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Volume 1

Testing of Aircraft Passenger Seat Cushion Materials — Full Scale — Test Description and Results

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16. Abstract

This report describes the work done by Douglas Aircraft Company under contract to the National Aeronautic and Space Agency, Johnson Space Center (NASA JSC) to determine the burn characteristics of presently used and proposed seat cushion materials and types of constructions. The tests were conducted under Contract NAS9-16062 in the Douglas Cabin Fire Simulator (CFS) at the Space Simulation Laboratory, Huntington Beach, California. Eight different seat cushion configurations were subjected to full-scale burn tests. Each cushion configuration was tested twice for a total of sixteen tests. Two different fire sources were used. They consisted of one liter of Jet A fuel for eight tests and a radiant energy source with propane flame for eight tests. Both fire sources were ignited by a propane flame. During each test, data were recorded for smoke density, cushion temperatures, radiant heat flux, animal response to combustion products, rate of weight loss of test specimens, cabin temperature, and for the type and content of gas within the cabin atmosphere. When compared to existing passenger aircraft seat cushions, the test specimens incorporating a fire barrier and those fabricated from advanced materials, using improved construction methods, exhibited significantly greater fire resistance. Flammability tests were performed by NASA-JSC in their JSC 737 fuselage. Their comparison tests were conducted upon one fire blocking configuration and one polyimide configuration. Results of these tests were similar to those obtained by Douglas Aircraft Company and are included in this report.

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PREFACE

This report is submitted under contract NAS9-16062 and covers the period 11 March 1980 through 10 May 1981. To aid the reader in its use, this report is presented in two volumes. Volume 1 contains test procedures and results of the program performed at Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach, California. Included as an appendix to Volume 1 is a NASA-JSC report on seat flammability tests performed in December 1980 by NASA. Volume 2 contains plotted test data of the Douglas Aircraft test program. Mr. Fred E. Duskin was Principal Investigator and Program Director at Douglas Aircraft Company and was assisted by the Materials and Producibility Engineering Section.

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SECTION 1
INTRODUCTION

Aircraft passenger seats represent a high percentage of the organic materials used in a passenger cabin. These organics can contribute to a cabin fire if subjected to a severe ignition source such as a postcrash fuel fire.

The series of tests reported upon in this report is the fourth phase of a NASA-funded program to improve the fire resistance of aircraft passenger seats. Specifically, it is directed toward identifying materials and design approaches that will improve the fire resistance of contemporary seat cushions. Eight different seat cushion configurations were subjected to two different ignition sources in the Douglas Cabin Fire Simulator. These configurations were selected on the basis of previous laboratory testing and design analysis.

SECTION 2
SYMBOLS AND ABBREVIATIONS

Btu	British thermal unit
°C	Degrees Celsius (centigrade)
Ca	Cardiac arrhythmias
CA	Cardiac arrest
cm	Centimeter
cm^2	Square centimeter
DAC	Douglas Aircraft Company
°F	Degrees Fahrenheit
ft	Feet
hr	Hour
in.	Inch
kg	Kilogram
kg/m^2	Kilogram per square meter
kw	Kilowatt
lb	Pound
lb/ft^2	Pounds per square foot
lb/ft^3	Pounds per cubic foot
m	Meter
MATS	Multiple Animal Test System
mm	Millimeter
min	Minutes
NASA	National Aeronautics and Space Administration
PARTS	Portable Animal Test System
PCT, %	Percent
PPM	Parts per million
psi	Pounds per square inch
sec	Second
TC	Thermocouple
Ti	Time to incapacitation
W	Watt

SECTION 3
TEST ARTICLES

3.1 TEST SPECIMENS

Eight different seat cushion configurations were tested and these are listed in Table 1. Fire blocking, when incorporated, covered all sides of the cushion. When more than one material was used for padding, e.g., 1/2-inch LS-200/polyimide foam, one layer of each material was incorporated. All upholstery materials were stitched with nylon beta thread. The overall dimensions for the back cushions were 43 by 61 by 5 centimeters (17 by 24 by 2 inches) and 46 by 50 by 8 centimeters (18 by 20 by 3 inches) for the bottom cushions.

3.2 MATERIALS

The eight test specimens were fabricated using a combination of the materials shown in Table 2. These materials were selected for use in this program on the basis of their performance in previous tests, Reference 1, and on their availability.

TABLE 1

SEAT DESIGN TEST CONFIGURATION

TEST NO.	UPHOLSTERY	FIRE BLOCKING	CUSHION REINFORCEMENT (ADHESIVE R2382 N/F)	CUSHION	REMARKS
1	ST4727-112 SUN ECLIPSE WOOL/NYLON (104)	NONE	COTTON MUSLIN 44/40 CNT (228)	2043FA URETHANE	BASELINE
2	ST4727-112 SUN ECLIPSE WOOL/NYLON (104)	400-11 DURETTE BATT (216)	NOMEX III (221)	2043FA URETHANE	FIRE BARRIER
3	ST4727-112 SUN ECLIPSE WOOL/NYLON (104)	VONAR 3/PS (229)	COTTON MUSLIN 44/40 CNT (228)	2043FA URETHANE	FIRE BARRIER
4	20787 KERMEL/WOOL BLEND (101)	NOMEX III (221) 1/2 IN. LS-200 NEOPRENE (317)	NONE	2043FA URETHANE FOAM WITH AIREX (414) CORE	FIRE BARRIER AND FLOTATION
5	20787 KERMEL/WOOL BLEND (101)	NOMEX III (221) 1/2 IN. LS-200 NEOPRENE (317)	NONE	2043FA URETHANE	FIRE BARRIER
6	20787 KERMEL/WOOL BLEND (101)	NONE	NOMEX III (221)	1/2 IN. LS-200/ POLYIMIDE FOAM	LIGHTWEIGHT COMBINED CUSHION
7	SEDELLIA BLUE 3177 100% WOOL (117)	NONE	COTTON MUSLIN 44/40 CNT (228)	POLYIMIDE FOAM	FIRE RETARDANT CUSHION
8	SEDELLIA BLUE 3177 100% WOOL (117)	NONE	COTTON MUSLIN 44/40 CNT (228)	POLYIMIDE FOAM WITH AIREX (414) CORE	FIRE RETARDANT CUSHION WITH FLOTATION

TABLE 2
CUSHION MATERIALS

MATERIAL DESCRIPTION	PRODUCT NO.	SUPPLIER
KERMEL/WOOL BLEND DECORATIVE FABRIC	20787	H. LELIEVRE PARIS, FRANCE
90 PERCENT WOOL/10 PERCENT NYLON BLEND SUN ECLIPSE BLUE DECORATIVE FABRIC	ST 4227-112	COLLINS AND AIKMAN CHARLOTTE, NC
100 PERCENT WOOL, SEDELLIA BLUE DECORATIVE FABRIC	3177	COLLINS AND AIKMAN CHARLOTTE, NC
DURETTE NEEDLE PUNCH FELT (CHLORINATED ARAMID) 10.4 OZ/YD^2	400-11	FIRE SAFE PRODUCTS ST. LOUIS, MO
NOMEX DUCK FABRIC (NATURAL) 7.5 OZ/YD^2	S/470	SOUTHERN MILLS SENOIA, GA
COTTON MUSLIN 44/40 COUNT	44/40	HANES CONVERTING CONOVER, NC
VONAR 3/PS INTERLINER WITH POLYESTER SCRIM	3/PS	ALLEN INDUSTRIES, INC. RICHMOND, VA
NEOPRENE FOAM 8 LB/FT^3	LS200	TOYAD CORPORATION LATROBE, PA
POLYIMIDE FOAM 1.5 LB/FT^3	1720-1	SOLAR TURBINE AND INTERNATIONAL SAN DIEGO, CA
URETHANE FOAM 2.0 LB/FT^3	2043 FA	NORTH CAROLINA FOAM IND. MOUNT AIRY, NC
CLOSED CELL PVC FOAM AIREX 3 LB/FT^3	S32.50	LONZA, INC. FAIR LAWN, NJ

