF READINGS =  3
          GROUP #  1 --     START =  1,     END = 56,     GAIN =  3
          GROUP #  2 --     START = 57,     END = 96,     GAIN =  7
          GROUP #  3 --     START = 97,     END =106,     GAIN =  5
          GROUP #  4 --     START =801,     END =812,     GAIN =  8
        ** REDUC PARAMETERS **
           NO. OF T/C GROUPS = 1      T/C CONVERSION MODE =-1
          GROUP #  1 --     START =  1,     END = 56
           NO. OF VELOCITY GROUPS =  0
           NO. OF POLYNOMIAL GROUPS =  2
          GROUP #  1 -- START = 57, END =106
                  COEFF.'S =  .00000E+00  .10000E+04  .00000E+00  .00000E+00  .00000E+00
          GROUP #  2 -- START =107, END =118
                  COEFF.'S =  .00000E+00  .10000E+01  .00000E+00  .00000E+00  .00000E+00
           NO. OF RATE GROUPS =  0
        ** EVENT PARAMETERS **
          'FIRST TIME ONLY' EVENTS --    START =  1,    END =  8
          'EVERY TIME'      EVENTS --    START =  0,    END =  0
        ** PRE-TEST SCAN  **
        T=  0: 0:     0.000
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FEB. 1985        REDUCED        NBS FIRE TEST  #1  ( UNITS APPLY AFTER TIME -10 SECONDS )
----------------------------------------------------------------------------------------------------
           15.1725 15.1725 15.1725 15.1725 15.1725 14.5057 14.5057 14.1721 16.1718 16.1718
           16.1718 15.5057 15.1725 15.1725 15.1725 15.1725 15.8388 15.5057 15.8388 15.8388
           15.1725 15.5057 15.1725 15.5057 15.5057 15.1725 14.8392 15.1725 15.5057 15.1725
           15.5057 15.8388 15.8388 15.8388 16.1718 15.1725 15.5057 15.1725 15.1725 15.1725
           15.8388 15.1725 15.5057 15.5057 15.1725 15.8388 15.1725 15.1725 15.1725 15.1725
           15.1725 14.5057 17.1700 17.1700 16.5047 15.8388 15.5057 15.1725 15.1725 14.8392
           17.1700 15.5057 13.1705 13.1705 13.1705 14.1721 16.8000 19.2000 15.2000 26.8000
           17.6000 13.5000 13.2000  7.6000  8.8000 17.2000 22.0000 22.8000  5.6000  6.0000
            8.4000 10.0000 21.2000 13.4667 10.8000 10.4000 10.2667 12.0000  9.2000 13.2000
          618.2667606.0001677.2000202.2667411.3333284.1334  1.5667   .0667  0.0000  1.8000
           94.9667   .1000  1.1333  -.3000  1.3000 83.1000  2.6317   .0367   .0067   .0050
            -.0167  0.0000   .0100  2.7333  2.6183  2.6000   .6933  2.9467  0.0000  0.0000
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FEB. 1985 REDUCED NBS FIRE TEST #1 (UNITS APPLY AFTER TIME -10 SECONDS)

TIME	61 T/C DEG.C	62 T/C DEG.C	63 T/C DEG.C	64 T/C DEG.C	65 T/C DEG.C	66 T/C DEG.C	67 1/M	68 1/M	69 1/M	70 1/M	71 1/M	72 1/M	73 1/M	74 1/M	75 1/M
- 0: 24.	17.17	15.17	13.17	13.84	13.17	13.84	16.80	19.20	15.20	25.60	17.60	13.60	13.33	7.60	8.80
- 0: 23.	17.17	15.51	13.17	14.17	13.17	14.17	16.80	19.20	15.20	25.60	17.60	13.60	13.33	7.60	8.80
- 0: 22.	17.17	15.51	13.17	13.84	13.50	14.17	16.80	19.20	15.20	25.60	17.60	13.60	13.20	7.60	8.80
- 0: 21.	17.17	15.17	13.17	13.84	13.17	14.17	16.80	19.20	15.20	25.60	17.60	13.60	13.20	7.60	8.80
- 0: 20.	17.17	15.51	13.17	13.17	13.17	14.17	16.80	19.20	15.20	25.60	17.60	13.60	13.20	7.50	8.80
- 0: 19.	17.17	15.84	13.17	13.84	13.17	14.17	16.80	19.20	15.20	25.60	17.60	13.60	13.20	7.50	8.80
- 0: 18.	16.84	15.51	13.17	13.50	13.17	14.17	16.57	19.20	15.20	25.60	17.60	13.60	13.20	7.60	8.80
- 0: 17.	16.84	15.51	13.17	13.50	13.17	14.17	16.40	19.20	15.20	25.73	17.50	13.60	13.33	7.73	8.30
- 0: 16.	16.84	15.17	13.17	13.84	13.17	13.84	16.80	19.20	15.20	25.50	17.60	13.60	13.33	7.60	8.80
- 0: 15.	17.17	15.84	13.17	13.17	13.17	14.17	16.80	19.20	15.20	25.73	17.60	13.60	13.47	7.80	8.30
- 0: 14.	17.17	15.51	13.17	13.50	13.17	14.17	16.67	19.20	15.20	25.60	17.50	13.60	13.33	7.50	8.40
- 0: 13.	17.17	15.17	13.17	13.17	13.17	14.17	16.67	19.20	15.20	26.00	17.60	13.50	13.20	7.60	8.80
- 0: 12.	17.17	15.17	13.17	13.84	13.17	14.17	16.67	19.20	15.20	25.87	17.50	13.60	13.33	7.60	8.80
- 0: 11.	17.17	15.17	13.17	13.17	13.17	14.17	16.80	19.20	15.20	26.00	17.60	13.60	13.20	7.60	8.80
- 0: 10.	17.17	15.17	13.17	13.17	13.17	14.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
- 0: 9.	17.17	15.17	13.17	13.50	13.17	14.17	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
- 0: 8.	17.17	15.17	13.17	13.50	13.17	14.17	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	-0.01	0.00
- 0: 7.	17.17	15.84	13.17	13.17	13.17	14.17	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
- 0: 6.	17.17	15.51	13.17	13.84	13.17	13.84	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
- 0: 5.	17.17	15.51	13.17	13.84	13.17	14.17	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
- 0: 4.	17.17	15.17	13.17	13.50	13.17	13.84	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- 0: 3.	17.17	15.17	13.17	13.17	13.50	13.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
- 0: 2.	17.17	15.17	13.17	13.50	13.17	13.84	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
- 0: 1.	17.17	15.51	13.17	13.50	13.17	13.50	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
0: 0.	17.17	15.51	13.17	13.84	13.50	13.17	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
0: 0.	17.17	15.51	13.17	13.84	13.50	13.17	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	[illegible]
0: 1.	17.17	15.51	13.17	13.50	13.17	13.17	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	[illegible]
0: 2.	17.17	15.51	13.17	13.50	13.50	13.50	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01	0.00
0: 3.	17.17	16.17	13.17	14.17	13.50	13.50	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
0: 4.	17.50	16.50	13.17	14.17	13.84	13.50	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
0: 5.	18.50	17.83	13.17	14.17	14.17	13.84	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	-0.01	0.00
0: 6.	19.83	17.83	13.17	14.17	14.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 7.	21.15	18.17	13.17	14.17	14.17	13.84	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 8.	22.14	18.83	13.84	14.17	14.17	14.17	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 9.	23.14	19.16	13.50	14.17	14.17	13.84	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 10.	25.12	19.83	13.50	14.17	14.17	13.84	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	-0.01	0.00
0: 11.	26.11	20.82	13.84	14.17	14.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 12.	27.09	21.48	13.84	14.17	14.17	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 13.	29.72	22.14	13.17	14.51	14.51	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00
0: 13.	29.72	22.14	13.17	14.51	14.51	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00

FEB. 1985 REDUCED NBS FIRE TEST #1 (UNITS APPLY AFTER TIME -10 SECONDS)

TIME	61 T/C DEG.C	62 T/C DEG.C	63 T/C DEG.C	64 T/C DEG.C	65 T/C DEG.C	66 T/C DEG.C	67 1/M	68 1/M	69 1/M	70 1/M	71 1/M	72 1/M	73 1/M	74 1/M	75 1/M
0: 14.	30.38	22.14	13.17	14.51	14.17	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
0: 15.	31.89	22.14	13.84	14.17	14.51	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 16.	33.00	22.48	13.17	14.17	14.51	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
0: 17.	34.64	23.14	13.50	14.17	14.51	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 18.	35.62	23.80	13.50	14.17	14.51	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00
0: 19.	37.25	25.12	13.50	14.17	14.17	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 20.	39.21	25.12	13.17	14.17	15.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00
0: 21.	40.83	26.11	13.50	14.51	14.51	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 22.	43.11	26.11	13.84	14.17	14.84	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 23.	44.73	26.44	13.84	14.17	14.84	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00
0: 23.	44.73	26.44	13.84	14.17	14.84	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00
0: 24.	46.68	28.08	13.84	14.17	15.17	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 25.	48.62	27.75	14.17	14.17	14.51	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00
0: 26.	50.56	29.07	13.84	14.17	14.51	14.17	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
0: 27.	53.46	30.05	13.84	14.17	14.84	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
0: 28.	54.43	30.05	14.17	14.17	14.84	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
0: 29.	56.36	30.05	13.84	14.17	14.84	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 30.	57.97	31.04	13.50	14.17	14.84	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 31.	59.90	32.02	13.50	14.17	14.84	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
0: 32.	61.83	32.35	13.84	14.17	14.84	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 33.	64.72	33.00	13.84	14.17	14.51	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 34.	66.01	33.00	13.84	14.17	15.17	14.17	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 35.	67.29	33.00	13.50	14.17	15.17	14.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0: 36.	68.89	33.00	13.84	14.17	15.17	13.84	0.01	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
0: 37.	69.53	33.00	14.17	14.17	15.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 38.	70.49	33.98	13.84	14.17	15.17	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 39.	71.78	33.98	13.84	14.17	15.17	13.84	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 39.	71.78	33.98	13.84	14.17	15.17	13.84	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 40.	73.06	33.98	13.17	14.17	15.17	14.17	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
0: 41.	74.66	34.96	13.50	14.17	15.17	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
0: 42.	75.62	35.94	13.50	14.17	15.17	14.17	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 43.	77.54	36.27	13.50	14.17	14.51	13.84	0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
0: 44.	79.14	36.27	13.50	14.17	14.51	14.17	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00
0: 45.	81.06	37.25	13.50	14.17	15.17	14.17	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00
0: 46.	82.34	36.92	13.50	14.17	15.17	14.17	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
0: 47.	83.30	37.58	13.50	14.51	15.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.02
0: 47.	83.30	37.58	13.50	14.51	15.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.02
0: 48.	84.58	37.90	13.84	14.17	15.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	-0.01	0.05
0: 49.	86.49	37.90	13.50	14.17	14.84	13.84	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.10
0: 50.	87.45	37.90	13.50	14.17	15.17	14.17	0.00	0.00	0.00	-0.02	0.00	0.00	0.01	-0.01	0.15

TABLE 9 B
DATA CHANNEL MAP, TEST 20
~~(Representative of Tests 20-31)~~

```
FEB. 1985        REDUCED        NBS FIRE TEST  #20 ( UNITS APPLY AFTER TIME -10 SECONDS )
-----------------------------------------------------------------------------------------
   AID4 REDUCTIONS OF CHANNELS 67-96  AND 109-118 REFERENCED TO INITIAL
      READINGS AVERAGED FROM -70 SECONDS TO -10 SECONDS (BEFORE IGNITION)

          DELAY TIMES FOR GAS CONCENTRATION MEASURMENTS
                      CHANNEL    SECONDS
                        97    :    23
                        98    :    23
                        99    :    15
                       100    :    15
                       101    :    18
                       102    :    22
                       103    :    20
                       104    :    37
                       105    :    38
                       106    :    58
                       107    :    14
                       108    :    28

   FRIO29 -- 10/30/78      FILE CREATED: 02/28/85
   NBS-MULTI ROOM TEST #20   01/23/85
   OJ2N8.RU          121
    1/23/85 START = 11:17:39:460 IGN = 11:20:57:970 END = 11:28:30:440 SCANS =  531

    SPRINKLERS:NONE

    TEST INFORMATION:
   1. 3 FT DIA. PAN
   2. 522 KW PROPYLENE (16 FLOW UNITS)
   3. GAS PRESSURE 25 PSIG
   4. NATURAL VENTILATION
   5. SOUTH CORRIDOR DOOR VENT CLOSED
   6. TARGET ROOM DOORS CLOSED
   7. FIRE ROOM DOOR CLOSED
   8. FIRE ROOM WINDOW OPEN

   NOTE: SMOKE DETECTORS 7 AND 8 (FIRE ROOM) HAVE BEEN REMOVED.
   NOTE: VENT TUBE SETRAS 0.5" H20 REPLACED WITH .2 PSID TRANS,
         EXCEPT WEST ROOM WHICH IS 5.0" H20.

    BARACEL RANGES:
       ROOM PRESSURE-ALL RANGES AT .3 EXCEPT PRESSURE 2-4 WHICH IS RANGE 1
                    ALSO 2-3 IS SET ON RANGE 1

    WEATHER CONDITIONS: WIND 5 @ 12 MPH, B.P. 29.48 INCHES,
                 INSIDE    DRY BULB 52  DEG F  WET BULB  42 DEG F  R.H. =   %
                 OUTSIDE   DRY BULB     DEG F  WET BULB     DEG F  R.H. =   %

    CHANNEL MAP:
```

