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Development of Aircraft Lavatory Compartments With Improved Fire Resistance Characteristics—Phase I

Fire Containment Test of a Wide-Body Aircraft Lavatory Module

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CONTENTS

Page

TABLES

FIGURES

DEVELOPMENT OF AIRCRAFT LAVATORY COMPARTMENTS WITH IMPROVED FIRE RESISTANCE CHARACTERISTICS–PHASE I

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1.0 SUMMARY

A test to evaluate containment of fire in a Boeing 747 lavatory was conducted. A production lavatory module, furnished with conventional materials, was installed in an enclosure and instrumented for recording temperature and heat flux. In addition, provisions were made for gas sampling, animal exposure tests, and television and photographic coverage. The initial fuel was four polyethylene bags containing paper and plastic waste materials representative of a maximum flight cabin waste load. The lavatory door was closed during the test while normal aircraft ventilation conditions were maintained.

The fire was contained within the lavatory module during the 30-minute test. Smoke from the lavatory module escaped primarily through the gaps between the bifold door and the jamb where the door distorted from the heat early in the test. The interior of the lavatory module was almost completely destroyed by the fire during the test.

2.0 INTRODUCTION

Unoccupied compartments or storage areas in which combustible material may be placed present a special problem in airplane cabin fire safety. Airplane lavatories, which are only intermittently occupied, may be the most likely of these locations for undetected fires because combustible waste material and passenger amenities are stored there and passengers may inadvertently (or sometimes purposely) introduce an ignition source. While such fires are generally rare and successfully controlled, efforts continue to minimize the possibility of a serious incident.

The fire containment test was established to (1) determine the capability of a production wide-body airplane lavatory to contain waste fires that might originate within, (2) assist in identification of design or material weakness in the event of containment failure, and (3) determine the need for subsequent tests with other lavatory panel materials and/or lavatory module redesign.

Dr. James G. Gaume of McDonnell-Douglas Corporation, Douglas Aircraft Company, provided the animal exposure test system and analyzed the associated test data. Dr. Eugene D. Vessel and Dr. Allen E. Senear of Boeing Commercial Airplane Company provided for product-of-combustion collection and analysis. G. R. Thorson of Boeing Commercial Airplane Company directed the test setup and data acquisition. Much of this report is based upon data provided by the above persons.

3.0 SYMBOLS AND ABBREVIATIONS

A	ampere
AETS	Animal Exposure Test System
AM	before noon
Btu/ft^2sec	British Thermal Units per square foot per second
^{o}C	degrees Celsius
cc	cubic centimeter
cfm	cubic feet per minute
Cl^-	chloride ion
ClCN	cyanogen chloride
cm	centimeter
cm^3/min.	cubic centimeters per minute
CN^-	cyanide ion
CO	carbon monoxide
CO_2	carbon dioxide
Conc.	concentration
CR	contract report
DC	direct current
Dr.	doctor
ECG	electrocardiograph or electrocardiogram
EKG	electrocardiograph or electrocardiogram
emf	electromotive force
^{o}F	degrees Fahrenheit
F^-	fluoride ion

fig.	figure
ft	foot
ft^3/min.	cubic feet per minute
GC	gas chromatograph
GS	gas sampling
$[H^+]$	hydrogen ion concentration
HCl	hydrogen chloride
HCN	hydrogen cyanide
HF	hydrogen fluoride
hr	hour
IE	instrumentation engineer
i.e.	that is
in.	inch
$in.^2$	square inch
$in.^3$	cubic inch
in.-Hg	inches of mercury
$in.^3$/min.	cubic inches per minute
kg	kilogram
kg/m^3	kilograms per cubic meter
lb	pound
lb/ft^3	pounds per cubic foot
$\log_{10}$	logarithm to the base ten
M	molar (moles per liter)
m	meter

mg/ml	milligrams per milliliter
min.	minute
ml	milliliter
ml/min.	milliliters per minute
mm	millimeter
m^3/min.	cubic meters per minute
N	normal (equivalents per liter)
N_2	nitrogen
NaCN	sodium cyanide
NaOH	sodium hydroxide
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
nm	nanometer
no.	number
NW	Northwest
O_2	oxygen
p.	page
PAA	Pan American Airlines
pH	$-\log_{10}[H^+]$
PM	afternoon
P.O.	post office
ppm	parts per million
PSU	passenger service unit
PVC	polyvinyl chloride

PVF	polyvinyl fluoride
RT	room temperature
RTV	room-temperature vulcanizing
sec.	second or section
STAR	Scientific and Technical Aerospace Reports
TC	thermocouple
TD	test director
TE	test engineer
TiO_2	titanium dioxide
TV	television
USA	United States of America
viz.	namely
W/cm^2	watts per square centimeter
x	by or times
%	percent
&	and
+	plus
$\simeq$	approximately
$<$	less than
$>$	greater than

4.0 TEST PROGRAM

The test program section has been divided into two separate sections:

1. Test Setup

2. Test Procedure

4.1 TEST SETUP

A detailed description of the test article, fuel load and ignition source, ventilation, test enclosure, instrumentation, and fire suppression provisions relative to the test setup is provided.

4.1.1 TEST ARTICLE

The test article was a production Boeing 747 wide-body airplane lavatory (see fig. 1) of the latest design as far as details that might affect fire containment capability. The lavatory contained production cabinets, toilet, toilet shroud, and lighting provisions. The passenger service unit (PSU) contained the hardware required in service, but the oxygen plumbing was not connected to a source. Electrical and water connections were not made to the lavatory. The dispenser cabinet and amenities drawer were supplied with paper towels, soap, cold drink cups, sanitary napkins, toilet paper, airsick bags, and toilet seat covers.

The compartment wall, ceiling, door, and cabinet panels were of phenolic-polyamide honeycomb core with epoxy-fiberglass skin construction. Details of the panel construction and the materials used for other major lavatory surfaces are given in table 1. In service, the lavatory back wall, the side wall across from the cabinet, and the door would have a decorative laminate of epoxy-fiberglass fabric and polyvinyl fluoride on both sides. This lavatory had not yet been designated for a particular airline; therefore, the decorative laminate on the outside surfaces, which is chosen by the customer, was not installed. The panels with the decorative laminate on one side only are shown in table 1.

In the corner of the lavatory ceiling, above the amenities cabinet, is a small access hole through which services (viz., electrical power, oxygen, and gasper air) are routed to the PSU. In service, this hole is covered by an aluminum slide. For this test, the slide was backed with a panel of the same material and thickness as the rest of the ceiling. This modification was made to eliminate the possibility that this area (hidden by the amenities cabinet) might burn through first, preventing complete evaluation of wall and ceiling panels. The patch over the access hole was not sealed tightly; therefore, if smoke could pass the slide during a fire developed in service, smoke should also leak in this test.

In service, two lavatories are served by a single toilet tank located under the toilet shrouds of two adjoining lavatories. It was judged that the tank would not play a part in this test and it was not installed. The hole in the lavatory wall for the tank installation was covered with a panel and sealed with General Electric RTV-106 compound (see fig. 2).

Two glass windows were installed in the bifold lavatory door. Another window was installed

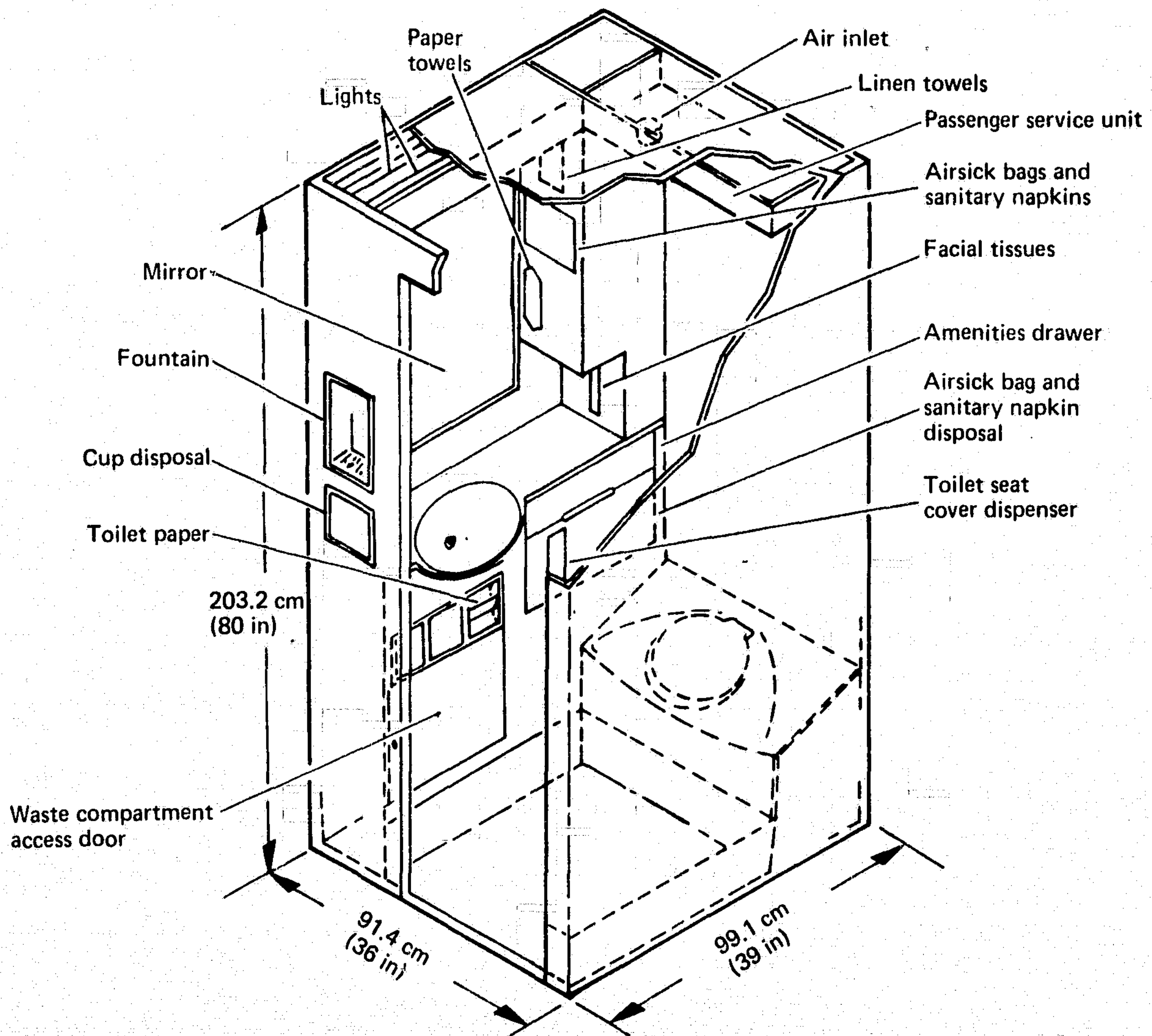


Figure 1.—Boeing 747 Aircraft Lavatory

Table 1.—Lavatory Materials

Component	Material
Ceiling (sandwich panel)	1. 0.051 mm (0.002 in) PVF (TiO_2 pigment). 2. Type 181 glass-epoxy. 3. Type 120 glass-epoxy. 4. 12.19 mm (0.48 in) thick, 3.05 mm (0.12 in) cell, 48 kg/m^3 (3.0 lb/ft^3) phenolic/polyamide core. 5. Type 120 glass-epoxy. 6. Type 181 glass-epoxy with 0.051 mm (0.002 in) PVF (TiO_2 pigment).
Front, back, and sidewall (sandwich panel)	1. 0.025 mm (0.001 in) PVF film. 2. Type 181 glass-epoxy with silk screened PVF (TiO_2 pigment) 0.051 mm (0.002 in) surface. 3. Type 120 glass-epoxy. 4. 24.38 mm (0.96 in) thick, 3.05 mm (0.12 in) cell, 48 kg/m^3 (3.0 lb/ft^3) phenolic/polyamide core. 5. Type 120 glass-epoxy.
Wall behind cabinet and mirror (sandwich panel)	1. Type 181 glass-epoxy with 0.051 mm (0.002 in) PVF (TiO_2 pigment) surface. 2. Type 120 glass-epoxy. 3. 12.19 mm (0.48 in) thick, 3.05 mm (0.12 in) cell, 48 kg/m^3 (3.0 lb/ft^3) phenolic/polyamide core. 4. Type 120 glass-epoxy. 5. Type 181 glass-epoxy with 0.051 mm (0.002 in) PVF (TiO_2 pigment).

Table 1.—(Concluded)

Component	Material
Cabinets (sandwich panel)	1. Type 120 glass-epoxy. 2. 6.35 mm (0.25 in) thick, 3.05 mm (0.12 in) cell, 48 kg/m^3 (3.0 lb/ft^3) phenolic/polyamide core. 3. Type 120 glass-epoxy. 4. Type 181 glass-epoxy with 0.051 mm (0.002 in) PVF (TiO_2 pigment) surface.
Toilet shroud	2.39 mm (0.094 in) thick laminate of type 181 glass cloth and fire resistant polyester resin.
Toilet seat	Polyphenylene oxide.
Floor pan	3.05 mm (0.12 in) thick polyphenylene oxide with floor mat of glass reinforced polyvinyl chloride.

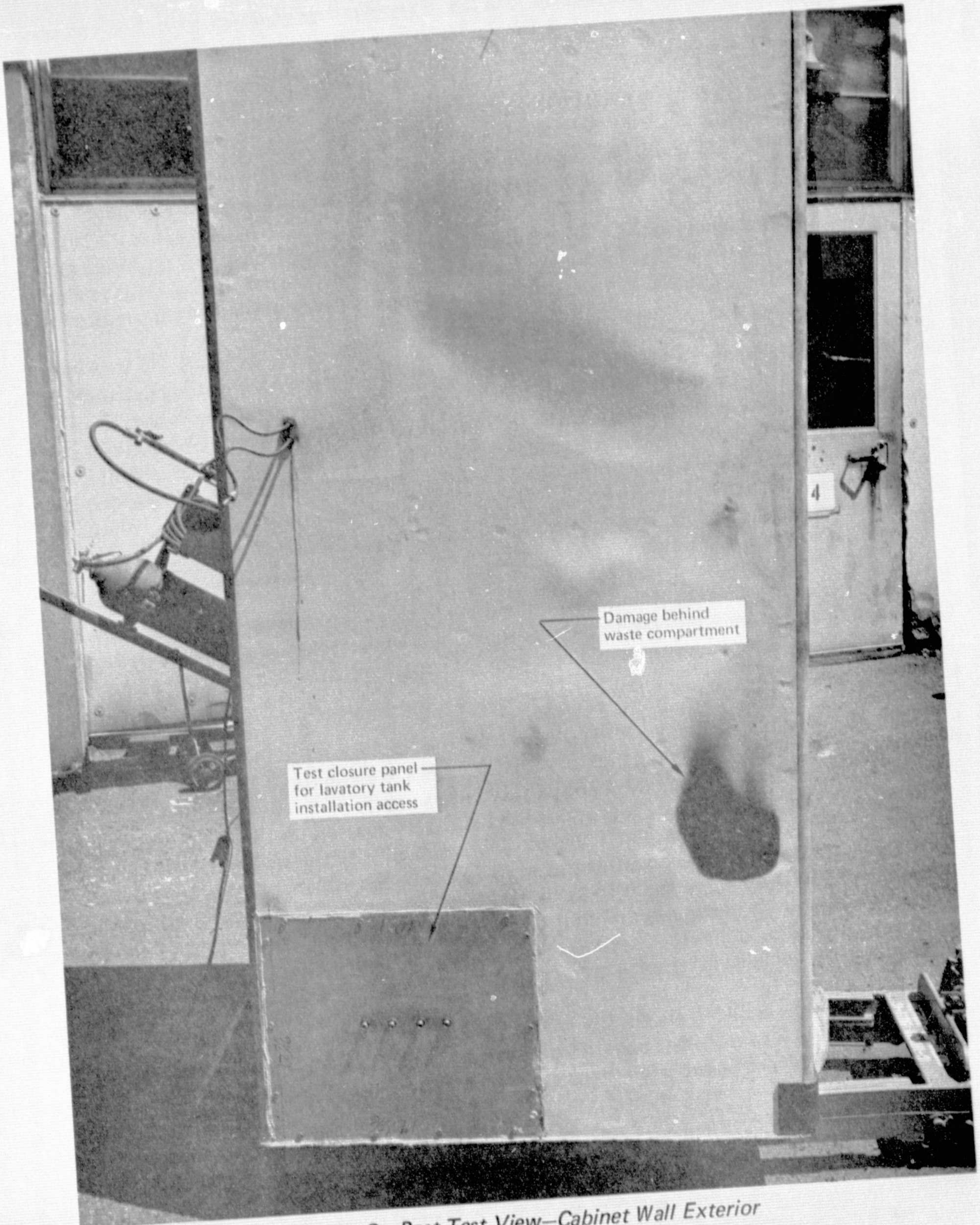


Figure 2.—Post-Test View—Cabinet Wall Exterior

in the side wall opposite the cabinets (see figs. 3 and 4). The windows were sized and positioned for good camera coverage and test observation. All the windows were framed with aluminum and sealed with General Electric RTV-106 compound.

4.1.2 FUEL LOAD AND IGNITION SOURCE

The waste load for the test was based on an analysis of material collected from waste compartments in wide-body airplane lavatories and on an estimate of the waste that might be stowed in a lavatory because of galley waste container overflow. The waste load development is detailed in appendix A. The study identified two waste loads: (1) predominantly paper towels (by weight) simulating a maximum waste compartment load, and (2) predominantly polystyrene glasses and soft drink cans to simulate galley overflow from an after-meal drink service.

The two simulated waste loads were burned in a simulated lavatory of noncombustible materials that was instrumented. Although the galley waste burned longer, it was determined that the waste compartment fire load produced the more severe fire condition because of the higher temperatures reached. The galley waste load contained roughly twice (by weight) the combustibles of the waste compartment load. The tests were repeated with some of the simulated lavatory panels made of materials used in Boeing 747 lavatories. The fire damage resulting from the tests confirmed that the waste compartment load was the more severe fire condition.

It was concluded that the test of the production lavatory should be run with waste stowed on the floor and toilet shroud of the lavatory module similar to the way galley overflow might be stowed. The waste should be a high percentage of paper to produce the higher temperatures.

To assure a maximum fire condition, the module fire load was set at four times the waste compartment load; viz., 3.6 kg (8.0 lb) of paper towels, 0.27 kg (0.60 lb) of "waxed" paper cold drink cups, and 0.6 kg (1.4 lb) of polystyrene glasses (see fig. 5). This load was divided evenly into four polyethylene bags and stowed in the lavatory on the floor and toilet shroud as shown in figure 6. In addition, the waste compartment with the waste container in place was filled with the waste compartment load (0.9 kg or 2.0 lb of paper towels, 0.07 kg or 0.15 lb of cold drink cups, and 0.16 kg or 0.35 lb of polystyrene glasses) by inserting it down through the towel and cup disposal chutes. The paper towels were taken singly and crumpled before being inserted into the bags and the waste compartment. None of the simulated waste was wetted with beverage or water as occurs in airplane service.

The ignition source was an electrically heated (28 volts DC) Nichrome wire coil inserted in the upper portion of the waste bag sitting on the floor next to the cabinet (see fig. 6). The igniter simulated a smoldering ignition source, such as a cigarette, which might be found in waste.

4.1.3 VENTILATION

The normal lavatory ventilation during flight is provided by overboard venting to ambient air. Flow is controlled by fixed orifices in the vent lines. Two outlets are vented from the

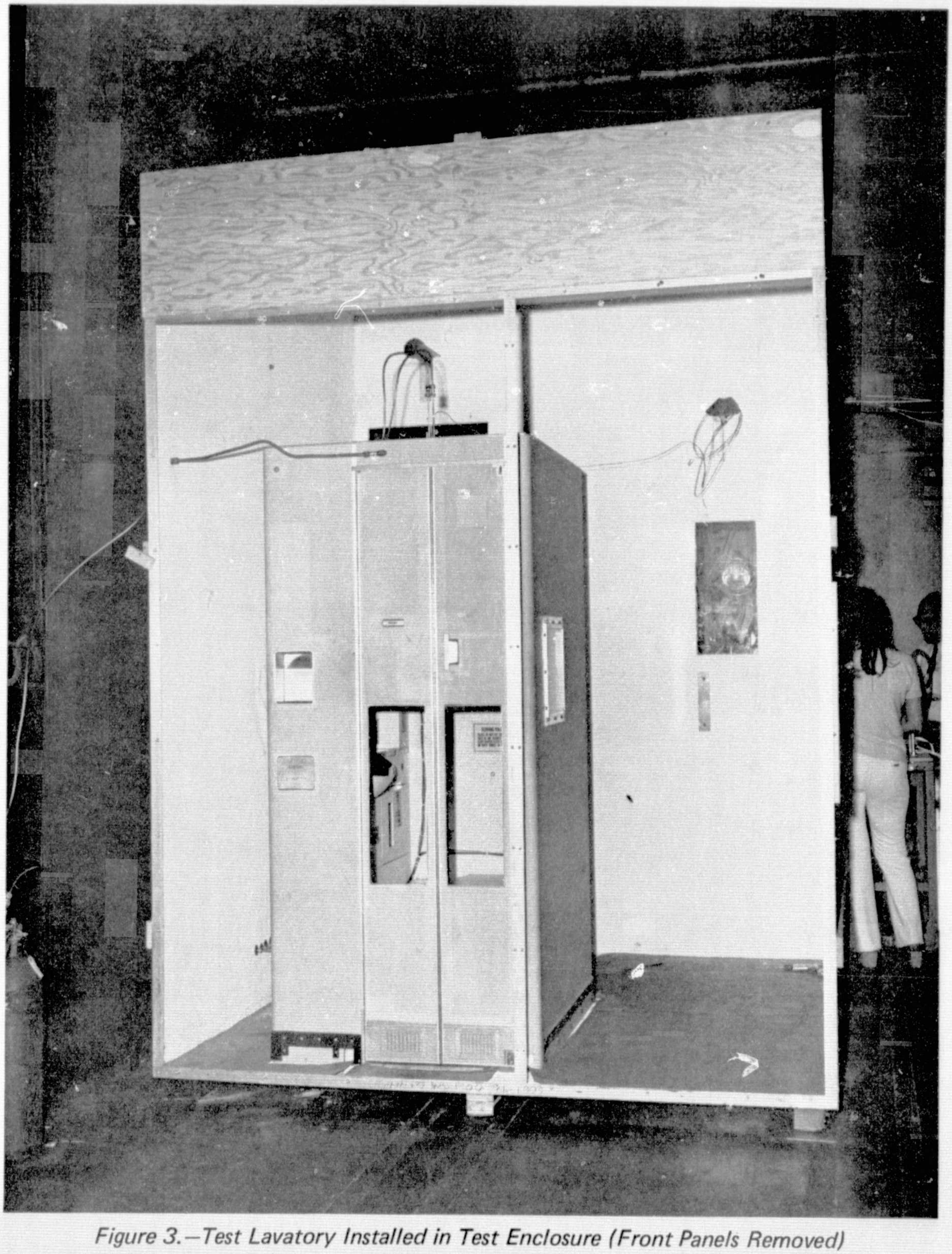


Figure 3.—Test Lavatory Installed in Test Enclosure (Front Panels Removed)

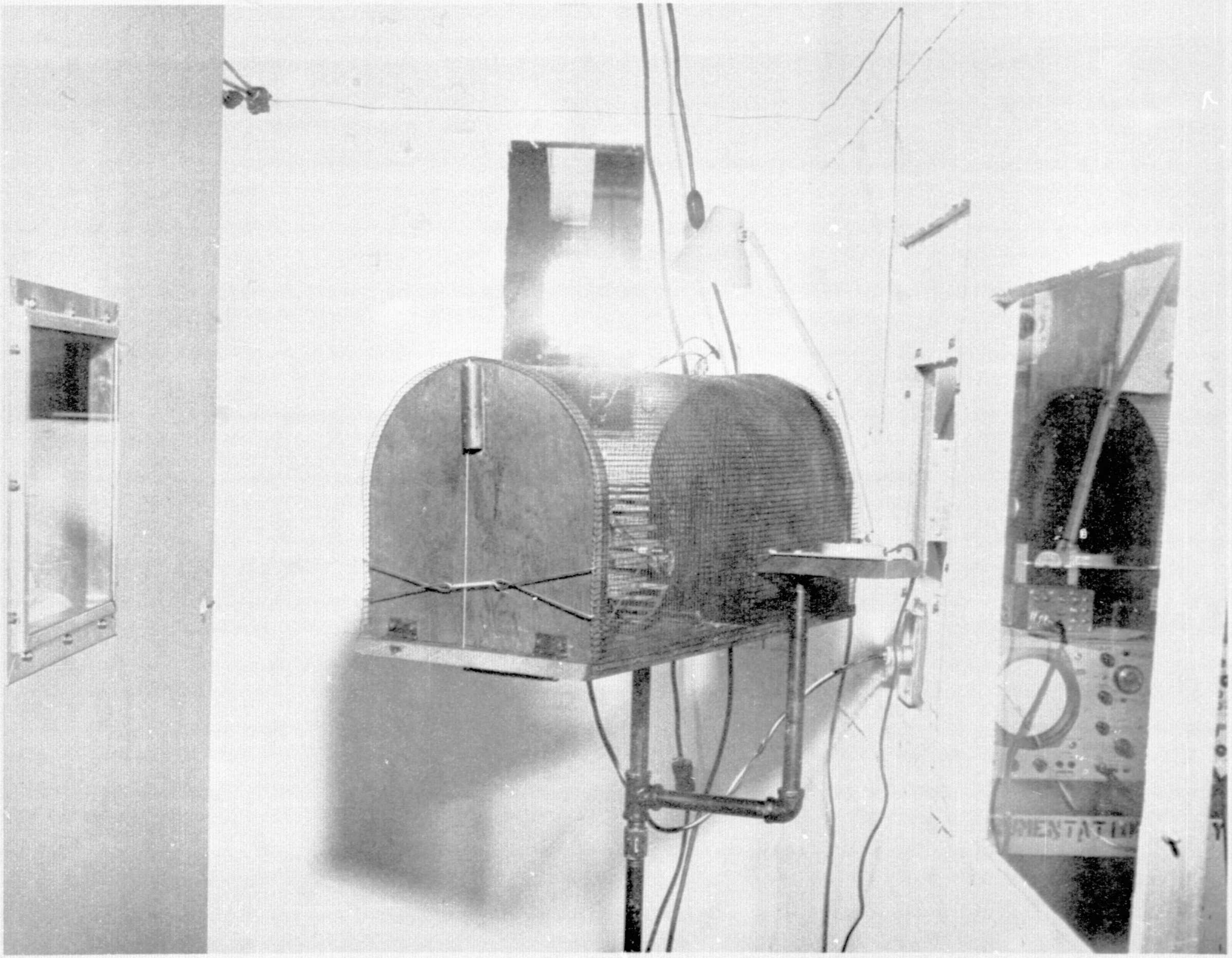


Figure 4.—Animal Exposure Test System (AETS) Cage within the Enclosure

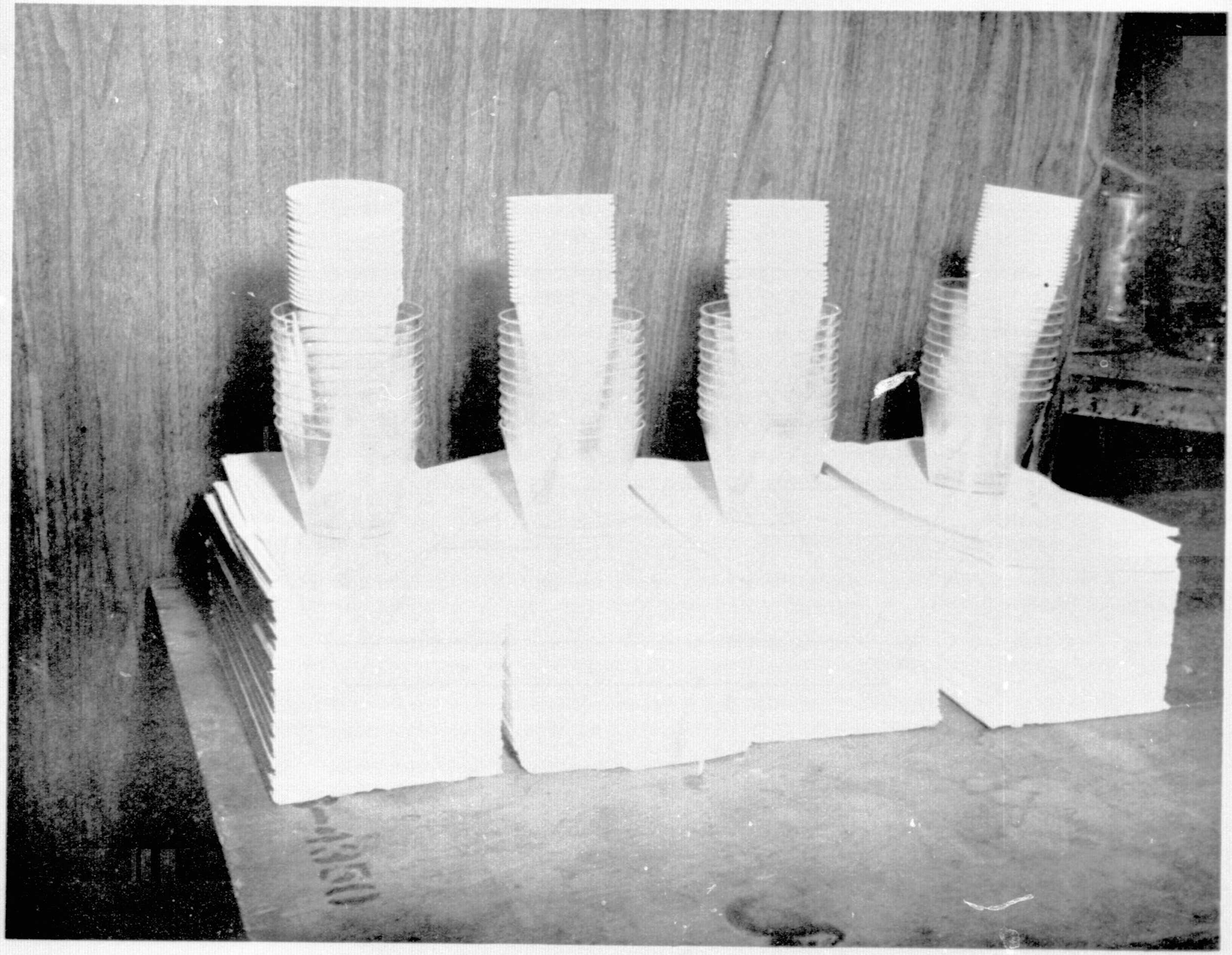


Figure 5.—Test Fire Load

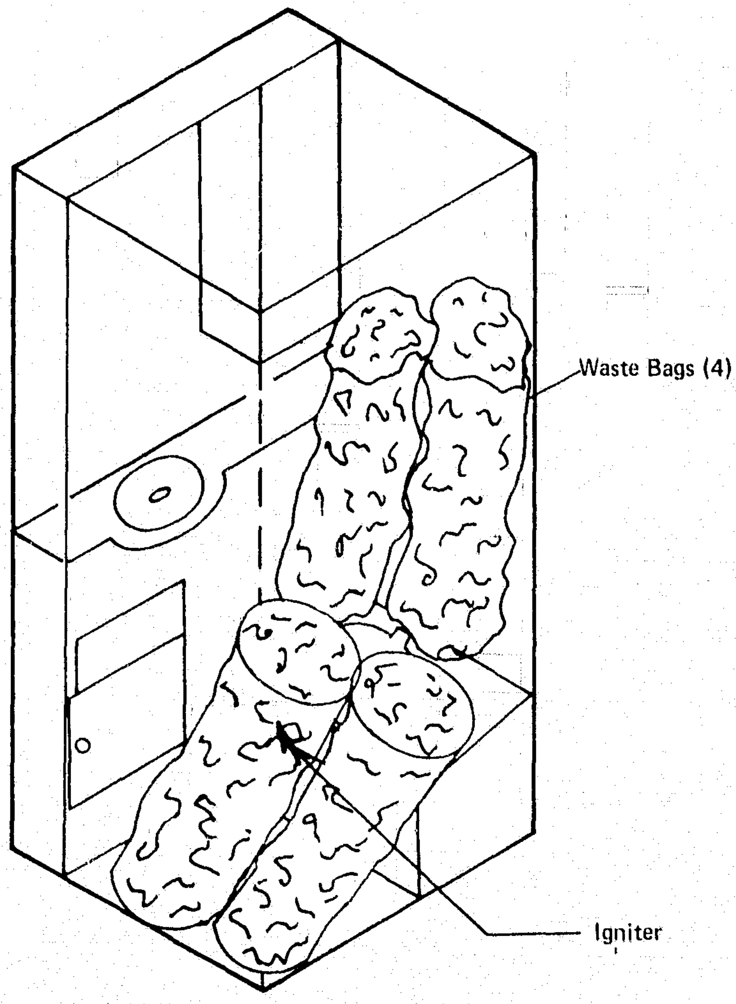


Figure 6.—Fire Load Arrangement

lavatory: one from above the toilet tank (under the toilet shroud) and the other from under the sink. The vent under the sink draws air through the sink drain, the overflow relief, and through a "muffler" in the drain line (which prevents whistling caused by drawing the full ventilation flow through the sink outlets). Total ventilation is 1.25m^3/min. (44 cfm) and consists of 0.79 m^3/min. (28 cfm) from the toilet vent and 0.45 m^3/min. (16 cfm) from the sink drains and muffler. Flow into the lavatory in service is provided by the gasper air in the PSU, which may be adjusted by the occupant up to 0.23 m^3/min. (8 cfm), and by air drawn through the door grill near the floor.