SECTION 4
TEST PROGRAM

4.1 TEST SETUP

All tests were conducted within the cabin fire simulator (CFS). The CFS is a double-walled steel cylinder 12 feet in diameter and 40 feet long, with a double-door entry airlock at one end and a full-diameter door at the other. It is equipped with a simulated cabin ventilation system and, for environmental reasons, all exhaust products are routed through a scrubber and charcoal filter system. A view port in the airlock door allows the tests to be monitored visually. The radiant heat panels and fuel pan used in these tests were positioned as shown in Figures 1, 2, and 3.

The 30- by 30- by 7.5-centimeter (12- by 12-inch) fuel pan was made from stainless steel sheet and welded at the edges and corners. The radiant panels consisted of 46 quartz lamps producing a 10-watt/square centimeter heat flux upon the right seat edge. Prior to testing, the heat flux upon the cushion surface was mapped using calorimeters. Figure 4 shows the positions at which heat flux measurements were taken and their recorded values.

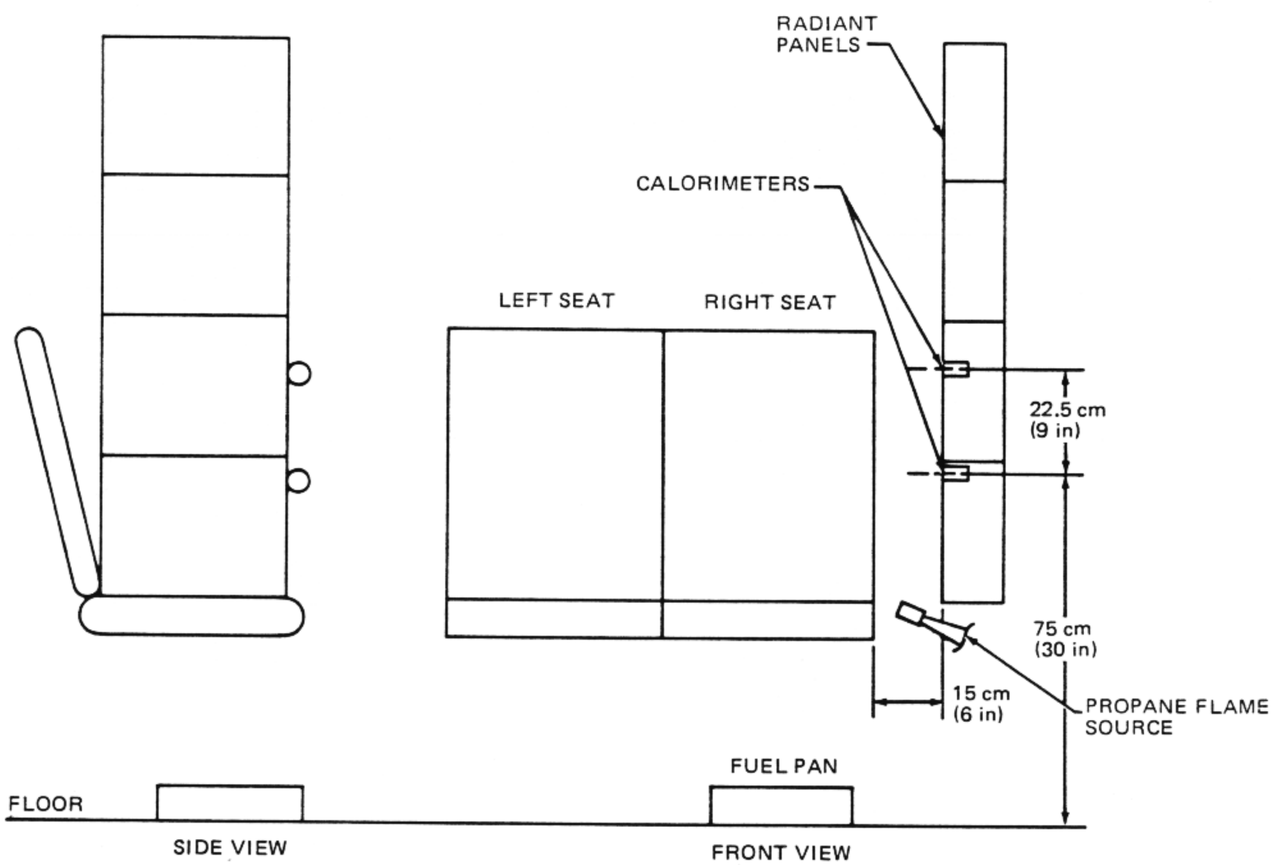

FIGURE 1. FUEL SOURCES – LOCATIONS

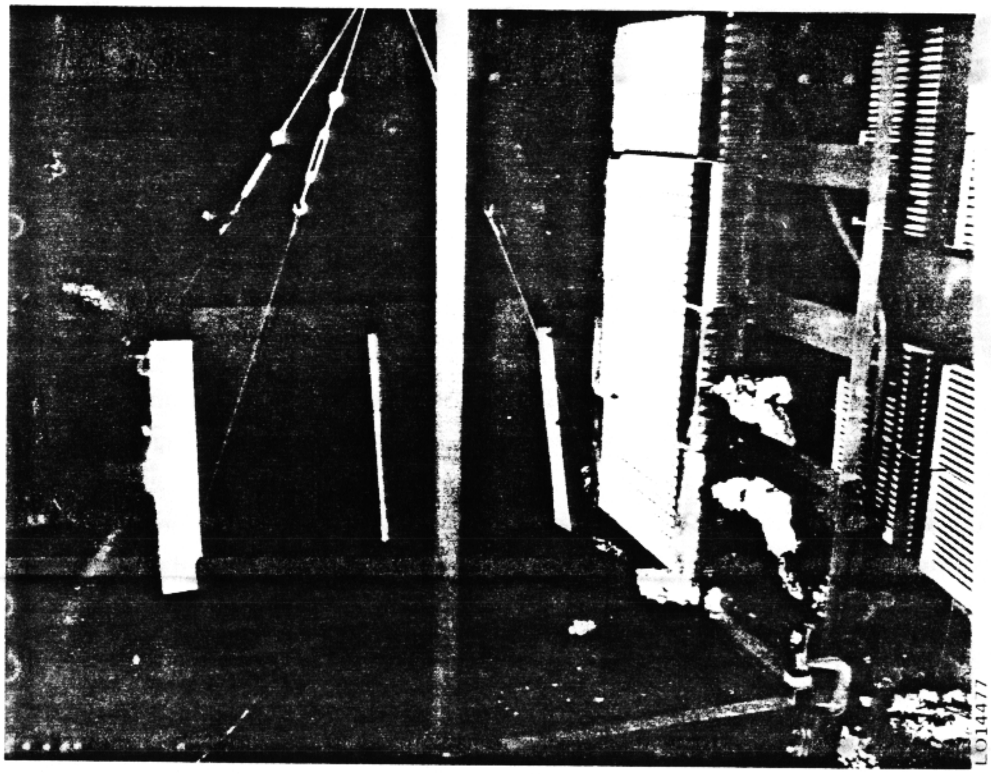

FIGURE 2. RADIANT PANEL TEST SETUP

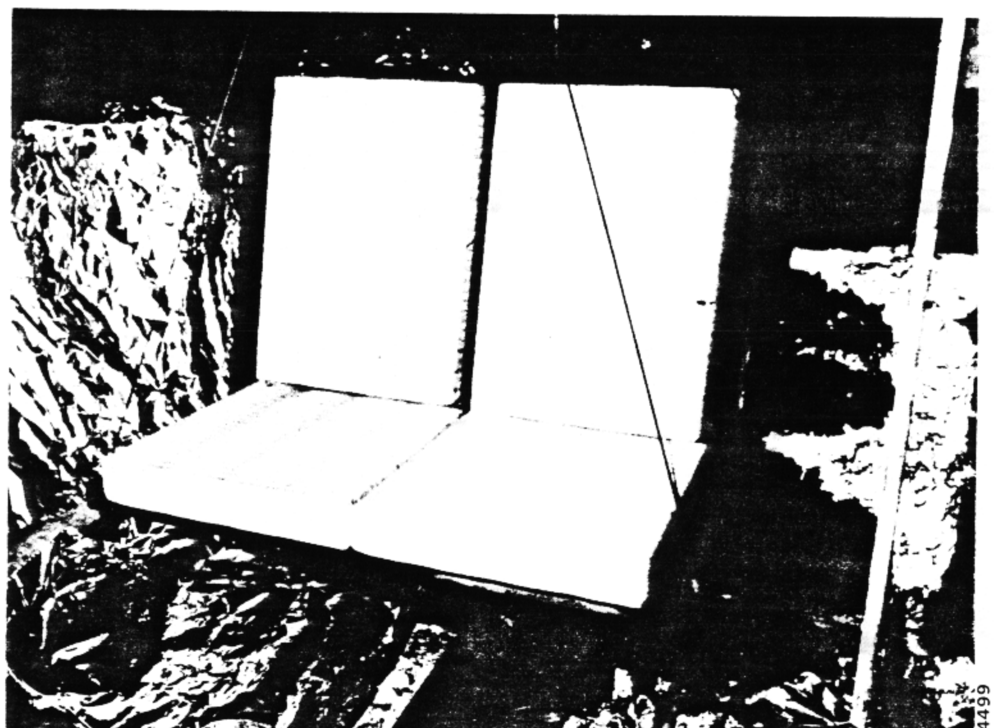

FIGURE 3. FUEL PAN TEST SETUP

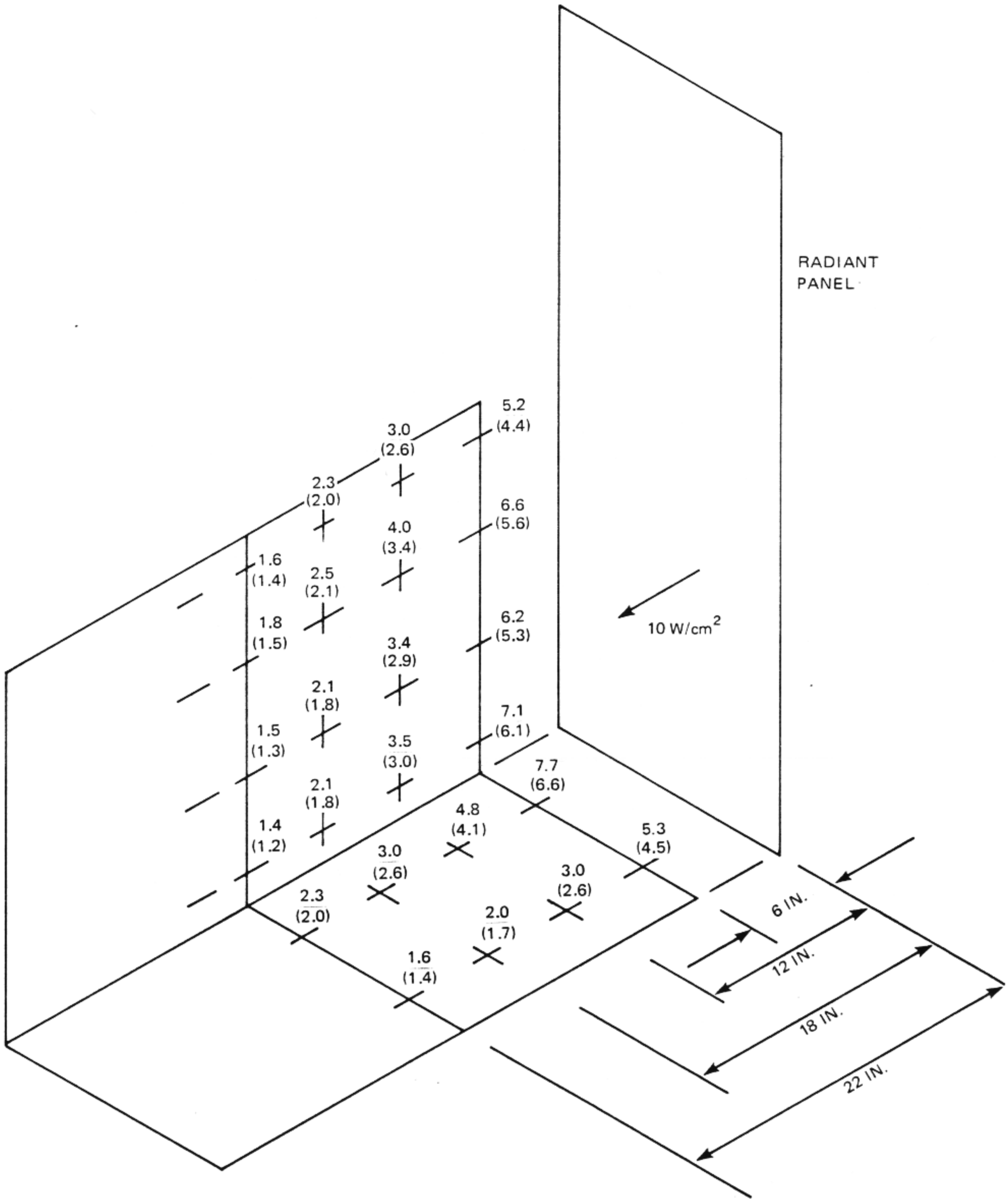

FIGURE 4. HEAT FLUX MAPPING OF RADIANT PANEL – WATTS/CM^2 (BTU/FT^2 SEC)

4.2 INSTRUMENTATION

4.2.1 Photo Instrumentation

Color still photographs were taken of the test setup before and after each test. The post-test photos are presented in Appendix A. In addition to the still photos, closed-circuit color TV with recorded video and color 16-millimeter motion pictures, operating at 24 frames per second, were taken of the seat during the tests. The TV tapes and motion pictures are presented separately from this report.