FEB. 1985 REDUCED NBS FIRE TEST #20 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#1 2° BELOW CEILING	DEG.C	C01	1	ST1 2DN
STA.#1 4° BELOW CEILING	DEG.C	C02	2	ST1 4DN
STA.#1 10° BELOW CEILING	DEG.C	C03	3	ST110DN
STA.#1 22° BELOW CEILING	DEG.C	C04	4	ST122DN
STA.#1 38° BELOW CEILING	DEG.C	C05	5	ST138DN
STA.#1 54° BELOW CEILING	DEG.C	C06	6	ST154DN
STA.#1 70° BELOW CEILING	DEG.C	C07	7	ST170DN
STA.#1 86° BELOW CEILING	DEG.C	C08	8	ST186DN
STA.#2 2° BELOW CEILING	DEG.C	C09	9	ST2 2DN
STA.#2 4° BELOW CEILING	DEG.C	C10	10	ST2 4DN
STA.#2 10° BELOW CEILING	DEG.C	C11	11	ST210DN
STA.#2 22° BELOW CEILING	DEG.C	C12	12	ST222DN
STA.#2 38° BELOW CEILING	DEG.C	C13	13	ST238DN
STA.#2 54° BELOW CEILING	DEG.C	C14	14	ST254DN
STA.#2 70° BELOW CEILING	DEG.C	C15	15	ST270DN
STA.#2 86° BELOW CEILING	DEG.C	C16	16	ST286DN
STA.#2 DISK 2° DN	DEG.C	C17	17	ST2DISK
STA.#2 CEILING T/C	DEG.C	C18	18	ST2CLTC
STA.#3 CEILING GAS T/C	DEG.C	C19	19	ST3CLTC
STA.#3 DISK	DEG.C	C20	20	ST3DISK
STA.#4 2° BELOW CEILING	DEG.C	C21	21	ST4 2DN
STA.#4 4° BELOW CEILING	DEG.C	C22	22	ST4 4DN
STA.#4 10° BELOW CEILING	DEG.C	C23	23	ST410DN
STA.#4 22° BELOW CEILING	DEG.C	C24	24	ST422DN
STA.#4 38° BELOW CEILING	DEG.C	C25	25	ST438DN
STA.#4 54° BELOW CEILING	DEG.C	C26	26	ST454DN
STA.#4 70° BELOW CEILING	DEG.C	C27	27	ST470DN
STA.#4 86° BELOW CEILING	DEG.C	H01	28	ST486DN
STA.#4 DISK 2° DN	DEG.C	H02	29	ST4DISK
STA.#4 CEILING T/C	DEG.C	H03	30	ST4CLTC
STA.#5 CEILING GAS T/C	DEG.C	H05	31	ST5CLTC
STA.#5 DISK 2° DN	DEG.C	H06	32	ST5DISK
STA.#6 2° BELOW CEILING	DEG.C	H07	33	ST6 2DN
STA.#6 4° BELOW CEILING	DEG.C	H08	34	ST6 4DN
STA.#6 10° BELOW CEILING	DEG.C	H09	35	ST610DN
STA.#6 22° BELOW CEILING	DEG.C	H10	36	ST622DN
STA.#6 38° BELOW CEILING	DEG.C	H11	37	ST638DN
STA.#6 54° BELOW CEILING	DEG.C	H12	38	ST654DN
STA.#6 70° BELOW CEILING	DEG.C	H13	39	ST670DN
STA.#6 86° BELOW CEILING	DEG.C	H14	40	ST686DN
STA.#6 DISK 2° DN	DEG.C	H15	41	ST6DISK
STA.#6 CEILING T/C	DEG.C	H16	42	ST6CLTC
STA.#7 2° BELOW CEILING	DEG.C	H17	43	ST7 2DN
STA.#7 DISK 2° DN	DEG.C	H18	44	ST7DISK
STA.#8 2° BELOW CEILING	DEG.C	H19	45	ST8 2DN
STA.#8 4° BELOW CEILING	DEG.C	H20	46	ST8 4DN
STA.#8 10° BELOW CEILING	DEG.C	H21	47	ST810DN
STA.#8 22° BELOW CEILING	DEG.C	H22	48	ST822DN
STA.#8 38° BELOW CEILING	DEG.C	H23	49	ST838DN
STA.#8 54° BELOW CEILING	DEG.C	H24	50	ST854DN

FEB. 1985 REDUCED NBS FIRE TEST #20 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#8 70° BELOW CEILING	DEG.C	H25	51	ST870DN
STA.#8 86° BELOW CEILING	DEG.C	H26	52	ST886DN
STA.#9 2° BELOW CEILING	DEG.C	H27	53	ST9 2DN
STA.#9 4° BELOW CEILING	DEG.C	H28	54	ST9 4DN
STA.#9 10° BELOW CEILING	DEG.C	D01	55	ST910DN
STA.#9 22° BELOW CEILING	DEG.C	D02	56	ST922DN
STA.#9 38° BELOW CEILING	DEG.C	D03	57	ST938DN
STA.#9 54° BELOW CEILING	DEG.C	D04	58	ST954DN
STA.#9 70° BELOW CEILING	DEG.C	D05	59	ST970DN
STA.#9 86° BELOW CEILING	DEG.C	D06	60	ST986DN
STA.#9 DISK 2° DN	DEG.C	D07	61	ST9DISK
STA.#9 CEILING T/C	DEG.C	D08	62	ST9CLTC
NORTH VENT TUBE T/C	DEG.C	D09	63	N-VT-TC
WEST VENT TUBE T/C	DEG.C	D10	64	W-VT-TC
FIRE VENT TUBE T/C	DEG.C	D11	65	F-VT-TC
GAS LINE T/C	DEG.C	D12	66	GASLNTC
STA.#1 PHOTOMETER 2°DN	OD/MV	C01/0267		ST1PH 2
STA.#1 PHOTOMETER 22°DN	OD/MV	C03/0468		ST1PH22
STA.#1 PHOTOMETER 54°DN	OD/MV	C05/0669		ST1PH54
STA.#1 PHOTOMETER 86°DN	OD/MV	C07/0870		ST1PH86
STA.#2 PHOTOMETER 2°DN	OD/MV	C09/1071		ST2PH 2
STA.#2 PHOTOMETER 22°DN	OD/MV	C11/1272		ST2PH22
STA.#2 PHOTOMETER 54°DN	OD/MV	C13/1473		ST2PH54
STA.#2 PHOTOMETER 86°DN	OD/MV	C15/1674		ST2PH86
STA.#4 PHOTOMETER 2°DN	OD/MV	C17/1875		ST4PH 2
STA.#4 PHOTOMETER 22°DN	OD/MV	C19/2076		ST4PH22
STA.#4 PHOTOMETER 54°DN	OD/MV	C21/2277		ST4PH54
STA.#4 PHOTOMETER 86°DN	OD/MV	C23/2478		ST4PH86
STA.#6 PHOTOMETER 2°DN	OD/MV	C25/2679		ST6PH 2
STA.#6 PHOTOMETER 22°DN	OD/MV	C27/2880		ST6PH22
STA.#6 PHOTOMETER 54°DN	OD/MV	C29/3081		ST6PH54
STA.#6 PHOTOMETER 86°DN	OD/MV	C31/3282		ST6PH86
STA.#8 PHOTOMETER 2°DN	OD/MV	C33/3483		ST8PH 2
STA.#8 PHOTOMETER 22°DN	OD/MV	C35/3684		ST8PH22
STA.#8 PHOTOMETER 54°DN	OD/MV	C37/3885		ST8PH54
STA.#8 PHOTOMETER 86°DN	OD/MV	C39/4086		ST8PH86
STA.#9 PHOTOMETER 2°DN	OD/MV	C41/4287		ST9PH 2
STA.#9 PHOTOMETER 22°DN	OD/MV	C43/4488		ST9PH24
STA.#9 PHOTOMETER 54°DN	OD/MV	C45/4689		ST9PH54
STA.#9 PHOTOMETER 86°DN	OD/MV	C47/4890		ST9PH86
STA.#2 TURBIDIMETER RED	MV	C49/5091		ST2TRED
STA.#2 TURBIDIMETER BLUE	MV	C51/5292		ST2TBLU
STA.#2 TURBIDIMETER IR.	MV	H19/2093		ST2T IR
STA.#6 TURBIDIMETER RED	MV	H21/2294		ST6TRED
STA.#6 TURBIDIMETER BLUE	MV	H23/2495		ST6TBLU
STA.#6 TURBIDIMETER IR.	MV	H25/2696		ST6T IR
STA.#1 CO 38° BELOW CLG	MV	I34/3587		ST1 CO
STA.#1 CO2 38° BELOW CLG	MV	I31/3288		ST1 CO2
STA.#4 CO 38° BELOW CLG	MV	I47/4889		ST4 CO
STA.#4 CO2 38° BELOW CLG	MV	I48/50100		ST4 CO2

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FEB. 1985        REDUCED        NBS FIRE TEST  #20 ( UNITS APPLY AFTER TIME -10 SECONDS )
------------------------------------------------------------------------------------------
     STA.#4 O2   38° BELOW CLG      MV    I43/44101 ST4 O2
     STA.#8 CO   38° BELOW CLG      MV    I24/25102 ST8 CO
     STA.#8 CO2 38° BELOW CLG       MV    I26/27103 ST8 CO2
     STA.#9 CO . 38° BELOW CLG .    MV    I22/23104 ST9 CO
     STA.#9 CO2 38° BELOW CLG       MV    I20/21105 ST9 CO2
     STA.#9 O2   38° BELOW CLG      MV    I18/19106 ST9 O2
     STA.#4 CO2   2° BELOW CLG      MV    I01/02107 ST4CO2T
     STA.#4 CO2 88° BELOW CLG       MV    I03/04108 ST4CO2B
     STA.#9 BIDIRECTIONAL F/P  VOLTS   H49/50801 ST9F/P
     ROOM PRESSURE 1-2          VOLTS   H37/38802 RPR1-2
     ROOM PRESSURE 2-3          VOLTS   H39/40803 RPR2-3
     ROOM PRESSURE 2-4          VOLTS   H41/42804 RPR2-4
     ROOM PRESSURE 3-5          VOLTS   H43/44805 RPR3-5
     ROOM PRESSURE 5-6          VOLTS   H45/46806 RPR5-6
     ROOM PRESSURE 7-8          VOLTS   H47/48807 RPR7-8
     NORTH ROOM VENT TUBE       VOLTS   H51/52808 N VT
      WEST ROOM VENT TUBE       VOLTS   H53/54809 N VT
      FIRE ROOM VENT TUBE       VOLTS   F41/42810 N VT
     NBS PMM                    VOLTS   D13/14811 NBSPMM
     GAS LINE PRESSURE          VOLTS   D01/02812 GASPRS

        EVENT CHANNEL MAP

          1 STA.#2 SMOKE DETECTOR (IONIZATION)        H 27
          2 STA.#2 SMOKE DETECTOR (PHOTOELECTRIC)     H 28
          3 STA.#4 SMOKE DETECTOR (IONIZATION)        H 29
          4 STA.#4 SMOKE DETECTOR (PHOTOELECTRIC)     H 30
          5 STA.#6 SMOKE DETECTOR (IONIZATION)        H 31
          6 STA.#6 SMOKE DETECTOR (PHOTOELECTRIC)     H 32
          7 STA.#9 SMOKE DETECTOR (IONIZATION)        H 33
          8 STA.#9 SMOKE DETECTOR (PHOTOELECTRIC)     H 34
             COMMON GROUND H 35
     == LOGG  PARAMETERS ==
       NO. OF GROUPS =  4          NO. OF READINGS =  3
       GROUP #  1 --     START =  1,     END = 56,     GAIN =  3
       GROUP #  2 --     START = 57,     END = 96,     GAIN =  7
       GROUP #  3 --     START = 97,     END =108,     GAIN =  5
       GROUP #  4 --     START =801,     END =812,     GAIN =  8
     == REDUC PARAMETERS ==
        NO. OF T/C GROUPS = 1       T/C CONVERSION MODE =-1
       GROUP #  1 --     START =  1,     END = 56
        NO. OF VELOCITY GROUPS =  0
        NO. OF POLYNOMIAL GROUPS =  2
       GROUP #  1 -- START = 57, END =108
              COEFF.'S =  .00000E+00  .10000E+04  .00000E+00  .00000E+00  .00000E+00
       GROUP #  2 -- START =109, END =120
              COEFF.'S =  .00000E+00  .10000E+01  .00000E+00  .00000E+00  .00000E+00
        NO. OF RATE GROUPS =  0
     == EVENT PARAMETERS ==
       'FIRST TIME ONLY' EVENTS --    START =  1,    END =  8
```

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FEB. 1985        REDUCED        NBS FIRE TEST  #20 ( UNITS APPLY AFTER TIME -10 SECONDS )
------------------------------------------------------------------------------------------
       'EVERY TIME'      EVENTS --    START =  0,    END =  0
     == PRE-TEST SCAN  ==
     T=  0: 0:     0.000
```

13.1705	13.1705	13.1705	12.8363	13.1705	12.1677	12.1677	11.1638	13.1705	12.5021
12.1677	12.1677	12.1677	11.8332	11.8332	11.1638	12.5021	12.1677	11.8332	12.1677
11.8332	12.1677	12.1677	12.1677	11.8332	11.4985	11.1638	11.1638	12.1677	11.1638
12.1677	11.8332	12.1677	12.1677	12.5021	12.1677	12.1677	12.1677	11.4985	11.1638
12.1677	12.1677	11.8332	12.1677	12.1677	12.1677	12.1677	12.1677	11.1638	11.1638
-.0059	11.1638	14.1721	14.1721	13.8383	13.1705	12.8363	12.1677	12.1677	11.1638
13.8383	12.8383	20.1581	18.1671	10.4938	10.8288	14.8667	12.8000	14.8000	28.0000
8.4000	14.8000	12.8000	9.2000	4.4000	16.8000	18.6000	21.3333	3.2000	4.8000
7.2000	11.6000	20.4000	13.6000	11.6000	12.0000	6.0000	2.4000	10.4000	12.8000
306.2667	271.7333	403.2000	52.4000	72.9333	125.2000	1.9000	.2333	1.0000	1.0000
98.8000	.2000	1.0000	0.0000	-1.0000	84.9867	2.7000	2.6000	2.6433	.0217
.0050	0.0000	0.0000	0.0000	.0050	-.1183	2.5700	-.0550	.4683	2.5233
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AUGUST 1985 REDUCED NBS FIRE TEST #32 (UNITS APPLY AFTER TIME -10 SECONDS)

AI04 REDUCTIONS OF CHANNELS 58-97 AND 110-119 REFERENCED TO INITIAL
READINGS AVERAGED FROM -70 SECONDS TO -10 SECONDS (BEFORE IGNITION)

DELAY TIMES FOR GAS CONCENTRATION MEASURMENTS

CHANNEL		SECONDS
98	:	23
99	:	23
100	:	15
101	:	15
102	:	18
103	:	22
104	:	20
105	:	21
106	:	20
107	:	39
108	:	14
109	:	28

TABLE 9 C

DATA CHANNEL MAP, TEST 32

~~(Representative of Tests 32-47)~~

FRI029 -- 10/30/76 FILE CREATED: 03/14/85
NBS-MULTI ROOM TEST #32 02/26/85
OJ2N8.RU 124
2/26/85 START = 9:21:19:180 IGN = 9:24:21:240 END = 9:29:27:160 SCANS = 488

SPRINKLERS:NONE

TEST INFORMATION:
1. 3 FT DIA. PAN
2. GROWTH TIME 240 SECONDS
3. GAS PRESSURE 25 PSIG
4. NATURAL VENTILATION
5. SOUTH CORRIDOR DOOR VENT CLOSED
6. TARGET ROOM DOORS CLOSED
7. FIRE ROOM DOOR OPEN
8. FIRE ROOM WINDOW OPEN

NOTE: SMOKE DETECTORS 7 AND 8 (FIRE ROOM) HAVE BEEN REMOVED.
NOTE: VENT TUBE SETRAS 0.5" H2O REPLACED WITH .2 PSID TRANS,
EXCEPT WEST ROOM WHICH IS 5.0" H2O.