For the test, air ejectors were used to draw air from an outlet positioned under the toilet shroud in the sealed space normally occupied by the toilet tank and from a line attached to the production drain line and muffler under the sink. Venturi tubes were used to establish ejector flow required to obtain the correct flow from two outlets. The PSU gasper was plumbed to shop air and instrumented so that the flow could be adjusted to 0.14 m^3/min. (5 cfm), which was chosen as a typical value. The ventilation provisions are shown in figure 7.

4.1.4 TEST ENCLOSURE

To collect gases and products of combustion emitted from the module, a sealed chamber of plywood lined with asbestos fabric (see fig. 3) was fabricated around the lavatory module with clearances as shown in figure 7. A 10- x 10-cm (4- x 4-in.) pressure relief vent (i.e., a "flapper" check valve) was installed on the back side of the enclosure, 5 cm (2 in.) from the floor. An aluminum chute (see fig. 8) was installed between the lavatory door grill and the enclosure door. The flapper valves (aluminum with elastomer seals) were sized and positioned such that: (1) ventilating air could be drawn into the lavatory through the grill with a minimum of additional pressure drop, and (2) if rapid fuel burning in the lavatory produced an overpressure condition, the ventilating valve would close and the smoke forced out the door grill would be vented into the test enclosure through the flapper valve in the top of the chute.

Four transparent observation windows were installed in the test enclosure. One was located on the back wall of the enclosure near the top to view the back and upper corners of the lavatory; i.e., the areas expected to receive the maximum fire exposure in the test. Another window was positioned in the back wall for motion picture filming of the animal exposure test system (see sec. 4.1.5). Two windows were installed in the side of the enclosure adjacent to the noncabinet side of the test lavatory. One of these windows was positioned for viewing the undersink cabinet, the back lavatory wall, and toilet shroud through the window installed in that side of the lavatory. The other window was positioned to view closely the animal exposure test system cage. All four observation windows were sealed.

A sealed camera access was installed through the enclosure and up to the observation windows in the lavatory door (see fig. 9). A retrieval door, hinged at the bottom and sealed when closed, was installed in the enclosure next to the animal exposure test system (see figs. 9 and 10).

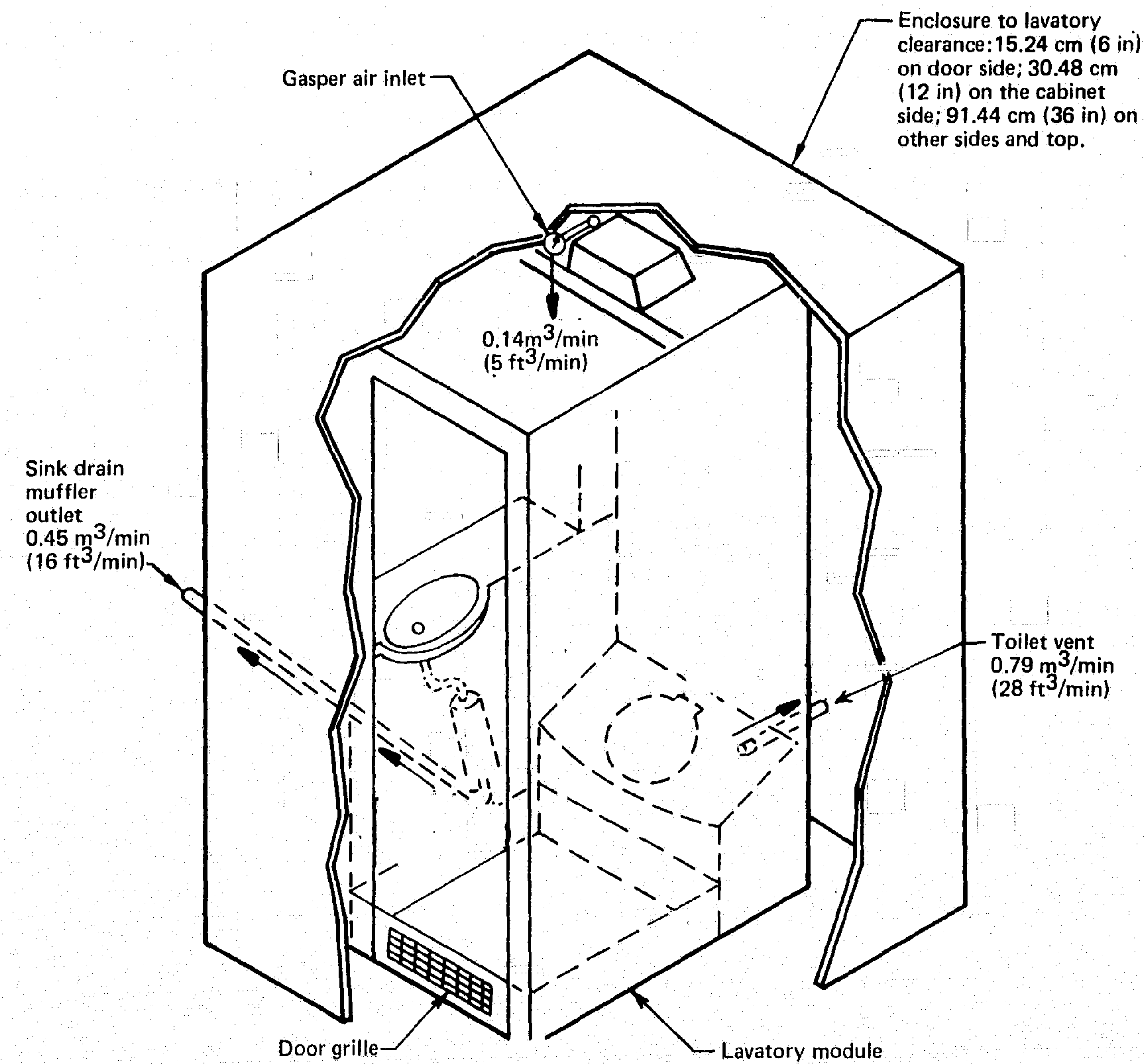


Figure 7.—Test Enclosure

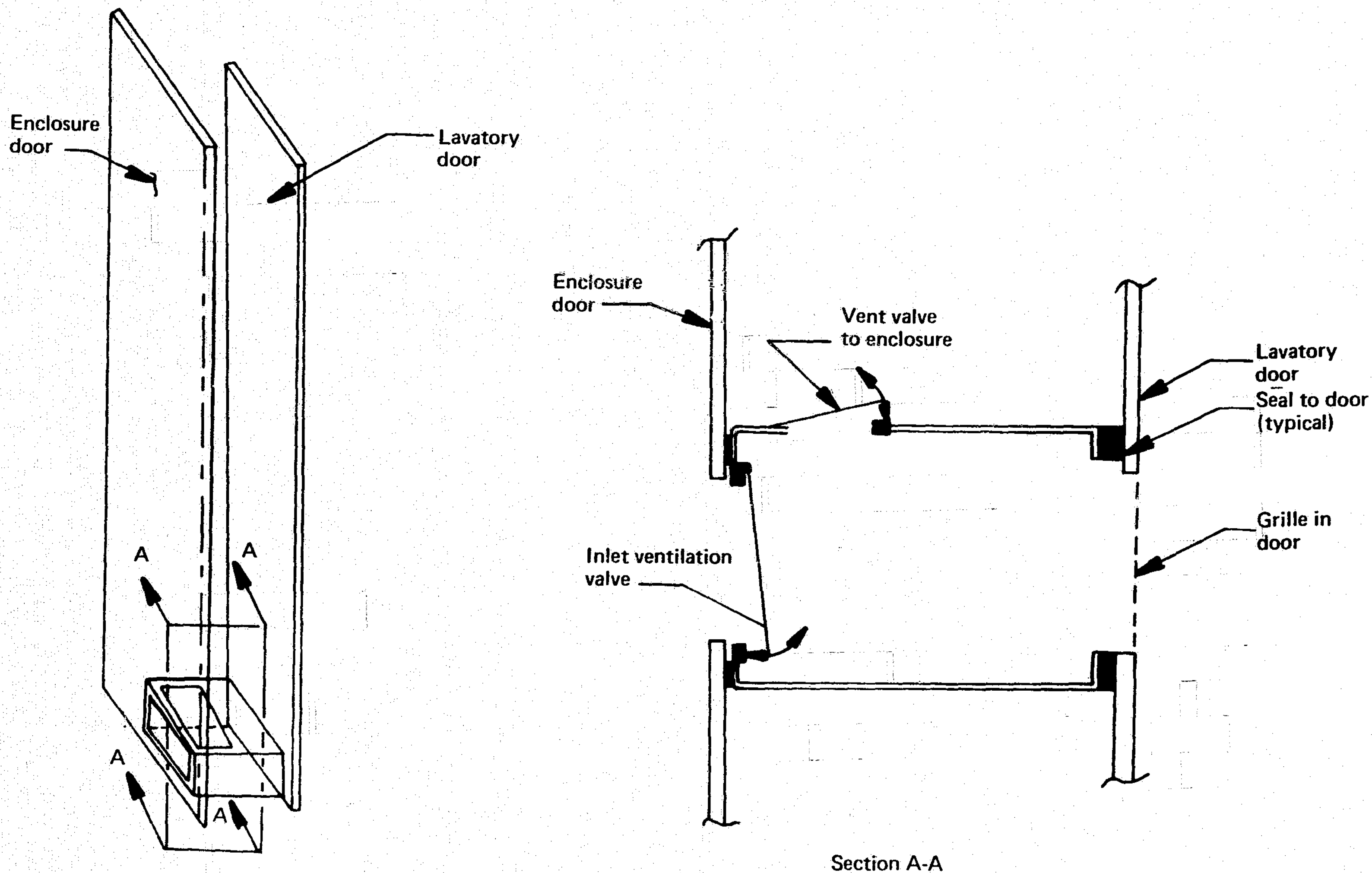


Figure 8.—Ventilation Chute

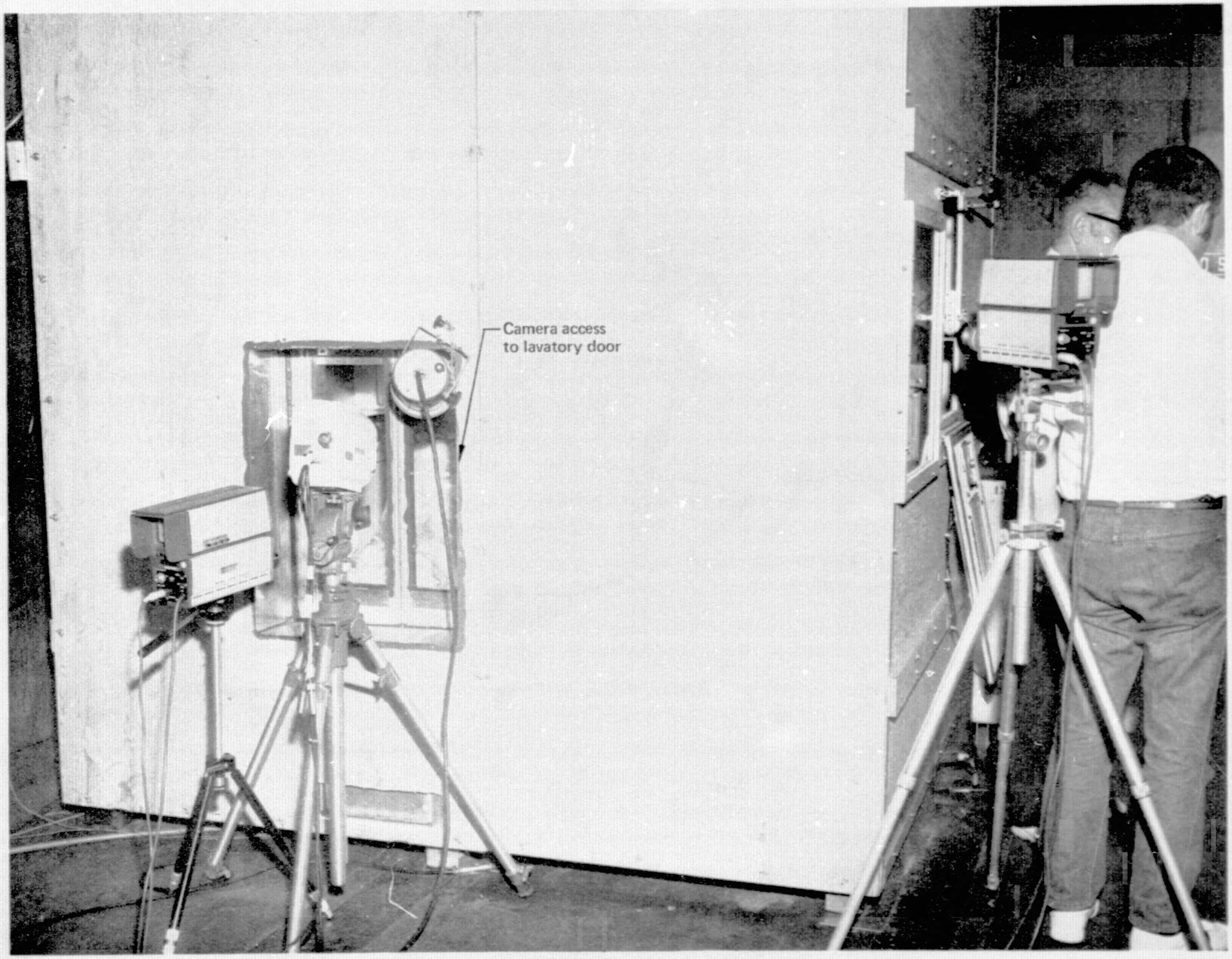
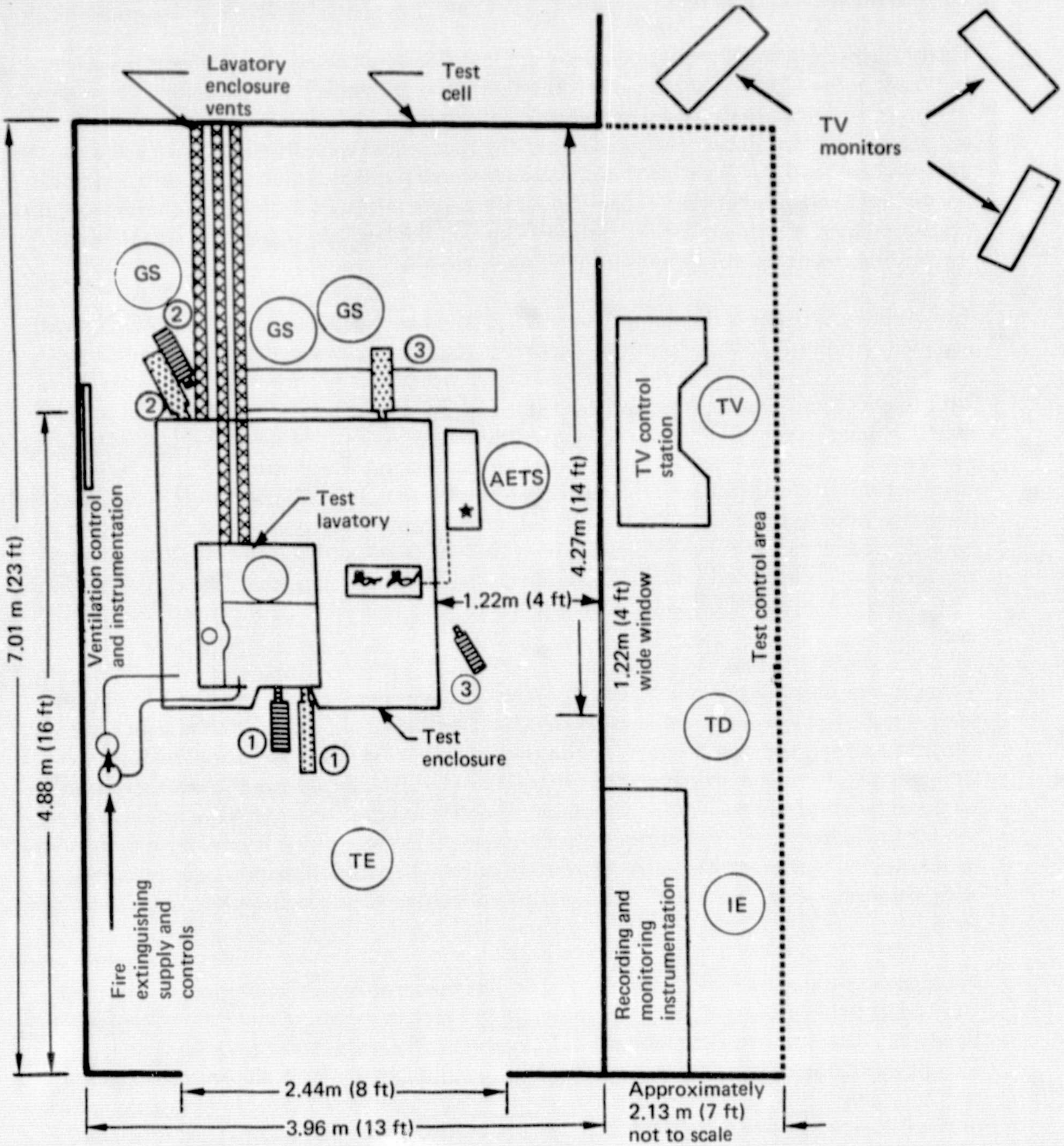


Figure 9.—Front of Test Enclosure



Legend:

AETS	AETS operator
GS	Gas sampling operator
IE	Instrumentation engineer
TD	Test director
TE	Test engineer
TV	TV controller
★	AETS monitoring equipment

16 mm cameras
1. Lavatory interior
2. Lavatory exterior
3. AETS

TV cameras
1. Lavatory interior
2. Lavatory exterior
3. Lavatory exterior

Figure 10.—Lavatory Module Test Layout

4.1.5 INSTRUMENTATION

Thirty Chromel-Alumel thermocouples were installed to monitor temperatures inside and outside the lavatory (see fig. 11). The thermocouples inside the module were mounted 2.5 cm (1 in.) from the surfaces to indicate environment temperature rather than surface temperature at that point. Outside surface thermocouples were bonded to the surfaces. Temperature readings from the thermocouples were recorded, sequentially, at 0.5-second intervals (15 seconds between recordings of the temperature from the same thermocouple). Four total heat calorimeters were installed through the lavatory panels (see fig. 12) and the readings recorded continuously by an oscillograph.

The overall test setup is shown in figure 10. An animal exposure test system (AETS) was installed within the test enclosure to assess the toxicity of the pyrolysis and combustion gases evolved from the lavatory. The AETS cage was placed within the 0.9-m (3-ft) space with the bottom 1.2 m (4 ft) above the floor (see fig. 4). The cage was supported by its own stand and was not in direct contact with the lavatory wall. One rat (Sprague Dollie) and six mice (Swiss Albino) were used as subjects. The rat was instrumented to record heart action by electrocardiograph (ECG) and respiration; hence, it was partly restrained. The mice were free to use an exercise wheel, providing an activity monitor. Both types of animals were used to provide information as to their relative toxic susceptibilities. Quick-connect-type connectors were used to connect the rat wiring harness to the external cables. The connectors were installed in an access door on the enclosure adjacent to the animal cage.

Two gas sampling lines were installed near the ceiling in the lavatory (see fig. 13) and two were installed in the enclosure near the AETS. The lines from each location were connected to sampling manifolds next to the enclosure (see fig. 14). The sampling lines were tubing with an inside diameter of 6.35 mm (0.25 in.). The lines from the lavatory ceiling to the exterior of the enclosure were stainless steel because of the high temperatures expected in the lavatory. All other lines were Teflon-lined rubber tubing to minimize absorption or reaction of active toxicants. As shown in figures 14 and 15, apparatus was installed to sample gases by three methods: (1) fixed gas collection, (2) microimpinger, and (3) Dräger tube.

Fixed gas components (CO, CO_2, N_2, and O_2) in the lavatory and enclosure atmospheres were collected in 125-ml (7.6-in.^{3}) gas sampling burettes using the manifold shown in figure 16. The burettes were continuously evacuated by pump no. 1 prior to filling. Except during sampling, gas streams were drawn continuously from the enclosure and lavatory by pump no. 2. Pump no. 2 was shut off at intervals for 15 seconds by manipulation of the valves, and gases from the enclosure and lavatory were allowed to flow into a pair of burettes. The burettes were filled to near ambient pressure with gas from the enclosure or lavatory.

The microimpinger apparatus, shown in figure 17, was installed for the analysis of toxic gases in the lavatory and enclosure atmospheres. The needle valves maintained a gas flow rate of 400 ml/min. (24.4 in.^{3}/min.) through the central bypass pathways of each side of the manifold. Periodically, the flow was diverted for 1.25 minutes through two microimpinger bubblers arranged in series. Each bubbler contained 10 ml (0.6 in.^{3}) of 0.1N sodium acetate

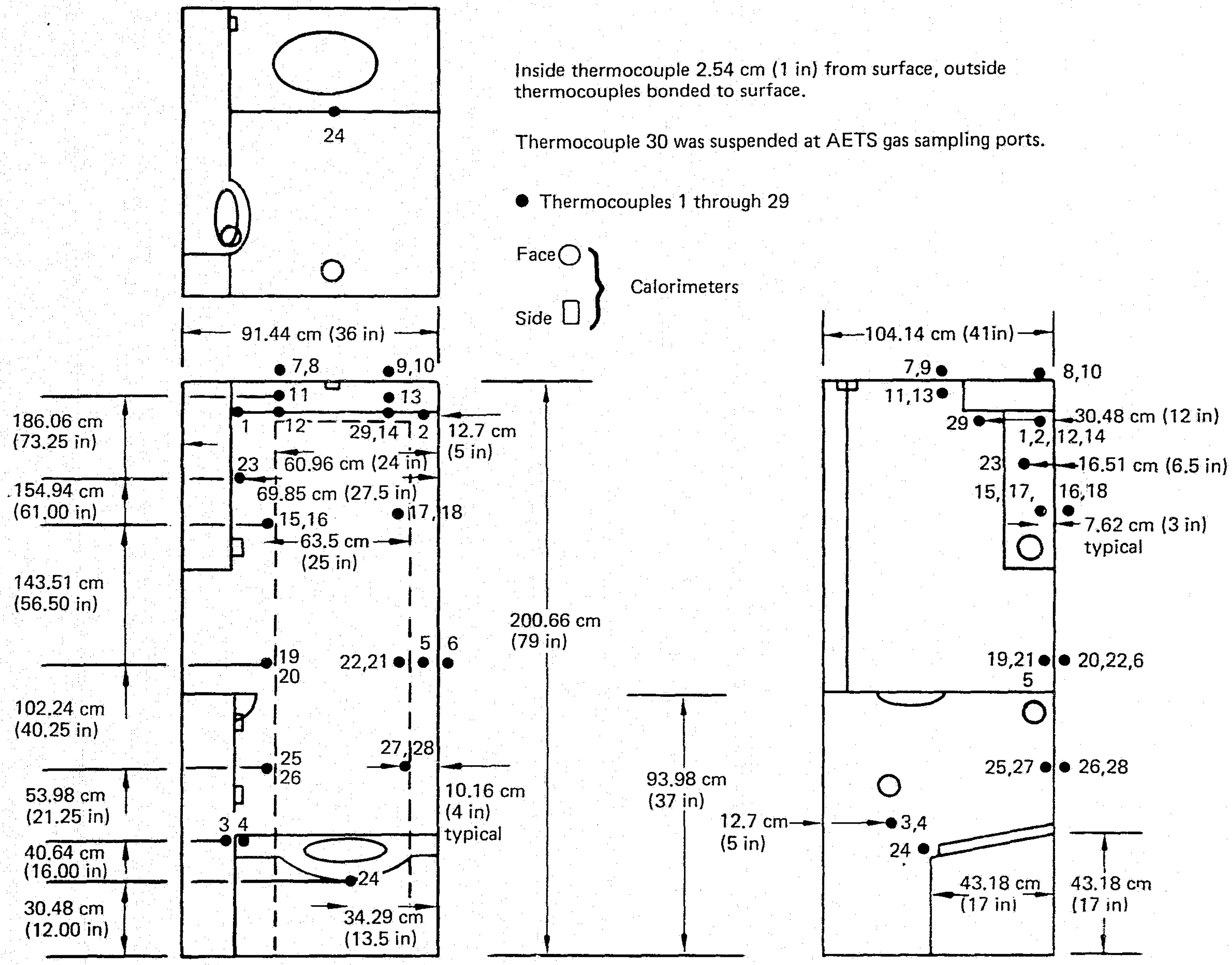


Figure 11.—Thermocouple Locations

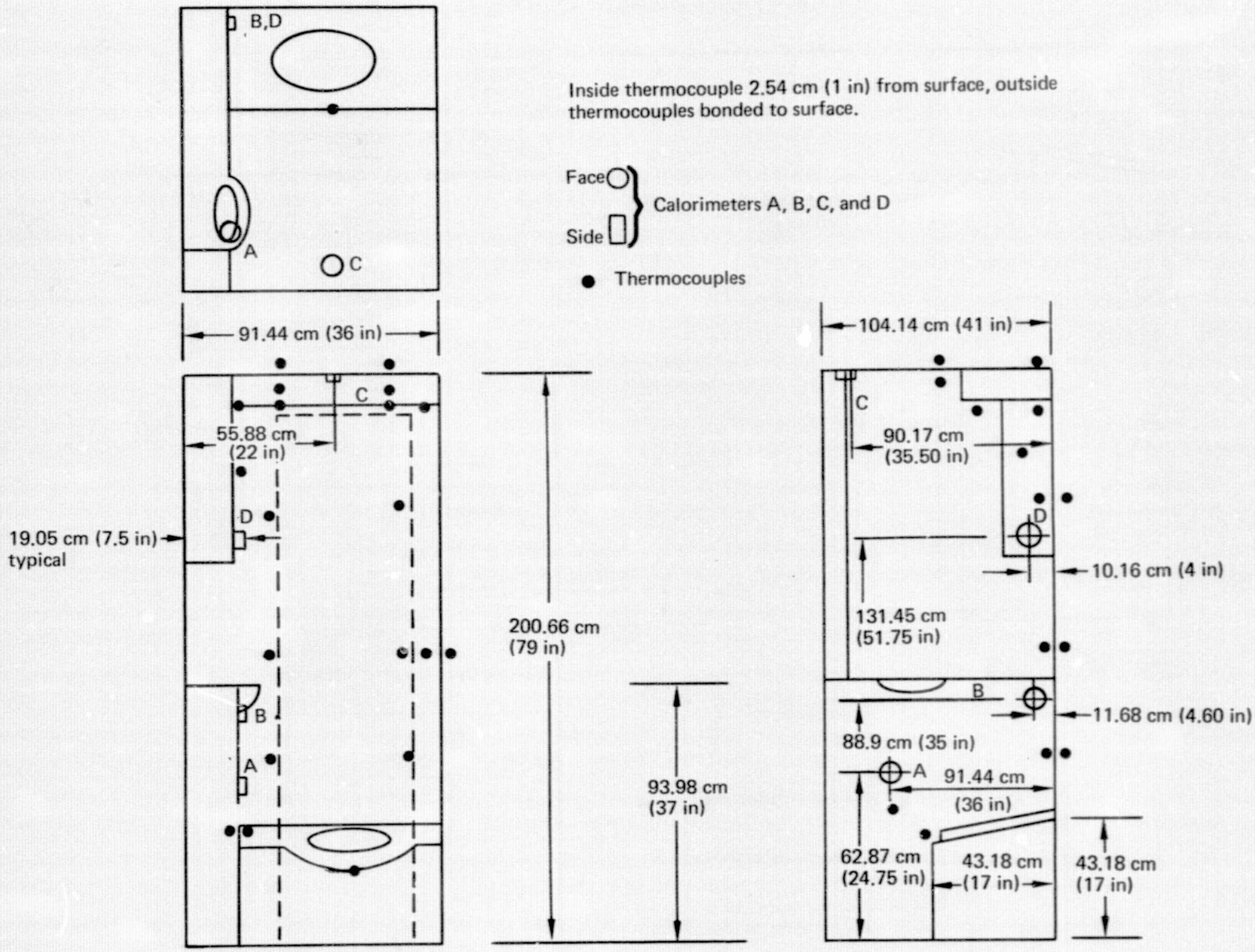


Figure 12.—Calorimeter Locations

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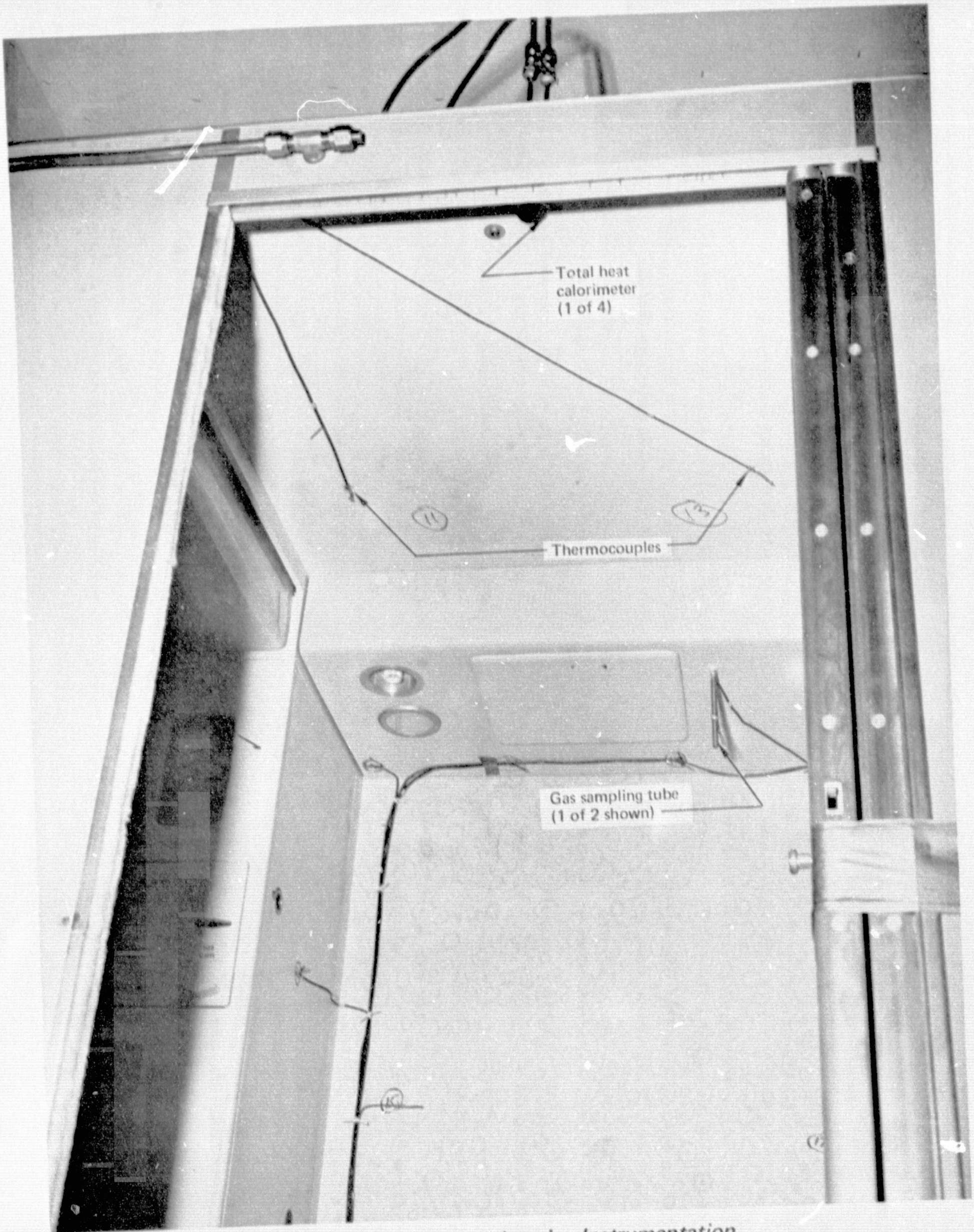