4.2.2 Thermal Instrumentation

Temperatures from each fire were obtained using chromel-constantan thermocouples sewn into the seat cushions and mechanically attached to the seat frame, Figure 5. In addition, thermocouples were located along the ceiling of the CFS, at the cabin air outlet, on the test animal cage, and at the load cell. Two heat flux sensors were installed facing the seat assembly. A pictorial representation of the cabin instrumentation is shown in Figure 6.

The thermocouple and calorimeter data were fed into a PDP-10 recording computer which in turn fed a PDP-15 printout computer. The raw computer data were then plotted by the data reduction center of McDonnell Douglas Astronautics Company, Huntington Beach.

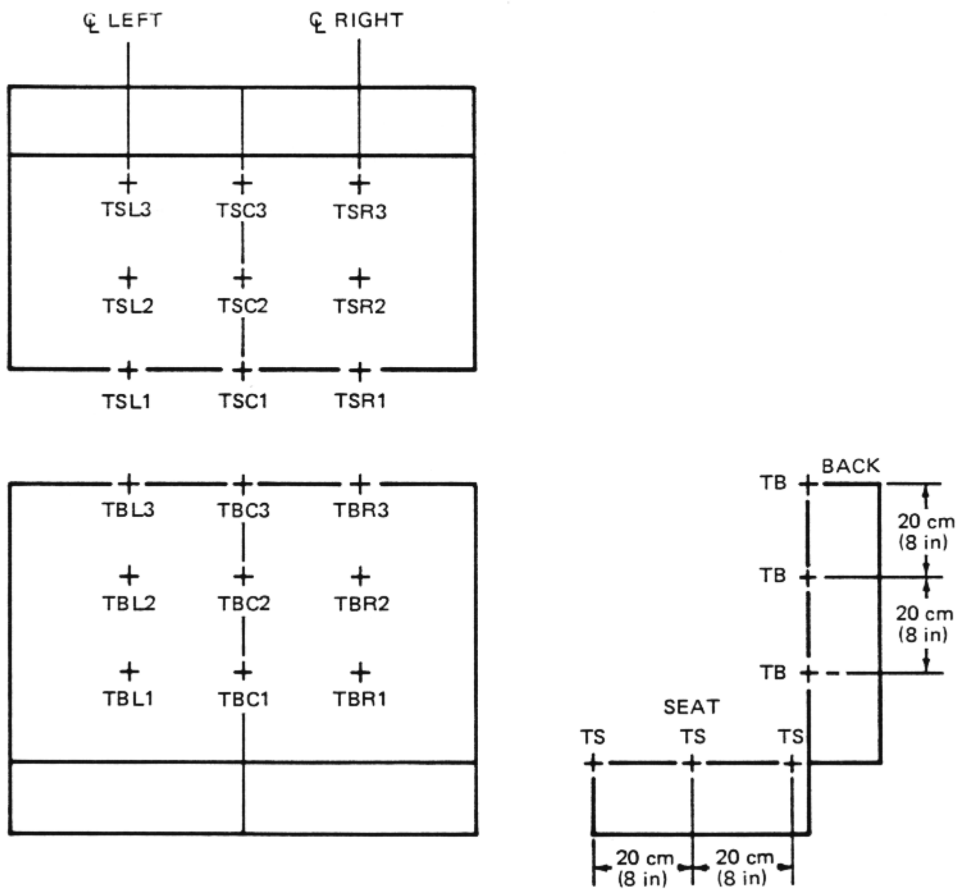

FIGURE 5. CUSHION THERMOCOUPLES (LOCATION AND IDENTIFICATION)

4.2.3 Gas and Smoke Instrumentation

A detailed description of the instrumentation used for gas and smoke analyses is presented in Appendix B. As shown in Figure 6, smoke meters were installed in two locations and were suspended at distances of 1, 3, and 6 feet above the CFS floor at both locations. The smoke meters were Weston Model 594 photocells with 36-centimeter path length calibrated to read in percent transmittance of light. Figure 7 shows calibration of real-time gas instruments.