BARACEL RANGES:
ROOM PRESSURE-ALL RANGES AT .3 EXCEPT PRESSURE 2-4 WHICH IS RANGE 1
WEATHER CONDITIONS: WIND SE @ 3 MPH, B.P. 30.29 INCHES.
INSIDE DRY BULB 55 DEG F WET BULB 45 DEG F R.H. = %
OUTSIDE DRY BULB DEG F WET BULB DEG F R.H. = %

CHANNEL MAP:

STA.#1	2" BELOW CEILING	DEG.C	C01	1	ST1 2DN
STA.#1	4" BELOW CEILING	DEG.C	C02	2	ST1 4DN

AUGUST 1985 REDUCED NBS FIRE TEST #32 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#1	10" BELOW CEILING	DEG.C	C03	3	ST110DN
STA.#1	22" BELOW CEILING	DEG.C	C04	4	ST122DN
STA.#1	38" BELOW CEILING	DEG.C	C05	5	ST138DN
STA.#1	54" BELOW CEILING	DEG.C	C06	6	ST154DN
STA.#1	70" BELOW CEILING	DEG.C	C07	7	ST170DN
STA.#1	86" BELOW CEILING	DEG.C	C08	8	ST186DN
STA.#2	2" BELOW CEILING	DEG.C	C09	9	ST2 2DN
STA.#2	4" BELOW CEILING	DEG.C	C10	10	ST2 4DN
STA.#2	10" BELOW CEILING	DEG.C	C11	11	ST210DN
STA.#2	22" BELOW CEILING	DEG.C	C12	12	ST222DN
STA.#2	38" BELOW CEILING	DEG.C	C13	13	ST238DN
STA.#2	54" BELOW CEILING	DEG.C	C14	14	ST254DN
STA.#2	70" BELOW CEILING	DEG.C	C15	15	ST270DN
STA.#2	86" BELOW CEILING	DEG.C	C16	16	ST286DN
STA.#2	DISK	DEG.C	C17	17	ST2DISK
STA.#2	CEILING T/C	DEG.C	C18	18	ST2CLTC
STA.#3	CEILING GAS T/C	DEG.C	C19	19	ST3CLTC
STA.#3	DISK	DEG.C	C20	20	ST3DISK
STA.#4	2" BELOW CEILING	DEG.C	C21	21	ST4 2DN
STA.#4	4" BELOW CEILING	DEG.C	C22	22	ST4 4DN
STA.#4	10" BELOW CEILING	DEG.C	C23	23	ST410DN
STA.#4	22" BELOW CEILING	DEG.C	C24	24	ST422DN
STA.#4	38" BELOW CEILING	DEG.C	C25	25	ST438DN
STA.#4	54" BELOW CEILING	DEG.C	C26	26	ST454DN
STA.#4	70" BELOW CEILING	DEG.C	C27	27	ST470DN
STA.#4	86" BELOW CEILING	DEG.C	H01	28	ST486DN
STA.#4	DISK	DEG.C	H02	29	ST4DISK
STA.#4	CEILING T/C	DEG.C	H03	30	ST4CLTC
STA.#5	CEILING GAS T/C	DEG.C	H05	31	ST5CLTC
STA.#5	DISK	DEG.C	H06	32	ST5DISK
STA.#6	2" BELOW CEILING	DEG.C	H07	33	ST6 2DN
STA.#6	4" BELOW CEILING	DEG.C	H08	34	ST6 4DN
STA.#6	10" BELOW CEILING	DEG.C	H09	35	ST610DN
STA.#6	22" BELOW CEILING	DEG.C	H10	36	ST622DN
STA.#6	38" BELOW CEILING	DEG.C	H11	37	ST638DN
STA.#6	54" BELOW CEILING	DEG.C	H12	38	ST654DN
STA.#6	70" BELOW CEILING	DEG.C	H13	39	ST670DN
STA.#6	86" BELOW CEILING	DEG.C	H14	40	ST686DN
STA.#6	DISK	DEG.C	H15	41	ST6DISK
STA.#6	CEILING T/C	DEG.C	H16	42	ST6CLTC
STA.#7	CEILING GAS T/C	DEG.C	H17	43	ST7CLTC
STA.#7	DISK	DEG.C	H18	44	ST7DISK
STA.#8	2" BELOW CEILING	DEG.C	H19	45	ST8 2DN
STA.#8	4" BELOW CEILING	DEG.C	H20	46	ST8 4DN
STA.#8	10" BELOW CEILING	DEG.C	H21	47	ST810DN
STA.#8	22" BELOW CEILING	DEG.C	H22	48	ST822DN
STA.#8	38" BELOW CEILING	DEG.C	H23	49	ST838DN
STA.#8	54" BELOW CEILING	DEG.C	H24	50	ST854DN
STA.#8	70" BELOW CEILING	DEG.C	H25	51	ST870DN
STA.#8	86" BELOW CEILING	DEG.C	H26	52	ST886DN

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AUGUST 1985     REDUCED     NBS FIRE TEST  #32 ( UNITS APPLY AFTER TIME  -10 SECONDS )
--------------------------------------------------------------------------------------
          STA.#9  2" BELOW CEILING DEG.C  H27     53  ST9 2DN
          STA.#9  4" BELOW CEILING DEG.C  H28     54  ST9 4DN
          STA.#9 10" BELOW CEILING DEG.C  D01     55  ST910DN
          STA.#9 22" BELOW CEILING DEG.C  D02     56  ST922DN
          STA.#9 38" BELOW CEILING DEG.C  D03     57  ST938DN
          STA.#9 54" BELOW CEILING DEG.C  D04     58  ST954DN
          STA.#9 70" BELOW CEILING DEG.C  D05     59  ST970DN
          STA.#9 86" BELOW CEILING DEG.C  D06     60  ST986DN
          STA.#9 DISK                DEG.C  D07     61  ST9DISK
          STA.#9 CEILING T/C         DEG.C  D08     62  ST9CLTC
          NORTH ROOM FAN T/C         DEG.C  D09     63  N-FN-TC
           WEST ROOM FAN T/C         DEG.C  D10     64  W-FN-TC
           FIRE ROOM FAN T/C         DEG.C  D11     65  F-FN-TC
           GAS LINE T/C              DEG.C  D12     66  GASLNTC
          VENT DUCT T/C              DEG.C  D13     67  VT DTTC
          STA.#1 PHOTOMETER   2"DN   OD/MV   C01/0268   ST1PH 4
          STA.#1 PHOTOMETER  22"DN   OD/MV   C03/0469   ST1PH22
          STA.#1 PHOTOMETER  54"DN   OD/MV   C05/0670   ST1PH54
          STA.#1 PHOTOMETER  86"DN   OD/MV   C07/0871   ST1PH86
          STA.#2 PHOTOMETER   2"DN   OD/MV   C09/1072   ST2PH 4
          STA.#2 PHOTOMETER  22"DN   OD/MV   C11/1273   ST2PH22
          STA.#2 PHOTOMETER  54"DN   OD/MV   C13/1474   ST2PH54
          STA.#2 PHOTOMETER  86"DN   OD/MV   C15/1675   ST2PH86
          STA.#4 PHOTOMETER   2"DN   OD/MV   C17/1876   ST4PH 4
          STA.#4 PHOTOMETER  22"DN   OD/MV   C19/2077   ST4PH22
          STA.#4 PHOTOMETER  54"DN   OD/MV   C21/2278   ST4PH54
          STA.#4 PHOTOMETER  86"DN   OD/MV   C23/2479   ST4PH86
          STA.#6 PHOTOMETER   2"DN   OD/MV   C25/2680   ST6PH 4
          STA.#6 PHOTOMETER  22"DN   OD/MV   C27/2881   ST6PH22
          STA.#6 PHOTOMETER  54"DN   OD/MV   C29/3082   ST6PH54
          STA.#6 PHOTOMETER  86"DN   OD/MV   C31/3283   ST6PH86
          STA.#8 PHOTOMETER   2"DN   OD/MV   C33/3484   ST8PH 4
          STA.#8 PHOTOMETER  22"DN   OD/MV   C35/3685   ST8PH22
          STA.#8 PHOTOMETER  54"DN   OD/MV   C37/3886   ST8PH54
          STA.#8 PHOTOMETER  86"DN   OD/MV   C39/4087   ST8PH86
          STA.#9 PHOTOMETER   2"DN   OD/MV   C41/4288   ST9PH 4
          STA.#9 PHOTOMETER  22"DN   OD/MV   C43/4489   ST9PH24
          STA.#9 PHOTOMETER  54"DN   OD/MV   C45/4690   ST9PH54
          STA.#9 PHOTOMETER  86"DN   OD/MV   C47/4891   ST9PH86
          STA.#2 TURBIDIMETER RED       MV   C49/5092   ST2TRED
          STA.#2 TURBIDIMETER BLUE      MV   C51/5293   ST2TBLU
          STA.#2 TURBIDIMETER IR.       MV   H19/2094   ST2T OD
          STA.#6 TURBIDIMETER RED       MV   H21/2295   ST6TRED
          STA.#6 TURBIDIMETER BLUE      MV   H23/2496   ST6TBLU
          STA.#6 TURBIDIMETER IR.       MV   H25/2697   ST6T OD
          STA.#1 CO  38" BELOW CLG      MV   I34/3598   ST1 CO
          STA.#1 CO2 38" BELOW CLG      MV   I31/3299   ST1 CO2
          STA.#4 CO  38" BELOW CLG      MV   I47/48100 ST4 CO
          STA.#4 CO2 38" BELOW CLG      MV   I49/50101 ST4 CO2
          STA.#4 O2  38" BELOW CLG      MV   I43/44102 ST4 O2
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AUGUST 1985     REDUCED     NBS FIRE TEST  #32 ( UNITS APPLY AFTER TIME  -10 SECONDS )
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          STA.#8 CO  38" BELOW CLG      MV   I24/25103 ST8 CO
          STA.#8 CO2 38" BELOW CLG      MV   I26/27104 ST8 CO2
          STA.#9 CO  38" BELOW CLG      MV   I22/23105 ST9 CO
          STA.#9 CO2 38" BELOW CLG      MV   I20/21106 ST9 CO2
          STA.#9 O2  38" BELOW CLG      MV   I18/19107 ST9 O2
          STA.#4 CO2  2" BELOW CLG      MV   I01/02108 ST4CO2T
          STA.#4 CO2 86" BELOW CLG      MV   I03/04109 ST4CO2B
          STA.#9 BIDIRECTIONAL F/P VOLTS   H49/50801 ST9F/P
          ROOM PRESSURE 1-2           VOLTS   H37/38802 RPR1-2
          ROOM PRESSURE 2-3           VOLTS   H39/40803 RPR2-3
          ROOM PRESSURE 2-4           VOLTS   H41/42804 RPR2-4
          ROOM PRESSURE 3-5           VOLTS   H43/44805 RPR3-5
          ROOM PRESSURE 5-6           VOLTS   H45/46806 RPR5-6
          ROOM PRESSURE 7-8           VOLTS   H47/48807 RPR7-8
          NORTH ROOM AIR FLOW FAN     VOLTS   H51/52808 N A-F
            WEST ROOM AIR FLOW FAN    VOLTS   H53/54809 N A-F
            FIRE ROOM AIR FLOW FAN    VOLTS   F41/42810 N A-F
            VENT DUCT AIR FLOW FAN    VOLTS   D03/04811 VDA-F
            VENT DUCT PLENUM PRESS.   VOLTS   D05/06812 VDPPR
          NBS PMM                     VOLTS   D13/14813 NBSPMM
          GAS LINE PRESSURE           VOLTS   D01/02814 GASPRS

             EVENT CHANNEL MAP

               1 STA.#2 SMOKE DETECTOR (IONIZATION)        H 27
               2 STA.#2 SMOKE DETECTOR (PHOTOELECTRIC)     H 28
               3 STA.#4 SMOKE DETECTOR (IONIZATION)        H 29
               4 STA.#4 SMOKE DETECTOR (PHOTOELECTRIC)     H 30
               5 STA.#6 SMOKE DETECTOR (IONIZATION)        H 31
               6 STA.#6 SMOKE DETECTOR (PHOTOELECTRIC)     H 32
               7 STA.#9 SMOKE DETECTOR (IONIZATION)        H 33
               8 STA.#9 SMOKE DETECTOR (PHOTOELECTRIC)     H 34
                  COMMON GROUND H 36
 ** LOGG  PARAMETERS **
   NO. OF GROUPS =  4          NO. OF READINGS =  3
   GROUP #  1 --     START =  1,     END = 67,     GAIN =  3
   GROUP #  2 --     START = 68,     END = 97,     GAIN =  7
   GROUP #  3 --     START = 98,     END =109,     GAIN =  5
   GROUP #  4 --     START =801,     END =814,     GAIN =  8
 ** REDUC PARAMETERS **
    NO. OF T/C GROUPS = 1      T/C CONVERSION MODE =-1
   GROUP #  1 --     START =  1,     END = 67
    NO. OF VELOCITY GROUPS =  0
    NO. OF POLYNOMIAL GROUPS =  2
   GROUP #  1 -- START = 68, END =109
           COEFF.'S =  .00000E+00  .10000E+04  .00000E+00  .00000E+00  .00000E+00
   GROUP #  2 -- START =110, END =123
           COEFF.'S =  .00000E+00  .10000E+01  .00000E+00  .00000E+00  .00000E+00
    NO. OF RATE GROUPS =  0
 ** EVENT PARAMETERS **
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AUGUST 1985 REDUCED NBS FIRE TEST #48 (UNITS APPLY AFTER TIME -10 SECONDS)

AID4 REDUCTIONS OF CHANNELS 68-97 AND 110-119 REFERENCED TO INITIAL READINGS AVERAGED FROM -70 SECONDS TO -10 SECONDS (BEFORE IGNITION)

DELAY TIMES FOR GAS CONCENTRATION MEASURMENTS

CHANNEL		SECONDS
98	:	23
99	:	23
100	:	15
101	:	15
102	:	18
103	:	22
104	:	20
105	:	21
106	:	20
107	:	39
108	:	14
109	:	28

TABLE 9 D

DATA CHANNEL MAP, TEST 48

~~(Representative of Tests 48-60)~~

FRI029 -- 10/30/76 FILE CREATED: 05/21/85
NBS-MULTI ROOM TEST #48 03/26/85
OJ2N8.RU 124
3/26/85 START = 11:49:53:640 IGN = 11:52:55:340 END = 11:59: 5:800 SCANS = 552

SPRINKLERS:NONE

TEST INFORMATION:

1. 3 FT DIA. PAN
2. GROWTH TIME 240 SECONDS
3. GAS PRESSURE 25 PSIG
4. NATURAL VENTILATION
5. SOUTH CORRIDOR DOOR VENT CLOSED
6. TARGET ROOM DOORS OPEN
7. FIRE ROOM DOOR OPEN
8. FIRE ROOM WINDOW CLOSED
9. VERTICAL PU SLAB INSTALLED IN EAST POSITION.
10. NORTH WEST POSITION IS IDLE.

NOTE: SMOKE DETECTORS 7 AND 8 (FIRE ROOM) HAVE BEEN REMOVED.
NOTE: VENT TUBE SETRAS 0.2 PSID IN FIRE ROOM,WEST ROOM 5" H20,
NORTH ROOM IS 0.5" H20.