Figure 13.—Lavatory Interior Instrumentation

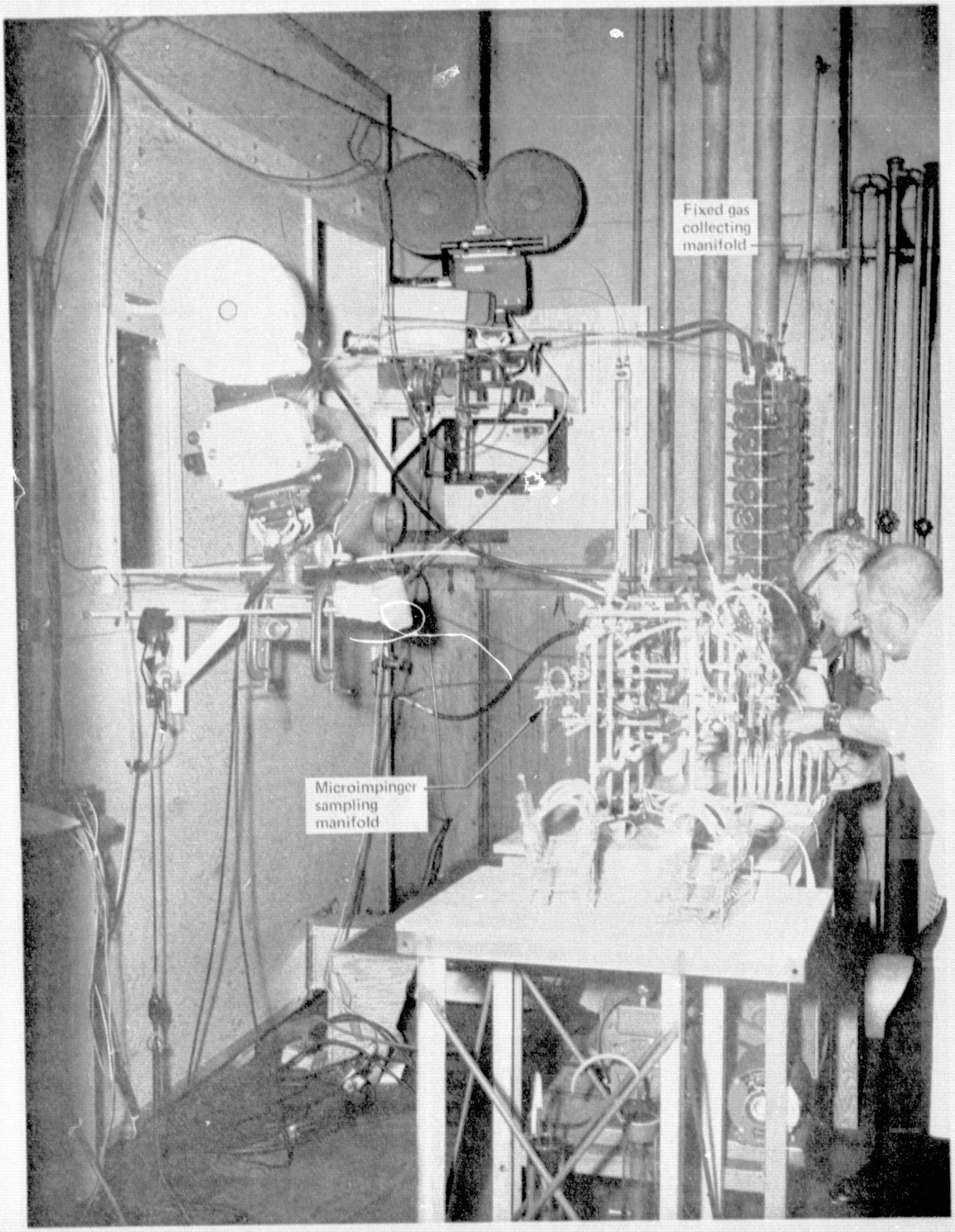


Figure 14.—Gas Sampling Equipment—Behind Test Enclosure

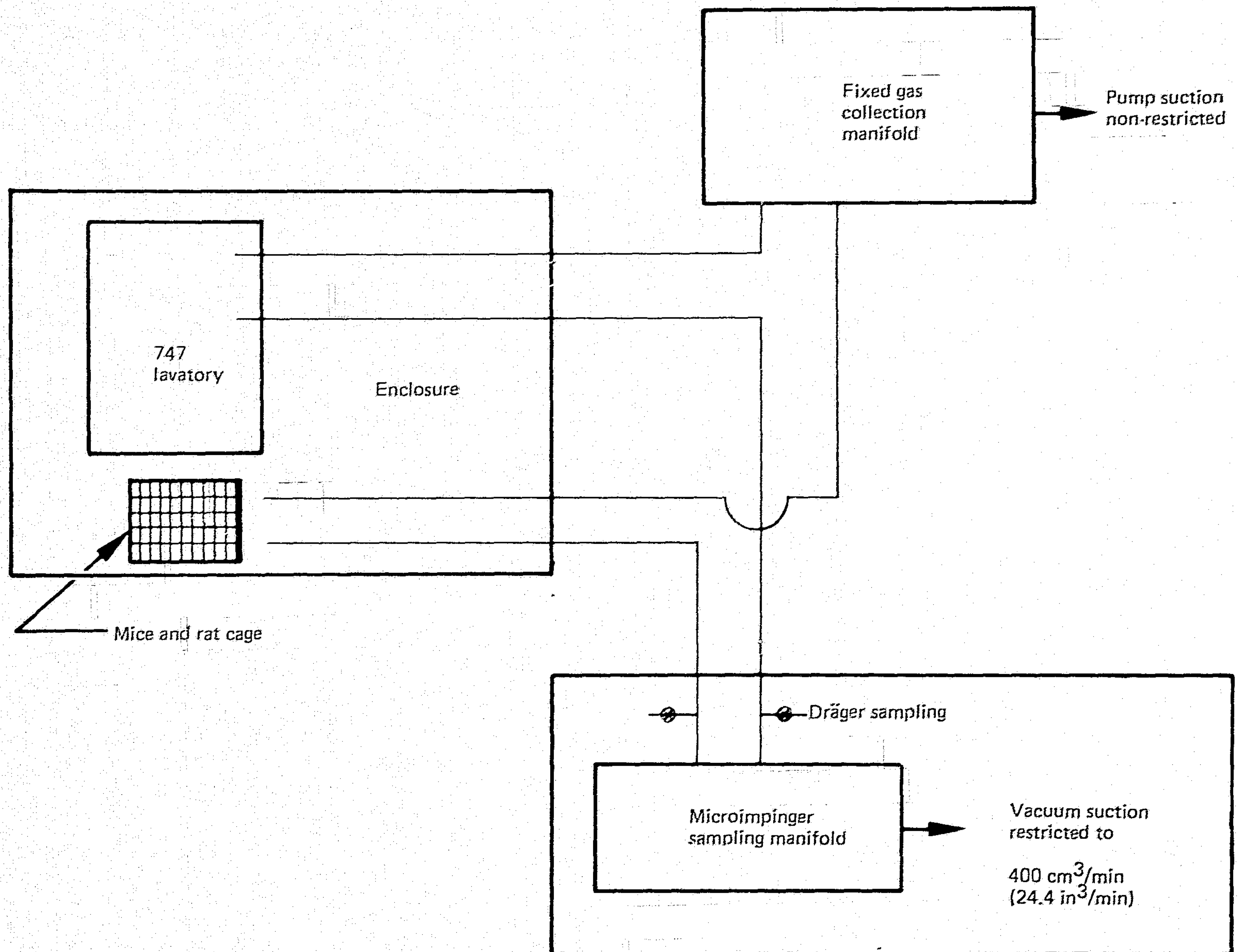


Figure 15.—Test Sampling Diagram

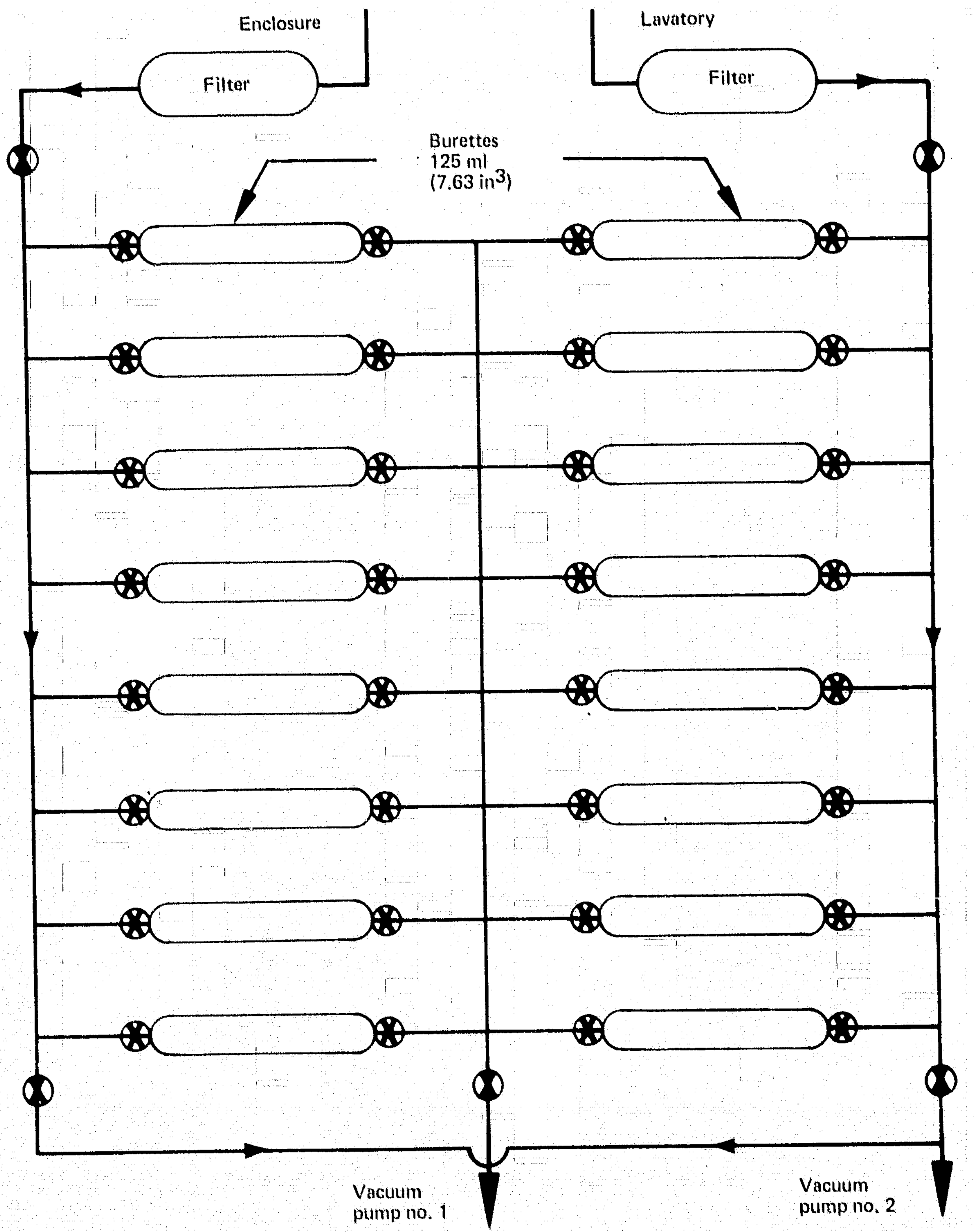
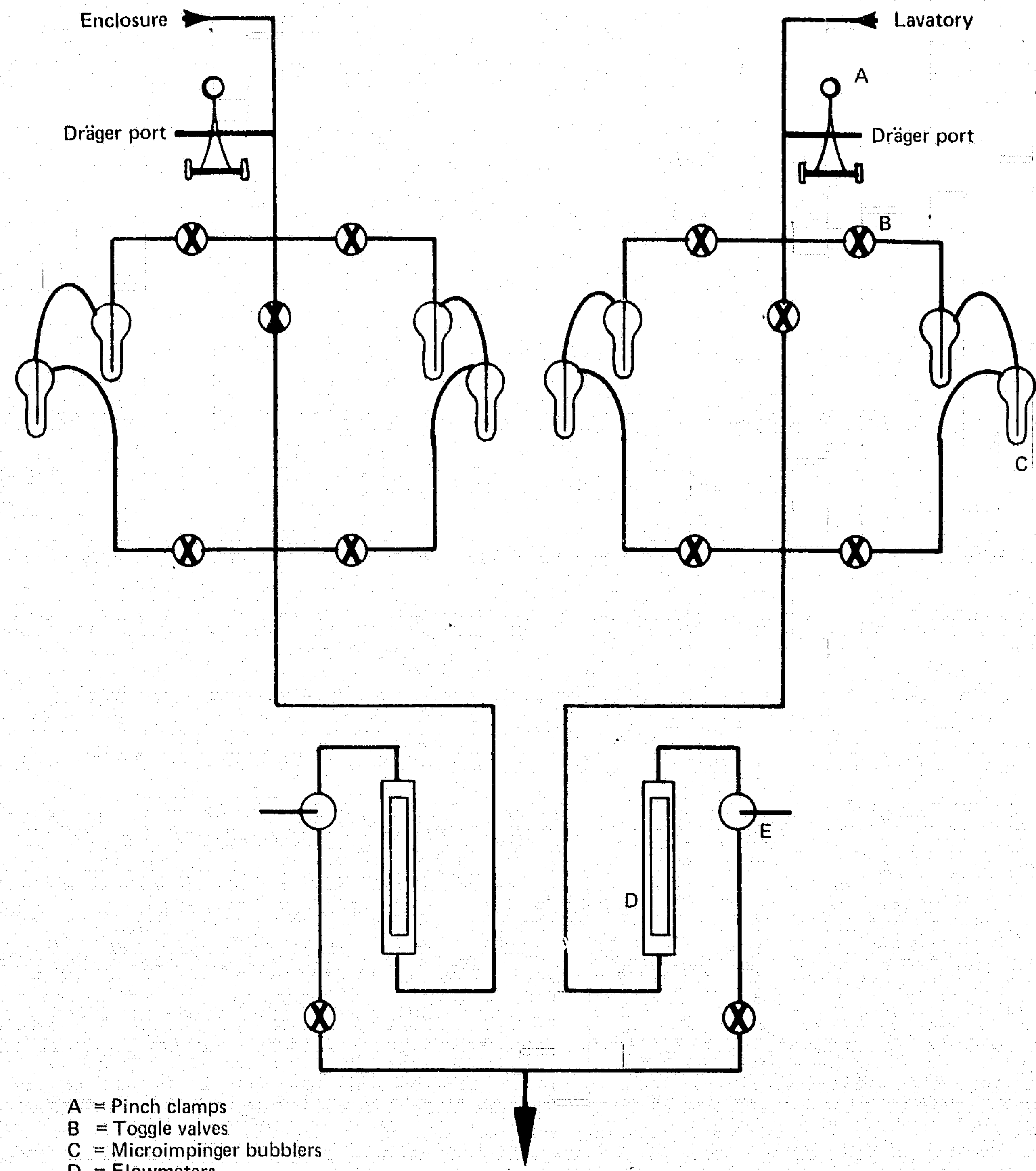


Figure 16.—Fixed Gas Sampling Manifold



A = Pinch clamps
B = Toggle valves
C = Microimpinger bubblers
D = Flowmeters
E = Needle valves

Figure 17.—Microimpinger Sampling Manifold

solution. In this fashion, the toxic gases (viz., HF, HCN, and HCl) were scrubbed from 500-ml (30.5-in.^{3}) samples of the lavatory or enclosure atmospheres. Used sets of bubblers were replaced while sampling through the alternate side of the apparatus. Dräger gas analysis tubes, attached to a Dräger pump, were inserted into the sampling lines using tees equipped with short rubber tubes and pinch clamps. Gas samples could then be pumped out of the lines through the Dräger tubes without upsetting the downstream flow through the bubblers and flowmeters.

Three 16-mm motion picture cameras and three television cameras were positioned to provide photographic instrumentation during the test (see fig. 10). The television coverage provided on-the-spot viewing of the test for observers through monitors as well as a video and audio tape record.

4.1.6 FIRE SUPPRESSION PROVISIONS

Two CO_2 fire extinguisher nozzles were installed in the test setup, one projecting into the test enclosure and the other into the lavatory module (see fig. 18). Enough CO_2 to inert the associated volume was plumbed to each nozzle and controlled by manually operated valves.

4.2 TEST PROCEDURE

The instrumentation and ventilation were turned on and baseline samples taken from each of the gas sampling positions. Television and motion picture cameras were turned on. The igniter was energized. Observation through the window into the lavatory confirmed ignition (time zero) and the test clock was started. The igniter was turned off. Gas samples were taken inside the lavatory module and inside the enclosure by the AETS at 3-minute intervals for the first 12 minutes, then at 6-minute intervals to test time 30 minutes. After the gas samples initiated at test time 30 minutes were complete, the test was terminated by shutting off ventilation and by discharging CO_2 into the lavatory module and the enclosure. The CO_2 discharge was made approximately 32.5 minutes after ignition.

If significant burning through the lavatory module had been observed before 30 minutes, the test would have been terminated to preserve the damage evidence at that time. Early termination was not necessary.

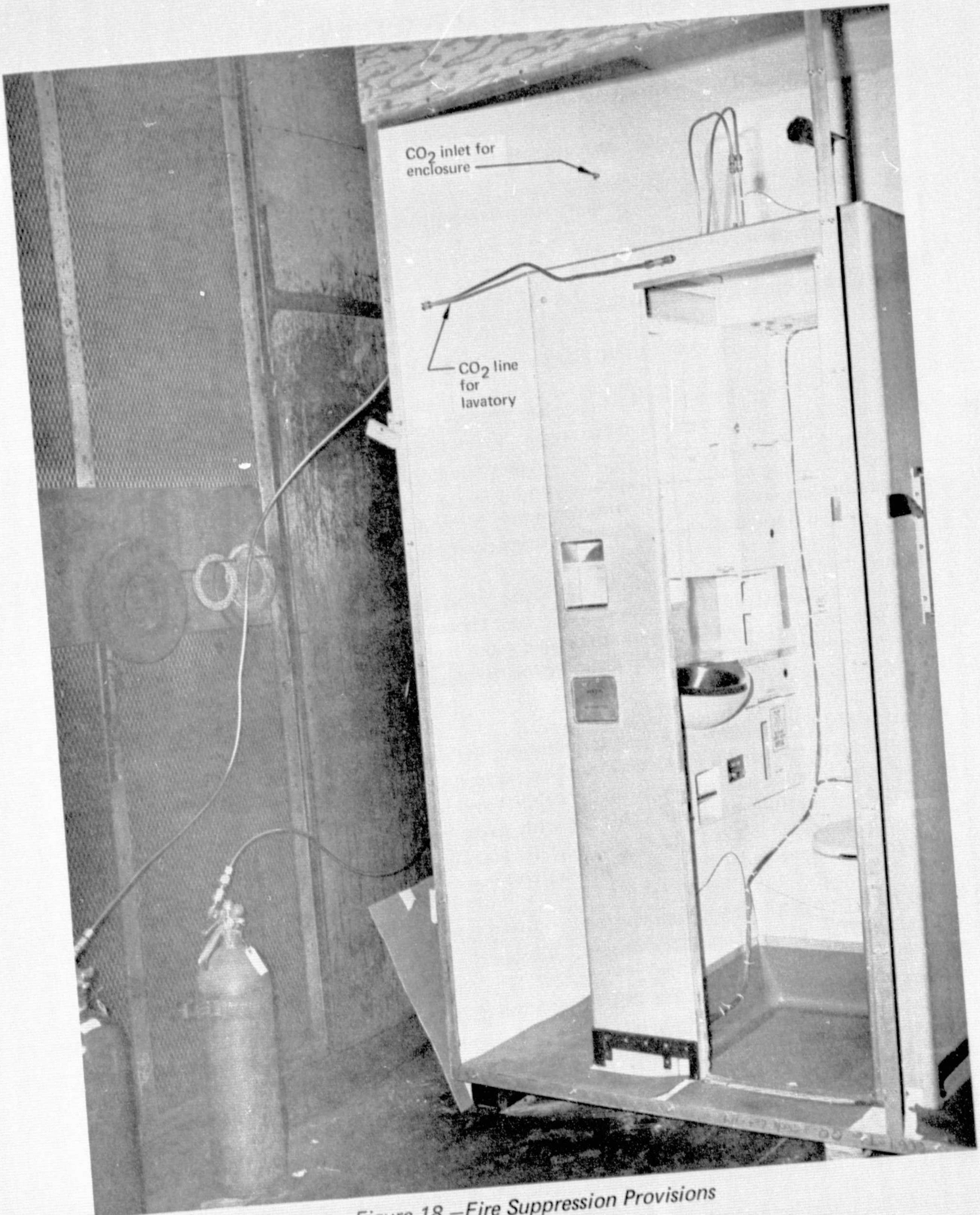


Figure 18.—Fire Suppression Provisions

5.0 RESULTS AND DISCUSSION

The Results and Discussion section has been divided into four separate sections:

1. Description and Damage Assessment
2. Thermal Data
3. Combustion Products Analysis
4. Animal Exposure Test Results

5.1 DESCRIPTION AND DAMAGE ASSESSMENT

After ignition near the top of the lower bag next to the cabinet, the fire burned across to the other lower bag on the surface of the waste. From there it burned toward the bottom of the bag to the floor just inside the door. Approximately 6 minutes into the test, the fire stopped spreading on the waste surface and burned in a concentrated area next to the door on the floor pan and floor mat. Approximately 12 minutes after ignition, fire climbed up the waste and burned at the back wall. At this time, all visibility in the lavatory was obscured.

Through the 30-minute test, there was no flame penetration of walls or ceiling. A small amount of smoke escaped through the passenger service access hole in the ceiling over the amenities cabinet. A larger amount of smoke and a few small flames escaped past the door hinge when the fire burned on the floor, distorting the door and leaving a gap between the door and the jamb.

Approximately 30 minutes after test termination, the door was opened and two deep-seated fires broke into renewed flaming with the new oxygen supply. The first one discovered was in waste still burning on the shroud in the cabinet and backwall corner. Several minutes were taken to carefully extinguish this fire with water fog without significantly disturbing the charred interior. Meanwhile, the second fire was allowed to burn unchecked in the waste compartment under the sink. This fire was then extinguished with water fog.

Figure 19 is an overall view of the lavatory after the test. All of the interior cabinet sandwich panels were charred and delaminated. Neither the lavatory walls nor the ceiling were penetrated by flames during the 30-minute test. The wall opposite the cabinets was distorted and bowed outward (see fig. 20). The bifold door suffered the most damage of all exterior panels (see fig. 21). The effect, relative to the extent of damage, of the observation windows cut in this door and the ventilation chute could not be determined.

The waste compartment door was destroyed by the fire (see fig. 22), permitting the waste inside to burn. When the oxygen supply was replenished by the opening of the lavatory door, it created a very hot fire after the test. This fire, before it was extinguished, charred and sooted the exterior of the wall behind the waste compartment (see fig. 2).