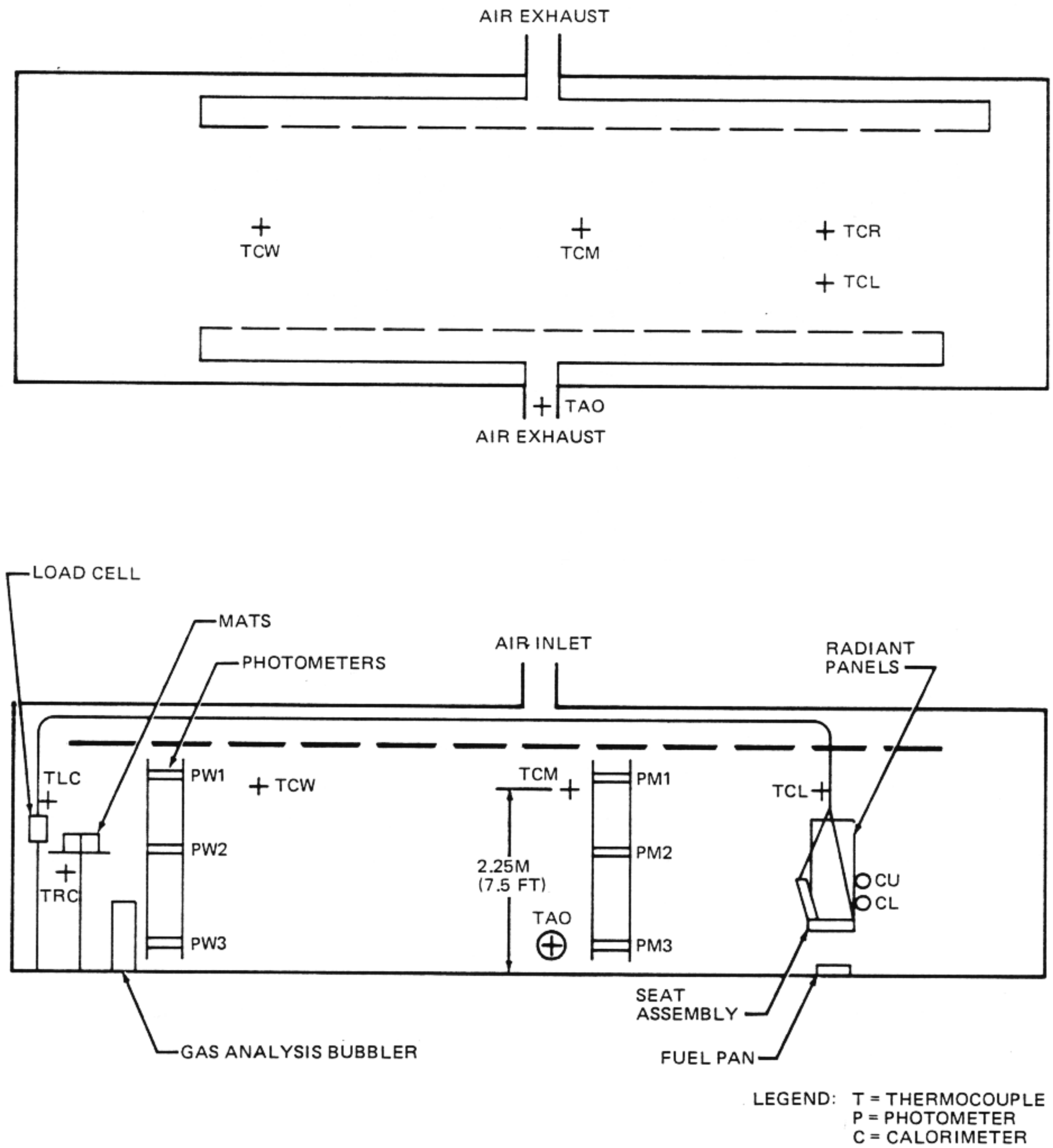

FIGURE 6. CFS INSTRUMENTATION

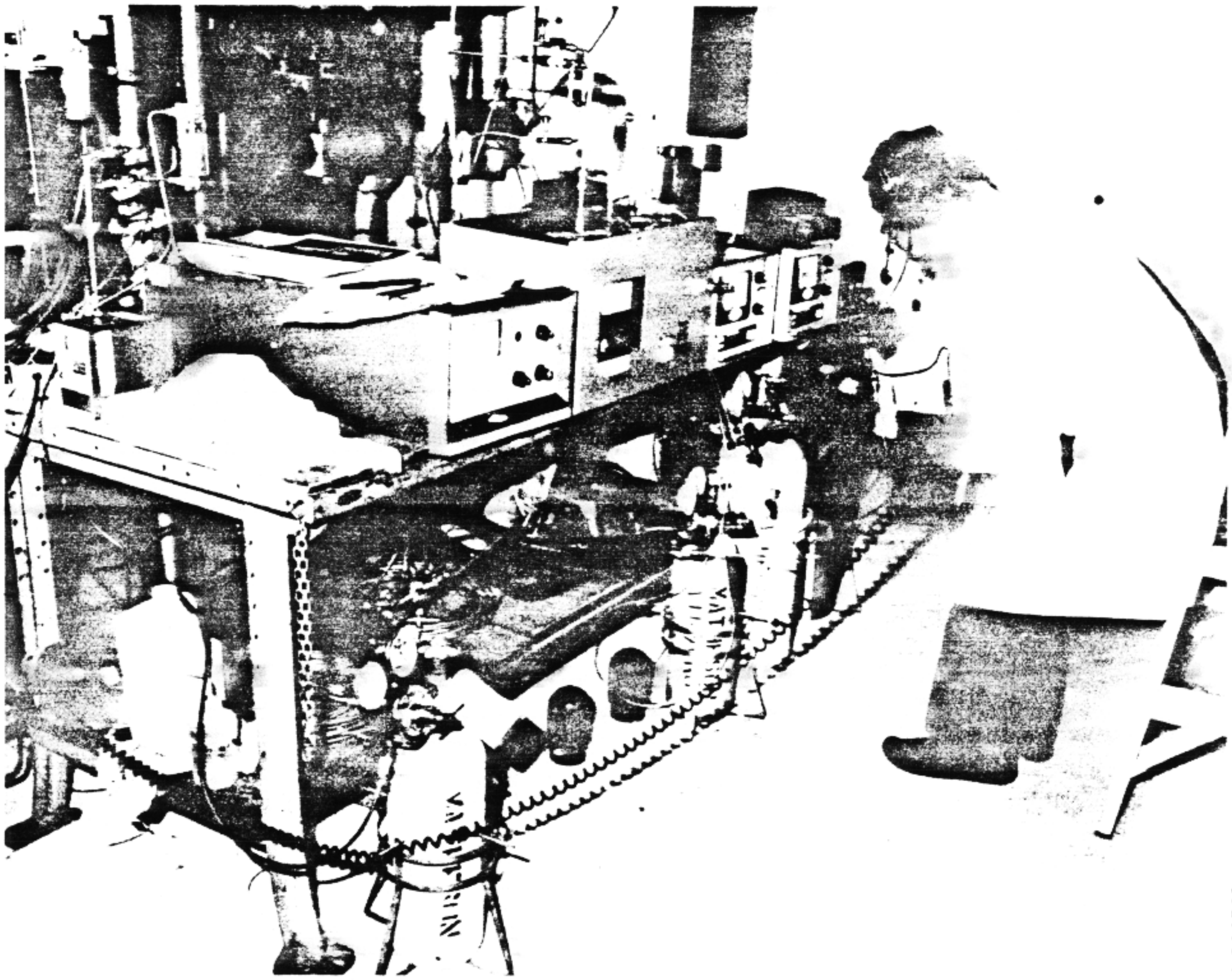

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FIGURE 7. REAL-TIME GAS ANALYSIS EQUIPMENT

4.2.4 Biomedical Instrumentation

Figure 8 is a diagram of the equipment setup. A bulkhead connector in the fire chamber allowed access for electrical power and transducer signals. Two animal cages were located inside the chamber: one was the multiple animal test system (MATS) which was located 48 inches above the floor at 20 feet from the burning specimen, and the other a single animal cage located in the same vicinity. Recorders, signal conditioning equipment, and motor and pump controls were located outside the chamber.

A fitted blanket was placed over each cage to protect the animals from radiant heat. Two half-inch diameter inlet pipes allowed the fire chamber gases to enter the cages. Two 18-liter-per-minute pumps provided ambient air circulation into the cages. These pumps were located on the cage platforms outside the blankets and were coupled to the cage via one-quarter-inch-diameter teflon tubing.