BARACEL RANGES:
ROOM PRESSURE-ALL RANGES AT .3 EXCEPT PRESSURE 2-4 WHICH IS RANGE 1
WEATHER CONDITIONS: WIND W @ 4 MPH, B.P. 30.12 INCHES.
INSIDE DRY BULB 59 DEG F WET BULB 42 DEG F R.H. = %
OUTSIDE DRY BULB DEG F WET BULB DEG F R.H. = %

CHANNEL MAP:

AUGUST 1985 REDUCED NBS FIRE TEST #48 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#1	2" BELOW CEILING	DEG.C	C01	1	ST1 2DN
STA.#1	4" BELOW CEILING	DEG.C	C02	2	ST1 4DN
STA.#1	10" BELOW CEILING	DEG.C	C03	3	ST110DN
STA.#1	22" BELOW CEILING	DEG.C	C04	4	ST122DN
STA.#1	38" BELOW CEILING	DEG.C	C05	5	ST138DN
STA.#1	54" BELOW CEILING	DEG.C	C06	6	ST154DN
STA.#1	70" BELOW CEILING	DEG.C	C07	7	ST170DN
STA.#1	86" BELOW CEILING	DEG.C	C08	8	ST186DN
STA.#2	2" BELOW CEILING	DEG.C	C09	9	ST2 2DN
STA.#2	4" BELOW CEILING	DEG.C	C10	10	ST2 4DN
STA.#2	10" BELOW CEILING	DEG.C	C11	11	ST210DN
STA.#2	22" BELOW CEILING	DEG.C	C12	12	ST222DN
STA.#2	38" BELOW CEILING	DEG.C	C13	13	ST238DN
STA.#2	54" BELOW CEILING	DEG.C	C14	14	ST254DN
STA.#2	70" BELOW CEILING	DEG.C	C15	15	ST270DN
STA.#2	86" BELOW CEILING	DEG.C	C16	16	ST286DN
STA.#2	DISK	DEG.C	C17	17	ST2DISK
STA.#2	CEILING T/C	DEG.C	C18	18	ST2CLTC
STA.#3	CEILING GAS T/C	DEG.C	C19	19	ST3CLTC
STA.#3	DISK	DEG.C	C20	20	ST3DISK
STA.#4	2" BELOW CEILING	DEG.C	C21	21	ST4 2DN
STA.#4	4" BELOW CEILING	DEG.C	C22	22	ST4 4DN
STA.#4	10" BELOW CEILING	DEG.C	C23	23	ST410DN
STA.#4	22" BELOW CEILING	DEG.C	C24	24	ST422DN
STA.#4	38" BELOW CEILING	DEG.C	C25	25	ST438DN
STA.#4	54" BELOW CEILING	DEG.C	C26	26	ST454DN
STA.#4	70" BELOW CEILING	DEG.C	C27	27	ST470DN
STA.#4	86" BELOW CEILING	DEG.C	H01	28	ST486DN
STA.#4	DISK	DEG.C	H02	29	ST4DISK
STA.#4	CEILING T/C	DEG.C	H03	30	ST4CLTC
STA.#5	CEILING GAS T/C	DEG.C	H05	31	ST5CLTC
STA.#5	DISK	DEG.C	H06	32	ST5DISK
STA.#6	2" BELOW CEILING	DEG.C	H07	33	ST6 2DN
STA.#6	4" BELOW CEILING	DEG.C	H08	34	ST6 4DN
STA.#6	10" BELOW CEILING	DEG.C	H09	35	ST610DN
STA.#6	22" BELOW CEILING	DEG.C	H10	36	ST622DN
STA.#6	38" BELOW CEILING	DEG.C	H11	37	ST638DN
STA.#6	54" BELOW CEILING	DEG.C	H12	38	ST654DN
STA.#6	70" BELOW CEILING	DEG.C	H13	39	ST670DN
STA.#6	86" BELOW CEILING	DEG.C	H14	40	ST686DN
STA.#6	DISK	DEG.C	H15	41	ST6DISK
STA.#6	CEILING T/C	DEG.C	H16	42	ST6CLTC
STA.#7	CEILING GAS T/C	DEG.C	H17	43	ST7CLTC
STA.#7	DISK	DEG.C	H18	44	ST7DISK
STA.#8	2" BELOW CEILING	DEG.C	H19	45	ST8 2DN
STA.#8	4" BELOW CEILING	DEG.C	H20	46	ST8 4DN
STA.#8	10" BELOW CEILING	DEG.C	H21	47	ST810DN
STA.#8	22" BELOW CEILING	DEG.C	H22	48	ST822DN
STA.#8	38" BELOW CEILING	DEG.C	H23	49	ST838DN
STA.#8	54" BELOW CEILING	DEG.C	H24	50	ST854DN

AUGUST 1985 REDUCED NBS FIRE TEST #48 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#8 70° BELOW CEILING	DEG.C	H25	51	ST870DN
STA.#8 86° BELOW CEILING	DEG.C	H26	52	ST886DN
STA.#9 2° BELOW CEILING	DEG.C	H27	53	ST9 2DN
STA.#9 4° BELOW CEILING	DEG.C	H28	54	ST9 4DN
STA.#9 10° BELOW CEILING	DEG.C	D01	55	ST910DN
STA.#9 22° BELOW CEILING	DEG.C	D02	56	ST922DN
STA.#9 38° BELOW CEILING	DEG.C	D03	57	ST938DN
STA.#9 54° BELOW CEILING	DEG.C	D04	58	ST954DN
STA.#9 70° BELOW CEILING	DEG.C	D05	59	ST970DN
STA.#9 86° BELOW CEILING	DEG.C	D06	60	ST986DN
STA.#9 DISK	DEG.C	D07	61	ST9DISK
STA.#9 CEILING T/C	DEG.C	D08	62	ST9CLTC
NORTH ROOM FAN T/C	DEG.C	D09	63	N-FN-TC
WEST ROOM FAN T/C	DEG.C	D10	64	W-FN-TC
FIRE ROOM FAN T/C	DEG.C	D11	65	F-FN-TC
GAS LINE T/C	DEG.C	D12	66	GASLNTC
VENT DUCT T/C	DEG.C	D13	67	VT DTTC
STA.#1 PHOTOMETER 2°DN	OD/MV	C01/0268		ST1PH 4
STA.#1 PHOTOMETER 22°DN	OD/MV	C03/0469		ST1PH22
STA.#1 PHOTOMETER 54°DN	OD/MV	C05/0670		ST1PH54
STA.#1 PHOTOMETER 86°DN	OD/MV	C07/0871		ST1PH86
STA.#2 PHOTOMETER 2°DN	OD/MV	C09/1072		ST2PH 4
STA.#2 PHOTOMETER 22°DN	OD/MV	C11/1273		ST2PH22
STA.#2 PHOTOMETER 54°DN	OD/MV	C13/1474		ST2PH54
STA.#2 PHOTOMETER 86°DN	OD/MV	C15/1675		ST2PH86
STA.#4 PHOTOMETER 2°DN	OD/MV	C17/1876		ST4PH 4
STA.#4 PHOTOMETER 22°DN	OD/MV	C19/2077		ST4PH22
STA.#4 PHOTOMETER 54°DN	OD/MV	C21/2278		ST4PH54
STA.#4 PHOTOMETER 86°DN	OD/MV	C23/2479		ST4PH86
STA.#6 PHOTOMETER 2°DN	OD/MV	C25/2680		ST6PH 4
STA.#6 PHOTOMETER 22°DN	OD/MV	C27/2881		ST6PH22
STA.#6 PHOTOMETER 54°DN	OD/MV	C29/3082		ST6PH54
STA.#6 PHOTOMETER 86°DN	OD/MV	C31/3283		ST6PH86
STA.#8 PHOTOMETER 2°DN	OD/MV	C33/3484		ST8PH 4
STA.#8 PHOTOMETER 22°DN	OD/MV	C35/3685		ST8PH22
STA.#8 PHOTOMETER 54°DN	OD/MV	C37/3886		ST8PH54
STA.#8 PHOTOMETER 86°DN	OD/MV	C39/4087		ST8PH86
STA.#9 PHOTOMETER 2°DN	OD/MV	C41/4288		ST9PH 4
STA.#9 PHOTOMETER 22°DN	OD/MV	C43/4489		ST9PH24
STA.#9 PHOTOMETER 54°DN	OD/MV	C45/4690		ST9PH54
STA.#9 PHOTOMETER 86°DN	OD/MV	C47/4891		ST9PH86
STA.#2 TURBIDIMETER RED	MV	C49/5092		ST2TRED
STA.#2 TURBIDIMETER BLUE	MV	C51/5293		ST2TBLU
STA.#2 TURBIDIMETER I.R.	MV	H19/2094		ST2T OD
STA.#6 TURBIDIMETER RED	MV	H21/2295		ST6TRED
STA.#6 TURBIDIMETER BLUE	MV	H23/2496		ST6TBLU
STA.#6 TURBIDIMETER I.R.	MV	H25/2697		ST6T OD
STA.#1 CO 38° BELOW CLG	MV	I34/3598		ST1 CO
STA.#1 CO2 38° BELOW CLG	MV	I31/3299		ST1 CO2
STA.#4 CO 38° BELOW CLG	MV	I47/48100		ST4 CO

AUGUST 1985 REDUCED NBS FIRE TEST #48 (UNITS APPLY AFTER TIME -10 SECONDS)

STA.#4 CO2 38° BELOW CLG	MV	I49/50101	ST4 CO2
STA.#4 O2 38° BELOW CLG	MV	I43/44102	ST4 O2
STA.#8 CO 38° BELOW CLG	MV	I24/25103	ST8 CO
STA.#8 CO2 38° BELOW CLG	MV	I26/27104	ST8 CO2
STA.#9 CO 38° BELOW CLG	MV	I22/23105	ST9 CO
STA.#9 CO2 38° BELOW CLG	MV	I20/21106	ST9 CO2
STA.#9 O2 38° BELOW CLG	MV	I18/19107	ST9 O2
STA.#4 CO2 2° BELOW CLG	MV	I01/02108	ST4CO2T
STA.#4 CO2 86° BELOW CLG	MV	I03/04109	ST4CO2B
STA.#9 BIDIRECTIONAL F/P	VOLTS	H49/50801	ST9F/P
ROOM PRESSURE 1-2	VOLTS	H37/38802	RPR1-2
ROOM PRESSURE 2-3	VOLTS	H39/40803	RPR2-3
ROOM PRESSURE 2-4	VOLTS	H41/42804	RPR2-4
ROOM PRESSURE 3-5	VOLTS	H43/44805	RPR3-5
ROOM PRESSURE 5-6	VOLTS	H45/46806	RPR5-6
ROOM PRESSURE 7-8	VOLTS	H47/48807	RPR7-8
NORTH ROOM AIR FLOW FAN	VOLTS	H51/52808	N A-F
WEST ROOM AIR FLOW FAN	VOLTS	H53/54809	N A-F
FIRE ROOM AIR FLOW FAN	VOLTS	F41/42810	N A-F
NBS PMM	VOLTS	D13/14811	NBSPMM
GAS LINE PRESSURE	VOLTS	D01/02812	GASPRS
FIRE ROOM NW LOAD CELL	VOLTS	D03/04113	NW LCL
FIRE ROOM EST LOAD CELL	VOLTS	D05/06114	ESTLCL

EVENT CHANNEL MAP

```
1 STA.#2 SMOKE DETECTOR (IONIZATION)        H 27
2 STA.#2 SMOKE DETECTOR (PHOTOELECTRIC)     H 28
3 STA.#4 SMOKE DETECTOR (IONIZATION)        H 29
4 STA.#4 SMOKE DETECTOR (PHOTOELECTRIC)     H 30
5 STA.#6 SMOKE DETECTOR (IONIZATION)        H 31
6 STA.#6 SMOKE DETECTOR (PHOTOELECTRIC)     H 32
7 STA.#9 SMOKE DETECTOR (IONIZATION)        H 33
8 STA.#9 SMOKE DETECTOR (PHOTOELECTRIC)     H 34
    COMMON GROUND H 36
** LOGG PARAMETERS **
  NO. OF GROUPS =  5          NO. OF READINGS =  3
  GROUP #  1 --     START =  1,     END = 67,     GAIN =  3
  GROUP #  2 --     START = 58,     END = 97,     GAIN =  7
  GROUP #  3 --     START = 98,     END =109,     GAIN =  5
  GROUP #  4 --     START =801,     END =812,     GAIN =  8
  GROUP #  5 --     START =110,     END =111,     GAIN =  5
** REDUC PARAMETERS **
  NO. OF T/C GROUPS = 1      T/C CONVERSION MODE =-1
  GROUP #  1 --     START =  1,     END = 67
   NO. OF VELOCITY GROUPS =  0
   NO. OF POLYNOMIAL GROUPS =  3
  GROUP #  1 -- START = 68, END =109
        COEFF.'S =  .00000E+00  .10000E+04  .00000E+00  .00000E+00  .00000E+00
  GROUP #  2 -- START =110, END =121
```

follows, with the channel number indicated in the next to last column. Channels 1-66 are thermocouple outputs in °C. Thermocouples were located: 1) at one of the numbered instrument stations (Figures 1, 12), either in the ceiling surface layer ("ceiling TC") or at given distances (in inches) below the ceiling level; 2) in the vent tubes attached to the room (Channels 63-65); and 3) in the propylene gas line ahead of the critical flow orifices (Channel 66). Channels 67-90 are the photometer outputs at various instrument stations and distances from the ceiling, recorded in mV but reduced to optical density per meter according to eq (2). Channels 91-93 and 94-96 are the outputs of the turbidimeters at Stations 2 and 6 (2 in. = 0.051 m below ceiling level), respectively, where "red" corresponds to a wavelength of 0.4579 μm; "blue" to 0.6328 μm; and "IR" to 1.060 μm; like the photometer channels, the mV outputs were reduced to optical density per meter according to eq (2). Channels 97-106 are the gas concentration channels, recorded in mV but reduced to volumetric concentrations (O_2 in* %, CO and CO_2 in ppm). The remaining channels were "high level", starting with (high level) Channel 1 (listed as Channel 107 in data tabulation) and ending with (high level) Channel 12 (listed as Channel 118 in data tabulation). Channel 107 is the output of the bidirectional flow probe in the burn room, reduced to velocity (m/s) and positive in the direction away from the fire source. Channels 108-113 are the room pressure differentials p_1-p_2, p_2-p_3, etc., where 1,2,3, etc. are the pressure taps identified in Figure 14. Channels 114-116 are the pressure differentials across the vent tube orifices, reduced to mass flow in g/s with the aid of the temperature data from Channels 63-65, positive flow corresponding to flow out of the room. Channel 117 was inoperative throughout the tests (originally assigned to a particle mass concentration monitor borrowed from NBS in a preliminary test). Channel 118 monitored the propylene pressure ahead of the critical flow orifices relative to atmospheric pressure, reduced to psi using a nominal calibration constant for the pressure transducer. True gas pressure was manually set to 25.0 psi (172 kPa) relative to the atmosphere (39.7 psi or 274 kPa absolute) soon after gas began flowing and efforts were made to maintain this pressure; the main purpose of Channel 118 was to

*Columns for O_2 Channels 101 and 106 in reduced data tabulations for Tests 1-19 are incorrectly labeled "ppm".

ascertain the degree to which the gas pressure remained constant. An Event Channel Map follows Channel 118, with events numbered 1-8 corresponding to actuation of smoke detectors as indicated. The occurrence of any of these events was assigned to an additional channel in the reduced data tabulation, Channel 119 (headed "Event Number"). Following a number of lines further down is a pretest scan of all the data channels.

The final page of Table 9A is a sample of the reduced data tabulation near the ignition event. Time is shown in min:sec, negative times being preignition. Channels 61-66 are temperature channels, indicating reduced temperatures in °C. Channels 67-75 are optical density channels, indicating output of photometers (in mV) up to within 11 s of ignition, subsequently indicating reduced optical densities in units of m^{-1}.

Beginning with Test 20, two additional CO_2 gas analyzers were added at Station 4, one sampling at 0.051 m (2 in.) and one sampling at 2.18 m (86 in.) below the ceiling. The two new channels were inserted after Channel 106 and the remaining channels renumbered. Table 9B shows the revised channel map, pertaining to Tests 20-31.