The door lintel, hanging from the CO_2 extinguisher plumbing, was in place until the

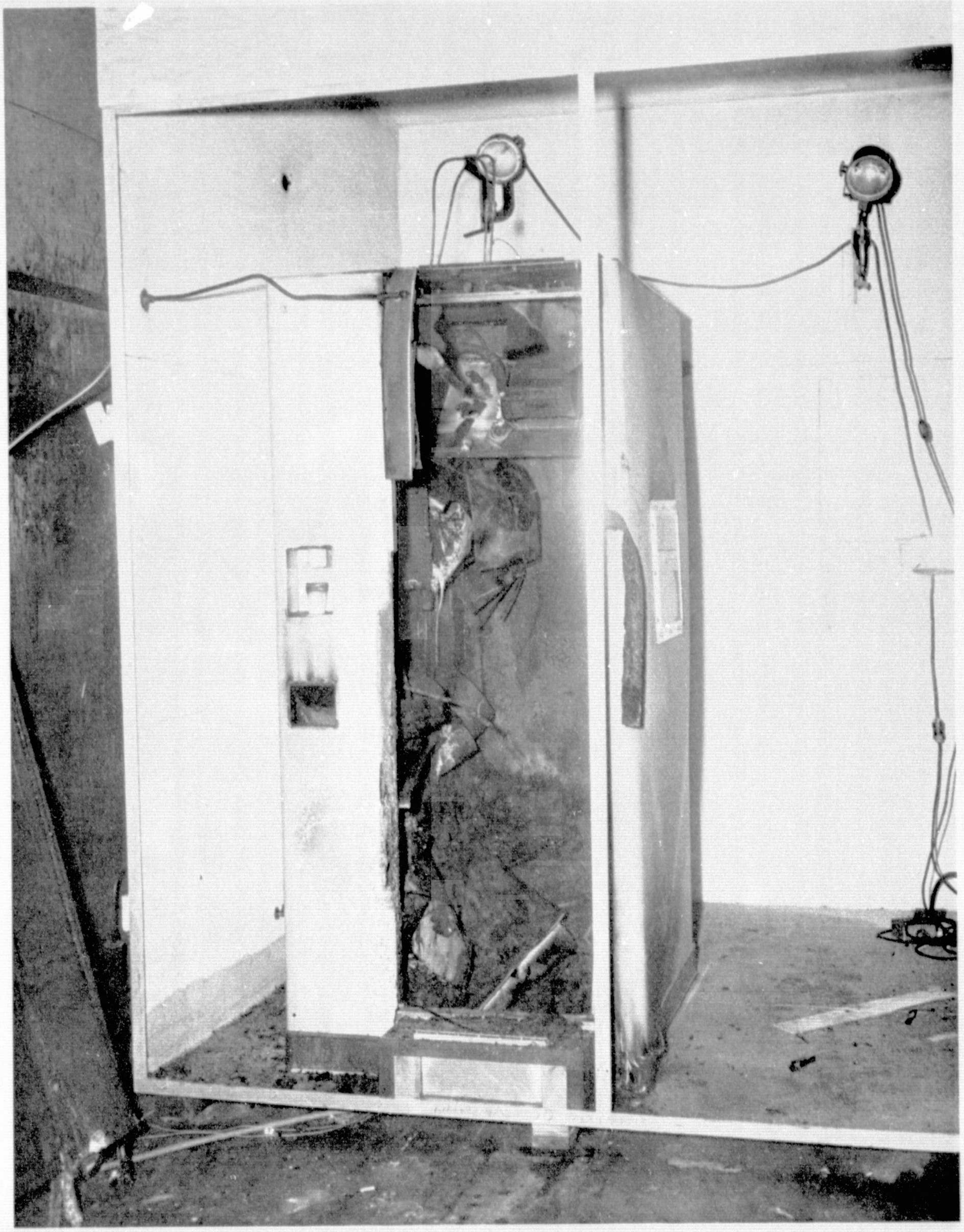


Figure 19.—Post-Test Overall View

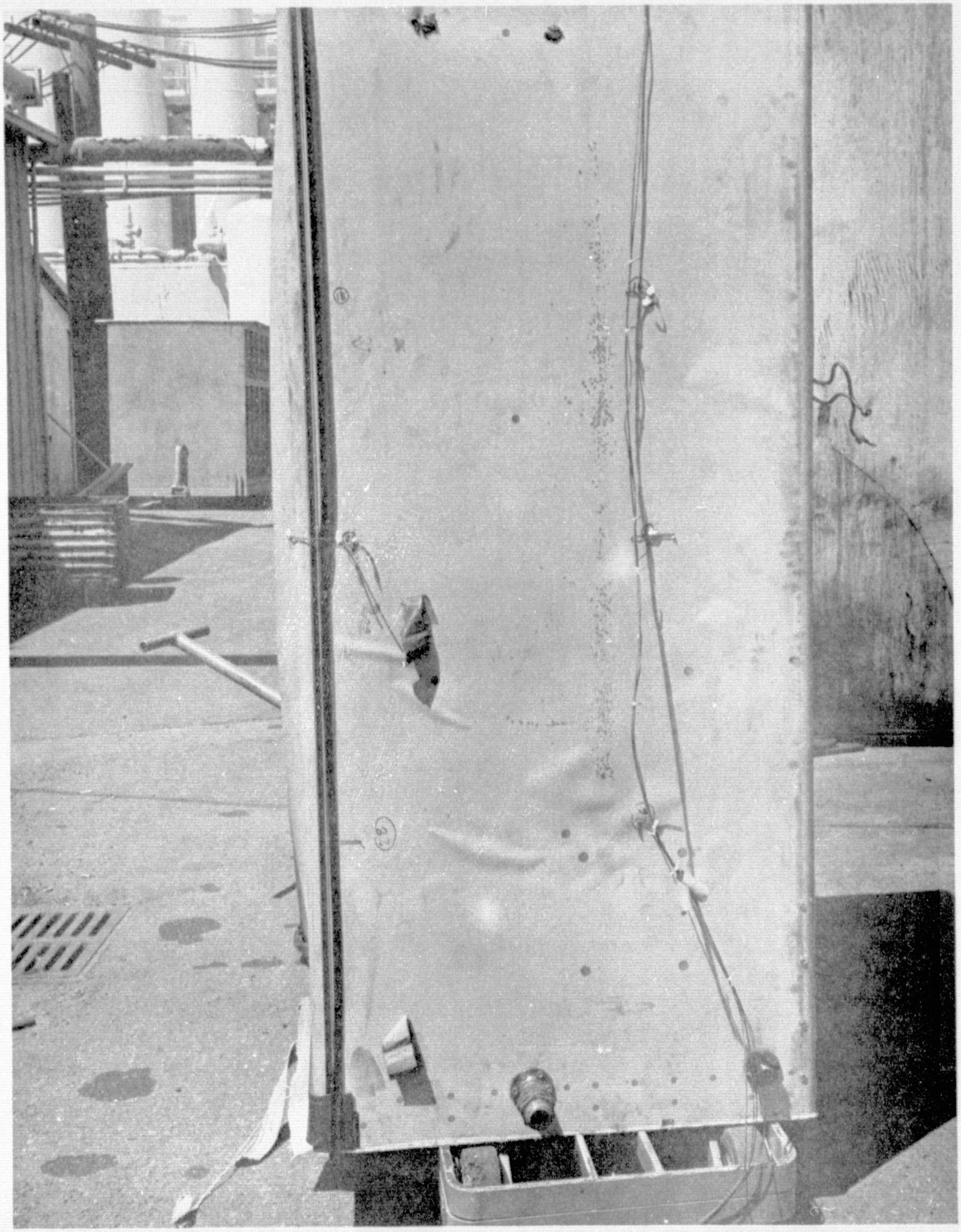


Figure 20.—Post-Test View—Lavatory Back Wall

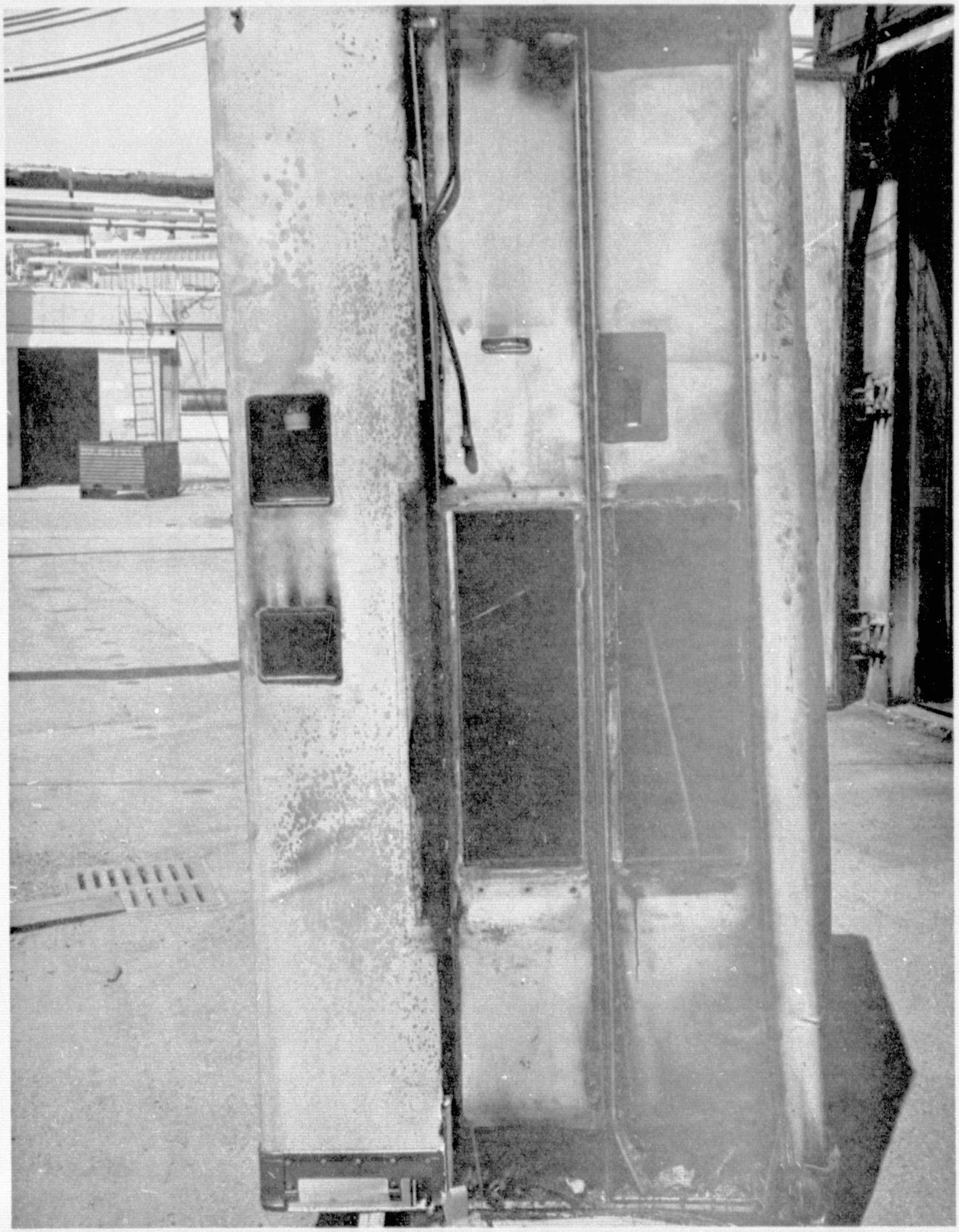


Figure 21.—Post-Test View—Front of Lavatory

Figure 22.—Post-Test View—Lavatory Cabinet

rapid CO_2 discharge at test termination wrenched it from the lavatory (see figs. 19 and 23). It also is probable that the CO_2 discharge stripped most of the glass fabric from the ceiling (shown hanging in fig. 23). The exterior skin of the ceiling shows no evidence of prolonged direct exposure to flames (see fig. 24).

5.2 THERMAL DATA

Table 2 contains the temperature history of all 30 thermocouples on the test lavatory during the 30-minute burn test. Figures 25 through 27 present a graphical representation of the readings of some of these thermocouples and depict maximum ceiling temperatures and the temperatures in the areas of the lavatory that received the greatest flame exposure. Figures 28 through 31 present a graphical representation of the total heat flux measurements recorded by the four calorimeters.

After the initial increase in temperature during the first 6 minutes, the ceiling temperature stabilized at 343-399°C (650-750°F). This shows that the rate of burning in the module was fairly constant as the result of a controlled ventilation rate. The thermocouple readings show how the fire developed during the late stages in the waste compartment, the shroud, and the corner between the cabinet and back wall. The maximum total heat flux was measured by the two calorimeters whose outputs are plotted in figures 28 and 30. The only air temperature recorded in the test enclosure was near the AETS cage (see fig. 32).

5.3 COMBUSTION PRODUCTS ANALYSIS

The fixed gases were analyzed by gas chromatography. Fluoride and chloride ion concentrations in the scrubbing solutions were determined by specific ion electrode analysis. Cyanide ion concentrations in the scrubbing solutions were measured colorimetrically (pyrazolone method). Concentrations of HF, HCN, HCl, and CO were also checked during the test using gas analysis tubes. Details of the gas analysis procedures are given in appendix B.

Figures 33 through 38 plot the results of the combustion products analysis. The maximum levels given for HCN and HF from the lavatory samples may actually be too low. The amount of HCl generated overwhelmed the buffering capacity of the absorbing solutions, which then became acidic. This may have decreased the scrubbing efficiency for HF and HCN.

The graphs of the atmospheric gases and toxicants appear consistent with the known fire progress. During the first 3 minutes, the vigorous waste fire depleted the oxygen in the lavatory and produced high concentrations of carbon dioxide and carbon monoxide. Toxicologically significant concentrations of HF and of HCl were produced in the lavatory by pyrolytic decomposition of the polyvinyl fluoride (PVF) decorative laminate covering the interior and of the polyvinyl chloride (PVC) floor mat, respectively. Due to the absence of hydrogen cyanide, it is probable that the fire had not yet involved the epoxy skins of the interior walls nor penetrated into the polyamide honeycomb core of the sidewall, door, and ceiling panels.

Table 2.— Lavatory Temperatures - °C (°F)

Test time, minutes	Thermocouples														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	35 (95)	35 (95)	30 (86)	33 (91)	37 (98)	36 (96)	42(107)	49(121)	42(108)	44(111)	37 (99)	35 (95)	36 (97)	35 (95)	35 (95)
0.25	42(107)	48(118)	31 (88)	43(109)	57(135)	36 (96)	42(107)	49(121)	42(108)	44(111)	131(267)	74(165)	132(269)	77(170)	82(179)
0.50	127(260)	136(276)	42(107)	121(249)	189(373)	36 (96)	42(108)	50(122)	43(109)	44(111)	367(692)	243(470)	393(740)	245(473)	291(556)
0.75	262(504)	263(505)	37 (98)	229(445)	254(490)	36 (96)	46(114)	50(122)	47(117)	44(111)	379(714)	309(588)	401(753)	301(574)	315(599)
1.00	234(454)	236(456)	38(101)	197(387)	216(421)	36 (97)	52(126)	50(122)	55(131)	44(111)	297(567)	244(471)	312(593)	246(475)	255(491)
1.25	204(400)	204(399)	44(111)	180(356)	214(417)	36 (97)	59(138)	51(123)	64(148)	44(112)	282(539)	228(443)	294(561)	230(446)	243(469)
1.50	199(391)	201(393)	49(121)	173(344)	203(397)	37 (98)	65(149)	51(123)	72(161)	44(112)	267(512)	219(426)	289(553)	218(424)	236(456)
1.75	198(388)	203(398)	53(128)	173(344)	208(407)	38(100)	71(160)	51(124)	78(173)	44(112)	310(590)	233(451)	323(614)	235(455)	258(497)
2.00	211(411)	214(417)	54(130)	182(359)	218(424)	94(201)	76(169)	52(125)	83(181)	44(112)	303(577)	238(461)	327(621)	235(455)	255(491)
2.25	218(424)	211(412)	58(137)	196(384)	225(437)	40(104)	81(178)	52(126)	87(189)	44(112)	314(598)	251(483)	349(660)	243(470)	266(511)
2.50	227(441)	226(438)	62(144)	205(401)	245(473)	41(106)	86(186)	53(127)	90(194)	45(113)	345(653)	274(526)	398(748)	277(531)	303(578)
2.75	238(461)	242(467)	61(141)	231(447)	276(528)	43(109)	89(192)	53(128)	93(199)	45(113)	343(650)	277(531)	371(700)	273(524)	301(573)
3.00	231(447)	241(466)	62(144)	237(459)	254(490)	45(113)	92(198)	54(129)	97(206)	46(114)	301(573)	272(521)	325(617)	277(530)	276(529)
3.25	234(454)	250(482)	63(145)	253(488)	248(478)	47(117)	95(203)	55(131)	102(215)	46(114)	301(574)	277(531)	343(650)	286(546)	280(536)
3.50	246(475)	252(485)	69(157)	252(485)	255(491)	49(120)	98(208)	56(133)	108(226)	46(115)	327(620)	284(544)	362(684)	296(564)	293(560)
3.75	256(493)	279(535)	67(152)	284(544)	270(518)	51(124)	103(217)	57(135)	113(236)	47(116)	353(667)	304(579)	261(501)	324(616)	317(602)
4.00	270(518)	278(532)	70(158)	278(532)	265(509)	53(128)	108(227)	58(137)	120(248)	47(117)	349(661)	305(581)	393(740)	315(599)	306(582)
4.25	267(513)	269(517)	72(162)	295(563)	276(529)	56(132)	114(237)	59(138)	127(260)	48(118)	318(605)	306(582)	379(715)	307(585)	314(597)
4.50	268(514)	269(516)	69(157)	296(564)	279(535)	57(135)	120(248)	60(140)	133(272)	48(119)	344(652)	298(569)	387(728)	308(587)	308(586)
4.75	271(520)	273(523)	73(163)	287(549)	276(529)	59(139)	126(258)	62(143)	140(284)	49(120)	339(643)	293(560)	368(695)	310(590)	297(567)
5.00	262(504)	279(535)	77(171)	289(552)	268(515)	62(143)	131(268)	63(145)	146(294)	49(121)	348(658)	304(580)	374(706)	312(594)	293(560)
5.25	259(499)	291(556)	81(178)	284(544)	268(515)	63(146)	137(278)	64(147)	152(305)	51(123)	350(662)	300(572)	389(733)	316(601)	295(563)
5.50	273(523)	282(539)	83(181)	287(548)	275(527)	66(150)	90(194)	64(148)	157(314)	51(124)	343(649)	297(566)	374(705)	304(580)	302(575)
5.75	277(530)	287(549)	86(187)	293(559)	282(540)	68(154)	148(298)	66(150)	162(323)	52(126)	349(661)	301(573)	383(722)	314(597)	315(599)
6.00	283(542)	283(542)	89(193)	298(568)	287(549)	69(157)	153(308)	67(152)	166(330)	53(127)	360(680)	304(579)	388(730)	318(604)	314(597)

Table 2.– (Continued)

Test time, minutes	Thermocouples														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0.00	35 (95)	37 (98)	38(101)	36 (97)	32 (90)	35 (95)	35 (95)	43(109)	33 (91)	32 (90)	30 (86)	34 (93)	31 (87)	48(118)	36 (96)
0.25	35 (95)	103(217)	38(101)	84(184)	32 (90)	94(202)	35 (95)	158(316)	47(116)	60(140)	30 (86)	69(156)	31 (87)	189(372)	36 (97)
0.50	36 (96)	304(579)	38(101)	249(480)	32 (90)	241(465)	35 (95)	333(631)	103(217)	126(258)	30 (86)	147(297)	31 (88)	384(723)	36 (97)
0.75	36 (96)	296(565)	39(102)	238(461)	33 (91)	228(442)	35 (95)	297(567)	105(221)	127(261)	30 (86)	137(278)	31 (88)	302(576)	37 (98)
1.00	36 (97)	246(474)	40(104)	217(423)	33 (91)	206(402)	36 (96)	263(505)	103(218)	126(258)	31 (87)	130(266)	31 (88)	267(512)	37 (98)
1.25	37 (99)	237(458)	41(106)	218(424)	33 (92)	201(394)	36 (97)	258(497)	109(229)	138(280)	31 (87)	126(258)	32 (89)	257(494)	37 (98)
1.50	39(102)	232(450)	42(108)	212(413)	34 (94)	201(393)	37 (98)	254(489)	114(238)	141(285)	31 (87)	126(259)	32 (89)	256(492)	37 (99)
1.75	41(105)	248(478)	44(112)	234(454)	36 (96)	216(420)	38(100)	281(538)	124(255)	154(310)	31 (88)	129(265)	32 (90)	270(518)	38(100)
2.00	42(108)	251(484)	47(116)	234(453)	37 (99)	213(415)	39(102)	275(527)	123(253)	156(312)	31 (88)	131(268)	33 (91)	274(526)	38(100)
2.25	45(113)	269(516)	49(120)	240(464)	39(102)	223(433)	41(105)	291(555)	123(254)	162(324)	32 (89)	136(276)	33 (92)	298(569)	38(100)
2.50	47(117)	304(580)	51(124)	280(536)	149(301)	248(479)	42(108)	326(619)	133(272)	184(363)	32 (90)	136(277)	34 (93)	329(625)	38(101)
2.75	50(122)	298(568)	54(129)	259(499)	43(110)	248(479)	44(112)	290(554)	129(264)	175(347)	33 (91)	137(278)	34 (94)	309(589)	38(101)
3.00	53(127)	285(545)	57(134)	243(469)	46(114)	243(470)	47(116)	279(535)	124(255)	171(340)	33 (92)	138(281)	35 (95)	309(589)	39(102)
3.25	56(132)	285(545)	60(140)	239(463)	48(118)	244(471)	49(120)	293(559)	130(266)	174(346)	34 (93)	142(287)	36 (97)	32[illegible](616)	39(103)
3.50	58(137)	301(573)	63(145)	257(494)	50(122)	260(500)	52(125)	303(577)	130(266)	182(360)	35 (95)	141(286)	37 (98)	343(650)	39(103)
3.75	61(141)	321(609)	65(149)	263(506)	52(126)	269(516)	54(129)	324(616)	131(268)	187(369)	36 (96)	142(287)	38(100)	343(650)	40(104)
4.00	63(146)	303(577)	67(153)	266(511)	54(130)	262(504)	56(133)	316(600)	137(279)	189(373)	37 (98)	142(287)	39(102)	347(656)	41(105)
4.25	65(149)	317(602)	69(157)	278(533)	57(134)	272(521)	58(137)	314(597)	140(284)	193(379)	38(100)	147(296)	39(103)	347(656)	41(106)
4.50	123(253)	318(604)	72(161)	261(501)	59(138)	271(519)	61(141)	317(602)	159(318)	152(378)	39(102)	148(298)	41(105)	343(649)	42(107)
4.75	69(157)	306(582)	74(165)	257(494)	61(141)	272(521)	63(145)	303(577)	165(329)	184(364)	40(104)	159(318)	42(107)	339(642)	42(108)
5.00	72(161)	305(581)	76(169)	257(495)	62(144)	271(519)	64(148)	299(571)	169(336)	182(360)	41(106)	162(324)	43(109)	333(632)	43(109)
5.25	74(165)	305(581)	78(173)	262(503)	64(147)	271(520)	67(152)	310(590)	168(335)	184(364)	43(109)	161(321)	43(110)	338(641)	43(110)
5.50	76(168)	304(580)	80(176)	268(514)	65(149)	273(523)	68(155)	312(593)	163(326)	189(372)	44(111)	159(319)	44(112)	334(633)	44(111)
5.75	78(172)	317(603)	82(179)	272(522)	67(152)	283(542)	71(159)	328(623)	162(323)	194(381)	45(113)	165(329)	46(114)	341(646)	44(112)
6.00	79(175)	319(606)	83(181)	274(526)	68(154)	286(547)	72(161)	328(622)	161(322)	195(383)	46(115)	168(334)	47(116)	339(643)	44(112)

Table 2. — (Continued)

Test time, minutes	Thermocouples														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6.25	282(540)	292(558)	94(201)	297(567)	282(539)	71(160)	158(317)	68(154)	169(336)	54(129)	360(680)	306(582)	384(724)	317(603)	313(596)
6.50	285(545)	289(553)	101(213)	298(569)	287(549)	73(163)	163(325)	69(156)	171(339)	55(131)	363(686)	306(582)	387(729)	318(605)	312(593)
6.75	288(550)	294(561)	107(225)	300(572)	286(547)	74(165)	167(332)	70(158)	172(341)	56(132)	363(685)	311(591)	386(726)	319(607)	315(599)
7.00	291(555)	295(563)	116(240)	299(571)	287(548)	76(168)	169(337)	71(160)	173(343)	57(134)	370(698)	309(588)	391(736)	320(608)	314(598)
7.25	291(556)	292(558)	119(247)	300(572)	288(551)	77(170)	172(342)	72(162)	175(347)	58(136)	368(694)	308(587)	384(724)	318(604)	316(600)
7.50	289(553)	295(563)	122(251)	299(570)	288(550)	78(173)	175(347)	73(164)	176(348)	59(138)	364(688)	311(591)	382(719)	322(612)	314(597)
7.75	288(550)	299(571)	123(254)	301(574)	291(555)	79(175)	177(350)	74(166)	177(351)	59(139)	361(682)	312(593)	379(715)	322(612)	313(596)
8.00	290(554)	299(570)	125(257)	304(579)	293(560)	81(177)	178(352)	76(169)	179(354)	61(141)	359(679)	313(596)	374(705)	323(613)	316(600)
8.25	291(555)	299(571)	128(262)	313(595)	298(568)	82(179)	179(354)	77(171)	179(355)	62(143)	361(682)	318(604)	377(711)	325(617)	323(613)
8.50	293(559)	303(577)	129(264)	323(613)	303(577)	83(181)	179(355)	78(173)	180(356)	63(145)	367(693)	319(606)	386(727)	331(627)	326(618)
8.75	299(570)	305(581)	129(264)	327(620)	302(576)	84(183)	181(357)	80(176)	181(357)	64(147)	368(694)	319(606)	383(722)	332(630)	325(617)
9.00	299(570)	306(583)	132(269)	331(627)	303(578)	85(185)	181(358)	81(178)	182(359)	64(148)	370(698)	322(612)	388(730)	332(630)	328(623)
9.25	295(563)	311(592)	134(274)	334(633)	306(582)	86(187)	181(358)	82(180)	182(360)	66(150)	370(698)	328(622)	383(722)	336(636)	324(616)
9.50	296(565)	316(600)	138(281)	339(643)	308(587)	87(188)	181(358)	83(182)	183(361)	67(152)	369(697)	323(614)	384(723)	335(635)	326(618)
9.75	297(567)	315(599)	140(284)	340(644)	310(590)	87(189)	182(359)	84(184)	183(362)	68(154)	367(693)	326(619)	384(723)	337(638)	327(620)
10.00	298(569)	316(600)	139(283)	344(652)	311(592)	87(189)	184(363)	86(186)	185(365)	68(155)	366(690)	331(627)	384(723)	339(642)	331(628)
10.25	299(571)	316(601)	144(292)	347(657)	313(595)	88(190)	184(364)	87(188)	186(366)	69(157)	368(694)	327(620)	381(718)	336(637)	331(627)
10.50	303(577)	316(601)	148(298)	352(665)	313(595)	88(190)	185(365)	88(190)	187(368)	71(159)	365(689)	334(630)	376(708)	341(646)	333(631)
10.75	302(575)	171(339)	150(302)	351(664)	316(600)	88(191)	186(367)	89(192)	187(369)	72(161)	365(689)	339(642)	377(711)	351(663)	333(631)
11.00	306(582)	173(343)	157(315)	352(665)	321(609)	89(193)	187(368)	90(194)	188(370)	73(163)	369(697)	342(648)	382(720)	356(672)	336(637)
11.25	308(586)	174(345)	168(334)	354(669)	323(613)	90(194)	188(370)	91(195)	188(371)	74(165)	370(698)	344(652)	384(724)	354(670)	337(639)
11.50	309(589)	174(346)	180(356)	357(675)	322(612)	91(195)	188(371)	92(197)	189(372)	75(167)	371(700)	347(656)	386(726)	357(675)	340(644)
11.75	166(331)	338(641)	191(376)	361(681)	323(614)	92(197)	189(372)	93(199)	190(374)	76(168)	375(707)	346(654)	391(735)	356(672)	341(646)
12.00	314(598)	337(638)	197(387)	363(685)	326(619)	93(199)	190(374)	93(200)	191(376)	77(170)	377(710)	346(655)	389(733)	355(671)	343(649)

Table 2. – (Continued)

Test time, minutes	Thermocouples														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
6.25	81(178)	317(602)	84(184)	276(529)	69(156)	286(547)	74(165)	326(619)	162(323)	195(383)	47(116)	169(337)	48(118)	342(648)	46(114)
6.50	82(180)	318(604)	86(186)	277(530)	70(158)	288(551)	76(168)	324(616)	161(321)	196(385)	47(117)	172(342)	49(120)	343(650)	46(115)
6.75	84(183)	318(604)	87(188)	279(535)	71(159)	290(554)	77(171)	326(618)	165(329)	197(387)	48(119)	180(356)	50(122)	343(650)	47(116)
7.00	85(185)	318(605)	87(189)	278(533)	72(161)	288(551)	79(174)	327(620)	159(318)	198(388)	49(120)	183(362)	51(124)	346(654)	47(117)
7.25	87(188)	320(608)	88(191)	282(540)	73(163)	292(557)	81(177)	329(624)	161(322)	198(389)	50(122)	183(361)	52(126)	342(647)	48(118)
7.50	88(190)	320(608)	89(193)	284(544)	74(165)	292(558)	82(180)	323(614)	161(322)	202(396)	51(124)	184(363)	54(129)	343(649)	48(119)
7.75	89(192)	322(612)	90(194)	285(545)	74(166)	293(560)	83(182)	323(613)	164(327)	204(400)	52(125)	187(368)	55(131)	344(651)	49(120)
8.00	89(193)	321(610)	91(195)	291(555)	76(168)	297(566)	84(183)	324(615)	170(338)	206(402)	53(127)	189(372)	56(133)	346(655)	49(121)
8.25	91(195)	328(622)	92(197)	297(567)	76(169)	304(580)	85(185)	331(628)	175(347)	208(406)	54(129)	184(363)	57(135)	351(664)	51(123)
8.50	91(196)	332(629)	92(198)	303(578)	77(171)	307(585)	86(187)	333(632)	183(361)	212(413)	54(130)	182(359)	58(137)	353(667)	51(124)
8.75	92(197)	331(627)	93(200)	301(574)	78(172)	307(584)	87(188)	333(632)	189(372)	213(415)	56(132)	183(362)	59(139)	353(668)	52(125)
9.00	92(198)	334(633)	94(202)	303(577)	79(174)	307(585)	87(189)	334(633)	192(377)	213(416)	57(134)	183(362)	61(141)	371(699)	52(126)
9.25	93(199)	333(631)	96(204)	304(579)	79(175)	311(592)	87(189)	334(633)	196(384)	216(421)	58(136)	186(366)	62(143)	354(669)	53(127)
9.50	93(200)	333(632)	97(206)	307(584)	81(177)	309(589)	88(190)	333(632)	199(390)	218(424)	58(137)	187(369)	63(145)	354(670)	53(128)
9.75	94(201)	334(633)	98(208)	308(587)	81(178)	312(594)	88(191)	334(634)	202(396)	219(427)	59(139)	189(373)	64(147)	354(669)	54(129)
10.00	94(202)	337(638)	100(212)	312(594)	82(179)	313(596)	89(192)	338(640)	206(402)	219(427)	61(141)	190(374)	64(148)	357(674)	54(130)
10.25	95(203)	337(639)	102(216)	312(593)	82(180)	317(603)	89(193)	340(644)	212(413)	221(430)	61(142)	191(375)	66(150)	356(673)	55(131)
10.50	96(205)	338(641)	106(222)	310(590)	83(181)	317(602)	90(194)	341(645)	201(394)	202(395)	62(144)	192(377)	67(152)	366(691)	56(132)
10.75	97(207)	340(644)	108(227)	311(592)	83(182)	321(610)	91(195)	343(649)	198(389)	199(391)	63(146)	194(381)	67(153)	368(695)	56(133)
11.00	98(209)	342(648)	111(231)	314(598)	84(184)	323(613)	91(195)	345(653)	200(392)	199(391)	64(147)	196(384)	68(155)	370(698)	57(134)
11.25	100(212)	343(650)	112(234)	318(605)	85(185)	325(617)	91(196)	347(656)	207(404)	198(388)	64(148)	198(389)	69(156)	371(699)	57(135)
11.50	102(216)	347(656)	114(238)	319(607)	86(187)	324(615)	92(198)	349(660)	208(407)	196(384)	66(150)	202(395)	70(158)	371(700)	58(136)
11.75	104(220)	347(656)	116(241)	322(611)	87(188)	327(621)	93(200)	351(663)	216(421)	196(385)	66(151)	206(402)	71(159)	374(705)	58(137)
12.00	107(224)	349(661)	118(244)	326(619)	88(190)	329(625)	94(201)	352(666)	217(423)	198(388)	67(153)	208(407)	71(160)	375(707)	59(138)

Table 2. – (Continued)