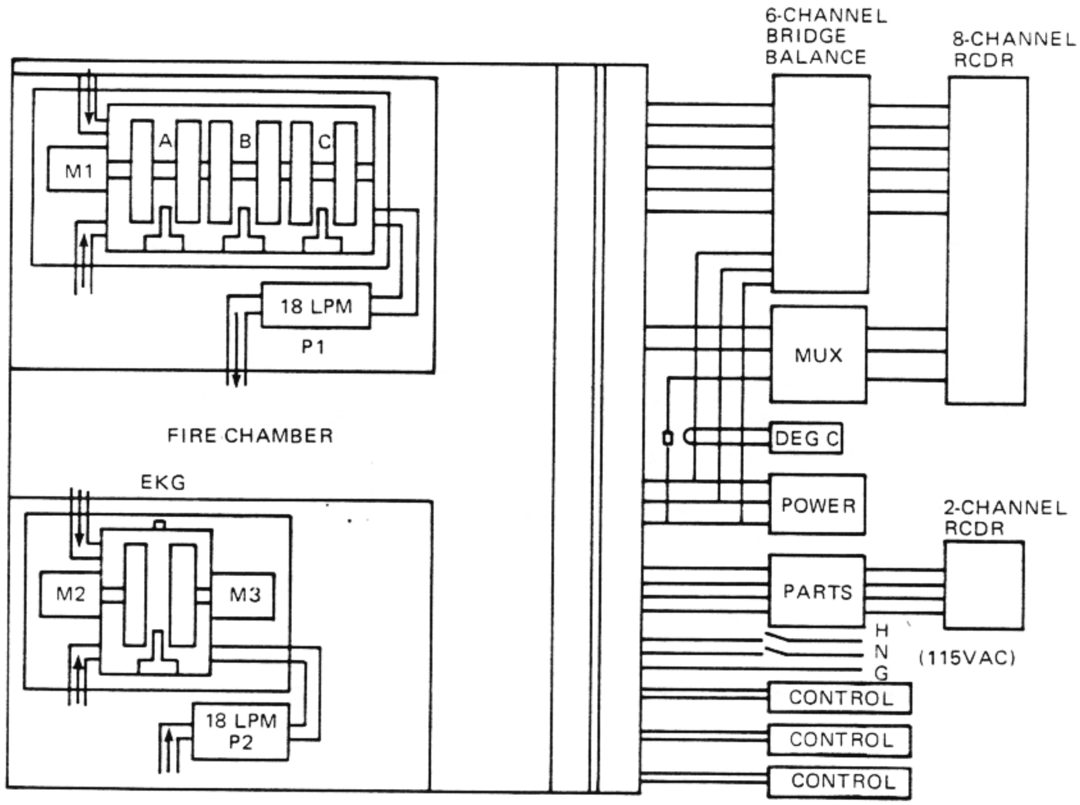

FIGURE 8. BIOMEDICAL INSTRUMENTATION

The MATS cage, Figure 9, consists of three adjacent split-wheel rotating cages mounted on a single shaft which is coupled to a variable speed (5 rpm) drive motor. Only the outer two cages (A and C) shown in Figure 8 were used during these tests.

A stepping bar, having the same radius as the rotating cage (about 9 inches) and protruding between the split wheel, was coupled to a load cell. Thus the collapse of the animal, indicating time to incapacitation (Ti), could be noticed as an increased and steady load on the chart recorder. The single-animal cage was similarly constructed except that each half of the split wheel was coupled to separate drive motors. This eliminated the axle shaft within the cage and permitted the use of an electrocardiogram (EKG) belt on the animal with an umbilical cable exiting at the top of the cage. Both cages contained a solid-state temperature sensor (Analog Devices AD-590) to monitor the animal's ambient environment.

Outside the fire chamber, Figure 10, signals from the load cells were conditioned with a 6-channel bridge-balance panel (3-channels required) and recorded on an Astromed Super 8 hot-pen recorder. Temperature data from the two cages were multiplexed along with ambient room temperature as a reference and recorded on one channel of the chart recorder. Ambient room temperature was monitored with a digital pyrometer. This hot-pen recorder was operated at 1 millimeter/second chart speed.