In anticipation of tests with corridor partition and ceiling vents in Tests 38-47, the channel map was revised again, beginning with Test 32, to accomodate the additional instruments when needed. Table 9C is the revised channel map, pertaining to Tests 32-47*, which now incorporates new Channel 67 (vent duct thermocouple) reduced to temperature; Channel 120 ("vent duct air flow fan" = pressure differential across orifice meter in venting duct) reduced to total mass venting rate in g/s with the aid of the reduced temperatures of Channel 67, positive rates corresponding to outflow from enclosure; and Channel 121 ("vent duct plenum pressure" relative to atmospheric pressure). Of course, the new channels did not become relevant until Test 38. Channels 117-119 are the previous Channels 116-118 (Table 9B), described in slightly different terminology than before.

Beginning with installation of polyurethane target slabs in Test 48, the channel map was revised again; see Table 9D which pertains to Tests 48-60*.

*This channel map should be used rather than the channel maps listed by the data tapes (and printouts) for the tests in question which contain some inaccuracies.

The new map deletes Channels 67 and 120 from the previous map and adds Channels 122 ("fire room NW load cell" = load cell output due to weight of polyurethane slab plus support in NW corner of burn room), and 123 ("fire room est load cell" = load cell output due to weight of polyurethane slab plus support near SE corner of burn room); the "reduced" data are listed in mV. Only one of these channels was active in a given test, corresponding to the location of the polyurethane slab installed; the load cell (the same one used in both locations) had a calibration constant of 70 g/mV.

Delay times of the gas analysis systems were measured at the beginning of the test program and after Test 19, following provision of two additional sampling tubes for CO_2 and some changes in the individual sampling pumps for the gas analyzers. In addition, delay times for the analyzers serving the burn room were measured after the plastic sampling tube had been discovered partially collapsed from heat (at the junction with the steel sampling tube) and repaired following Test 26. After Test 55, the same plastic tubing was found to be partially collapsed again, but there was insufficient plastic tubing available for repairs. The partial collapse of the sampling tube serving the burn room increased the associated delay times. In order to identify the tests which were affected by the collapsed tubing and associated adjustments in delay times, data from all tests were used to establish the time interval between 1) the first rise in temperature attributable to hot gases at the thermocouple located next to the sampling port in the burn room, and 2) the first rise in recorded CO_2 concentration for the burn room. For the initial tests without collapse, it was verified that these time intervals corresponded closely to the delay times established by the initial calibration. Calibrated and adjusted delay times are presented in Table 10, where delay times in parentheses have been assumed from previous calibrations. These delay times do not neccessarily agree with the delay times entered on the data channel header for each test.

Depending on test conditions, times in the data tabulations are referenced to different events:

1) In tests with steady heat sources and no forced ventilation, times are referenced to the establishment of stable flaming according to visual observations (Tests 1-11, 16-22).

TABLE 10

DELAY TIMES OF GAS ANALYSIS SYSTEMS

Channel	Delay Time (seconds) for Tests				
	1-19	20-26	27-31	32*-47	48-60
97	33	23	(23)**	-	-
98	27	23	(23)	(23)	(23)
99	15	15	(15)	(23)	(23)
100	18	15	(15)	(15)	(15)
101	19	18	(18)	(15)	(15)
102	17	22	(22)	(18)	(18)
103	21	20	(20)	(22)	(22)
104	18	37	21	(20)	(20)
105	21	36	20	21	37
106	31	69	39	20	36
107	-	14	(14)	39	69
108	-	28	(28)	(14)	(14)
109	-	-	-	(28)	(28)

*Channel numbers increased by 1 due to inclusion of new instrument.

**Delay times in parentheses assumed from previous calibration.

2) In tests with forced room ventilation, times are referenced to the starting of ventilation fans. Gas supply to the burner was initiated 60 s later, and flaming was established a few seconds afterwards (Tests 12-15, 23-25).

3) In tests with growing fires and no forced corridor ventilation, times are referenced to the start of the computer relay program controlling the gas flow (according to the equation included in Figure 11). Flames were usually established between the second and third relay operations, the delay being associated with saturating the sand bed of the burner with propylene (Tests 26-40, 42, 44, 47-59).

4) In tests with growing fires and forced corridor ventilation, times are referenced to the starting of the corridor ventilation blower. The computer relay program controlling the gas flow to the burner was started 60 s later, with flames being established between the second and third relay operations (Tests 41, 43, 45, 46).

5) In the final test (Test 60), which incorporated a pyrolyzing fuel, times are referenced to the instant the cotton ignitor (soaked in gasoline) was touched off with the propane ignition flame.

5.3 DATA CHANNEL INTEGRITY

The most difficult instruments to keep operational were the photometers, which often developed shorts in the wiring near the fire and had low outputs.

Other recurring problems near the fire were brass disks disengaging from their thermocouples and ceiling surface thermocouples disengaging from the ceiling.

Efforts have been made to identify the malfunctioning and marginal (low signal-to-noise) data channels, Table 11. Irrelevant channels are listed together with the malfunctioning ones, i.e., channels not connected to active instruments in a given test.

Optical densities calculated from the photometer outputs should be interpreted with caution in dense-smoke situations because of soot buildup on the lenses (wiped off between tests). It should be possible to estimate effects of sooting by analysis of the recorded data, e.g., by comparing optical densities from the turbidimeters (apertures not subject to sooting) with those of companion photometers.

TABLE 11

MALFUNCTIONING AND MARGINAL

DATA CHANNELS

Test	Malfunctioning or Irrelevant	Marginal
1 - 5	117	
6	110, 117	
7	62, 97-106, 117	
8- 15	62, 117	
16	62, 117	114 - 116
17	62, 115, 117	79
18	62, 82, 115, 117	79, 88
19	62, 82, 117	79, 88
20	62, 51, 119	88
21	62, 88, 90, 119	
22	62, 79, 88, 90, 109, 116-119	67, 75
23	62, 79, 88, 90, 119	75
24	62, 79-81, 88, 90, 119	75
25	62, 61, 67-90, 119	94, 95
26	62, 79-81, 88-90, 119	71, 94, 95
27	61, 62, 79-82, 88-90, 119	71, 75, 94, 95
28	61, 62, 79, 88, 90, 94, 95, 119	67, 71, 75
29	41, 61, 62, 75, 79, 88, 90, 119	67, 71
30	61, 62, 75, 119	67, 71
31	61, 62, 79, 88, 90	71, 75
32	67, 120-122	
33-35	67, 76, 120-122	39
36	67, 120-122	95
37	67, 76, 120-122	95
38	67, 120-122	
39	121,122	76, 88, 95
40	76, 88, 95-97, 121, 122	
41	88, 95-97, 121, 122	
42	88, 95-97, 121, 122	
43	88, 121, 122	95

TABLE 11 (Concluded)

Test	Malfunctioning or Irrelevant	Marginal
44	88, 122	95
45	88, 122	95
46	88, 95, 122	96
47	67, 88, 120-122	
48	67, 120, 122	95
49	67, 95, 96, 120, 122	97
50	44, 62, 67, 76, 95, 120, 122	96
51	44,62,67,88,92-94,95,120,122	96
52	41,61,62,67,76,88,92-97,120,122	
53	44,61,62,67,88,95,96,120,122	76,97
54	44,61,62,67,76,88,95,111-113, 120, 122	
55	44,61,62,67,76,88,90,91,95,96 111-113,120,123	97
56	44,61,62,67,76,77,88-91,95-97 111-113,120,123	
57	20,44,61,62,67,76,77,88-91,92-97, 111-113,120,122,123	
58	20,44,61,62,67,76,77,88-91,95-97, 111-113,120,122,123	
59	20,44,61,62,67,76,77,88-91,95-97, 111-113,120,122,123	
60	44,61,62,67,76,88-91,95-97,120,123	77

5.4 SAMPLE DATA

For ease of reference, the response times of smoke detectors have been extracted from the data along with the associated optical densities (from the photometers closest to the ceiling at the respective instrument stations). The results are presented in Table 12.

Figure 29 presents photographic views of a 522 kW steady fire (Test 22) and Figure 30 shows photos from a growing fire, including flames projecting from the window (Test 54).

Extracts of the large body of data that may be of immediate interest will now be presented.

Figure 31 shows the times at which the smoke front under the ceiling crosses the three corridor instrument stations with photometers (Stations 6,4,2; see Figures 1 and 12). Tests 1,2 and 6 were replicates with the 0.30 m diameter burner at 56 kW, closed windows in the burn room, door open from burn room to corridor, and doors to target rooms closed. Tests 16 and 17 were duplicate runs with the 0.91 m diameter burner at 522 kW, but otherwise the same conditions as in Tests 1,2 and 6.

Figure 32 is limited to Test 17 and shows values of temperature rise versus time at various levels y/H (where y is the distance beneath the ceiling and H is the ceiling height) at Station 4. Note that plume fluid arrives simultaneously at the y/H levels 0.021, 0.042, 0.104 and 0.229, corresponding to the arrival of the forward smoke front. The forward smoke front is reflected at the end of the corridor to form a return smoke front practically filling the remaining clear space above the floor, as evidenced by visual observations and the approximate simultaneous rise in Figure 32 of temperatures at the y/H levels 0.395, 0.562, 0.729 and 0.896.

Average transit times and speeds of the forward and return smoke fronts, from Station 6 to Station 2 and back, have been determined for Tests 16 and 17 from the photometer signals, the top photometers for the forward front and the y/H = 0.56 photometers for the return front.* The results for the two tests

*The time of arrival of a smoke front was taken as the time of the first scan showing a rise in optical density greater than preceding signal fluctuations (noise) and followed by scans of increasing optical density.

TABLE 12

DETECTOR RESPONSE TIMES AND ASSOCIATED OPTICAL DENSITIES (D_u)

	Station 2				Station 4				Station 6				Station 9			
	Time(min.s)		D_u (m^{-1})		Time(min.s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})	
Test	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P
1	1:14	1:23	0.42	0.61		1:5		0.61	0:39	0:47	0.28	0.48	0.13	0:23	0.34	0.77
2	1:8	1:18	0.43	0.62		1:0		0.65	0:32	0:43	0.20	0.61	0:10	0:25	0.47	1.03
3	1:12	1:25	0.37	0.58		1:7		0.66		0:46		0.54	0:12	0:31	0.53	1.18
4										1:52		0.27	0:9	0:28	0.36	1.21
5										8:46		0.05	0:9	0:30	0.42	1.20
6	1:6	1:17	0.39	0.58		1:1		0.65		0:42		0.52	0:8	0:31	0.24	1.21
7	1:15	1:26	0.38	0.58		1:8		0.64		0:50		0.47	0:8	0:32	0.24	1.00
8	1:6	1:22	0.41	0.67	0:48*	0:60	0.29	0.64	0:30*	0:48	0.25	0.70	0:6	0:46	0.22	1.80
9	2:36		0.13		1:36	4:33	0.16	0.50	0:50	1:53	0.07	0.24	0:7	0:41	0.17	1.61
10					5:1		0.23		2:13	4:17	0.12	0.21	0:6	0:43	0.26	1.83
12	2:15	2:31	0.42	0.71	1:58	2:8	0.37	0.66	1:40	1:51	0.24	0.61		1:49		1.40
13	2:11	2:29	0.39	0.72	1:53	2:6	0.33	0.66	1:38	1:54	0.11	0.69	1:10	2:7	0.16	1.69
15					2:51	5:44	0.17	0.49	2:4	4:56	0.38	0.57	1:9	2:21	0.12	1.91
16	0:39	0:43	0.97	1.31	1:40	0:34	2.12	1.14	0:20	0:26	0.43	1.02	Detectors Removed			
17	0:40	0:43	1.22	1.73	0:35	0:34	1.32	1.17	1:33	0:26		1.10		"	"	
18	3:7	0:50		1.69	0:33	0:38	0.85	1.49		0:31		1.26		"	"	
19		0:49		1.95		0:36		1.67		0:28		1.10		"	"	
20	4:37*		0.41		1:54*	3:10	0.45	0.79	1:18	2:22	0.64	0.93		"	"	
21	0:40	0:52	0.85	2.35	0:31	0:39	0.36	1.10	0:22	0:33	0.50	1.34		"	"	
22	1:2		0.80		0:45	1:11	0.58	0.99	0:29	0:54				"	"	
23	1:36	1:43	0.96	1.87	1:28	1:34	0.51	1.61	1:19*	1:28				"	"	
24	0:16	1:58			2.26	0:17	1:43			1:19	1:38			"	"	
25		2:0				1:38				1:16	1:35			"	"	

TABLE 12
(Continued)

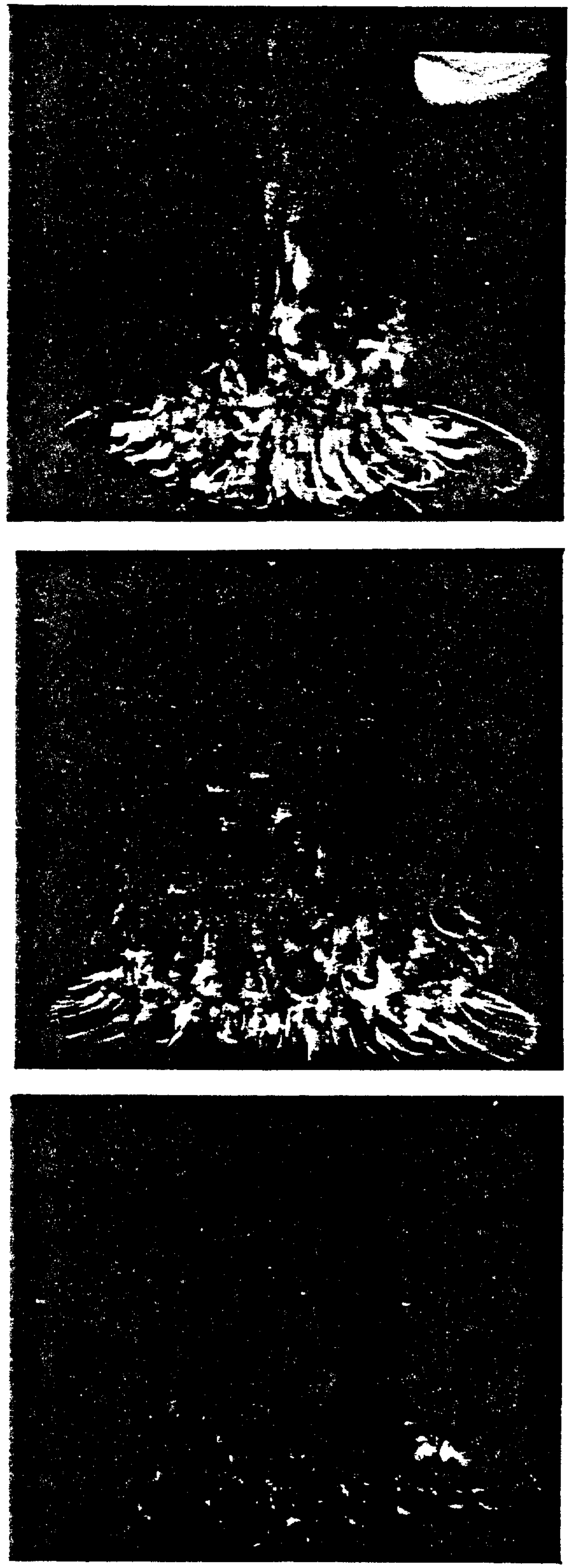
	Station 2				Station 4				Station 6				Station 9			
	Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})	
Test	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P
26					3:45*		0.51		2:44*	4:21*				Detectors	Removed	
27	2:14*	2:46	0.41	1.79	2:47	2:29	0.51	1.61	1:55	2:8				"	"	
28	1:29	1:52	0.93	2.03	1:18	1:36	0.86	1.96		1:23				"	"	
29					2:43		0.41							"	"	
30	1:29	1:49	0.92	1.61	1:18	1:35	0.81	1.10		1.20				"	"	
31	2:11	2:45	0.41	1.61	1:59	2:27	0.21	1.59		2:7				"	"	
32	2:12	2:22*	0.17	0.53	2:00	2:52*	0.22	2.30	1:51*	1:57*	0.22	0.44		"	"	
33	2:8	2:24	0.18	0.80	1:56	2:41			1:45	1:58	0.16	0.59		"	"	
34	1:32	1:36	0.49	0.90	1:21	1:49				1:21		1.21		"	"	
35	2:42	2:53	0.25	0.41	2:20					2:16		0.42		"	"	
36	1:36	1:42	0.59	1.22	1:24	1:48	0.34	2.35		1:21		0.83		"	"	
37	2:3	2:7	0.38	0.38	1:40		0.29			1:32		0.38		"	"	
38					2:6	2:45		1.70	1:59	2:10	0.17	0.65		"	"	
39	2:58	3:12	0.41	0.74	2:3	2:40			1:57*	2:6	0.27	0.71		"	"	
40		2:9		0.80	1:19	1.46	0.48	1.57	1:10	1:21	0.27	1.23		"	"	
41					2:56	3:40	0.11	2.25	4:11	3:2	3.25	0.95		"	"	
42					1:59	2:48	0.19	2.82	1:55	2:8	0.45	1.02		"	"	
43					2:56	3:47	0.13	2.83		3:4		0.95		"	"	
44					1:28	1:54	0.64	2.83		1.25		1.39		"	"	
45					3:10	3:48	0.23	2.63	4:58	3:13		1.10		"	"	
46					3:16	4:22	0.30	2.79		3:12		1.04		"	"	
47					1:55	2:49	0.19	2.83						"	"	
48	2:15	2:23	0.22	0.60	2:5*	2:11*	0.23	0.45	1:55*	2.10	0.24	0.93		"	"	
49	2:15	2:28	0.18	0.79	2:3	2:13	0.25	0.66	1:53*	2:15	0.21	1.31		"	"	
50	5:45		1.00		3:41	4:2	0.69	0.69	2:44*	5:26	0.33	1.27		"	"	