Test time, minutes	Thermocouples														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12.25	314(598)	336(636)	201(393)	366(690)	329(624)	94(201)	191(375)	94(202)	192(378)	78(172)	379(715)	351(663)	391(736)	359(678)	344(652)
12.50	314(598)	331(628)	202(395)	368(694)	331(628)	96(204)	192(377)	95(203)	193(380)	79(174)	381(717)	348(659)	396(745)	357(674)	347(657)
12.75	315(599)	329(625)	206(403)	371(699)	332(630)	97(207)	193(380)	96(204)	194(382)	80(176)	383(721)	351(663)	395(743)	355(671)	348(659)
13.00	316(601)	336(636)	209(408)	372(702)	336(636)	99(211)	195(383)	97(206)	196(384)	81(178)	385(725)	352(665)	398(749)	354(670)	350(662)
13.25	317(603)	337(638)	211(411)	374(706)	339(643)	101(214)	197(386)	98(208)	196(385)	82(180)	386(726)	354(669)	398(749)	358(676)	352(665)
13.50	320(608)	338(641)	212(413)	374(706)	339(642)	103(217)	198(388)	98(209)	198(388)	83(181)	384(724)	354(669)	396(745)	359(679)	351(664)
13.75	323(613)	342(648)	211(411)	375(707)	340(644)	105(221)	199(391)	99(211)	199(390)	84(183)	386(726)	356(672)	400(752)	360(680)	354(669)
14.00	326(618)	344(651)	211(411)	377(711)	344(652)	107(224)	201(393)	100(212)	201(393)	85(185)	387(729)	358(677)	399(750)	365(689)	356(673)
14.25	327(621)	348(659)	209(409)	379(714)	347(657)	108(227)	202(396)	101(214)	202(396)	86(187)	392(737)	354(670)	402(755)	362(684)	357(674)
14.50	326(619)	345(653)	208(406)	380(716)	351(663)	109(229)	204(399)	102(215)	203(398)	87(189)	392(737)	358(676)	401(753)	363(686)	358(677)
14.75	328(622)	348(659)	208(407)	381(717)	354(669)	111(232)	206(402)	103(217)	204(399)	88(191)	389(733)	345(653)	401(754)	355(671)	356(673)
15.00	323(614)	349(661)	205(401)	378(712)	354(669)	113(235)	206(403)	104(219)	205(401)	89(192)	387(729)	334(633)	401(753)	349(661)	352(665)
15.25	323(614)	348(659)	207(404)	378(713)	356(672)	114(238)	207(405)	105(221)	206(403)	90(194)	384(724)	333(631)	397(746)	347(657)	349(660)
15.50	319(607)	350(662)	207(405)	379(714)	353(668)	116(241)	208(407)	106(222)	206(403)	91(196)	386(727)	329(624)	396(744)	347(657)	349(661)
15.75	324(616)	351(663)	207(404)	383(722)	356(672)	117(243)	208(407)	107(224)	207(404)	92(198)	390(734)	332(630)	400(752)	348(658)	351(664)
16.00	328(622)	352(666)	206(403)	386(726)	354(669)	119(246)	209(408)	108(226)	208(406)	93(200)	393(739)	336(636)	403(758)	351(664)	354(670)
16.25	330(626)	353(668)	208(407)	387(728)	358(676)	121(249)	209(409)	108(227)	208(407)	94(202)	394(742)	336(636)	405(761)	351(663)	356(672)
16.50	331(627)	355(671)	212(414)	388(730)	357(675)	122(252)	210(410)	109(229)	209(409)	96(204)	398(748)	339(642)	406(763)	355(671)	358(677)
16.75	333(631)	357(675)	211(411)	390(734)	356(672)	123(254)	211(412)	111(231)	211(411)	97(206)	398(749)	335(635)	407(764)	353(667)	359(679)
17.00	335(635)	357(675)	208(406)	391(735)	354(669)	125(257)	213(415)	111(232)	212(413)	98(208)	401(753)	336(636)	409(769)	353(668)	357(674)
17.25	337(638)	362(683)	208(406)	392(738)	353(668)	127(260)	213(416)	112(234)	212(414)	98(209)	402(755)	340(644)	409(769)	354(669)	357(675)
17.50	336(636)	365(689)	207(405)	394(741)	353(668)	128(262)	214(418)	113(236)	213(416)	99(211)	400(752)	340(644)	410(770)	355(671)	358(677)
17.75	339(643)	364(688)	208(406)	396(745)	353(667)	129(264)	216(420)	114(237)	214(418)	100(212)	402(756)	344(651)	407(765)	356(673)	364(687)
18.00	344(651)	361(682)	245(473)	397(746)	352(665)	130(266)	216(421)	115(239)	216(420)	101(214)	402(755)	347(656)	404(760)	356(673)	366(690)

Table 2. – (Continued)

Test time, minutes	Thermocouples														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
12.25	108(227)	352(665)	118(245)	329(624)	89(193)	332(629)	96(204)	353(668)	218(424)	199(391)	68(154)	210(410)	72(162)	376(708)	59(139)
12.50	111(231)	353(667)	119(247)	328(622)	91(195)	333(631)	97(207)	355(671)	220(428)	201(394)	68(155)	211(412)	73(163)	377(711)	61(141)
12.75	112(234)	355(671)	121(250)	331(627)	92(198)	334(634)	99(211)	357(674)	222(432)	203(397)	69(156)	213(415)	74(165)	381(717)	61(142)
13.00	114(237)	358(677)	123(253)	335(635)	94(201)	339(643)	102(216)	359(679)	223(434)	202(396)	70(158)	218(424)	74(166)	382(720)	62(143)
13.25	116(240)	360(680)	124(256)	336(636)	96(204)	340(644)	104(219)	359(679)	226(438)	203(397)	71(159)	220(428)	75(167)	383(722)	62(144)
13.50	117(243)	359(679)	126(258)	336(637)	97(207)	340(644)	107(224)	361(682)	228(443)	203(398)	71(160)	223(433)	76(169)	385(725)	63(145)
13.75	119(246)	361(682)	127(261)	338(641)	98(209)	343(649)	108(227)	362(684)	232(450)	204(399)	72(161)	226(439)	77(170)	385(725)	63(146)
14.00	120(248)	362(684)	128(263)	341(646)	100(212)	345(653)	109(229)	364(687)	237(458)	205(401)	73(163)	229(445)	77(171)	387(728)	64(147)
14.25	122(251)	363(686)	130(266)	343(649)	102(215)	348(659)	112(233)	364(688)	242(467)	207(404)	73(164)	234(454)	78(172)	388(730)	65(149)
14.50	123(254)	365(689)	131(268)	345(653)	103(217)	355(671)	113(236)	367(693)	248(479)	208(406)	74(165)	239(462)	79(174)	389(732)	66(150)
14.75	124(256)	366(691)	133(271)	343(649)	104(220)	356(672)	115(239)	359(678)	257(494)	208(407)	74(166)	241(465)	79(175)	386(726)	66(151)
15.00	126(258)	365(689)	134(273)	343(650)	106(222)	357(674)	117(242)	357(674)	266(511)	209(409)	75(167)	246(474)	81(177)	385(725)	67(152)
15.25	127(261)	363(686)	134(274)	341(646)	107(225)	355(671)	118(245)	356(673)	276(528)	211(412)	76(168)	247(477)	81(178)	383(722)	67(153)
15.50	128(263)	364(688)	136(276)	342(647)	108(227)	358(677)	119(247)	357(675)	291(555)	213(415)	76(169)	253(488)	82(179)	386(727)	68(154)
15.75	130(266)	367(693)	137(278)	344(651)	110(230)	361(682)	121(250)	361(681)	303(578)	214(418)	77(170)	256(493)	83(181)	389(733)	69(156)
16.00	131(267)	368(695)	138(281)	345(653)	111(232)	361(682)	123(253)	363(685)	315(599)	215(419)	77(171)	262(504)	83(182)	392(737)	69(157)
16.25	132(269)	369(697)	139(283)	346(654)	112(234)	358(677)	124(255)	365(689)	337(638)	214(417)	78(172)	261(502)	84(184)	394(741)	70(158)
16.50	133(271)	372(702)	141(286)	346(654)	114(237)	358(677)	125(257)	369(696)	333(631)	213(416)	78(172)	268(514)	85(185)	398(748)	71(159)
16.75	134(273)	372(702)	142(288)	345(653)	115(239)	357(674)	127(260)	369(697)	334(634)	214(417)	78(172)	272(522)	86(187)	397(746)	71(160)
17.00	134(274)	374(705)	143(290)	341(645)	116(241)	352(665)	128(262)	371(699)	328(623)	215(419)	78(173)	274(526)	87(189)	395(743)	72(162)
17.25	136(276)	374(706)	144(292)	343(650)	117(243)	352(665)	129(264)	370(698)	331(627)	219(427)	79(174)	284(543)	88(190)	397(746)	73(163)
17.50	137(278)	374(706)	146(295)	349(661)	118(245)	352(666)	130(266)	372(701)	337(638)	226(439)	79(174)	283(542)	89(192)	396(744)	73(164)
17.75	138(280)	376(708)	147(297)	361(681)	119(247)	353(667)	131(268)	375(707)	365(689)	232(450)	79(175)	279(535)	89(193)	396(744)	74(165)
18.00	139(283)	375(707)	148(299)	364(688)	121(249)	353(668)	132(270)	377(710)	361(681)	238(460)	80(176)	277(531)	91(195)	394(742)	74(166)

Table 2. — (Continued)

Test time, minutes	Thermocouples														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
18.25	342(648)	359(678)	255(491)	395(743)	352(665)	131(268)	217(423)	116(241)	216(420)	102(216)	401(754)	347(656)	406(762)	356(672)	365(689)
18.50	342(648)	362(684)	264(508)	396(744)	351(664)	132(270)	217(423)	117(243)	216(421)	103(218)	399(751)	347(656)	405(761)	356(672)	366(690)
18.75	343(650)	359(679)	272(521)	396(744)	351(663)	133(272)	218(425)	118(245)	216(421)	104(220)	396(744)	344(652)	403(758)	354(670)	363(685)
19.00	335(635)	355(671)	267(513)	391(735)	348(659)	134(274)	218(425)	119(247)	217(422)	106(222)	385(725)	340(644)	392(737)	353(668)	354(670)
19.25	329(624)	348(658)	273(524)	392(737)	346(655)	136(276)	218(425)	121(249)	216(421)	107(224)	379(714)	336(636)	387(729)	350(662)	351(664)
19.50	325(617)	342(647)	282(539)	384(724)	343(650)	136(277)	218(424)	122(251)	216(420)	108(226)	375(707)	333(632)	384(723)	347(656)	349(661)
19.75	323(613)	336(637)	283(541)	383(722)	342(648)	137(279)	217(422)	123(253)	214(418)	108(227)	372(702)	331(628)	382(719)	343(650)	347(656)
20.00	319(606)	336(636)	291(555)	384(723)	341(646)	138(280)	216(420)	124(255)	213(416)	109(229)	372(702)	328(623)	380(716)	341(646)	344(652)
20.25	317(602)	337(639)	288(551)	387(729)	339(642)	139(282)	214(418)	124(256)	212(413)	111(231)	372(702)	326(619)	381(718)	339(643)	343(650)
20.50	314(597)	336(636)	285(545)	392(737)	339(642)	139(283)	213(415)	126(258)	211(412)	112(233)	373(703)	324(616)	381(717)	338(640)	341(646)
20.75	314(597)	339(642)	284(544)	395(743)	338(641)	140(284)	212(414)	126(259)	210(410)	113(235)	374(706)	323(614)	384(723)	338(640)	341(646)
21.00	313(596)	336(636)	284(544)	401(754)	339(643)	141(285)	212(413)	127(261)	209(409)	114(237)	376(709)	323(613)	386(726)	338(640)	344(651)
21.25	311(591)	337(638)	284(544)	403(757)	339(642)	141(286)	211(412)	128(262)	210(410)	114(238)	376(708)	322(612)	387(728)	337(638)	343(649)
21.50	311(592)	337(638)	284(543)	407(764)	339(642)	142(287)	211(411)	129(264)	210(410)	116(240)	375(707)	321(610)	385(725)	337(638)	343(649)
21.75	310(590)	338(641)	286(547)	410(770)	339(642)	142(287)	211(411)	129(265)	210(410)	116(241)	375(707)	321(610)	385(725)	337(638)	343(649)
22.00	309(589)	339(642)	287(549)	414(777)	338(641)	142(288)	211(411)	130(266)	209(409)	117(243)	375(707)	321(609)	384(724)	336(637)	344(651)
22.25	309(588)	341(646)	291(556)	414(777)	340(644)	143(289)	211(411)	130(266)	210(410)	118(244)	376(708)	321(609)	384(723)	336(637)	343(650)
22.50	309(588)	339(643)	289(553)	417(783)	339(643)	143(289)	210(410)	131(267)	211(411)	119(246)	375(707)	320(608)	296(565)	336(636)	344(652)
22.75	310(590)	336(636)	289(553)	418(784)	340(644)	143(290)	210(410)	131(268)	211(411)	119(247)	373(703)	320(608)	384(724)	336(636)	344(651)
23.00	307(585)	338(640)	290(554)	420(788)	339(643)	143(290)	211(411)	132(269)	211(412)	120(248)	373(704)	320(608)	384(724)	336(636)	344(651)
23.25	310(590)	337(638)	289(553)	423(793)	339(643)	143(290)	210(410)	132(270)	211(412)	121(250)	371(699)	320(608)	381(718)	335(635)	343(649)
23.50	309(589)	338(641)	289(553)	427(801)	341(646)	144(291)	210(410)	133(271)	211(412)	122(251)	371(700)	321(610)	382(719)	334(633)	347(656)
23.75	311(592)	337(638)	294(561)	434(813)	344(651)	144(291)	210(410)	133(271)	211(412)	122(252)	367(693)	321(609)	378(712)	333(632)	344(651)
24.00	309(588)	337(639)	293(560)	429(805)	341(645)	144(291)	210(410)	133(272)	211(412)	123(253)	368(695)	319(607)	378(713)	334(633)	343(650)

Table 2. — (Continued)

Test time, minutes	Thermocouples														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
18.25	141(285)	374(706)	150(302)	364(688)	122(251)	353(667)	133(272)	374(706)	356(672)	242(468)	81(177)	287(548)	91(195)	394(741)	76(168)
18.50	142(287)	374(705)	151(304)	367(692)	123(253)	353(668)	134(273)	372(702)	366(691)	247(477)	81(178)	297(566)	91(195)	392(737)	76(168)
18.75	143(290)	371(700)	152(306)	361(682)	123(254)	352(666)	135(275)	371(700)	367(692)	251(484)	82(179)	304(579)	91(195)	387(728)	77(170)
19.00	144(292)	366(690)	153(307)	351(664)	124(256)	349(661)	136(277)	361(682)	357(675)	259(498)	82(180)	303(577)	92(197)	381(717)	77(170)
19.25	146(294)	361(682)	153(308)	348(658)	126(258)	346(655)	137(278)	359(679)	352(665)	255(491)	83(181)	306(582)	92(198)	377(710)	78(172)
19.50	147(296)	357(675)	154(309)	346(654)	127(260)	343(650)	138(280)	356(673)	354(669)	259(498)	83(182)	308(586)	93(199)	373(704)	78(173)
19.75	147(297)	357(675)	154(310)	343(650)	127(261)	343(649)	138(281)	353(667)	353(667)	264(508)	84(184)	310(590)	92(198)	371(700)	79(174)
20.00	148(299)	355(671)	155(311)	342(647)	128(263)	342(647)	139(282)	351(663)	357(675)	272(522)	85(185)	312(594)	93(199)	369(697)	79(175)
20.25	149(301)	354(669)	156(312)	341(645)	129(265)	339(643)	140(284)	349(661)	361(682)	282(540)	86(186)	314(597)	93(200)	368(695)	80(176)
20.50	150(302)	354(669)	156(313)	340(644)	130(266)	340(644)	140(284)	347(656)	364(687)	296(564)	86(187)	316(600)	94(202)	370(698)	80(176)
20.75	151(303)	355(671)	156(313)	340(644)	131(268)	341(645)	141(285)	348(658)	369(696)	309(589)	87(189)	317(602)	96(204)	372(702)	81(178)
21.00	151(304)	356(673)	157(314)	341(646)	132(269)	341(646)	142(287)	351(664)	373(704)	321(610)	88(190)	319(606)	97(207)	371(699)	82(179)
21.25	152(305)	354(670)	157(314)	342(647)	132(270)	340(644)	142(287)	352(665)	383(721)	330(626)	89(192)	321(610)	99(211)	371(700)	82(180)
21.50	152(306)	355(671)	157(314)	342(648)	133(272)	341(646)	142(288)	351(664)	382(720)	336(637)	89(193)	321(610)	101(214)	371(700)	82(180)
21.75	153(307)	356(673)	157(314)	342(647)	134(273)	342(647)	142(288)	352(665)	385(725)	342(647)	91(195)	322(612)	103(218)	371(699)	83(181)
22.00	153(308)	354(669)	157(314)	342(647)	134(274)	341(645)	143(289)	352(666)	389(733)	346(654)	92(197)	323(613)	105(221)	371(699)	83(181)
22.25	153(308)	354(670)	157(314)	343(649)	135(275)	341(646)	143(289)	352(665)	393(739)	349(660)	92(198)	323(613)	107(224)	370(698)	83(182)
22.50	154(309)	354(670)	157(314)	343(649)	136(276)	342(648)	143(290)	354(669)	393(740)	352(666)	93(200)	323(614)	108(227)	371(700)	83(182)
22.75	154(310)	354(669)	157(314)	343(649)	136(277)	342(647)	143(290)	353(667)	397(746)	356(672)	94(202)	324(615)	110(230)	370(698)	84(183)
23.00	155(311)	353(667)	157(314)	342(648)	137(278)	341(646)	144(291)	353(667)	398(749)	357(674)	96(204)	323(614)	111(232)	369(697)	84(184)
23.25	155(311)	354(669)	157(314)	342(647)	137(279)	342(648)	144(291)	351(664)	410(770)	359(678)	97(206)	323(614)	113(235)	368(695)	84(184)
23.50	156(312)	355(671)	157(315)	345(653)	138(280)	344(652)	144(291)	351(663)	411(771)	361(682)	98(208)	323(614)	114(237)	370(698)	85(185)
23.75	156(313)	354(670)	157(315)	343(650)	138(281)	342(648)	144(292)	349(661)	416(781)	364(688)	99(210)	323(613)	115(239)	369(696)	85(185)
24.00	156(313)	354(669)	157(315)	343(650)	139(282)	342(647)	144(292)	348(659)	423(794)	367(692)	100(212)	324(615)	117(242)	368(694)	86(187)

Table 2. – (Continued)

Test time, minutes	Thermocouples														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
24.25	310(590)	336(637)	295(563)	438(821)	341(646)	144(292)	210(410)	133(272)	211(412)	123(254)	366(691)	319(606)	374(705)	334(633)	341(646)
24.50	307(584)	336(636)	295(563)	431(807)	339(642)	144(292)	210(410)	134(273)	211(412)	124(255)	363(686)	318(605)	374(706)	333(632)	339(643)
24.75	309(588)	334(634)	297(567)	433(812)	338(641)	145(293)	210(410)	134(274)	211(412)	124(256)	366(690)	317(603)	374(706)	333(631)	339(642)
25.00	309(589)	335(635)	301(574)	431(808)	337(638)	145(293)	209(409)	134(274)	211(412)	126(258)	364(687)	317(602)	372(702)	333(631)	338(641)
25.25	308(587)	336(637)	304(580)	430(806)	336(637)	145(293)	209(408)	134(274)	211(411)	126(258)	362(683)	317(602)	371(700)	332(630)	337(638)
25.50	307(585)	333(632)	305(581)	438(820)	337(639)	145(293)	209(408)	135(275)	210(410)	126(259)	360(680)	316(600)	371(700)	332(629)	336(637)
25.75	306(582)	331(628)	304(580)	428(802)	334(633)	146(294)	208(407)	136(276)	209(409)	127(260)	356(672)	315(599)	365(689)	330(626)	336(636)
26.00	304(579)	322(612)	306(582)	411(772)	329(625)	146(294)	208(407)	136(276)	209(408)	127(261)	344(652)	314(598)	352(666)	326(618)	329(625)
26.25	301(574)	316(601)	303(578)	393(739)	324(616)	146(294)	208(406)	136(276)	207(404)	128(262)	333(631)	312(594)	341(646)	321(609)	323(613)
26.50	298(569)	312(593)	303(577)	395(743)	321(609)	146(294)	206(403)	136(277)	204(399)	128(263)	336(636)	309(588)	346(654)	318(604)	324(615)
26.75	301(574)	321(610)	305(581)	411(771)	326(618)	146(295)	204(400)	136(277)	202(396)	129(264)	347(656)	308(587)	359(678)	319(606)	332(630)
27.00	302(575)	323(614)	308(587)	419(786)	331(627)	146(295)	203(398)	137(278)	201(394)	129(265)	355(671)	309(589)	367(692)	321(610)	334(634)
27.25	304(580)	330(626)	310(590)	428(803)	333(632)	146(295)	203(397)	137(278)	201(394)	130(266)	358(677)	309(589)	368(694)	323(613)	336(637)
27.50	308(586)	330(626)	313(595)	434(814)	336(636)	146(295)	203(397)	137(278)	202(395)	131(267)	358(676)	312(593)	367(692)	324(615)	336(636)
27.75	307(584)	331(628)	314(598)	432(810)	335(635)	146(295)	203(398)	137(278)	202(396)	131(268)	359(678)	311(591)	366(691)	325(617)	336(636)
28.00	306(583)	331(627)	319(607)	433(811)	337(638)	146(295)	203(398)	137(279)	203(397)	131(268)	358(677)	312(593)	369(697)	325(617)	338(641)
28.25	308(586)	330(626)	318(605)	433(811)	337(639)	146(294)	203(398)	137(278)	202(396)	131(267)	357(674)	313(595)	367(692)	325(617)	339(642)
28.50	308(586)	333(631)	323(614)	438(821)	339(643)	146(294)	204(399)	137(278)	202(395)	131(267)	361(682)	311(592)	369(697)	326(619)	341(645)
28.75	311(591)	334(633)	323(614)	438(820)	338(641)	146(294)	204(399)	137(278)	201(393)	131(267)	362(684)	313(595)	372(702)	327(620)	341(646)
29.00	310(590)	334(634)	330(626)	442(827)	339(643)	146(294)	204(399)	136(277)	200(392)	131(267)	361(682)	314(598)	370(698)	327(620)	342(647)
29.25	312(594)	332(630)	328(622)	444(832)	341(646)	146(294)	204(400)	136(277)	199(391)	131(268)	362(683)	314(598)	371(699)	328(622)	342(647)
29.50	312(593)	334(633)	333(632)	446(834)	339(642)	146(294)	205(401)	136(277)	199(390)	131(267)	362(684)	314(597)	371(699)	329(624)	341(645)
29.75	312(593)	333(631)	333(631)	448(838)	339(642)	146(295)	205(401)	136(277)	199(390)	131(267)	361(682)	314(597)	370(698)	330(626)	339(642)
30.00	313(595)	333(631)	337(638)	449(840)	341(645)	146(295)	206(402)	136(277)	199(390)	131(267)	361(682)	314(598)	371(699)	329(625)	342(647)

Table 2. — (Concluded)

Test time, minutes	Thermocouples														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
24.25	157(314)	353(667)	157(315)	342(647)	139(282)	341(646)	145(293)	347(656)	431(807)	369(696)	101(214)	324(615)	118(244)	367(693)	86(187)
24.50	157(315)	351(664)	157(315)	340(644)	139(283)	339(643)	145(293)	344(652)	427(801)	372(701)	103(217)	324(615)	119(246)	366(690)	87(188)
24.75	157(315)	350(662)	157(315)	339(642)	139(283)	339(642)	146(294)	343(650)	432(809)	374(705)	104(219)	323(613)	120(248)	366(690)	87(188)
25.00	158(316)	351(664)	157(315)	339(642)	140(284)	342(647)	146(295)	345(653)	428(803)	376(708)	106(222)	324(615)	121(250)	364(687)	87(189)
25.25	158(316)	348(658)	158(316)	337(638)	141(285)	337(639)	146(295)	342(647)	433(811)	375(707)	107(224)	323(614)	122(251)	363(686)	87(189)
25.50	158(317)	347(656)	158(316)	337(638)	141(286)	336(637)	146(295)	341(645)	427(801)	376(708)	108(227)	324(615)	123(253)	361(681)	88(190)
25.75	158(317)	344(651)	158(317)	334(633)	141(286)	334(633)	147(296)	337(638)	406(762)	376(708)	109(229)	322(611)	123(254)	354(669)	88(190)
26.00	158(317)	336(637)	158(317)	327(621)	142(287)	329(624)	147(297)	327(620)	390(734)	376(708)	111(231)	320(608)	124(256)	345(653)	89(192)
26.25	158(317)	329(624)	158(317)	321(610)	142(287)	323(613)	147(297)	321(610)	389(722)	376(708)	112(233)	318(604)	125(257)	339(643)	89(192)
26.50	158(317)	332(629)	158(317)	324(616)	142(288)	325(617)	147(297)	328(622)	397(747)	377(710)	113(235)	318(604)	126(258)	346(655)	89(192)
26.75	158(318)	339(643)	158(317)	331(627)	142(288)	329(624)	148(298)	334(634)	413(775)	378(713)	114(237)	319(606)	127(260)	353(667)	89(193)
27.00	158(317)	343(650)	159(318)	334(633)	143(289)	334(633)	148(298)	341(645)	419(787)	379(714)	115(239)	319(607)	127(261)	358(676)	89(193)
27.25	158(317)	347(657)	158(317)	337(638)	143(289)	337(639)	148(298)	342(647)	423(793)	380(716)	116(241)	321(610)	128(262)	359(678)	90(194)
27.50	158(317)	345(653)	158(317)	336(636)	143(289)	336(636)	148(299)	341(645)	427(801)	381(717)	117(243)	321(610)	128(263)	358(677)	90(194)
27.75	158(317)	347(656)	158(317)	336(636)	143(289)	337(639)	148(299)	339(643)	438(821)	409(769)	118(245)	322(611)	129(264)	358(677)	90(194)
28.00	158(316)	348(659)	158(317)	338(640)	143(289)	338(641)	148(299)	343(650)	431(808)	384(724)	119(247)	321(610)	129(265)	359(679)	90(194)
28.25	158(316)	348(659)	158(317)	338(641)	143(289)	338(641)	148(299)	343(649)	432(809)	386(727)	120(248)	323(613)	130(266)	359(679)	90(194)
28.50	158(316)	350(662)	158(317)	340(644)	143(289)	340(644)	149(300)	346(655)	433(811)	388(731)	121(250)	323(614)	131(267)	362(684)	89(193)
28.75	158(316)	350(662)	158(317)	341(646)	143(289)	341(646)	149(300)	347(656)	445(833)	389(732)	122(252)	324(616)	131(267)	362(683)	90(194)
29.00	158(316)	351(664)	159(318)	342(647)	143(289)	343(649)	148(299)	346(654)	444(832)	391(735)	123(254)	324(616)	131(268)	362(684)	90(194)
29.25	158(316)	351(664)	158(317)	342(647)	143(289)	341(646)	149(300)	346(654)	449(840)	392(737)	124(255)	326(618)	132(269)	363(685)	90(194)
29.50	158(316)	350(662)	159(318)	340(644)	143(290)	342(647)	149(300)	344(651)	443(829)	393(740)	125(257)	326(618)	132(270)	363(686)	90(194)
29.75	158(317)	349(661)	159(318)	340(644)	143(290)	341(645)	149(300)	344(651)	451(844)	396(744)	126(258)	326(618)	132(270)	363(685)	90(194)
30.00	158(317)	351(664)	158(317)	341(646)	143(290)	342(647)	149(300)	344(652)	446(834)	397(747)	127(260)	327(620)	133(271)	363(685)	90(194)