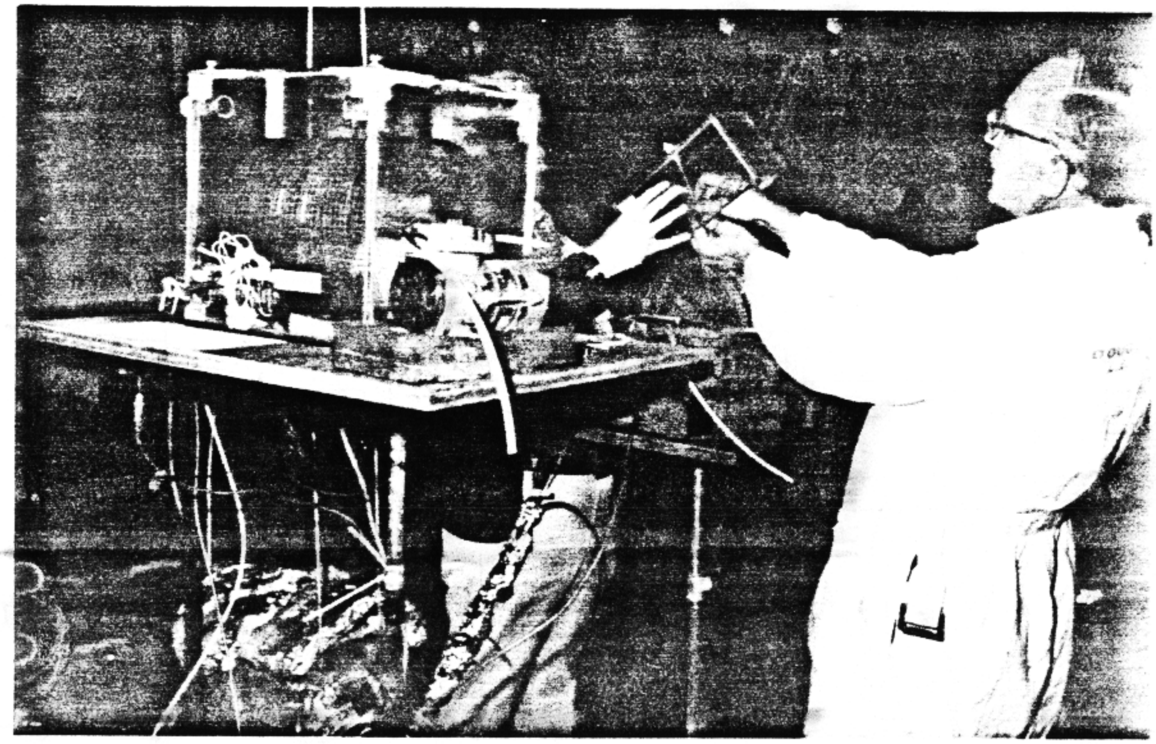

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FIGURE 9. MATS CAGES

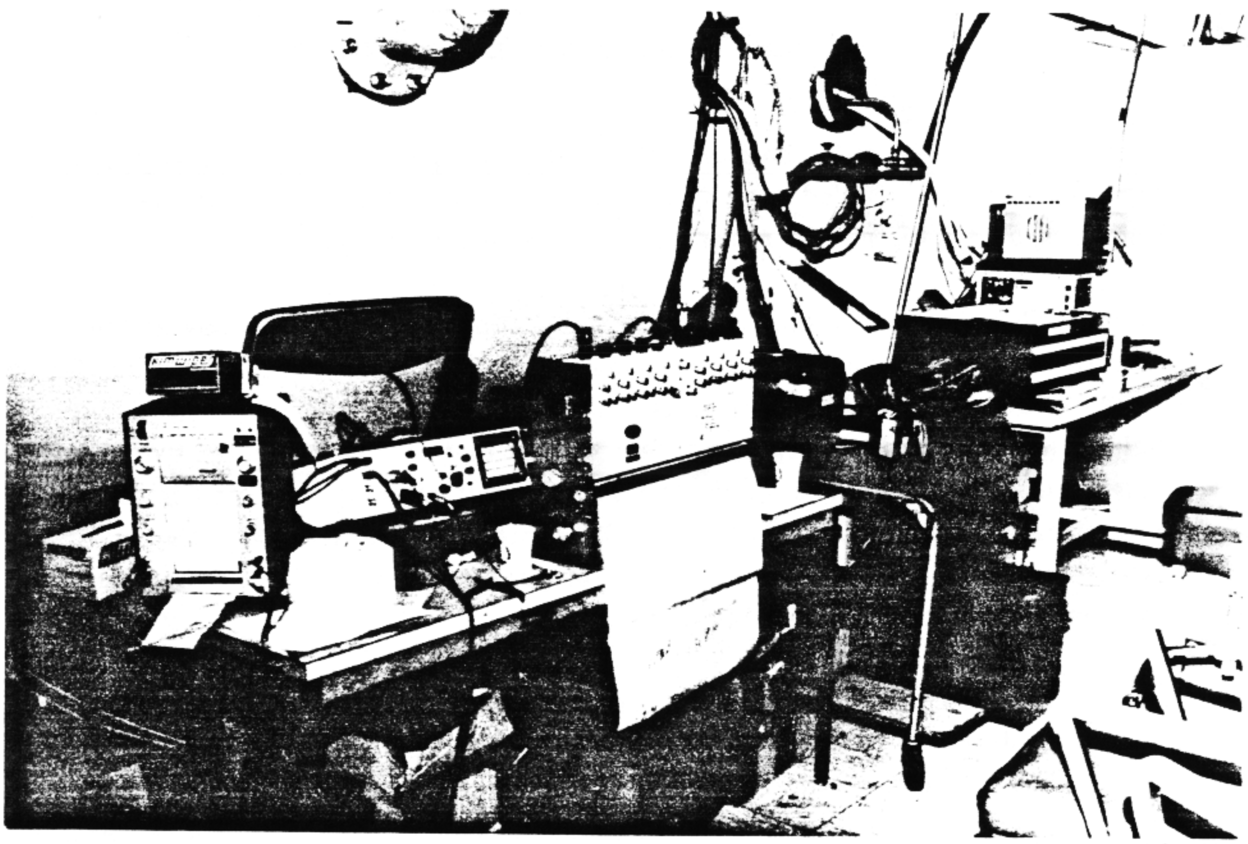

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FIGURE 10. PARTS AND CHART RECORDERS

EKG signals were processed with a portable animal test system (PARTS) which allows data to be recorded on a magnetic cassette tape as well as a two-channel chart recorder. The chart recorder (Gould 222) was operated at 5 millimeter/second chart speed.

4.3 TEST PROCEDURE

Instrumented cushions were weighed, then positioned on the modified seat frame. The seat frame with instrumented cushions was rigged with suspension cables and hung from a cable located in the ceiling of the CFS. The other end of the ceiling cable was attached to the load cell. Thermocouples, calorimeters, gas analysis equipment, photometers, and load cell were checked and calibrated. The test animals were then placed in their cages. Still photographs were taken of the cushions. These procedures were identical for both radiant panel and fuel pan tests.

For the fuel pan tests, one liter of Jet A fuel was placed into a 30- by 30-centimeter (12- by 12-inch) pan just prior to closing the cabin chamber door. The cabin chamber was closed and the cabin ventilating air of approximtely 500 CFM was started.

4.3.1 Radiant Panel Test

The computer, video, and motion picture camera were started at T−0 seconds. At T+15 seconds the propane gas was ignited. At T+20 seconds the radiant panel was switched on and remained on for 5 minutes. At T+30 minutes the computer, video, and motion picture camera were shut off. Photos were taken of the test seats. Remaining cushion materials were removed from the seat frame and weighed.

4.3.2 Fuel Pan Test

The computer, video, and motion picture camera were started when the Jet A fuel ignited. At T+30 minutes the computer, video, and motion picture camera were shut off. Photos were taken of the burned seats. Remaining cushion materials were removed from the seat frame and weighed.

SECTION 5
TEST RESULTS

5.1 GENERAL

The radiant panel subjected the front and top surfaces of the cushions to radiant energy while the fuel pan subjected the bottom of the right seat cushion and occasionally the bottom of the left seat to heat from the Jet A-fuel fire. This resulted in the radiant and fuel pan test cushions having a different final appearance. Photographs of the test results are to be found in Appendix A.

Test data from fuel pan and radiant panel tests are presented in Tables 3 and 4 respectively. This information was taken from the plotted data in Appendix B and Volume 2 and is presented in a form to aid in comparing cushion performances.

Gas analysis, calorimeter values, cushion temperatures, ceiling temperatures and air exhaust temperatures from the radiant panel tests were relatively the same for all seat cushion configurations with the exception of the baseline seat. This was also true for the data obtained from fuel pan tests. In the radiant tests, the percentage of light transmittance was just slightly better for the advance cushion (45 to 58 percent) than for the fire barrier cushions (30 to 55 percent). In the fuel pan tests, the Jet A fuel alone reduced the percentage of light transmittance to a value (35 percent) where comparisons of smoke from the cushions were questionable.

The quantities of CHX, CO, CO_2, HF, HCL and HCN resulting from the tests were relatively small. Their concentrations for a short exposure time of 10 minutes would be at most irritating to the eyes and nose with no immediate danger to life, Reference 2.

After each test, the remains of the seat cushions were removed from the seat frame and weighed. Cushion weights before and after the test are presented in Table 5.

Three 180- to 200-gram female Simonsen Albino (Sprague-Dawley derived) rats were used in each test. Time-to-incapacitation (Ti) data were recorded from all subjects while EKG data were recorded from one subject.

All rats survived the cushion burn tests with one exception. One rat died in the fuel pan fire testing of Seat Cushion Configuration 8. Death of the rat was due to cardiac arrest (CA) and occurred one minute after completion of the 30-minute test. No autopsy was performed on the rat as this was beyond the scope of the program. Gas analysis data showed no unusual quantities of toxic gas for Configuration 8 when compared to the other configurations.

Biological test data for radiant panel and Jet-A fuel tests are presented in Tables 6 and 7. These tables indicate the materials burned in each test, whether or not Ti occurred, and cardiac

TABLE 3
FUEL PAN TEST DATA

DOUGLAS AIRCRAFT COMPANY, INC.

FUEL PAN SEAT NUMBER (SEE FIGURE 1)	PHOTOMETER MIDDLE %	PHOTOMETER WEST %	CHX %	CO %	CO_2 %	O_2 %	CALORIMETER UPPER W/CM2	CALORIMETER LOWER W/CM2	LEFT CUSHION BOTTOM °C	LEFT CUSHION BACK °C	CEILING/LEFT °C	CEILING/RIGHT °C	CEILING/MIDDLE °C	CEILING/WEST °C	AIR OUT °C	TOTAL WEIGHT LOSS KG	HF PPM	HCL PPM	HCN PPM
FUEL PAN	35	35	0	0	0.5	20	0.4	0.4			100	100	75	60	50	--	5	15	0.27
ONLY	600S	600S				500S					500S	500S	500S	500S	600S				
1B	25	22	0	0	2.5	18.5	4	4	650	700	400	400	250	200	75	3.0	39	15	0.63
	200S	200S			250S	250S	150S	150S	125S	200S	150S	150S	150S	150S	250S				
2B	20	22	0	0	1	19	1.5	1.7	400	350	200	175	120	100	55	1.04	8.5	15	0.27
	350S	350S			350S	400S	300S	300S	300S	300S	320S	320S	320S	320S	400S				
3B	20	25	0	0	1	19.5	1.5	2	250	300	150	150	100	85	50	1.26	5	15	0.32
	350S	350S			380S	400S	300S	300S	300S	350S	350S	350S	350S	350S	410S				
4B	25	25	0	0	1	20	1	1.5	100	100	100	100	75	70	45	0.76	5	15	0.27
	400S	450S			410S	410S	350S	350S	400S	400S	400S	400S	400S	400S	410S				
5B	25	30	0	0	1	20	0.7	1	80	90	100	100	75	70	50	0.41	5	15	0.27
	400S	400S			420S	420S	300S	300S	400S	400S	400S	400S	350S	350S	400S				
6B	30	30	0	0	1	20	0.5	1	75	80	90	90	65	55	45	0.17	5	15	0.27
	400S	450S			450S	450S	300S	300S	400S	400S	380S	380S	400S	400S	450S				
7B	35	25	0	0	1	20.5	0.4	.5	200	75	90	90	60	55	50	0.22	5	15	0.27
	450S	550S			450S	450S	200S	200S	450S	450S	450S	450S	450S	450S	500S				
8B	18	16	0	0	1	20	0.7	1.2	400	230	105	105	75	70	40	0.59	5	15	0.56
	300S	300S			400S	400S	250S	250S	100S	250S	300S	300S	350S	350S	400S				

S = SECONDS

TABLE 4
RADIANT PANEL TEST DATA

DOUGLAS AIRCRAFT COMPANY, INC.