OJ2N8.RU

TABLE 12
(Concluded)

Test	Station 2				Station 4				Station 6				Station 9			
	Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})		Time(min:s)		D_u (m^{-1})	
	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P
51	2:9	2:24	0.18	0.75	1:59	2:7	0.21	0.50	1:50	2:9	0.22	1.07	Detectors Removed			
52	4:48	4:41	0.36	0.36	3:41	5:7	0.33	0.74	2:34*	3:29*	0.13	0.69		"	"	
53	5:17		0.31		3:55		0.22		2:50	4:20	0.22	0.96		"	"	
54	5:11		0.51		3:42	4.45	0.07	0.48	2:30	3:26	0.22	0.73		"	"	
55	2:14	2:33	0.10	1.01	2:3	2:15			1:54	1:58	0.21	0.33		"	"	
56		2:48		1.69	2:2	2:21			Detectors Removed					"	"	
57	2:25*	1:27*	0.69	0.88	1:16*	1:18*			1:4*	1:8*	0.37	0.60		"	"	
58	1:7	1:7	1.39	1.39	0:57	0:59			0:48	0:51	0.47	0.79		"	"	
59	3:6	3:24	0.13	0.29	2:54	3:9			2:41	2:59	0.14	0.33		"	"	
60	0:50	1:20	0.13	0.29	0:40	1:10			0:34*	1:10	0.11	0.73		"	"	

*New detector unit; see Table 8



4048-7

4048-8

4048-9

Figure 29 Test 22: Views of 522 kW fire source (times increasing from top to bottom)

4048-10

4048-11

4048-12

4048-13

Figure 30 Test 54: Views of growing fire
(times increasing from top to bottom)

4048-14

4048-15

4048-16

Figure 30 (Concluded)

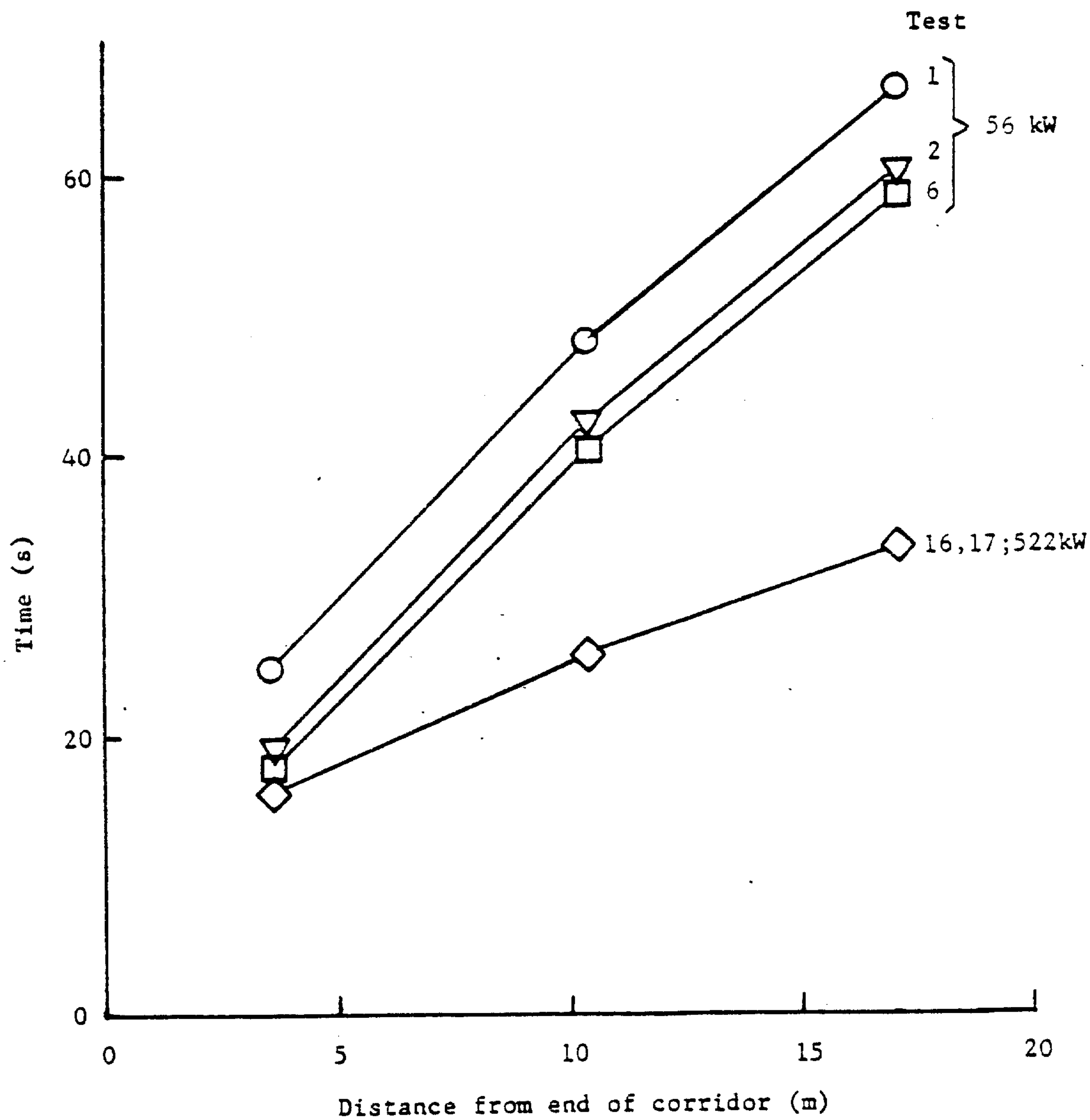


Figure 31 Position of smoke front under ceiling (y/H = 0.021) as function of time

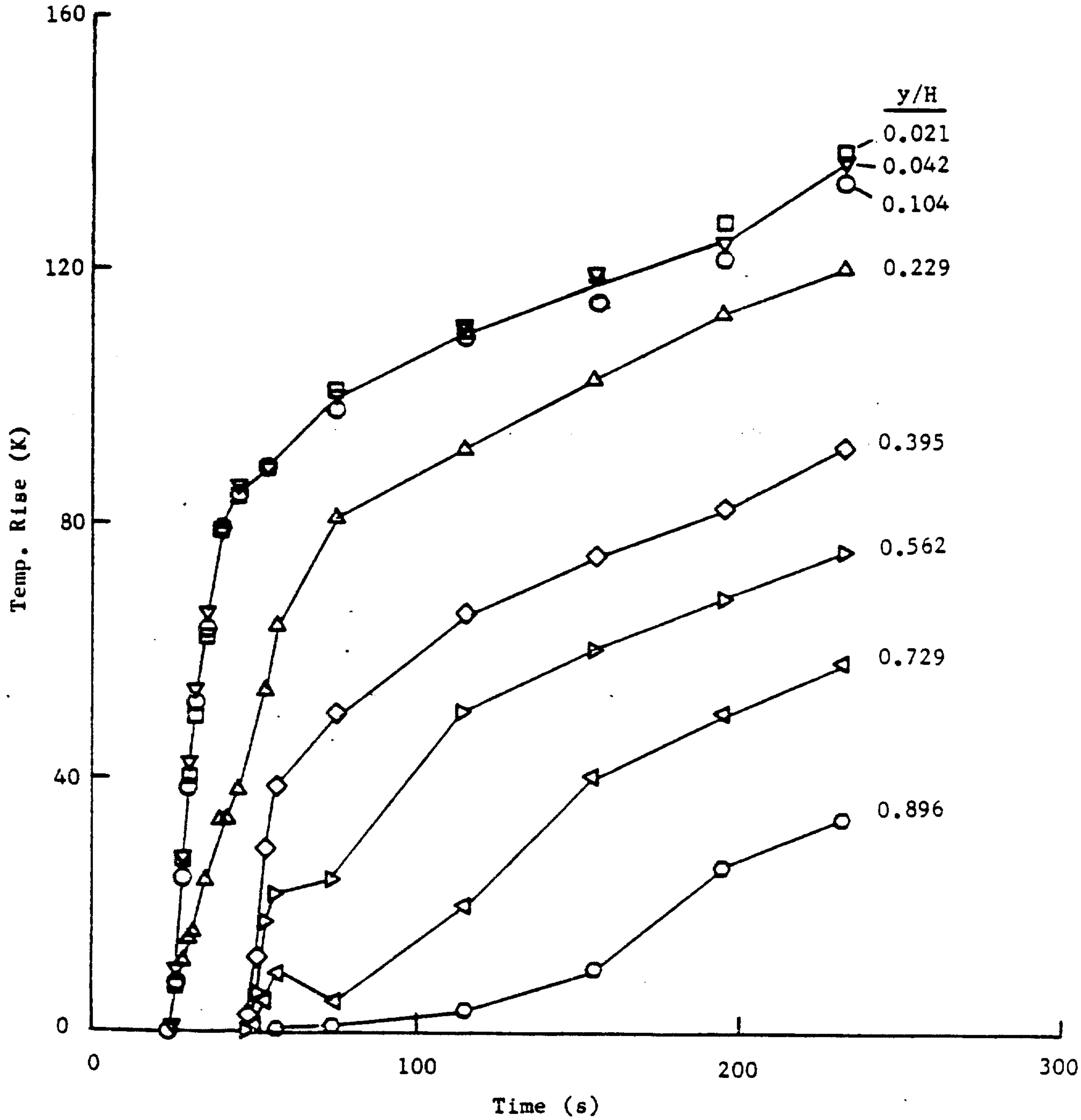


Figure 32 Test 17: Temperature rise at Station 4

were very similar, with an average forward speed of 0.74 m/s and an average return speed of 0.65 m/s.

Table 13 presents smoke transit times between Stations 6 and 2 for the forward smoke front of the steady state fires. (Results for the growing fires were much more difficult to establish because of the very gradual rise in optical density associated with the smoke front.) The transit times were in this case established from the response of the two turbidimeters. Results have been segregated into two columns, one for configurations with open door to the burn room and the other for configurations with closed doors to the burn room. All transit times for a given fire size with open door to the burn room are similar, regardless of whether the target room doors or the burn room window are open or closed. The effect of increasing the fire size about eight-fold in Table 13 is to decrease the transit time by a factor of about 2, consistent with Froude modeling principles[37] which predict a $\dot{Q}_c^{-1/3}$ dependence of transit time. With closed door to the burn room, the transit times are very sensitive to whether the burn room window is open or closed (being smaller with closed window) and perhaps even sensitive to the disposition of the target room doors (being slightly smaller with open target room doors).

Figure 33 illustrates the penetration of smoke through closed doors into the target rooms in terms of optical densities at $y/D = 0.56$. The open symbols pertain to Test 17, which incorporated a closed window in the burn room. The buildup of smoke at Station 4 in the corridor is rapid as the return smoke front passes by near 50 s. Significant buildup of smoke in the target rooms (Stations 1 and 8) appears to occur after about 180 s. The solid symbols pertain to Test 18 with an open window in the burn room, but otherwise similar conditions to Test 17. There is much less infiltration of smoke into the target rooms in this case, attributed to the absence of a significant buildup of pressure in the burn room and corridor as a result of the open window.