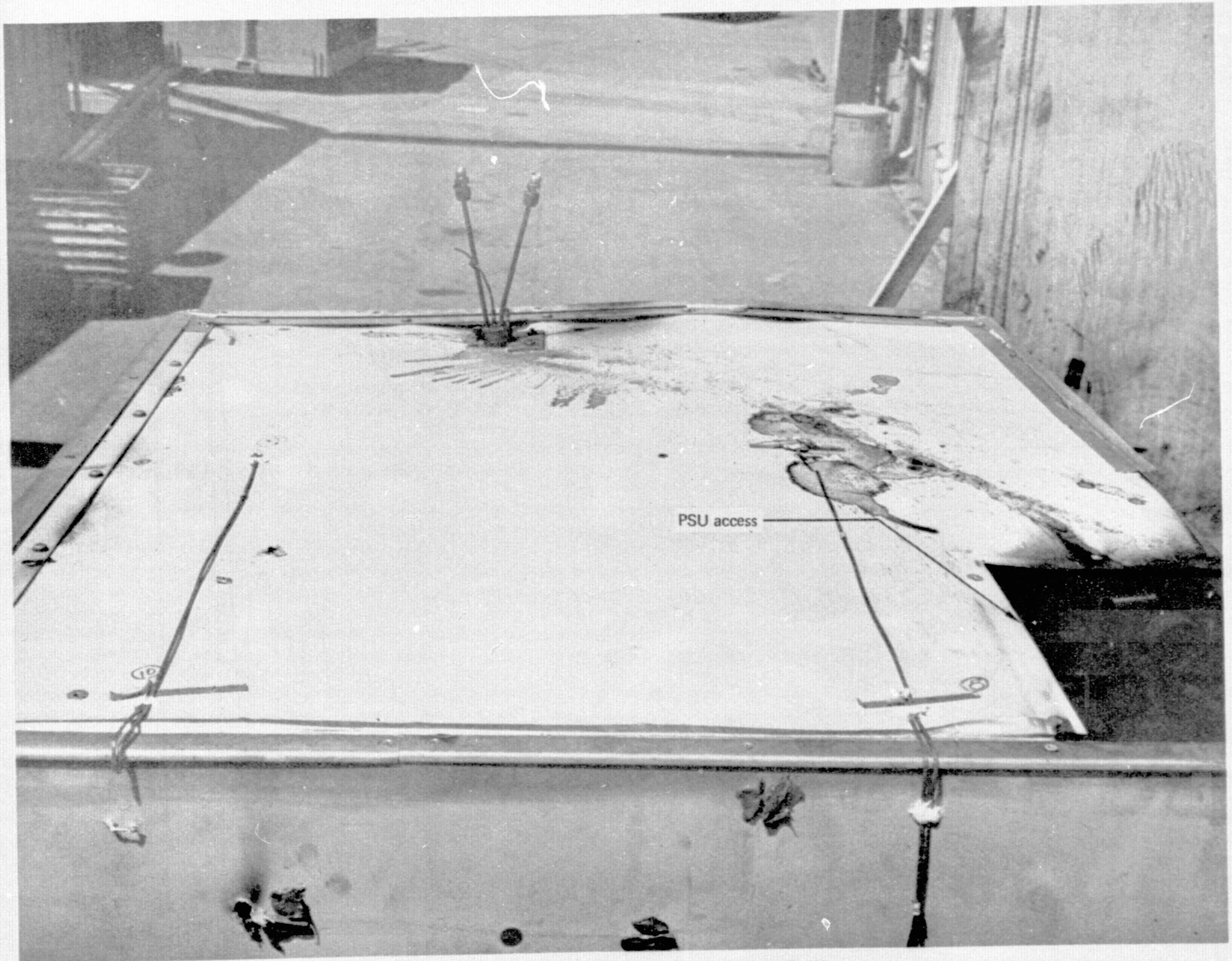


Figure 24.—Post-Test View—Lavatory Ceiling

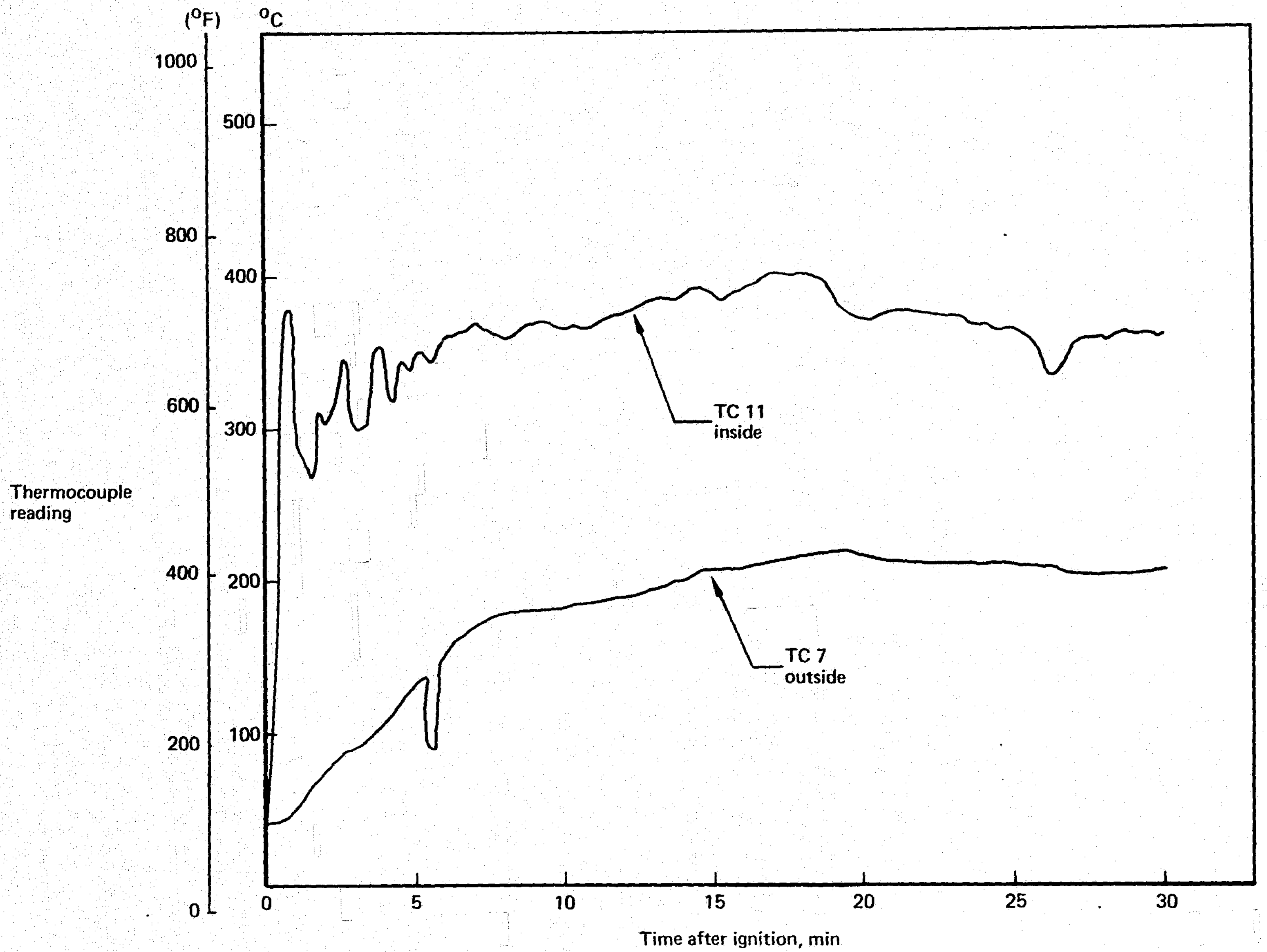


Figure 25.—Ceiling Temperature

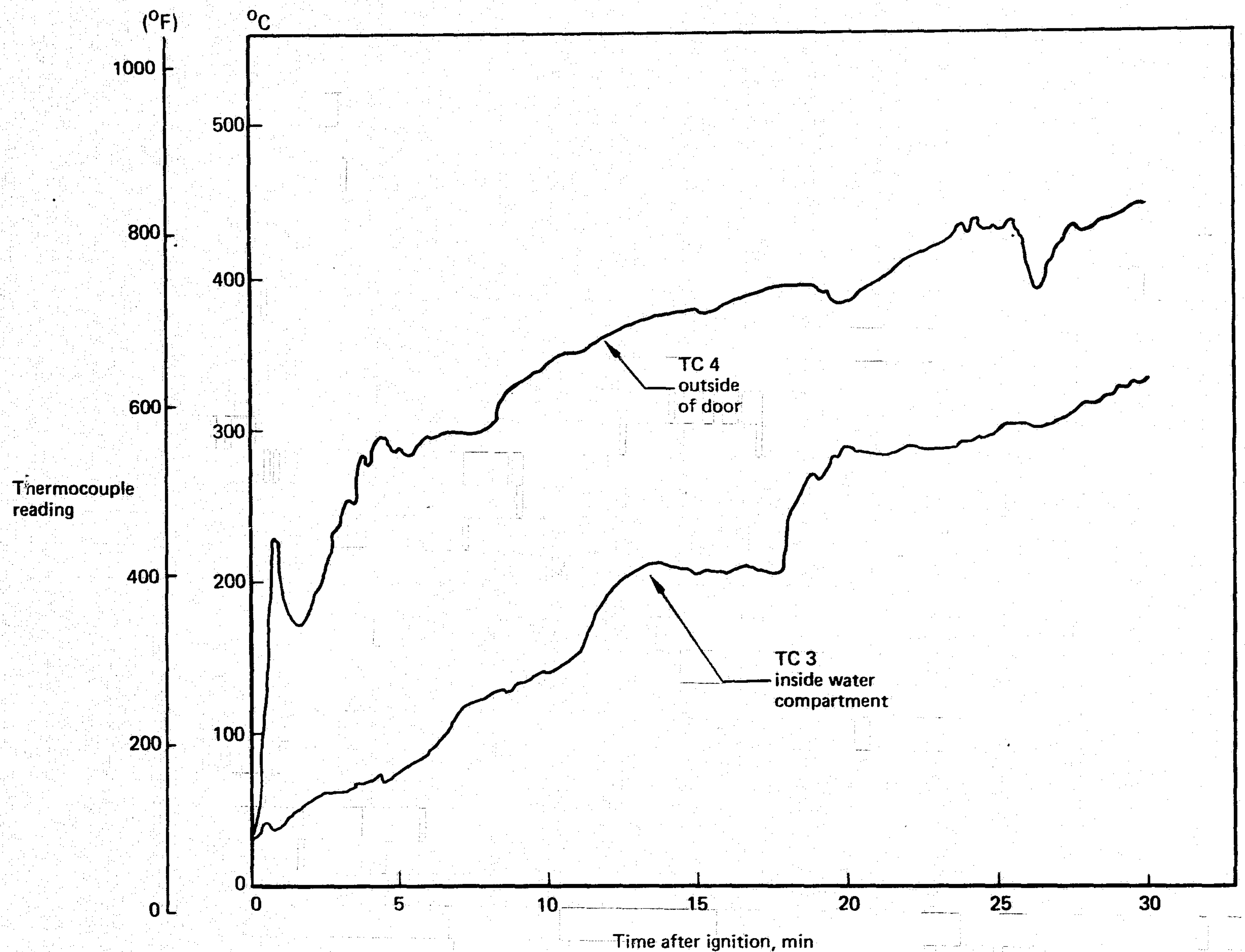


Figure 26.—Waste Compartment Door Temperature

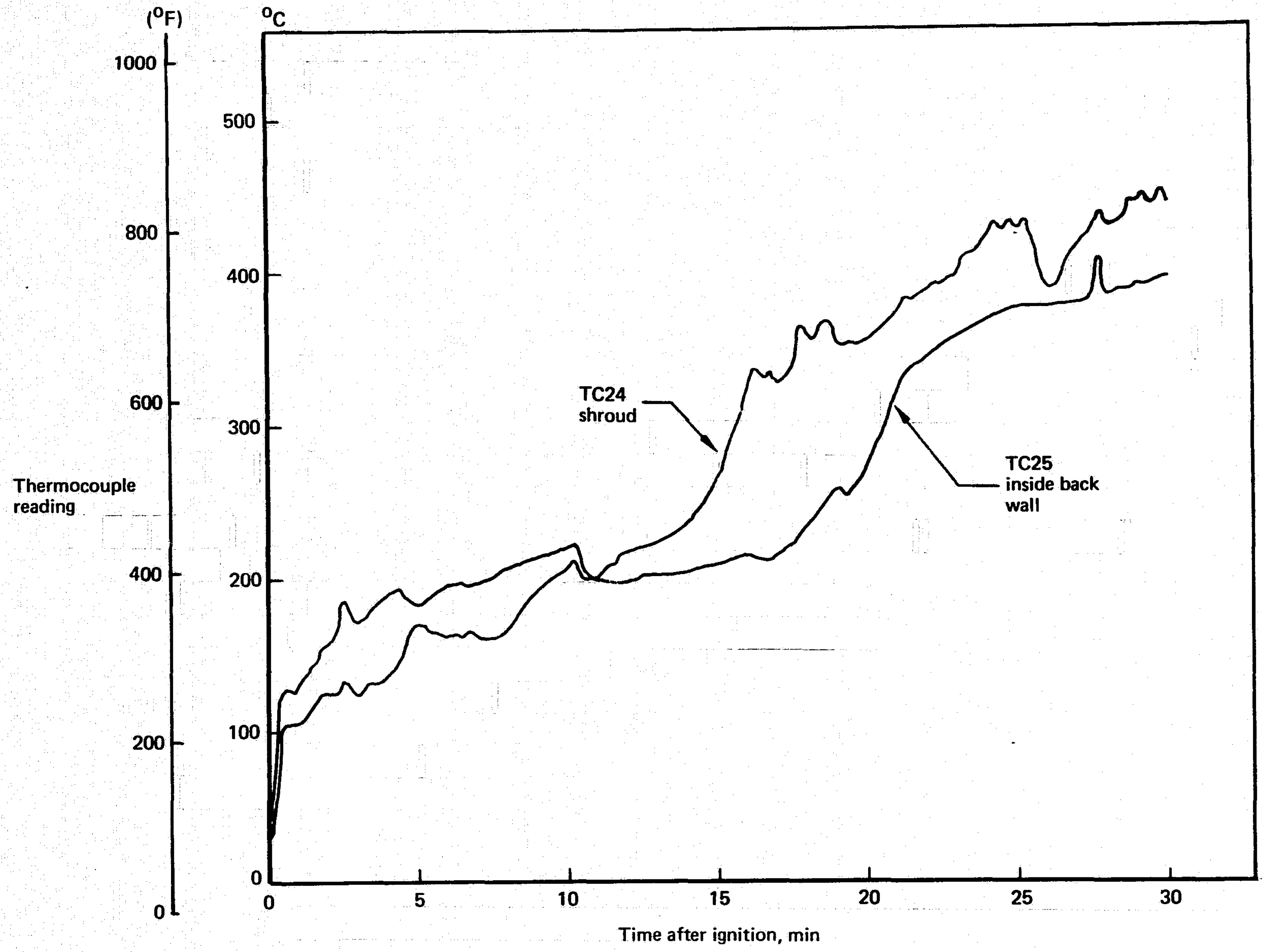


Figure 27.—Temperature Near Flame

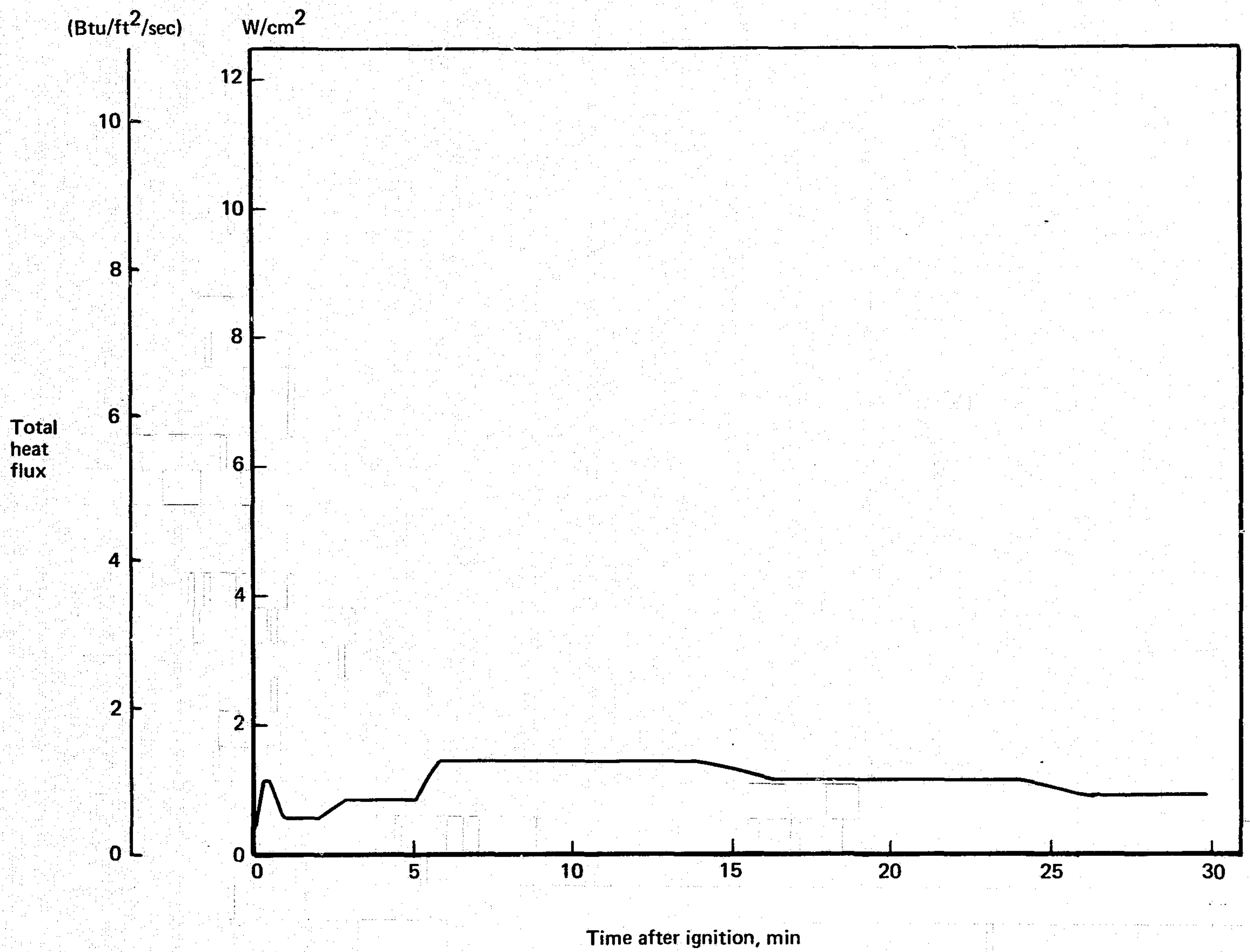


Figure 28.—Heat Flux at Calorimeter A—Waste Compartment Door

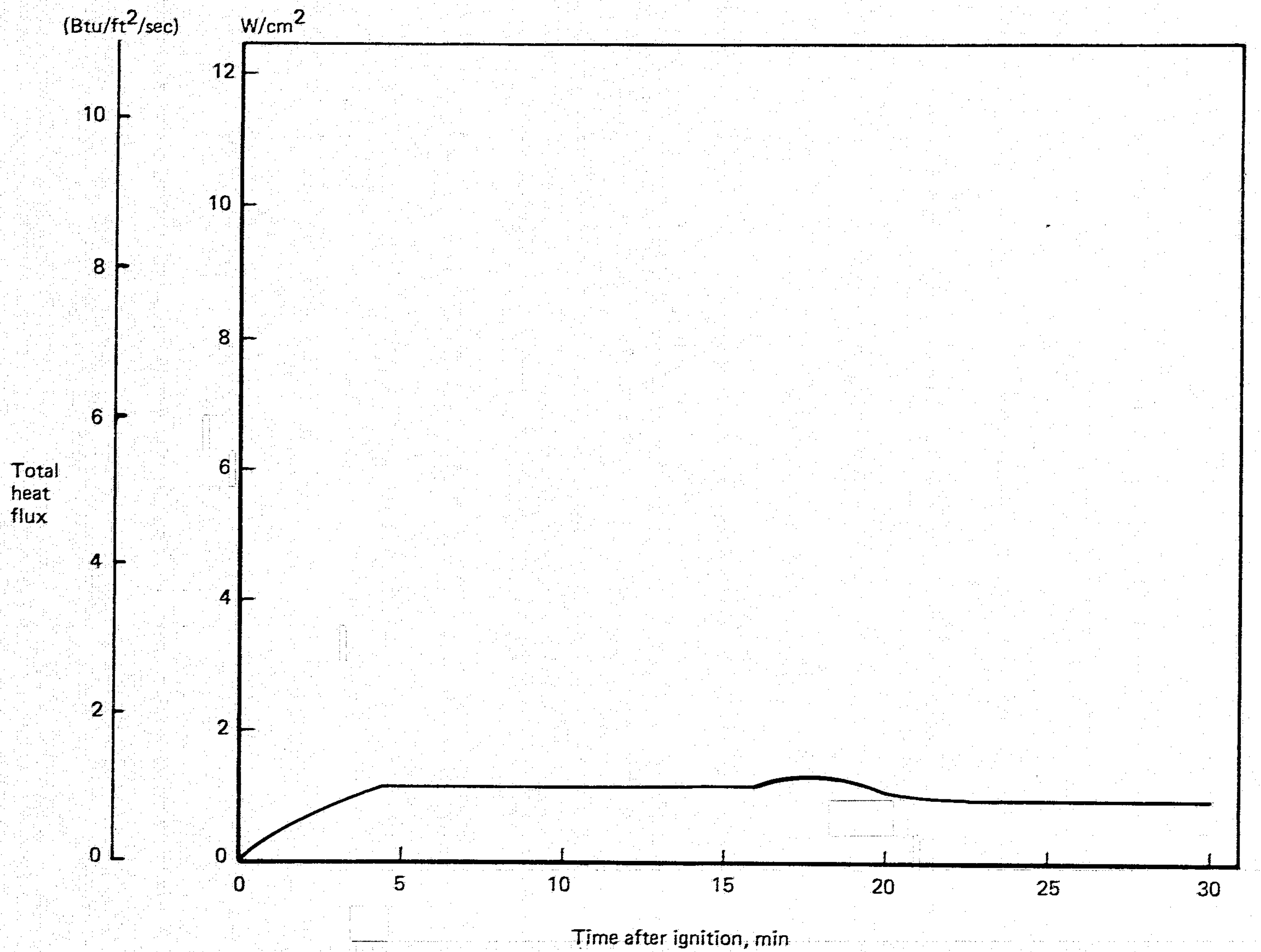


Figure 29.—Heat Flux at Calorimeter B—Lower Wall

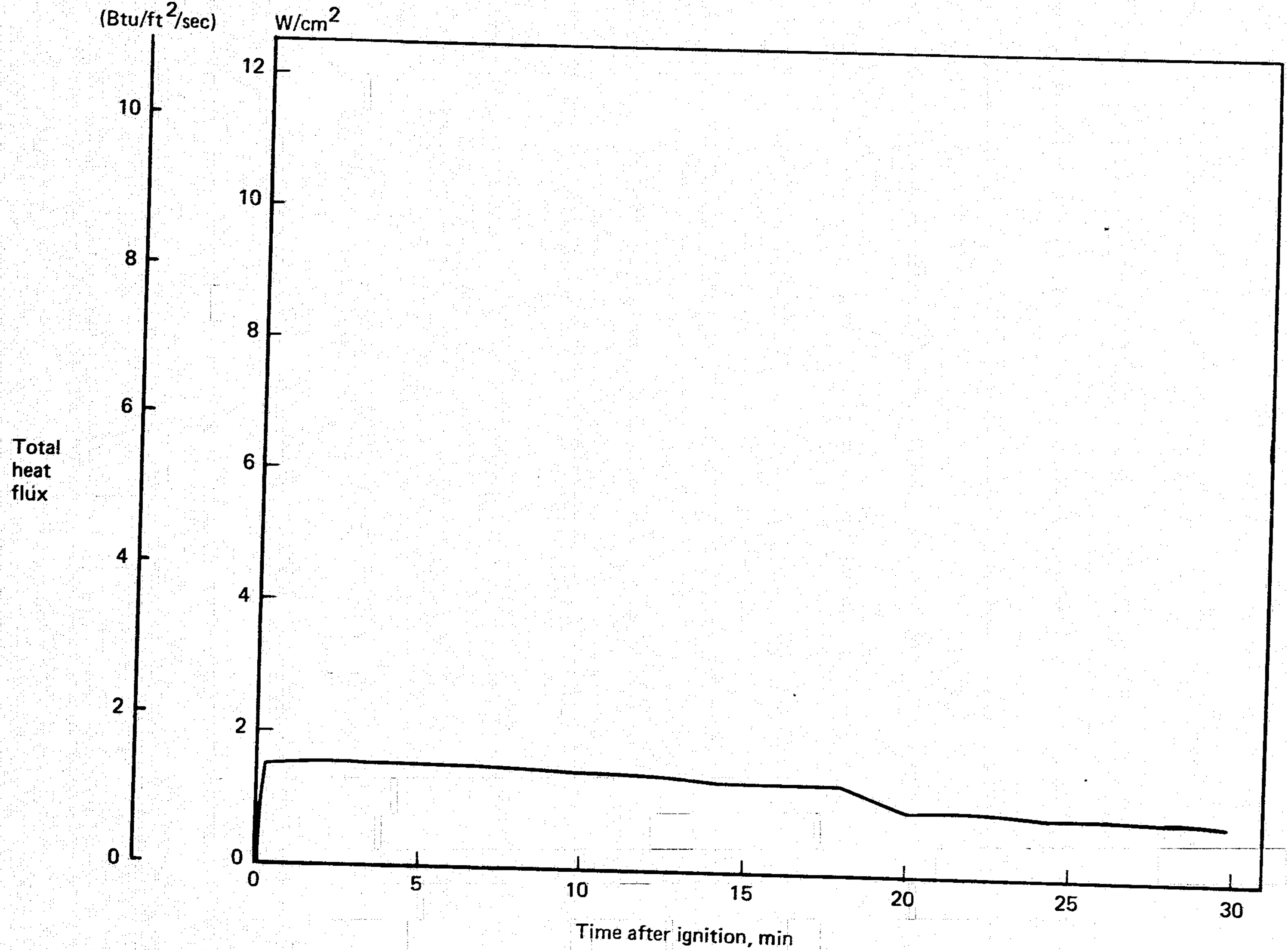


Figure 30.—Heat Flux at Calorimeter C—Ceiling

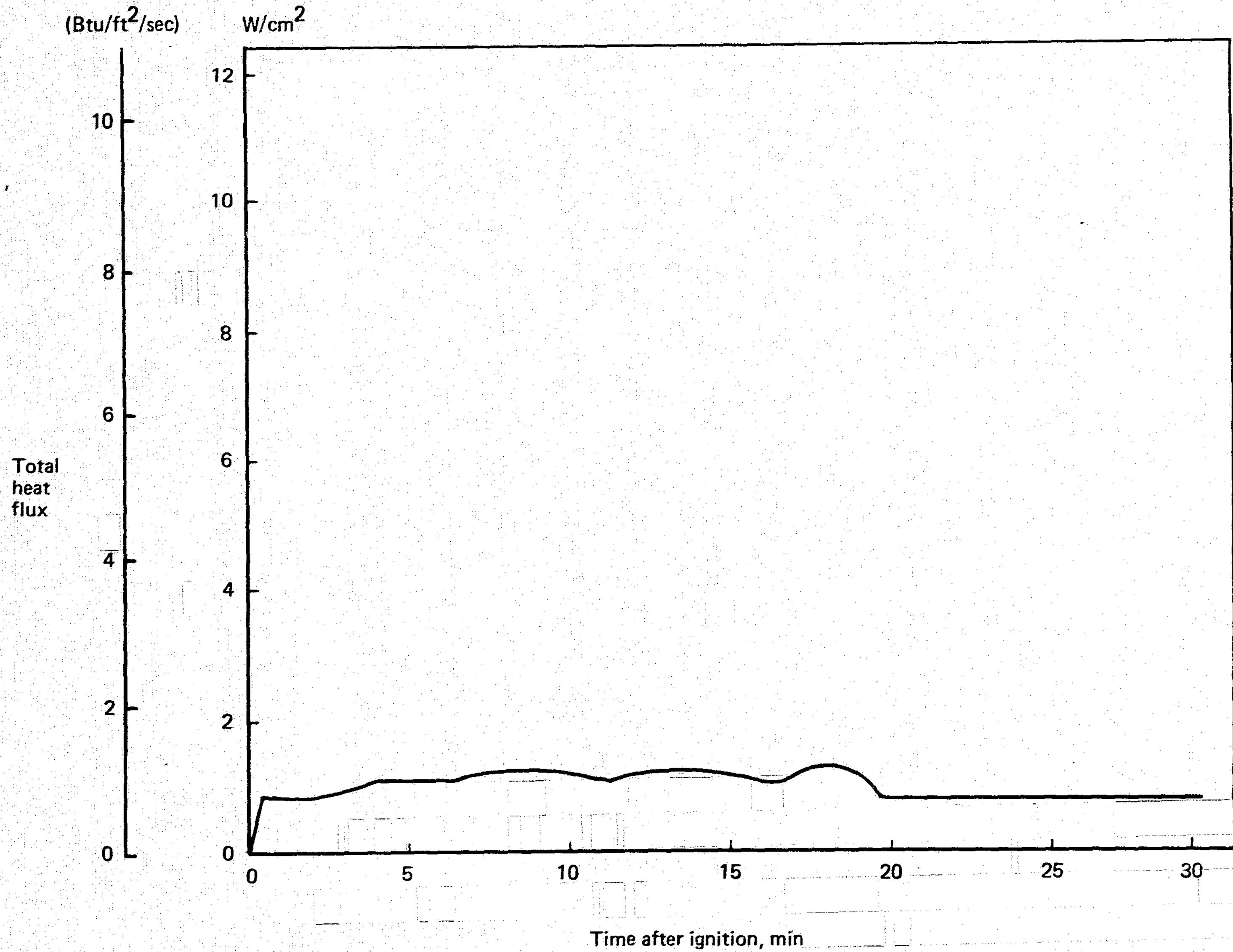


Figure 31.—Heat Flux at Calorimeter D—Upper Wall

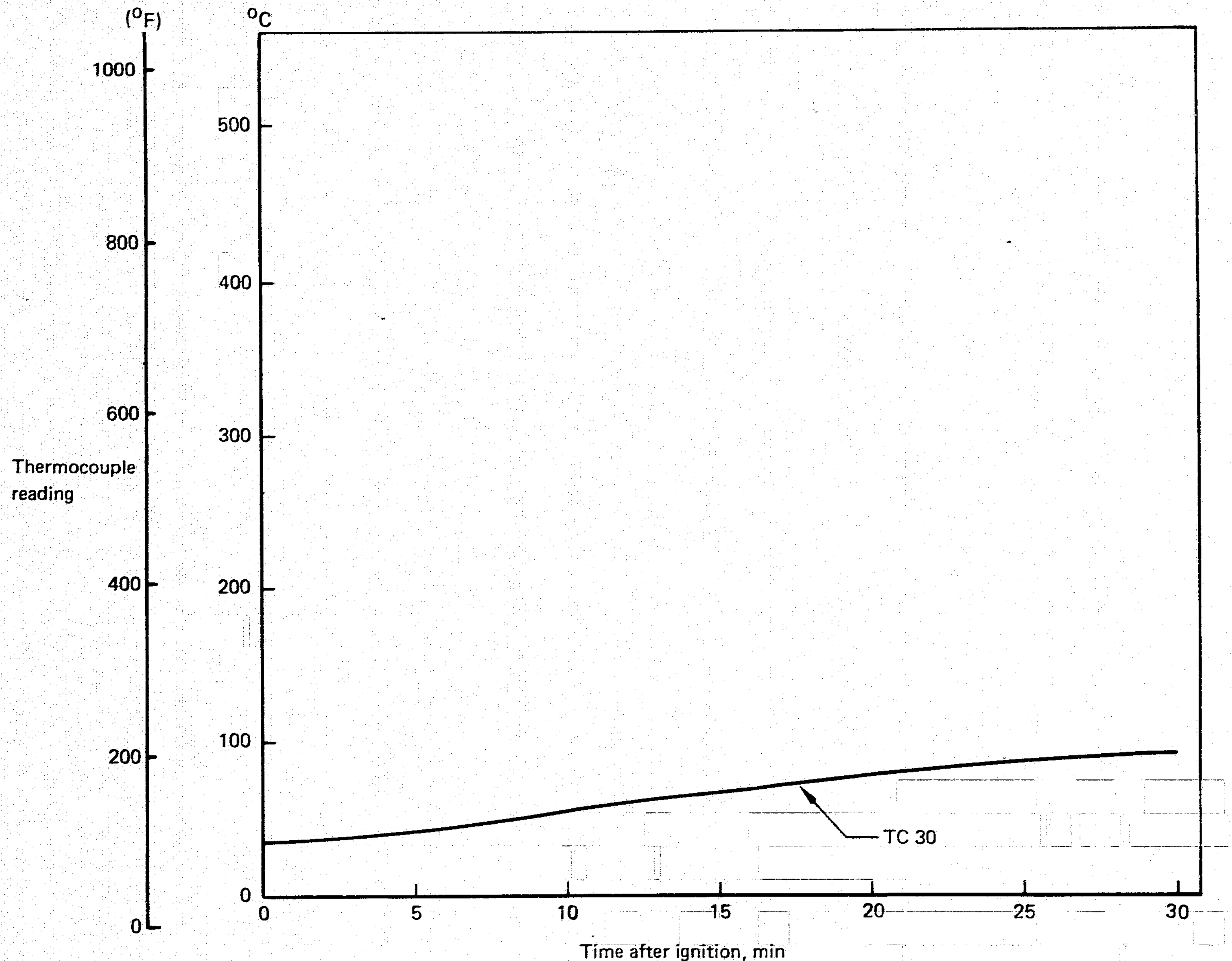


Figure 32.—Temperature Near AETS

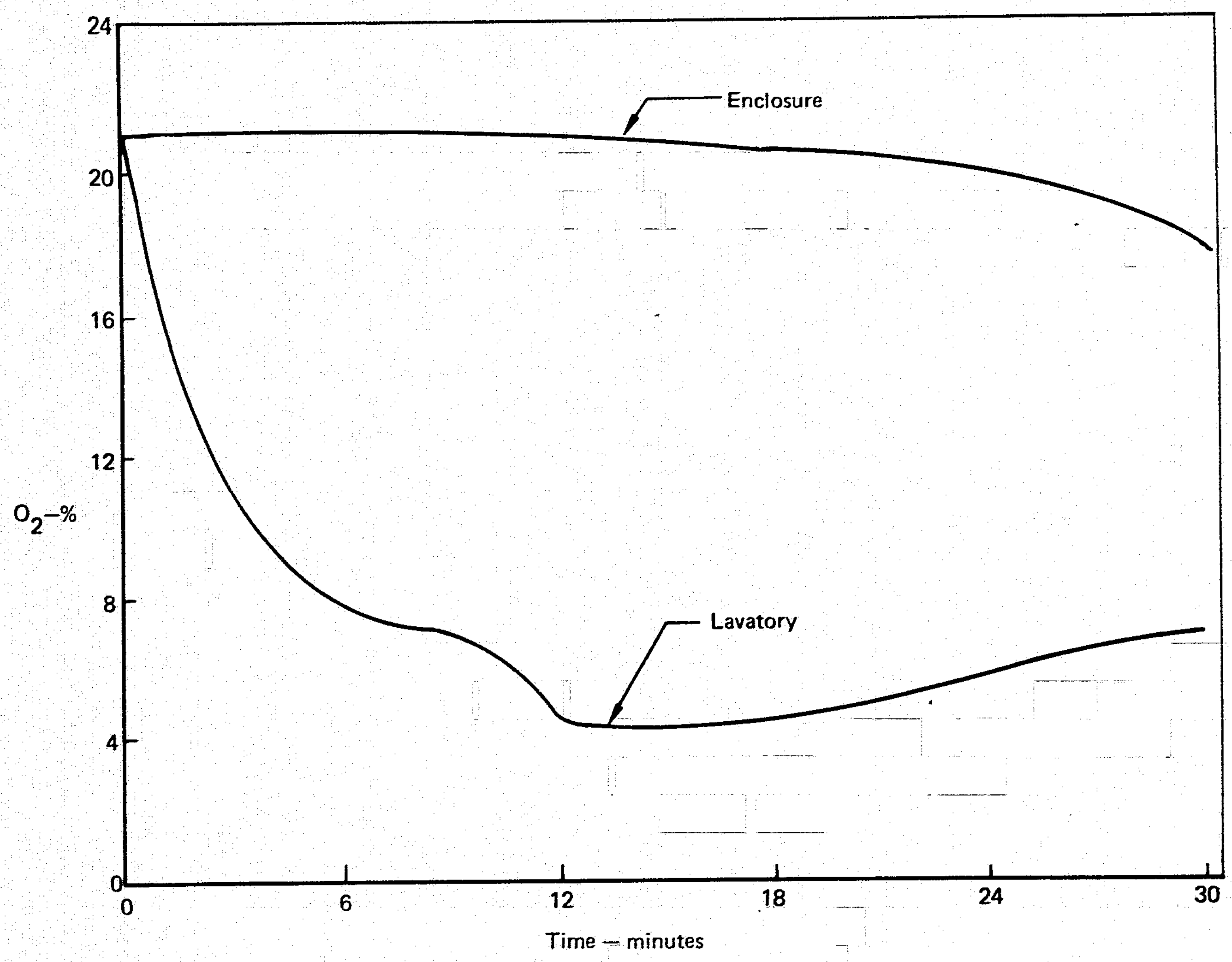


Figure 33.–Oxygen Concentration

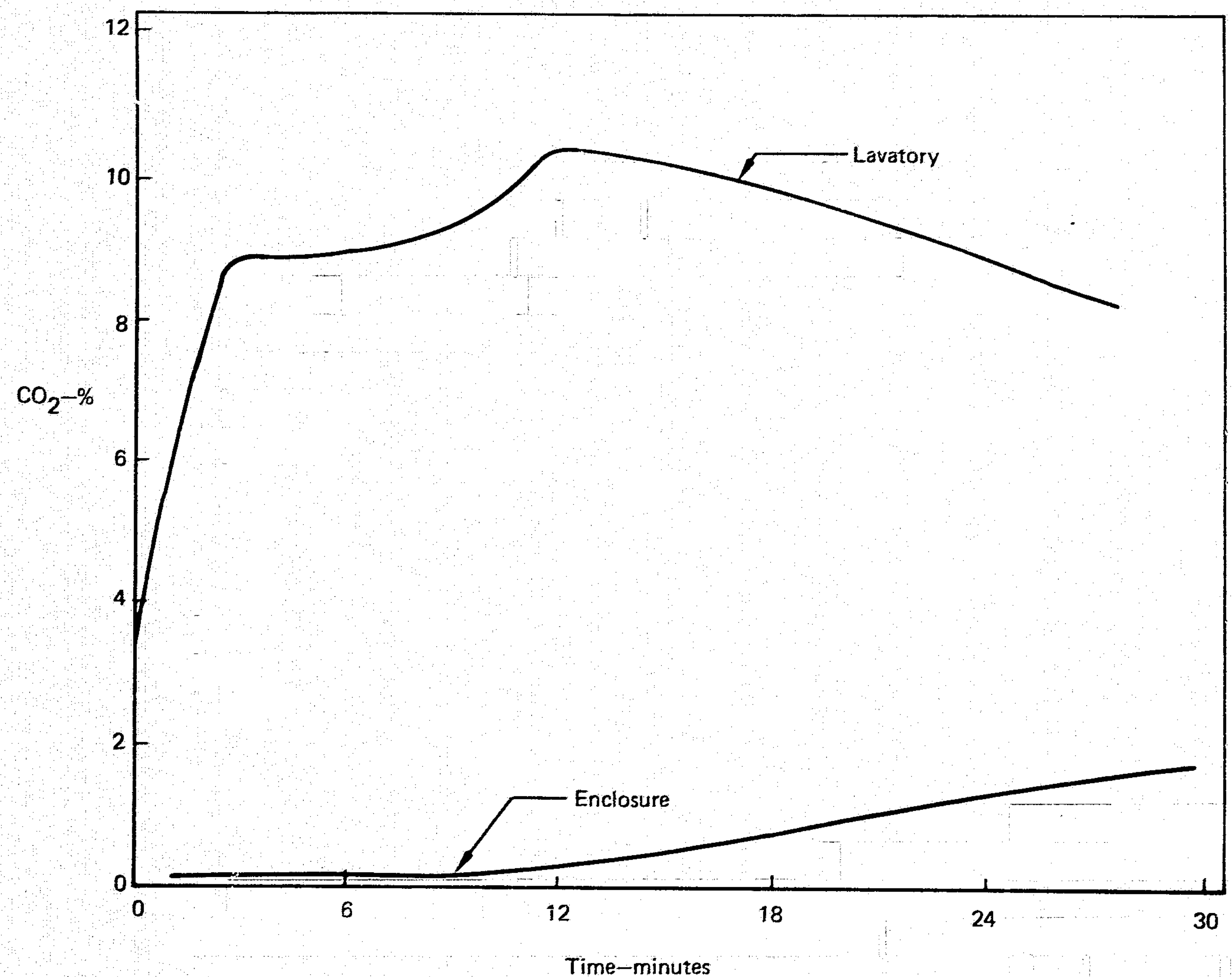


Figure 34.—Carbon Dioxide Concentration

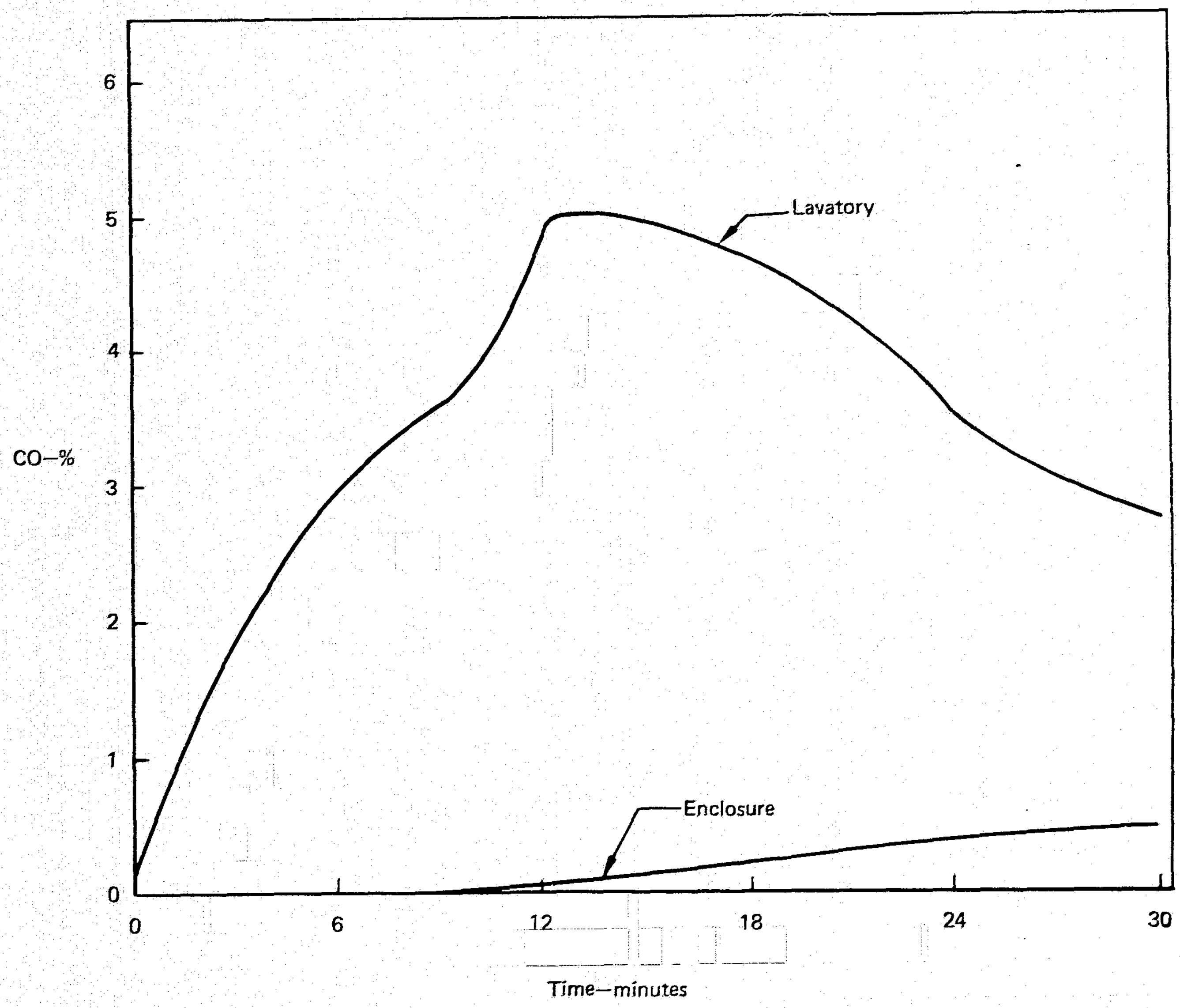


Figure 35.—Carbon Monoxide Concentration

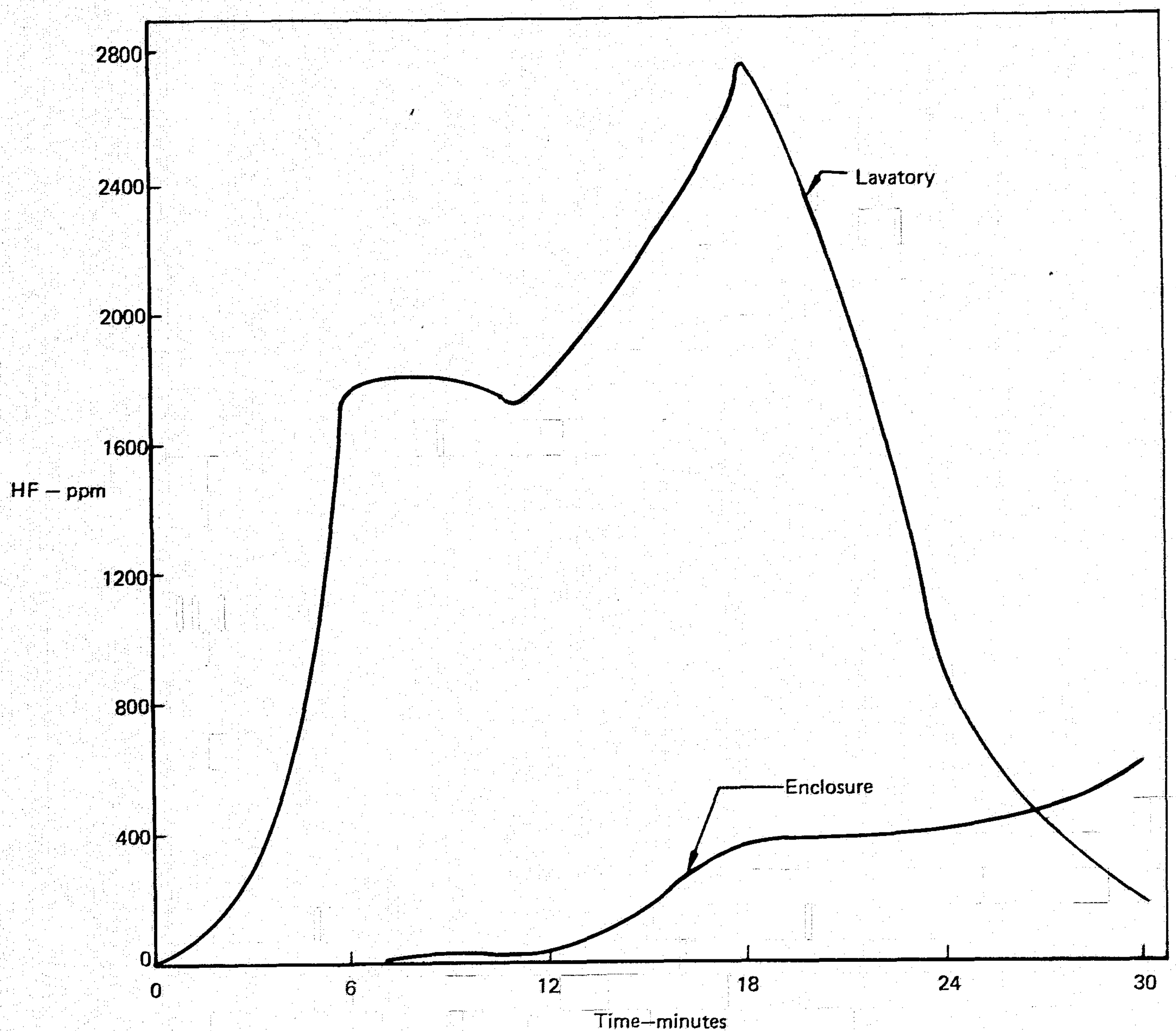


Figure 36.—Hydrogen Fluoride Concentration

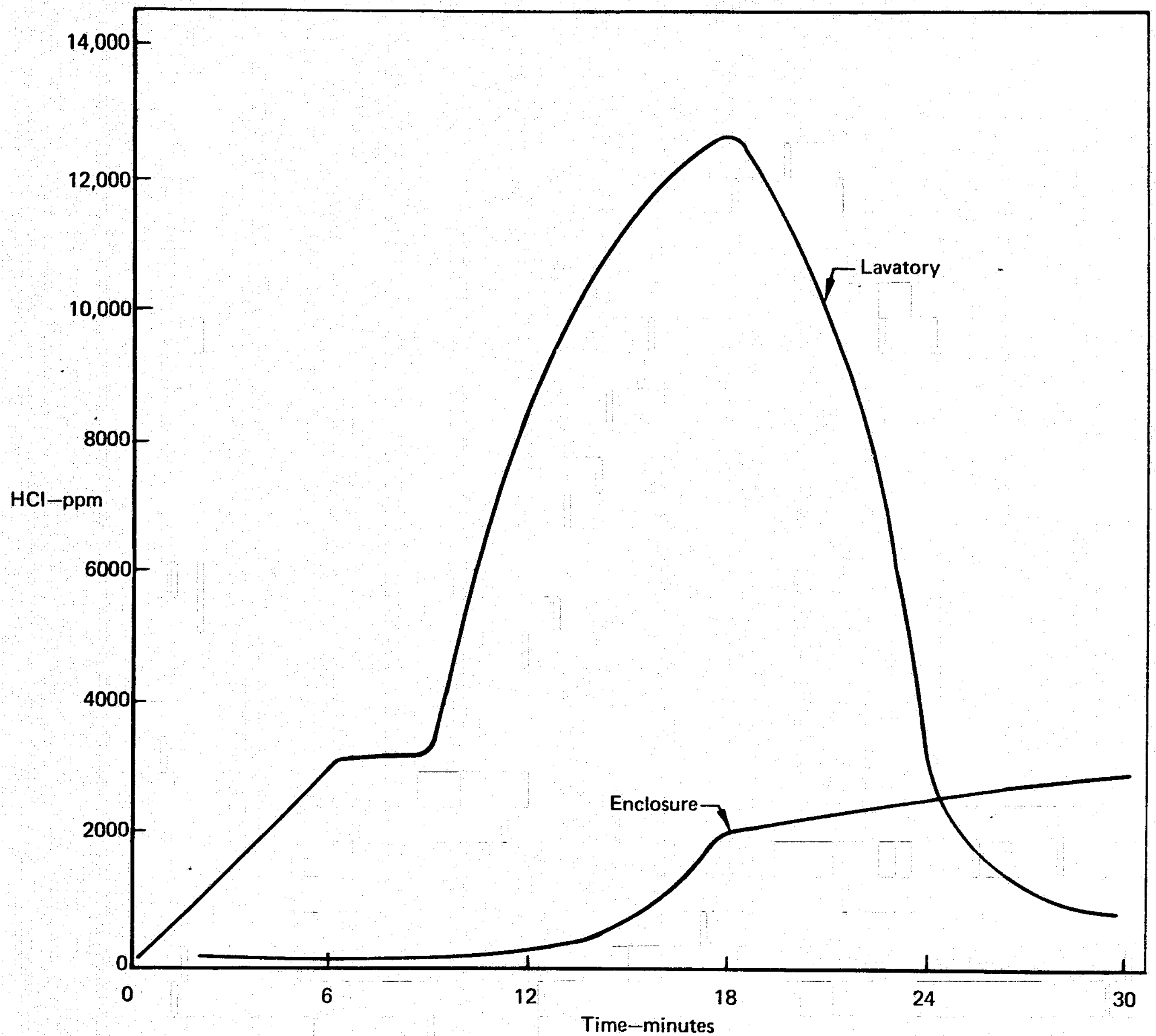


Figure 37.—Hydrogen Chloride Concentration

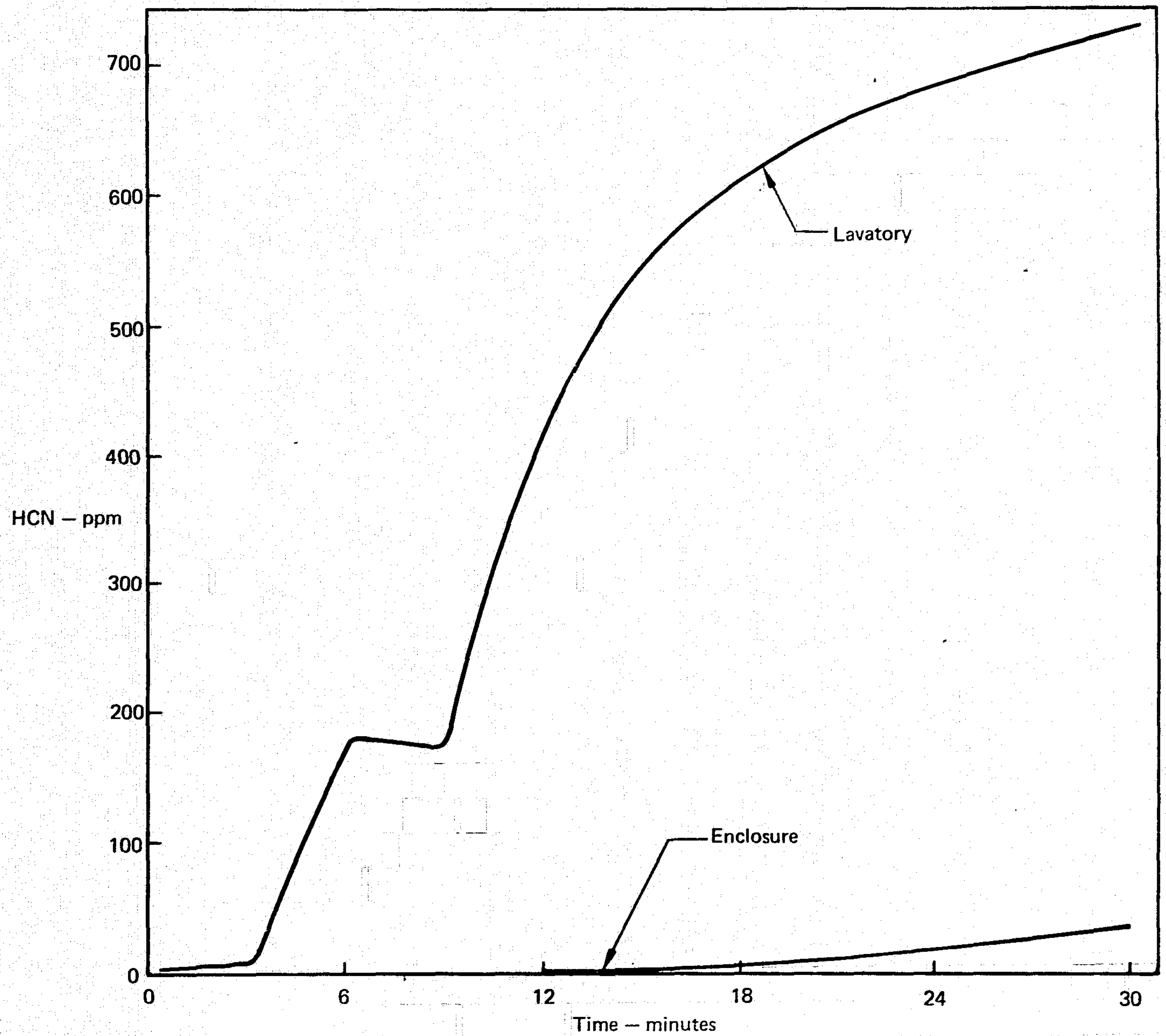


Figure 38.—Hydrogen Cyanide Concentration

At 6 minutes, the HF and HCl levels had increased significantly. HCN evolution had begun, indicating involvement of the basic lavatory structure. Due to temporary plugging of the fixed gas sampling lines, data points for O_2, N_2, and CO are not available for this time.

The data indicate a resurgence of the fire, in the interval from 12 to 18 minutes, involving the lavatory components as fuel. The oxygen concentration reached its minimum value within the lavatory, while carbon monoxide, hydrogen fluoride, and hydrogen chloride concentrations reached a maximum.

After 18 minutes, the HF, HCl, and CO concentrations in the lavatory all decreased rapidly. This can be attributed to loss of lavatory interior gas by sweeping with ventilating air and, in the case of HF and HCl, by absorption on the charred interior. The HCN concentration continued to increase, indicating continuing pyrolytic decomposition of the polyamide honeycomb from the intense heat in the lavatory.

The data from the enclosure atmosphere samples indicate that the toxicant buildup outside the lavatory lagged behind the buildup inside. The oxygen concentration decreased slightly. After 30 minutes, the CO concentration had reached a level presenting a serious health hazard, while the HCN level in the enclosure did not. Between 18 and 30 minutes, toxicologically hazardous levels of HF and HCl were observed.

5.4 ANIMAL EXPOSURE TEST RESULTS

Data from the instrumented rat were recorded on 2.54-cm (1-in.) magnetic tape. Electrocardiograph and respiration data were observed simultaneously on a dual-beam oscilloscope at the test enclosure observation window and also on individual scopes outside the test enclosure at the recording station. The tape was pen-recorded on an eight-channel strip chart. The ECG was examined for changes in pattern and integrated respiratory volume, and the AETS cage temperature profile was recorded.

The temperature recorded adjacent to the AETS cage is shown in figure 32. The mice died approximately 18 minutes into the test.

An analysis of the recorded information from the instrumented rat indicated that the first cardiac arrhythmia appeared at 7 minutes 40 seconds. Arrhythmias numbered approximately 14 during the next minute, after which they seemed to disappear until nearly 17 minutes into the test. Coincident with the frequent arrhythmias and for the previous 30 seconds, the R wave of the ECG diminished in amplitude by nearly 55%.

A summary of the ECG/respiration history of the exposed rat is as follows:

ECG/Respiration	Time into Test Min.	Sec.
First arrhythmia (skipped beat)	7	40
Fourteen arrhythmias	8	40
ECG amplitude diminished	15	0
Bradycardia and respiratory arrest	17	0
Cardiac arrhythmias, marked bradycardia, sporadic arrest for 2-7 seconds	17	25
Permanent cardiac arrest	18	0

During the test, it was observed that the ECG signal reflected physical activity of the rat. This is easily recognizable in the ECG channel on the strip chart. Therefore, it appears that the ECG record would serve as an indicator of physical activity of the instrumented subject, obviating the necessity for cinematic or television coverage except for visual documentation of the test. Data recorded on the strip chart recorder are shown in figures 39 through 41.

Data include:

1. Raw respiration pattern

2. Filtered respiration pattern. The respiratory sensor is sufficiently sensitive to pick up the heart beat; this is filtered out.

3. Integrated respiratory volume. An arbitrary respiratory volume is selected electronically and when a series of single breath volumes are summed to achieve this volume, the integrator starts over adding up the next aliquot. Time per aliquot is the significant factor in determining this volume of respiration. For example, respiratory integration time varied from 10-12 seconds in the first test minute to 50 seconds in the fourteenth test minute.

4. Electrocardiogram (ECG)

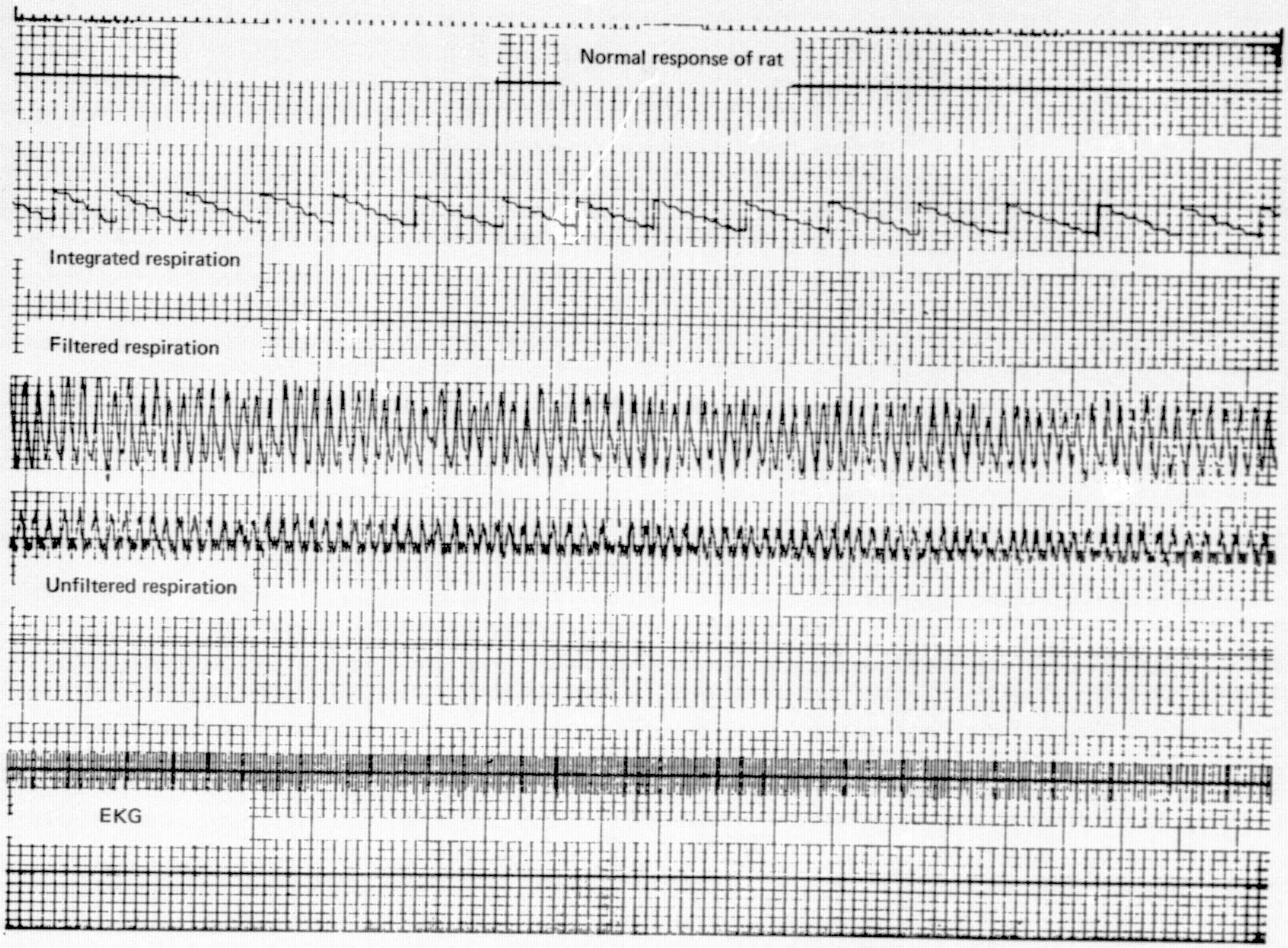


Figure 39.—Normal Response of Rat

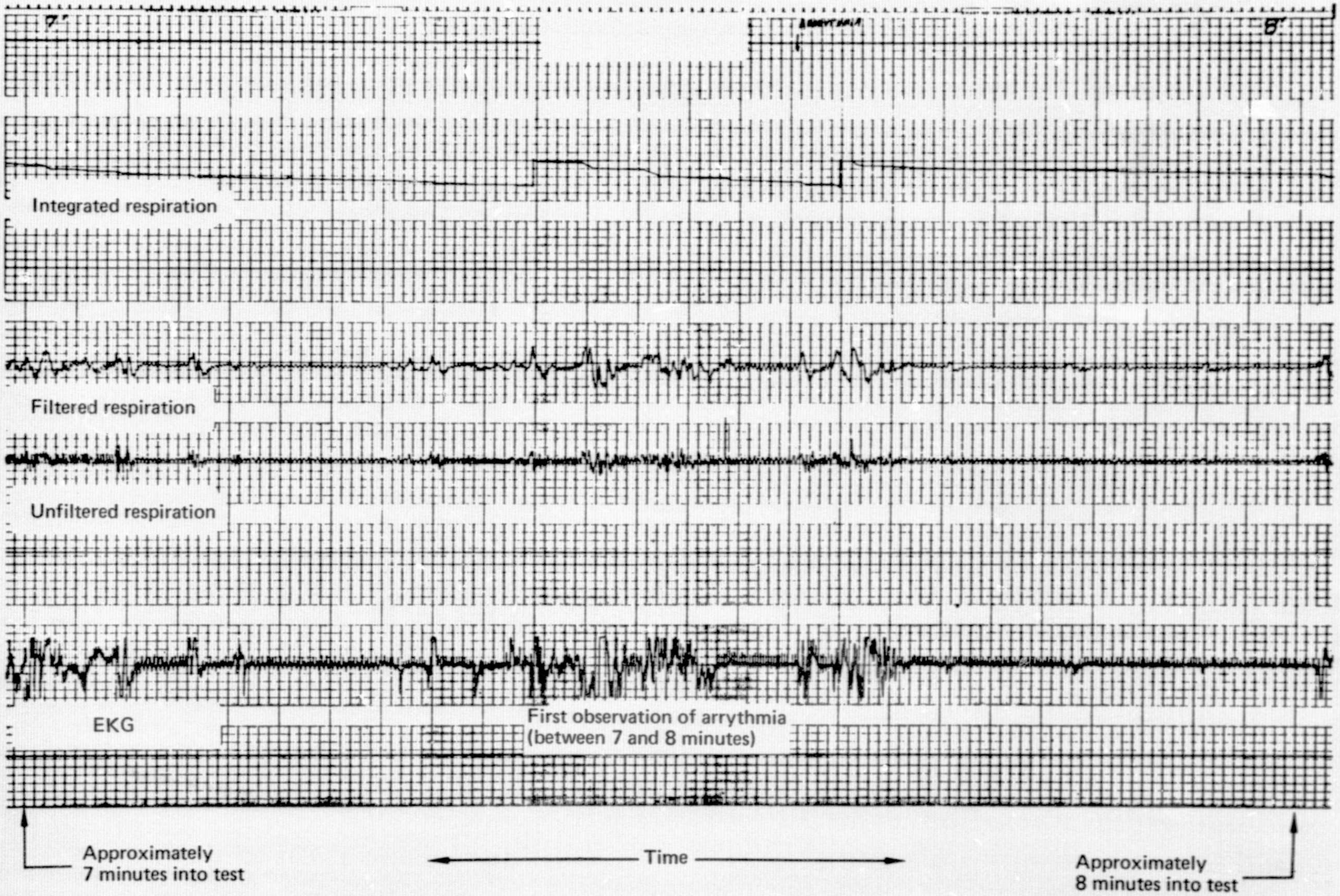


Figure 40.—First Observation of Arrhythmia (between 7 and 8 Minutes)