Another set of data of some immediate interest is presented in Table 14, which lists CO/CO_2 volumetric concentration ratios, referenced to initial concentration readings ($\Delta C_{CO}/\Delta C_{CO2}$), for selected tests. The ratios are similar to the freeburn calibrations for the 56 kW source fire (0.016 deduced from Table 4) and the 522 kW source fire (0.025 deduced from Figure 25e); however, in the 522 kW cases (Tests 17 and 21), there is a tendency to

TABLE 13

SMOKE TRANSIT TIMES FOR STEADY FIRES,

STATION 6 - STATION 2, ACCORDING TO TURBIDIMETERS

Test	Fire Size (kW)	Forced Vent(g/s)	Transit Time(s) Open BR Door	Closed BR Door
1	56	None	42	
2	"	"	41	
3	"	"	45	
4	"	"		109
5	"	"		468
6	"	"	40	
7	"	"	45	
8	"	"	39	
9	"	"		86
10	"	"		305
11	"	"	42	
12	"	18	41	
13	"	9	40	
14	"	"		107
15	"	18		120
16	522	None	20	
17	"	"	21	
18	"	"	22	
19	"	"	21	
20	"	"		132
21	"	"	21	
22	"	"		33
23	"	36	20	
24	"	72	21	
25	"	144	20	

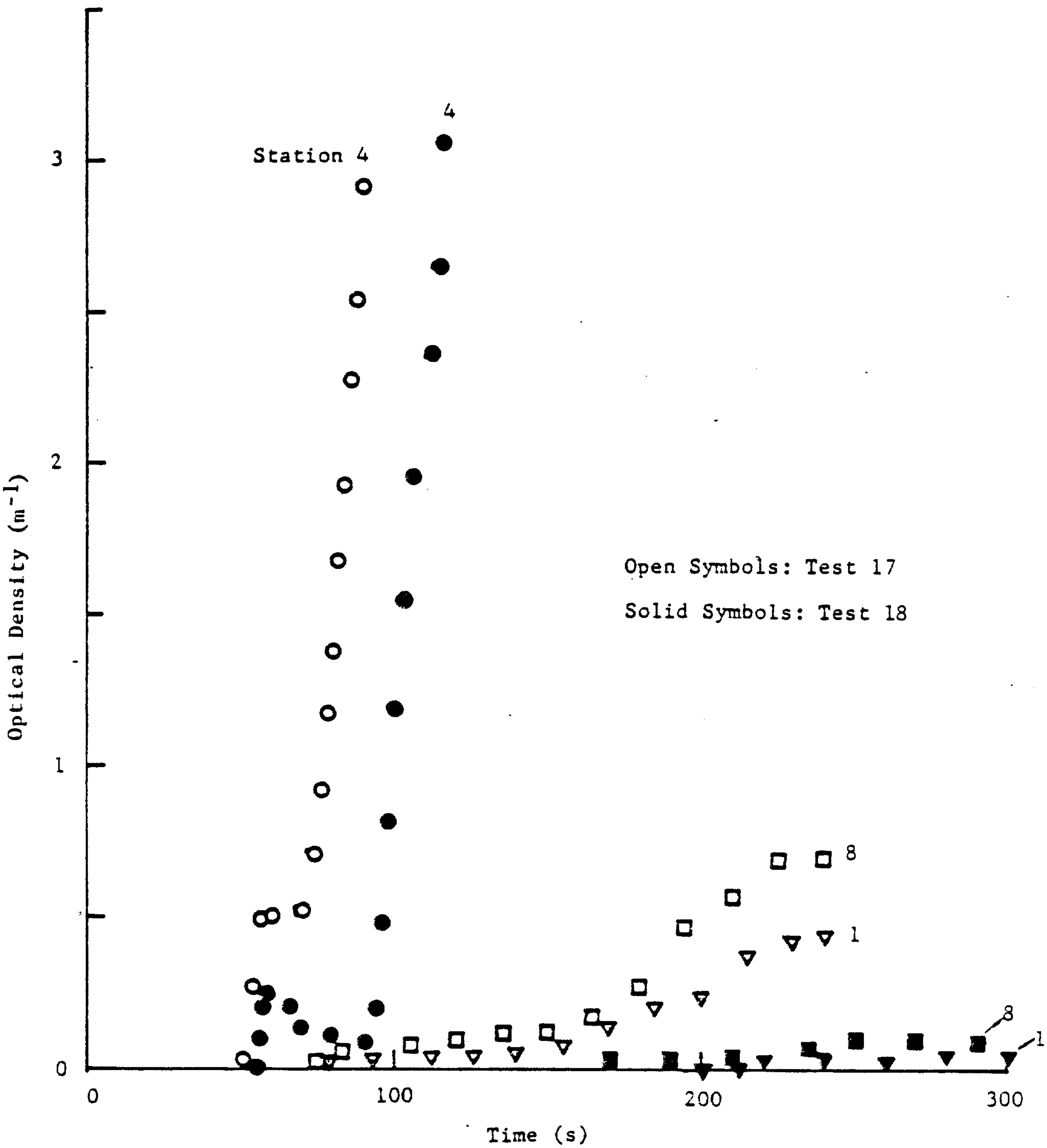


Figure 33 Optical densities at y/H = 0.56 in tests with open burn room door, closed target room doors, and either closed window in burn room (Test 17 - open symbols) or open window (Test 18 - solid symbols)

TABLE 14

VOLUMETRIC CO/CO_2 CONCENTRATION RATIOS IN SELECTED TESTS
(Not Corrected for Delay Time)

Test	Time (min:s)	$\Delta C_{CO}/\Delta C_{CO2}$ Sta 1	Sta 4	Sta 8	Sta 9
1	10:00		0.011		0.016
2	10:00		0.011		0.015
3	10:00		0.011		0.019
4	3:00				0.013
5	10:00				0.020
6	3:00		0.009		
	5:00		0.010		0.022
	7:00		0.010		0.019
	9:00		0.010		0.017
	10:00		0.011		0.017
7	7:00	0.014	0.009	0.012	
	10:00	0.014	0.010	0.012	0.008
17	1:00				0.016
	2:00		0.017		0.020
	3:00		0.020		0.027
	4:00		0.029	0.026	0.041
21	1:30	0.014	0.010	0.014	0.013
	2:00	0.016	0.016	0.018	0.017
	3:00	0.019	0.020	0.021	0.025
	4:00	0.021	0.022	0.023	0.025
	5:00	0.022	0.023	0.024	0.025
31	2:00				0.022
	3:00	0.017	0.019		0.030
	4:00	0.020	0.027	0.022	0.052
	5:00	0.032	0.051	0.052	
	6:00	0.072	0.082	0.088	

increasing ratios with time, probably associated with oxygen depletion. Depletion effects appear to be especially significant at advanced times of the growing fire in Test 31 where large concentation ratios are observed.

The only direct measurement attempted for gas velocity was the measurement with the bidirectional flow probe in the burn room. However, the response of the several brass disks, combined with the output of the adjacent gas thermocouples at the same level, can also be interpreted as gas velocity, using the following analysis*. The heat balance for the highly conductive, isolated brass disk can be written

$$dT_d/dt = \tau^{-1}(T-T_d) \quad . \tag{11}$$

In this equation, T_d is the disk temperature; t is time; T is the gas temperature; and τ is the time constant of the sphere, defined as

$$\tau = mc/h_cA \tag{12}$$

where
- m = disk mass;
- c = specific heat of disk material;
- h_c = convective heat transfer coefficient; and
- A = surface area of disk.

For objects similar to the size of the brass disks as well as gas velocities and temperatures of the expected order of magnitude, the Reynolds mumbers are in a range where the Nusselt number can be taken proportional to the square root of the Reynolds number. This is fortunate, because the resulting relation between the heat transfer coefficient and the gas velocity becomes independent of gas temperature for air-like gas properties[36] (kinematic viscosity and thermal conductivity). For a given disk it follows that:

$$h_c \propto u^{1/2} \tag{13}$$

and consequently:

*Based on a previous application of "cool-sphere" anemometers[35].

$$\tau \propto u^{-1/2}$$

or:

$$\tau u^{1/2} = \text{constant} \; . \tag{14}$$

This constant is the so-called "response time index", or RTI, introduced in automatic sprinkler applications;(23) i.e.,

$$RTI = \tau u^{1/2} \; . \tag{15}$$

With the aid of eq (15), eq (11) can be solved for the gas velocity:

$$u = [RTI \; (dT_d/dt) \; / \; (T-T_d)]^2 \; . \tag{16}$$

As described in Section 2.4.2, the RTI value for the disks had been calibrated at 28.0 $m^{1/2}s^{1/2}$ with the plane of the disk facing the flow, the orientation used in the program. At first thought the gas temperature indicated by the thermocouple at the same level in the adjacent vertical array might be selected as the gas temperature, T, in eq (16). However, this temperature may not be accurate enough because of the thermal lag of the thermocouple. The thermal lag can be evaluated from a relation like eq (11):

$$T-T_{TC} = \tau_{TC} \; (dT_{TC}/dt) \tag{17}$$

where T_{TC} is the indicated thermocouple temperature and τ_{TC} is the time constant of the thermocouple. The latter can be evaluated from the RTI value of the 28-gage thermocouples used in the program, measured in FMRC's Plunge Test Tunnel(23) as 4.2 $m^{1/2} \; s^{1/2}$, i.e., $\tau_{TC} = 4.2/u^{1/2}$.

These interpretations of the disk output may be checked against the indications of the bidirectional flow probe in the burn room. In Test 1, the bidirectional flow probe indicated a velocity fluctuating about an average value of 1.10 m/s in the time interval 10-32 s from ignition. Using eq (16) based on the response of the brass disk and adjacent thermocouple, with corrections for thermal lag of the gas thermocouple according to eq (17) and $\tau_{TC} = 4.2/u^{1/2}$, velocities can be evaluated for each computer scan. The average velocities over about four scans (4 s) centered at the beginning, middle and end of the 10-32 s interval have been determined as 1.19, 1.14 and 1.18 m/s, respectively, close to the overall average of 1.10 m/s indicated by the bidirectional flow probe.

VI
SUMMARY AND CONCLUSIONS

The purpose of this program was to furnish validation data for theoretical fire models of multiroom fire situations with particular emphasis on health care facilities.

6.1 FACILITY

The basic facility consisted of a 2.44 m wide x 18.90 m long corridor with two rooms attached at one end, one of which served as burn room, and a third room attached at the other end of the corridor. Each of the three rooms was provided with a vent to the outside near the floor level. The vent mass flow was monitored, both in the case of natural ventilation and forced ventilation with exhaust fans; in the case of forced exhaust, make-up air was provided through a low vent at one end of the corridor. Gypsum board on wood studs was used throughout. In addition, the walls and ceiling of the burn room were overlaid with Marinite I to harden against repeated fire exposure. All three doors were braced when in the closed position to prevent heat warping; door cracks were characterized for leakage in special experiments.

Each room and several stations along the corridor were furnished with instruments. Instrumentation consisted of thermocouples to measure temperature (several levels and in ceiling surface layer); photometers to measure optical densities (several levels), gas sampling for CO, CO_2 and O_2; pairs of smoke detectors, photoelectric and ionization; instrumented brass disks simulating heat detectors; turbidimeters at two stations in the corridor measuring optical densities at three discrete wavelengths; several pairs of pressure taps to measure pressure differentials; and a bidirectional flow probe under the ceiling in the burn room to measure gas velocities (other gas velocities obtainable from the thermal response of the brass disks and associated thermocouples). Depending on the experiments, between 125 and 130 data channels were monitored with a computer-based data acquisition system at a rate of one scan per second.

6.2 EXPERIMENTS

Three types of fire sources were employed: 1) steady propylene fires at 56 and 522 kW using "sandbox" burners; 2) propylene fires programmed under computer control to grow with the square of time, reaching and surpassing 1 MW in one, two, four, or eight minutes; and 3) a naturally growing fire in a configuration of so-called "Standard Plastic Commodity" (Factory Mutual test fuel consisting of corrugated boxes with polystyrene tubs in compartments).

In the basic experiments, various combinations were investigated of fire source, open and closed doors, open or closed window in burn room, and natural or forced ventilation in all rooms (40 tests). Then followed a series of fire experiments with a sealed corridor partition and ceiling vents on either side of the partition, ducted to a common supply or common return plenum; here, it was the intent to investigate smoke migration in certain ventilation situations (10 tests). Next, a continuously weighed polyurethane slab was installed as a target for flashover ignition in the burn room, both in the horizontal and vertical orientations and with the intent of comparing flashed-over mass loss rates with previously measured freeburn mass loss rates (9 tests). Finally, a single fire with the "Standard Plastic Commodity" was conducted to explore generation and dispersion across open and closed doors of carbon monoxide in a pyrolyzing enclosure fire.

The data have been filed with the Center for Fire Research, NBS, and consist of scan-to-scan computer printouts and tapes of reduced data. A guide to the reduced data is presented in the report together with an assessment of data channel integrity.

6.3 SAMPLE DATA

For ease of reference, the response times of smoke detectors were first extracted from the data and presented together with the associated optical densities near the detectors. Then data of possible immediate interest were sampled, focusing on the propagation of smoke from the burn room down the corridor and the CO/CO_2 ratios developed in the fires.

A number of tests displayed a forward smoke front propagating away from the burn room under the corridor ceiling as well as a return front filling the remaining clear space above the floor. An analysis of forward front propagation with open door to the burn room indicated only minor effects of open or closed doors to the other rooms or open or closed window in the burn room. With closed door to the burn room, the propagation speed of the smoke front was very sensitive to open or closed window in the burn room. The fire intensity had a marked effect on the propagation speed of the smoke front, consistent with Froude modeling principles.

CO/CO_2 volumetric concentration ratios developed for the steady source fires (56 kW and 522 kW) and early for a growing source fire were quite similar to ratios seen in freeburn calibrations of the fire sources. However, for the growing source fire the ratios tended to increase considerably at advanced times.

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NOMENCLATURE

A	surface area of disk
A_c	throughflow area of crack
C	discharge coefficient
C_{CO}	volumetric concentration of CO
C_{CO2}	volumetric concentration of CO_2
C_p	mass concentration of particulates
c	specific heat of disk material
D_u	$\ell^{-1}\ell(I_o/I)$, optical density (per unit length)
D_{uo}	characteristic optical density, a smoke detector characteristic
D_{ur}	D_u at response of smoke detector
H	ceiling height
h	height of undercut on door
h_c	convective heat transfer coefficient
I	photometer (or turbidimeter) signal with smoke
I_o	photometer (or turbidimeter) signal without smoke
L	characteristic length, a smoke detector characteristic
L_c	crack length
ℓ	length of light beam
m	disk mass
$\dot{m}$	mass flow rate
$\dot{m}'$	mass leakage rate per unit crack length
$\dot{m}_{CO}$	mass generation rate of CO
$\dot{m}_{CO2}$	mass generation rate of CO_2
$\dot{m}_f$	mass flow rate of fuel
$\dot{m}_p$	mass generation rate of particulates
p	pressure
Δp	pressure differential
$\dot{Q}_c$	convective heat release rate
$\dot{Q}_t$	total heat release rate
RTI	$\tau u^{1/2}$, response time index
T	gas temperature
T_d	disk temperature
T_{TC}	thermocouple temperature

t	time
t_d	door thickness
t_g	growth time, time for fire to exceed 1000 kW
u	air velocity
$\dot{V}$	volumetric flow rate
$\dot{V}'$	$\dot{m}'/\rho$, volumetric flow rate per unit crack length
w	crack width
w_c	characteristic crack width; see eq (7)
y	distance below ceiling
β	ratio of orifice diameter to pipe diameter
μ	dynamic viscosity
ρ	fluid density
τ	time constant

APPENDIX
NOTES ON TESTS

Test 1 - Fire terminated after 10 min from ignition (at time zero). Distinct smoke layers persisted for a long time in burn room and corridor. Smoke interface was especially sharp in burn room. Target rooms (doors closed) stayed clean for quite some time. Inspection after fire showed that housing of ionization detector in burn room (9I) had begun to deform. Also, lenses of photometers were quite sooty and were cleaned.

Test 2 - (Repeat of Test 1).

Test 3 - Burn room appeared cleaner underneath smoke layer than in Tests 1 and 2. Fire terminated after approximately 10 min.

Test 4 - Fire was allowed to run until view lost of flames through smoke (approximately 3 min).

Test 5 - Inflow from window deflected flames away from window and generated clock-wise swirl in flame column (viewed from above). Fire terminated after approximately 10 min.

Test 6 - (Repeat of Tests 1 and 2). Video record was obtained of fire source throughout fire duration from viewport. Fire terminated after approximately 10 min.

Test 7 - Lower layers of corridor and target rooms appeared smokier than lower layer of burn room. Main pump for gas analyzers was inadvertently left off. Fire terminated after approximately 10 min.

Test 8 - (Repeat of Test 7, gas analyzer main pump running in normal mode). Fire terminated after approximately 10 min.