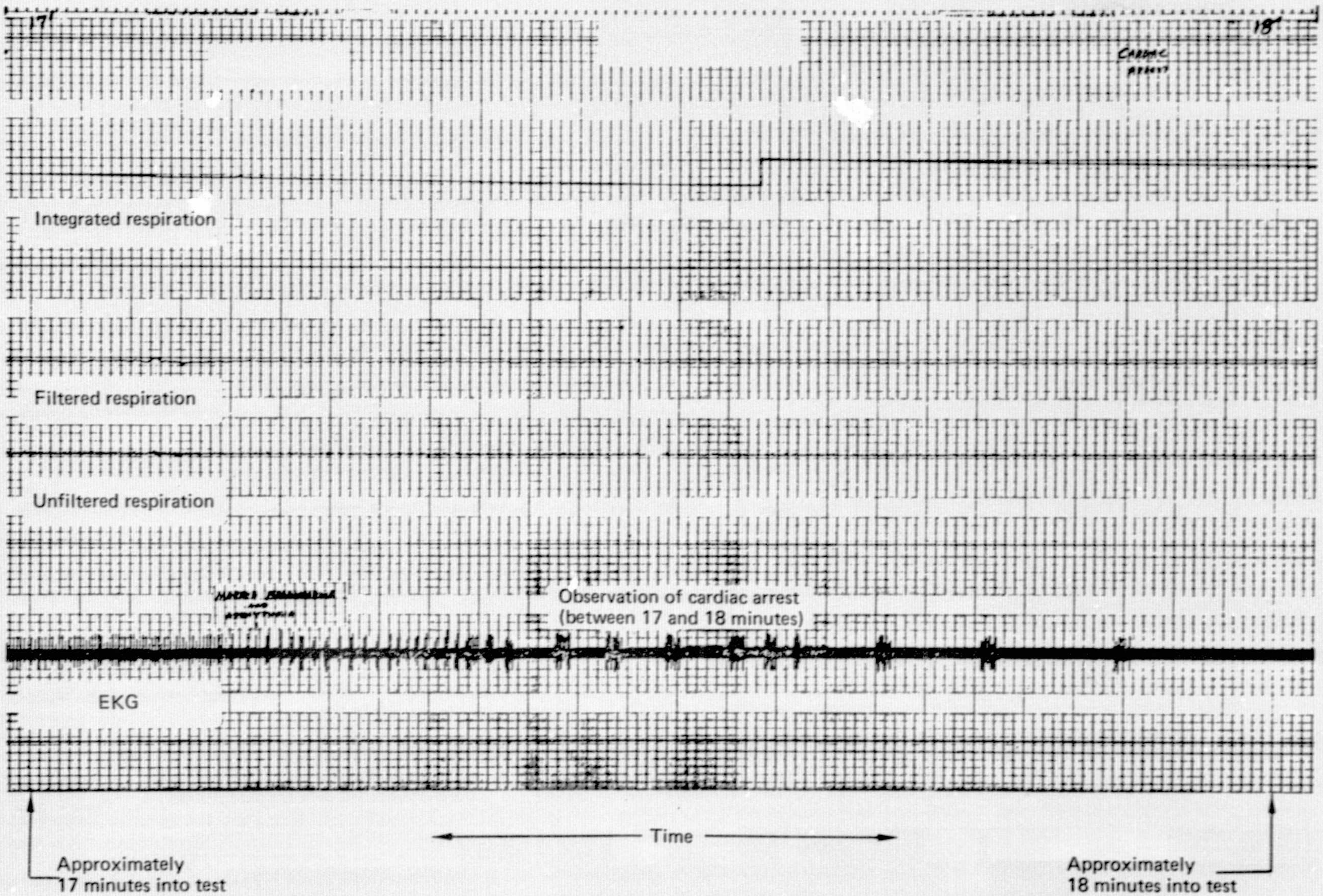


Figure 41.—Observation of Cardiac Arrest (between 17 and 18 Minutes)

6.0 CONCLUSIONS

The lavatory module contained the large waste fire for the 30-minute test period with the door closed. The resistance of the lavatory wall and ceiling panels and general lavatory construction to burn-through under the test conditions was demonstrated. The bifold lavatory door was badly damaged and no conclusion can be made as to the fire resistance of this door because the effect of the observation windows cut in the door and the ventilation chute cannot be established.

If lavatory fire containment were to be pursued further, a test of the door would be required to determine the capability of the hinges and latch to keep the door in place with the buckling and stress that accompany the differential expansion of door and lavatory parts.

This fire condition (with the lavatory door closed) produced a maximum heat flux of 1.59 W/cm^2 (1.4 $Btu/ft^2/sec$). Maximum recorded air temperature to which panels were exposed was about 449° C (840° F). The temperature of the initial waste fire was not measured, but data from earlier Boeing tests show this to be approximately 649° C (1200° F) in the flames. Data from this test permit the testing of other panel materials and panel construction without the burning of a lavatory. The fire condition could be simulated by exposing the panels to the appropriate heat flux and temperature.

HCl and HF had reached levels that would present serious health hazards in the test enclosure at the conclusion of the test, but O_2 depletion was not serious. It is tentatively concluded that the animals in the AETS cage in the test enclosure expired primarily from the combined hypoxic effects of HCl and HF gases and high temperature with minor contribution to hypoxia being made by CO and possibly other unknown gases.

APPENDIX A

LAVATORY TEST FIRE LOAD CALCULATIONS

Two trips were made to Seattle-Tacoma Airport to collect the contents of lavatory waste compartments on wide-body airplanes for analysis and to determine contents of excess waste stowed in lavatory modules. The results of these trips are shown in table 3.

A.1 MAXIMUM WASTE COMPARTMENT LOAD

The London-Seattle flight (PAA 125) on 8-8-74 had the greatest collection of waxed cups, paper towels, and other cellulose products. The waste compartments averaged about one-half full, although the aft corner lavatory containers and upper deck containers were nearly empty and the main deck center lavatory containers were nearly full. If the airplane passenger load had been greater, the less used lavatories probably would have been used more and the waste load more evenly distributed.

The highest average load per container, proportioned upward to 100% passenger load factor, was established as the test load.

For cellulose material test load calculations, the known quantities are:

1. PAA 125 Cellulose Load (8-8-74) = 5.75 kg (12.67 lb)

2. Number of PAA 125 lavatories = 13

3. Estimated 747 Average Capacity = 365

4. PAA 125 Passengers (8-8-74) = 187

5. PAA 125 Waxed Cups (8-8-74) = 0.39 kg (0.87 lb)

For paper towels:

$$\frac{5.75}{13} \times \frac{365}{187} = 0.86 \text{ kg } (1.9 \text{ lb}). \text{ Use } 0.91 \text{ kg } (2.0 \text{ lb}).$$

For waxed cups:

$$\frac{0.39}{13} \times \frac{365}{187} = 0.06 \text{ kg } (0.13 \text{ lb}). \text{ Use } 0.07 \text{ kg } (0.15 \text{ lb}).$$

Table 3.— Lavatory Combustible Waste Survey

Date	Airline	Airplane type	Flight information: Number	Origin: City	Origin: Local time	Destination: City	Destination: Local time	Elapsed time, hr	Number of passengers: Total	First class	Tourist	Number of lavatories: Total	Checked	Waste compartment material: Cellulose material, kg(lb)	Waxed cups kg(lb)	Plastic products kg(lb)	Cigarettes	Matches	Miscellaneous
6-11-74	Northwest	747	7	New York	10:00 am	Seattle	12:27 pm	5.5	74	20	54	12	10	1.1(2.5)	0.07(0.15)	0.18(0.40) polystyrene	1—soaked in cup of water	1—soaked in cup of water	12—small bars of soap.
6-11-74	Pan American	747	125	London	2:30 pm	Seattle	4:00 pm	9.5	127	–	–	13	13	3.4(7.5)	0.23(0.50)	0.05(0.1)[a]	1—soaked. 1—unlit.	1	2—tomato juice cans. 1—soft drink can.
6-11-74	United	747	286	Los Angeles	5:00 pm	Seattle	7:22 pm	2.5	114	16	98	11	11	0.7(1.5)	0.05(0.10)	0.09(0.20) polystyrene	–	–	10—liquor miniatures. 1—baby food jar.
6-11-74	Northwest	DC-10	27	Chicago	5:20 pm	Seattle	7:30 pm	4.25	70	20	50	7	7	1.2(3.9)	0.02(0.05)	0.05(0.10) polystyrene	–	–	1—miniature breath spray (aerosol)
6-11-74	United	747	157	Chicago	6:20 pm	Seattle	8:35 pm	4.25	275	34	241	11	11	2.1(4.7)	0.18(0.40)	0.07(0.15)[b]	1—soaked with water	–	–
2-2-74	Northwest	747	7	New York	10:00 am	Seattle	12:27 pm	5.5	109	–	–	13	13	1.57(3.47)	0.12(0.26)	0.31(0.69)[c]	2—in heavy polystyrene cup.	2—in heavy polystyrene cup.	7—liquor miniatures.
2-2-74	Pan American	747	125	London	2:30 pm	Seattle	4:00 pm	9.5	187	–	–	13	13	5.75(12.67)	0.39(0.87)	0.09(0.19)[c]	1—soaked.	–	16—small bars of soap. 1—beer can (tin).
2-2-74	United	747	228	Los Angeles	5:00 pm	Seattle	7:22 pm	2.5	134	12	122	11	11	0.81(1.78)	0.09(0.19)	0.02(0.05)[c]	–	–	1—glass juice bottle (large)
2-2-74	Northwest	DC-10	27	Chicago	5:20 pm	Seattle	7:30 pm	4.25	71	–	–	7	7	1.75(3.85)	0.08(0.18)	0.03(0.07)[c]	–	–	2—beer can pull tabs.
2-2-74	United	DC-10	157	Chicago	6:20 pm	Seattle	8:35 pm	4.25	90	–	–	7	7	1.50(3.30)	0.05(0.10)	0.005(0.01)[c]	–	–	–

[a] 20% polystyrene + 20% polyethylene.
[b] 70% polystyrene + 30% polyethylene.
[c] 95% polystyrene + 5% polyethylene.

Following the same rationale, NW Flight 7 was used as the maximum plastic load. So, for plastic material test load calculations, the known quantities are:

1. NW 7 Plastic Load (8-8-74) = 0.31 kg (0.69 lb)

2. Number of NW 7 Lavatories = 13

3. Estimated 747 Average Capacity = 365

4. NW 7 Passengers (8-8-74) = 109

For plastic material:

$$\frac{0.31}{13} \times \frac{365}{109} = 0.08 \text{ kg } (0.17 \text{ lb})$$

Since plastic is considered an undesirable waste because of its burning characteristics (i.e., smoky and long-burning), the test load was arbitrarily doubled to 0.16 kg (0.35 lb) of polystyrene plastic cups.

A.2 LAVATORY MODULE LOAD

There was no excess waste found stowed in any lavatory on airplanes checked. Flight attendants and airplane cabin cleaning personnel were questioned about the frequency, amount, and type of excess galley or cabin waste that is stored in lavatories. All agreed that it was very infrequent on the wide-body airplanes; in fact, of the roughly 20 flight attendants questioned, none could specifically recall such storage on wide-body airplanes. However, it must sometimes happen on wide-body airplanes since the cabin attendants indicated that on standard-body airplanes it is not uncommon. The excess waste, then, is mostly comprised of napkins, polystyrene glasses, glass bottles, beer cans, and soft drink cans from a beverage service after the meal.

A galley service survey conducted by Boeing indicates that roughly 5% of the passengers accept a beverage after a meal. Based on this, a maximum test load was made up of 100 polystyrene cups (1.66 kg or 3.65 lb), 100 paper towels (0.474 kg or 1.046 lb, simulating napkins), 24 tin soft drink cans, and 3 aluminum beer cans, simulating drink service to 25% of a 747 or 40% of a DC-10. This test load was burned in an instrumented simulated lavatory supplied with ventilation approximating that of a 747 lavatory module. Results were compared to those obtained when burning the waste compartment fire load under the same conditions.

It was judged by the temperatures reached and the fire damage produced that the waste compartment fire load is a more severe test fire than the beverage waste load. To assure that a maximum condition was tested, a load four times the size of the waste compartment load was used to simulate galley waste overflow.

APPENDIX B

COMBUSTION PRODUCTS ANALYSIS

Three analytical procedures were employed and will be discussed separately. The three are:

1. Fixed Gas Analysis
2. Wet Chemical Analysis
3. Dräger Tube Analysis

B.1 FIXED GAS ANALYSIS

A Varian 1800-series gas chromatograph, equipped with a thermal conductivity detector, was used for analyzing the gas burette samples. Operating parameters were:

1. For CO, O_2, and N_2:

   a. Column

      Molecular sieve, 13X, 30/60 mesh, 3.175 mm x 3.048 m (0.125 in. x 10 ft) stainless steel

   b. Carrier Gas

      Helium, 30 ml/min. (1.8 in.^{3}/min.)

   c. Detector

      Thermal conductivity at 0.2 A, 230°C (446°F)

   d. Column Temperature

      50°C (122°F)

   e. Retention Times

      O_2–1 min. 30 sec.; N_2–1 min. 55 sec; CO–5 min. 15 sec.

2. For CO_2:

   a. Column

      Silica Gel, 30/60 mesh, 3.175 mm x 3.048 m (0.125 in. x 10 ft) stainless steel

b. Carrier Gas

Helium, 60 ml/min. (3.7 in.^{3}/min.)

c. Detector

Thermal conductivity at 0.2 A, 230°C (446°F)

d. Column Temperature

100°C (212°F)

e. Retention Time

CO_2–2 min. 55 sec.

Burette contents were expanded into an evacuated 5-cc (0.3-in.^{3}) sampling loop. After recording the pressure with an attached manometer, the sample was injected into the chromatograph. Peak areas were measured manually with a planimeter. Calibration curves for CO and CO_2 were generated by injecting various volumes of pure gas into the chromatograph, using gas-tight syringes, and then plotting instrument response (i.e., peak area times attenuation) versus volume. Calibration curves for N_2 and O_2 were generated by injecting various pressures of air, using the 5-cc (0.3-in.^{3}) loop, and then plotting instrument response versus sample volume corrected to ambient pressure.

The volume of each gas present in the test samples at ambient pressure was calculated from the observed peak area, the attenuation, and the sample pressure. The volumes were then compared to the total gas sample volume injected. The gas concentrations expressed either as percent or as ppm (volume basis) are given in table 4.

B.2 WET CHEMICAL ANALYSIS

The scrubbing solutions from the bubblers (microimpinger apparatus) were transferred to plastic bottles immediately after the test. At that time, the solution pHs were measured, using test paper. If the pH was less than 7, it was adjusted to greater than 7 by adding 0.1N NaOH dropwise.

Colorimetric analyses for CN^- and specific ion electrode analysis for F^- were carried out on the same day as the test. Specific ion analysis for Cl^- was carried out the following day.

B.2.1 COLORIMETRIC DETERMINATION OF CYANIDE

The cyanide concentrations of the scrubbing solutions were measured using the colorimetric method of Epstein ("Estimation of Microquantities of Cyanide," Analytical Chemistry, 19, p. 272, 1947). This method has been used extensively in the Boeing laboratories for analyzing bubbler solutions acquired in conjunction with the NBS smoke chamber. It is based upon conversion of CN^- to ClCN, reaction of ClCN with pyridine to form a

Table 4.— Fixed Gas Analysis Results

Gas	Sampling time, min.	Enclosure: Sample pressure at RT, cm-Hg (in-Hg)	Enclosure: GC peak area, $cm^2(in^2)$	Enclosure: GC attenuation	Enclosure: Concentration, ppm	Enclosure: Concentration, %	Lavatory: Sample pressure at RT, cm-Hg (in-Hg)	Lavatory: GC peak area, $cm^2(in^2)$	Lavatory: GC attenuation	Lavatory: Concentration, ppm	Lavatory: Concentration, %
CO	0	54.6 (21.5)	0 (0)	1	0	–	76.2(30.0)	0 (0)	1	0	–
	3	54.9(21.6)	0 (0)	1	0	–	20.1 (7.9)	7.61(1.18)	8	19000	–
	9	54.6(21.5)	3.16(0.49)	1	360	–	40.1(15.8)	7.16(1.11)	32	37000	–
	12	31.2(12.3)	2.97(0.46)	1	580	–	53.8(21.2)	6.52(1.01)	64	50000	–
	18	31.0(12.2)	4.97(0.77)	2	1960	–	54.6(21.5)	6.32(0.98)	64	49000	–
	24	54.1(21.3)	8.45(1.31)	4	3800	–	54.6(21.5)	4.77(0.74)	64	36000	–
	30	53.8(21.2)	5.81(0.90)	8	5250	–	53.6(21.1)	3.68(0.57)	64	28000	–
CO_2	0	74.7(29.4)	1.55(0.24)	1	260	–	31.2(12.3)	0.77(0.12)	1	312	–
	3	40.6(16.0)	1.87(0.29)	1	560	–	12.2 (4.8)	5.48(0.85)	16	88000	–
	9	40.1(15.8)	5.16(0.80)	1	1580	–	29.7(11.7)	7.16(1.11)	32	94000	–
	12	23.1 (9.1)	1.48(0.23)	4	3150	–	29.2(11.5)	7.74(1.20)	32	104000	–
	18	23.1 (9.1)	3.48(0.54)	4	7400	–	40.1(15.8)	9.94(1.54)	32	97000	–
	24	40.4(15.9)	5.29(0.82)	8	13000	–	40.1(15.8)	4.58(0.71)	64	90000	–
	30	39.4(15.5)	3.48(0.54)	16	17400	–	40.1(15.8)	8.32(1.29)	32	82000	–
O_2	0	53.8(21.2)	1.48(0.23)	1024	–	21.3	53.6(21.1)	1.48(0.23)	1024	–	21.0
	3	54.6(21.5)	1.48(0.23)	1024	–	21.3	20.1 (7.9)	1.03(0.16)	256	–	9.8
	9	54.6(21.5)	1.48(0.23)	1024	–	21.3	53.8(21.2)	0.97(0.15)	512	–	6.9
	12	31.2(12.3)	0.84(0.13)	1024	–	20.9	53.8(21.2)	0.65(0.10)	512	–	4.6
	18	41.1(16.2)	1.10(0.17)	1024	–	20.7	54.6(21.5)	2.58(0.40)	128	–	4.5
	24	54.1(21.3)	1.42(0.22)	1024	–	20.4	54.6(21.5)	3.29(0.51)	128	–	5.7
	30	53.8(21.2)	1.23(0.19)	1024	–	17.7	53.6(21.1)	1.94(0.30)	256	–	6.9

conjugated unsaturated dialdehyde, and condensation of the latter with 3-methyl-l-phenyl-2-pyrazolin-5-one to form a dye absorbing at 530 nm. The method produces a satisfactory linear calibration curve covering the concentration range of 0.1 to 1.0 micrograms of CN^- per milliliter. Unknown solutions are diluted as required, using standard volumetric techniques, to bring the CN^- concentration into this range.

Freshly prepared standards containing NaCN in 0.1N sodium acetate were prepared by diluting a fresh stock solution of sodium cyanide in water (1.0 mg/ml) with sodium acetate solution (lambda pipettes and volumetric flasks were used). The pyrazolone agent was freshly prepared for the day of the test. Solution absorbances were read using a Bausch and Lomb Spectronic 20 colorimeter. The concentrations of hydrogen cyanide in the 500-ml atmosphere samples were calculated from the total cyanide ion detected in the two bubblers in series. Test results are given in table 5.

B.2.2 POTENTIOMETRIC DETERMINATION OF FLUORIDE

The fluoride ion concentrations in the bubbler solutions were measured potentiometrically. An Orion Model 801 pH meter equipped with an Orion 94-09 fluoride electrode and an Orion 90-02 double junction reference electrode was used. A calibration curve covering the F^- concentration range of 10^{-5} through 10^{-1} M was generated using freshly made standards. These standards were prepared by serial dilution, with 0.1M sodium acetate, of a 0.1M solution of sodium fluoride in 0.1M sodium acetate.

The total amount of HF in each 500-ml (30.5-in.^{3}) gas sample was calculated from the total quantity of F^- found in the two bubblers. The corresponding atmospheric concentrations of HF, expressed as volumetric ppm, are given in table 6.

B.2.3 POTENTIOMETRIC DETERMINATION OF CHLORIDE

Chloride ion concentrations in the bubbler solutions were measured using an Orion Model 801 pH meter that was equipped with an Orion 94-17 chloride ion electrode and an Orion 90-02 double junction reference electrode. A calibration curve covering the Cl^- concentration range of 10^{-5} through 10^{-1} M was generated. Fresh standards were prepared by serial dilution with 0.1M sodium acetate, of a 0.1M solution of sodium chloride in 0.1M sodium acetate. Five drops of concentrated nitric acid were added to 10 ml (0.61 in.^{3}) of each standard immediately before measuring the emf for the calibration curve.

Five drops of concentrated nitric acid were added to each bubbler solution before measuring the emf to convert the CN^- present to HCN and minimize the cyanide interference. Chloride ion concentrations were read from the calibration curve. From the total amount of Cl^- in both bubblers, the concentrations of HCl in the 500-ml (30.5-in.^{3}) gas samples were calculated. Results, expressed as ppm (by volume) of HCl, are given in table 7.

B.3 DRÄGER TUBE ANALYSIS

Dräger tubes are designed for detecting and quantitatively analyzing specific atmospheric contaminants. They are glass tubes containing colorimetric chemical reagents specific for particular contaminants. The length of the tube packing that changes color when a known volume of air is pumped through the tube indicates the contaminant concentration. They

Table 5.— Analytical Results - Cyanide

Sample number	Time, minutes	Lavatory: Dilution factor A	Lavatory: Dilution factor B	Lavatory: Absorbance A	Lavatory: Absorbance B	Lavatory: Bubbler conc., ppm A	Lavatory: Bubbler conc., ppm B	Lavatory: Atmospheric conc., ppm A	Lavatory: Atmospheric conc., ppm B	Lavatory: Atmospheric conc., ppm Total	Enclosure: Dilution factor A	Enclosure: Dilution factor B	Enclosure: Absorbance A	Enclosure: Absorbance B	Enclosure: Bubbler conc. ppm A	Enclosure: Bubbler conc. ppm B	Enclosure: Atmospheric conc., ppm A	Enclosure: Atmospheric conc., ppm B	Enclosure: Atmospheric conc., ppm Total
1	0	1:1	1:1	0.000	0.000	0.00	0.00	0	0	0	1:1	1:1	0.00	0.00	0.0	0.0	0	0	0
2	3	1:1	1:1	0.036	0.000	0.075	0.00	1.4	0	1.4	1:1	1:1	0.00	0.00	0.0	0.0	0	0	0
3	6	12.5:1	12.5:1	0.335	0.087	7.5	2.13	144	41	185	1:1	1:1	0.00	0.00	0.0	0.0	0	0	0
4	9	12.5:1	12.5:1	0.364	0.050	8.1	1.25	149	24	173	1:1	1:1	0.00	0.00	0.0	0.0	0	0	0
5	12	12.5:1	12.5:1	0.658	0.308	15.6	6.88	301	132	433	1:1	1:1	0.00	0.00	0.0	0.0	0	0	0
6	18	25:1	12.5:1	0.530	0.361	24.3	7.88	467	152	619	1:1	1:1	0.004	0.00	<0.02	0.0	<0.5	0	Trace
7	24	25:1	12.5:1	0.616	0.292	29.3	6.63	563	127	690	1:1	1:1	0.016	0.00	<0.05	0.0	<1.0	0	Trace
8	30	12.5:1	12.5:1	0.100	0.036	2.5	0.93	48	1	49	1:1	1:1	0.028	0.00	0.75	0	1.4	0	1.4

Note: For each analysis, bubbler A was nearest to the area sampled.

Table 6.— Analytical Results - Fluoride

Sample number	Time, min.	Lavatory: Bubbler fluoride concentration, M x 10^{-5} A	B	Lavatory: Atmospheric HF concentration, ppm A	B	Total	Enclosure: Bubbler fluoride concentration, M x 10^{-5} A	B	Enclosure: Atmospheric HF concentration, ppm A	B	Total
1	0	<1	<1	<2.5	<2.5	≃0	<1	<1	<2.5	<2.5	≃ 0
2	3	38	9.6	192	48	240	<1	<1	<2.5	<2.5	≃ 0
3	6	350	9.3	1760	47	1810[a]	<1	<1	<2.5	<2.5	≃ 0
4	9	305	55	1540	280	1820	3.1	3.4	16	17	33
5	12	290	9.6	1460	48	1510[a]	4.8	2.0	24	10	34
6	18	530	15.5	2670	78	2750[a]	57.5	20.0	290	101	391
7	24	165	11	820	55	875	43.0	25.0	217	126	343
8	30	30	5	151	25	176	61.0	64.0	307	322	629

[a]Rounded off to three significant figures.

Table 7.— Analytical Results - Chloride

Sample number	Sampling Time, minutes	Lavatory: Chloride concentration, M x 10^{-5} A	B	Lavatory: Atmospheric HCl concentration, ppm A	B	Total	Enclosure: Chloride concentration, M x 10^{-5} A	B	Enclosure: Atmospheric HCl concentration, ppm A	B	Total
1	0	8.6	13	43	65	108	6.8	2.5	34	10	44
2	3	280	64	1400	320	1720	2.0	10.0	10	50	60
3	6	580	40	2900	200	3100	4.3	1.2	22	6	28
4	9	450	168	2250	840	3090	10.0	14.1	50	71	121
5	12	1700	900	8500	450	8950	16.7	13.0	84	65	149
6	18	2400	157	12000	785	12785	380	15.0	1900	75	1975
7	24	380	156	1900	780	2680	480	360	2400	180	2580
8	30	98	16	490	80	570	540	86	2700	430	3130

are manufactured by Drägerwerke A.G. of Lubeck, West Germany, and are sold in the USA by National Mine Service Company of Pittsburgh. A special pump, which draws 100 ml (6.1 in.^{3}) per stroke through the tube, is used.

Concentrations of HF, HCN, and CO were measured. Details of the tubes used are as follows:

Compound	Dräger Part Number	Optimum Range Pump Strokes	Optimum Range ppm	Test Range Strokes	Test Range ppm
Hydrogen cyanide	2/a CH30901	5	2-30	5	2-30
				1	10-150
Hydrogen fluoride	1.5/b CH30301	20	1.5-15	1	6-60
Carbon monoxide	10/b CH20601	1	10-3000	5	10-3000

These tubes are designed for atmospheric trace contaminant analysis. The concentrations of all three gases in the lavatory rapidly exceeded the optimum measuring ranges for the tubes. Ranges for HF and HCN were extended by using a small number of pump strokes, but the concentrations were still too large to measure (off scale) in the lavatory. Dräger tube results are listed in tables 8 and 9.

Table 8.—Dräger Tube Results—HCN and HF

Sampling time, min.	Enclosure				Lavatory			
	HCN		HF		HCN		HF	
	Strokes	ppm	Strokes	ppm	Strokes	ppm	Strokes	ppm
0	5	0	5	0	5	0	5	0
3	5	0	5	0	5	15	5	>60*
6	5	0	5	4	5	>30*	5	>60*
9	5	1	5	6	5	>30*	5	>60*
12	5	1	5	4	1	>150*	5	>60*
18	5	2	5	6	1	>150*	5	>60*
24	5	20	5	6	1	>150*	5	>60*
30	3	42	5	0	1	>150*	5	>60*

* Off scale on colorimetric tube.

Table 9.—Dräger Tube Results—Carbon Monoxide

Sampling time, min.	CO, ppm	
	Enclosure	Lavatory
5	0	>3000*
8	50	>3000*
11	300	>3000*
17	800	>3000*
23	900	>3000*
29	2400	>3000*

*Off scale on colorimetric tube.