Test 9 - Gas supply was left on until view of flames was lost through smoke, approximately 4.5 min.

Test 10 - Flames leaned in response to inflow at window. Swirl imposed on flames. Fire terminated after approximately 10 min.

Test 11 - Flames began to lean away from window after approximately 20 s. Smoke detectors did not operate (not reset before test). Fire terminated after approximately 10 min.

Test 12 - In preparation for this first fire test with forced ventilation, the 0.093 m^2 vent hole was opened up in south access door to corridor and ventilation (exhaust) fans were installed at each vent tube, setting flow rates to about 18 g/s per room according to indications of orifice meters in the vent tubes. A 3-min count-down was used. At time zero, we began starting ventilation fans. At 1 min, gas supply to burner was activated; flames were established at 1:06. Terminated fire at 11 min (approximately 10 min flaming as in most other tests to this point). Note: 100 CFM (57 g/s) ventilation per room had been intended and header of computer record shows this value. The actual value was set smaller because of a misunderstanding.

Test 13 - Before test, ventilation rate was set to 9 g/s per room. As in Test 12, ventilation fans were started at time zero, gas supply activated at 1 min, and fire terminated at 11 min. Flames leaned away from door, sometimes with a swirl component. Note: 50 CFM (28 g/s) ventilation per room had been intended and header of computer record shows this value. As in Test 12, the actual value was set smaller because of a misunderstanding.

Test 14 - Detectors were not reset before test. Test initiation and termination were as in Tests 12 and 13. Also, see Note for Test 13.

Test 15 - Test initiation and termination were as in Tests 12, 13 and 14. Also, see Note for Test 12.

Test 16 - In preparation for this first test at 522 kW, a number of tasks were first undertaken: 0.30-m diameter burner was removed from its resting place in the 0.91-m diameter burner, sand was replenished to fill the void, and the gas distributor of the larger burner was connected to gas supply; vent-tube fans were removed; smoke detectors were removed from burn room and bases were covered with Kaowool insulation; the top three photometers and associated cables were insulated with Kaowool; and the south corridor vent was resealed. During the test, the air flow out of the room vent tubes appeared very strong to the feel of a hand. It was later discovered that all vent tube pressure transducers "pegged" (transducers exceeded nominal design range). Observers said smoke layer in corridor dropped very rapidly. Fire terminated after 2.5 min from ignition (at time zero).

Test 17 - (Repeat of Test 16) Original, 0.5 "H_2O transducers used for orifice meters in vent tubes replaced with new, 0.2 psi (5.5 "H_2O) transducers. Gas to burner was shut off after about 4 min. Smoke descended quickly in corridor, especially at far end of corridor (away from fire room). One of the new vent tube transducers (Target Room 1) was not functioning, but left in since no replacement was immediately available.

Test 18 - Fire terminated after approximately 5 min. Video viewed fire source through viewport.

Test 19 - Malfunctioning vent-tube transducer (TR1) was replaced with original, 0.5 "H_2O unit. Video viewed burn room window from outside. Fire terminated after approximately 5 min.

Test 20 - 0.5 "H_2O vent-tube transducer in TR1 was replaced with 5 "H_2O unit. Two additional sampling tubes for CO_2 were installed at Station 4, one at 0.051m and on at 2.184m below the ceiling. Photos were taken of the fire source through viewport and of flames in the open window. Fire terminated after approximately 5 min. Lenses of top photometer in burn room cracked during the test.

Test 21 - UV sensor in ignition circuit had been damaged and was bypassed. Smoke detectors were not cleaned before test because of time constraints. Pressure 2-3 recorded on Barocel Range 1, not 0.3 as indicated in data header. Fire terminated after approximately 5 min.

Test 22 - Vent tube and velocity pressure transducers not energized. Gas supply to burner terminated manually near 1.7 min after temperatures in fire room had begun to drop (UV sensor still bypassed). Smoke was observed to puff through closed door to fire room. Photos.

Test 23 - Smoke was observed to puff through open vent in south corridor door. Forced ventilation was employed in this and the next two tests with ventilation fans started at time zero, gas supply activated at 1 min, and fire terminated at approximately 6 min.

Test 24 - Only occasional puffs of smoke were observed coming out vent in south end of corridor. Video viewed north through port in south end of corridor.

Test 25 - All photometers shorted. The brass disk at Station 9 fell off. Video viewed south from alcove in north end of corridor.

Test 26 - Photometer short was located and repaired. Ceiling over burner had cracked in previous testing and was reinforced with a 1.65m x 1.22m overlay of 12.7mm thick Marinite. This was the first test with a growing fire, controlled by the computer. With times referenced to start of the computer relay program, flames were established at 1.08 min (just before 3rd relay or time step). Fire was allowed to develop to about 1 MW (the maximum available being 2 MW). After the fire, plastic transfer tube connected to steel sampling tube in fire room was found to be partially collapsed near the attachment to the steel tube and was repaired.

Test 27 - Fire was allowed to develop to approximately 1 MW. Still photography and video (from alcove) were employed.

Test 28 -Some of the malfunctioning photometers were repaired. RTV caulking was applied around reinforcement panel in ceiling of fire room to reduce leakage. Although faster growing than the preceding fire, this fire was also allowed to reach approximately 1 MW.

Test 29 - An attempt was made to clean turbidimeter at Station 6 before the test. The fire developed to about 1 MW.

Test 30 - It had been the intent to let the fire develop beyond 1 MW in this test for the first time, but circuit breakers serving the fuel control tripped and terminated the fire just beyond 1 MW.

Test 31 - Test was allowed to develop to about 2 MW. Wet cloth was wrapped around junction of plastic transfer tube with steel sampling tube for burn room, but after the test the plastic tube had again collapsed near the junction.

Test 32 - Before the test, cracks were sealed in fire room with RTV; detector bases in fire room were covered with 12.7mm Marinite panels; and the junction between the plastic transfer tube and the steel sampling tube for the fire room was made to pass through a pool of water. The ceiling thermocouple in the fire room had detached in previous testing and was re-installed. Brass disks at Stations 6 and 9 had fallen down and were re-welded to the thermocouple wire. A replacement was installed for the UV flame sensor. Furthermore, ducting and associated equipment were installed in readiness for Tests 38-47, remaining inoperative until needed. Three new data channels were added in anticipation of Tests 38-47 (still remaining inactive). The test itself went smoothly. The fire went to approximately 1 MW.

Test 33 - The fire was allowed to develop to 1 MW.

Test 34 - Forward smoke front down corridor ceiling as well as return front underneath clearly discernable by eye. It appeared that smoke had not reached floor in corridor at the time the fire was terminated, near 1 MW, in this fast-developing fire.

Test 35 - This was a closed room fire and was not allowed to develop quite to the 1 MW level.

Test 36 - Forward and return smoke fronts in corridor were very obvious to the eye. Return front reached back to the fire room near the end of the tests, at a fire output of about 1 MW.

Test 37 - Solenoid lights on fuel control panel flickered at times after the 1 1/2 min mark, as if the UV sensor saw no flame. Fire was terminated at 2 min (1 MW). The UV sensor was cleaned after the test.

Test 38 - This was the first test of a new series employing a partition in the corridor and ceiling vents on either side of the partition. In this test, the ceiling vents were blocked. The test itself was satisfactory. However, at the moment of termination near 1 MW (gas supply to burner shut off), the low pressure developing on the fire side of the partition broke the partition apart as the two panels of the partition pivoted (about their supports on the corridor walls) toward the low pressure side. Bracing was installed for the next test.

Test 39 - The ceiling vents on either side of the partition were opened but the blower was not turned on ("natural ventilation" through ducting arranged in "return" mode). In this case, with the window closed and relatively high fire-induced pressures, smoke was observed both on the non-fire side of the partition and emerging from the blower plenum. The fire developed to about 1 MW.

Test 40 - In this test with shorter fire-growth time, less smoke was observed on the nonfire side of the partition than in the preceding these. The fire was terminated near 1 MW.

Test 41 - This was the first test with forced ventilation through the ceiling vents, approximately 170 g/s (total) in return mode. No smoke was apparent to the eye on the nonfire side of the partition as the fire was allowed to grow to about 1.6 MW. Station 6 turbidimeter malfunctioned and lamp was replaced for next test. Pressure transducer for blower plenum appeared to malfunction (spikes in output) and was replaced with new 0.5 "H_2O unit for next test.

Test 42 - With blower shut off, fire room window open and relatively low overpressures in fire area, smoke was nevertheless observed emerging from the ceiling vents on the nonfire side and from the blower plenum as the fire developed to about 1.6 MW.

Test 43 - With 170 g/s return vent flow and open fire room window, no smoke was observed on the nonfire side of the partition with the fire building to about 1.6 MW. It was discovered after this test that 0.5 "H_2O pressure transducer in blower plenum was pegged in Tests 41 and 43; separate calibrations later indicated that the plenum pressure was 250 Pa below atmospheric pressure in these two tests.

Test 44 - (Switched 0.5 "H_2O transducer in blower plenum with 0.2 psid transducer in TR2 vent tube to avoid future pegging). Forward smoke front and return smoke front on fire side of partition were well displayed as viewed from port in south end of corridor. The fire was allowed to develop to 1 MW.

Test 45 - Smoke fronts were not so evident to the eye in this case of 170 g/s supply air through ceiling vents. No smoke was evident to the eye on the nonfire side of the partition. The fire built to 1.6 MW.

Test 46 - No smoke observed on nonfire side of the partition for a fire developing to about 1.6 MW.

Test 47 - This was the last test of the partition/ceiling vent series, with the ceiling vents blocked and the fire developing to about 1.6 MW.

Test 48 - This was the first test with a polyurethane (PU) slab target, installed in a vertical orientation near the SE corner of the burn room. Fire was allowed to build to approximately 1.6 MW. Target did not ignite, but some melting took place (maximum 6 mm depth near top, tapering to 0 near mid-height).

Test 49 - Conditions for this test were the same as for the preceding one, except that a 25 mm high propane pilot flame from a 8 mm dia. tube was installed centrally and about 25 mm above the top of the target slab, with exit of tube flush with the front of the slab. Fire was allowed to build to approximately 1.4 MW, but target did not ignite. Melt pattern on slab was similar to that seen in preceding test.

Test 50 - Before test, one corner of reinforcement panel in ceiling of burn room was observed to have sagged and was refastened with a screw. This test employed closed door to fire room and open window, but no pilot for vertical target slab. The fire was allowed to build to about 1.5 MW with vigorous flaming out through the window of the fire room. No ignition of target slab was evident.

Test 51 - Conditions were the same as in Tests 48 and 49, except that crumpled newsprint (25g) was placed centrally on a shelf in front of the bottom of the vertical slab to act as a pilot to be ignited by heat from the fire. The fire was allowed to build to approximately 1.6 MW. Within seconds after the gas was turned off to the burner, the slab ignited, as evidenced by weight loss of the slab. Inspection of the slab after the test indicated that approximately 1/2 of the slab depth had burned or run off as melt.

Test 52 - For this test, all doors were closed and the fire room window open. The vertical PU slab and newsprint pilot remained as in Test 51. Safety system automatically terminated fire after it had built to approximately 1.3 MW. (This shutdown was judged premature, caused by chance accumulation of heavy smoke densities near UV detector). Neither newsprint pilot nor slab ignited.

Test 53 - With nominal conditions as in Test 52, the safety system again shut down the burner, this time at a burner output of approximately 1.5 MW. Neither newsprint pilot nor slab ignited.

Test 54 - The UV flame sensor in the safety system was bypassed in this test in order to allow increased heat output. Otherwise, nominal conditions were as in the preceding two tests. Fire built to maximum output possible with fuel control system employed, approximately 2 MW. Newsprint pilot scorched, but did not ignite. PU target slab melted to some extent (25 mm depth on top tapering to zero depth on bottom), but did not ignite (no weight loss).

Test 55 - This test was the first with horizontal slab, installed in the NW corner of the fire room. A pilot of crumpled newsprint (25g) was again used, placed centrally on top of the slab. Otherwise, nominal conditions were as in Test 51. Fire was allowed to build to the maximum, approximately 2 MW. After test was terminated and smoke partially cleared, flaming was observed in PU slab, intensifying with time. Residual fire was extinguished with dry chemical. Weight loss record for target slab indicates ignition near a heat-release rate of the exposure fire of approximately 1.8 MW. A slab weight loss rate of approximately 3.6 g/s is indicated by the data during the first 20 s.

Test 56 - Nominal conditions were as in Test 55, except that the PU slab was mounted vertical in the NW location of the fire room, its face parallel with the west and east walls and generally turned toward the exposure fire. The weight loss record indicates that the slab ignited 1-2 s before maximum output of 2 MW was reached by the burner. When smoke cleared, there were no flames on the slab; foam depth removed varied from 6 mm at the bottom to 25 mm at the top.

Test 57 - This was the first test with the intent of expanding information available on the effects of fire "growth time", i.e., fire growth rate, with the enclosure in a particular configuration: open target room doors, no forced ventilation, open fire room door and closed fire room window. Three of the tests in the PU-slab target series were conducted under these conditions until the slabs may have ignited at quite advanced time, i.e., Tests 51, 55 and 56 at t_g=240 s. (Test 30 at t_g=120 s and Test 31 at t_g=240 s may belong to the same family except for any effects associated with absence of load cell enclosures.) The current test was conducted at a fire growth time of t_g=120 s with a maximum output of about 1 MW.

<u>Test 58</u> - Conditions were as in Test 57, except for a fire growth time of t_g=60 s.

<u>Test 59</u> - Conditions were as in Test 58, except for a fire growth time of t_g=480 s.

<u>Test 60</u> - This, the final test of the program, was conducted with a pyrolyzing fuel, four cartons of an FM test commodity referred to as "Standard Plastic Commodity". The array was ignited with a standard FM ignitor (cotton soaked with gasoline), which in turn was ignited by a remotely controlled propane flame. A horizontal PU slab target was installed in the NW position and provided with a newsprint pilot as in Test 55. In this test only, one target room door was kept open (N) and one was kept closed (W). The burn room door was open and the burn room window was closed. Practically all the fuel was consumed in the test. The PU slab ignited near 200 s into the test, somewhat before maximum fire activity, losing mass at a rate of about 1.7 g/s.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

A series of 60 fire tests have been conducted in an enclosure consisting of a corridor and three attached rooms, one of which served as a burn room. The purpose was to establish validation data for theoretical fire models of multi-room fire situations with particular emphasis on health care facilities. Fire sources were propylene gas burners, producing steady fires at 56 and 522 kW as well as fires growing with the square of time at several growth rates up to a maximum output of 2 MW. Measurements were made of gas temperatures; ceiling surface temperatures; optical densities in white light and at three discrete wavelengths; concentrations of CO, CO_2, and O_2; gas velocities; and pressure differentials. In addition, smoke detectors and simulated heat detectors were installed and monitored. In the experiments, various combinations were investigated of fire source, open and closed doors, open or closed window in burn room, and natural or forced ventilation in all rooms. A number of tests were devoted to examining smoke migration via ventilation ducting, and others were designed to examine burning rates of polyurethane slabs installed in the burn room as targets for flashover ignition. The data have been filed with the Center for Fire Research, NBS.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Building fires; burning rate; corridor tests; door leakage; fire measurements; fire research; flashover; flow measurements; smoke detection; smoke movement

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