RADIANT PANEL SEAT NUMBER (SEE FIGURE 1)	PHOTOMETER MIDDLE %	PHOTOMETER WEST %	CHX %	CO %	CO_2 %	O_2 %	CALORIMETER UPPER W/CM^2	CALORIMETER LOWER W/CM^2	LEFT CUSHION BOTTOM °C	LEFT CUSHION BACK °C	CEILING/LEFT °C	CEILING/RIGHT °C	CEILING/MIDDLE °C	CEILING/WEST °C	AIR OUT °C	TOTAL WEIGHT LOSS KG	HF PPM	HCL PPM	HCN PPM
1	20	28	0	0	2	19.9	0.2	0.2	550	350	280	450	200	150	50	3.0	33	15	0.27
	600S	600S			350S	400S			350S	550S	320S	320S	320S	320S	400S				
2	50	55	0	0	0.5	20.5	0.2	0.2	220	200	160	230	95	80	50	1.58	8.1	15	0.27
	600S	600S			350S	350S			320S	320S	320S	320S	320S	320S	320S				
3	40	40	0	0	0.5	20.5	0.2	0.2	220	210	210	250	100	90	50	2.40	5	15	0.27
	300S	350S			350S	350S			320S 320 600S	320S	320S	320S	320S	320S	320S				
4	35	40	0	0	0.5	20.5	0.2	0.2	220	220	175	250	100	95	50	1.77	5.5	15	0.30
	300S	300S			350S	350S			320S	320S	250S	320S	320S	320S	320S				
5	30	30	0	0	0.5	20.5	0.2	0.2	240	240	180	205	90	80	50	1.84	5	15	0.27
	600S	500S			350S				320S	320S	320S	320S	320S	320S	320S				
6	55	60	0	0	0.5	20.5	0.2	0.2	300	250	150	175	80	75	40	0.81	5	15	0.27
	400S	300S			350S				320S	320S	320S	320S	320S	320S	320S				
7	58	66	0	0	0.5	20	0.2	0.2	780	800	160	160	90	80	40	1.17	19	15	0.27
	600S	600S			350S	400S			250S	250S	320S	320S	320S	320S	320S				
8	45	50	0	0	0.5	20.5	0.2	0.2	310	240	150	160	90	80	40	0.98	21	15	0.27
	250S	300S			350S				320S	320S	320S	320S	320S	320S	320S				

S = SECONDS

TABLE 5

CUSHION WEIGHT LOSS*

	SEAT NO.	CUSHION WEIGHT BEFORE kg (LB)	CUSHION WEIGHT AFTER kg (LB)	DELTA WEIGHT kg (LB)	% LOSS
RADIANT PANEL	1	3.55 (7.8)	0.55 (1.21)	3.0 (6.59)	84
	2	4.70 (10.37)	3.12 (6.89)	1.58 (3.48)	34
	3	6.50 (14.32)	4.10 (9.06)	2.40 (5.26)	37
	4	6.65 (14.66)	4.88 (10.77)	1.77 (3.89)	27
	5	7.10 (15.66)	5.26 (11.60)	1.84 (4.06)	26
	6	4.15 (9.15)	3.34 (7.36)	0.81 (1.79)	20
	7	2.65 (5.84)	1.48 (3.26)	1.17 (2.58)	44
	8	2.97 (6.54)	1.99 (4.38)	0.98 (2.16)	33
FUEL PAN	1B	3.58 (7.90)	0.58 (1.31)	3.0 (6.59)	83
	2B	4.81 (10.60)	3.77 (8.31)	1.04 (2.29)	22
	3B	6.55 (14.44)	5.29 (11.66)	1.26 (2.78)	19
	4B	7.04 (15.52)	6.28 (13.84)	0.76 (1.68)	10
	5B	6.49 (14.30)	6.08 (13.41)	0.41 (0.9)	6
	6B	4.15 (9.14)	3.98 (8.76)	0.17 (0.38)	4
	7B	2.35 (5.18)	2.13 (4.7)	0.22 (0.48)	9
	8B	2.91 (6.41)	2.32 (5.12)	0.59 (1.29)	20

*ASSEMBLY CONSISTED OF 2 BACK AND 2 BOTTOM CUSHIONS

TABLE 6

BIOLOGICAL RESULTS FOR RADIANT PANEL TESTS

TEST NO.	PEAK CAGE TEMP °F	HEAT FLUX W/cm²	Ti	Ca	CA	COMMENTS
1 (A)	81	10	1	11	0	WOOL/NYLON, MUSLIN, URETHANE BASELINE OCCASIONAL PUC's S (EKG) Ti –– 20 MIN. MULTIPLE Ca's – 19.3 MIN.
2 (A)	77	10	0	4	0	WOOL/NYLON, NOMEX III, URETHANE DURRETTE FIRE BARRIER PUC AT 12.6 MIN, SINGLE Ca's AT 13 THROUGH 15 MIN.
3 (A)	81	10	0	0	0	WOOL/NYLON, MUSLIN, URETHANE VONAR 3/PS, FIRE BARRIER
4 (A)	81	10	0	0	0	KERMEL/WOOL, NONE, URETHANE NOM. III/LS200, FIRE BAR-FLOAT
5 (A)	81	10	0	6	0	KERMEL/WOOL, NONE, URETHANE NOMEX III/LS200, FIRE BARRIER OCCASIONAL PUC (ONE PUC NOTICED BEFORE START OF TEST)
6 (A)	77	10	0	4	0	KERMEL/WOOL, NOMEX III, LS200/ PI FOAM, (LIGHTWEIGHT CUSHION)
7 (A)	81	10	0	9	0	100% WOOL, MUSLIN, PI FOAM FIRE RETARDANT CUSHION OCCASIONAL SINGLE AND MULTIPLE ARRHYTHMIAS 1ST 6–MIN.
8 (A)	78	10	0	0	0	100% WOOL, MUSLIN, PI FOAM/AIREX FIRE RET., CUSHION/FLOTATION

TABLE 7

BIOLOGICAL RESULTS FOR FUEL PAN TESTS

TEST NO.	PEAK CAGE TEMP °F	HEAT FLUX W/cm²	Ti	Ca	CA	COMMENTS
1 (B)	84	0	0	101	0	WOOL/NYLON, MUSLIN, URETHANE BASELINE EKG DATA UNUSABLE
2 (B)	82	0	0	6	0	WOOL/NYLON, NOMEX III, URETHANE DURRETTE FIRE BARRIER MULTIPLE Ca's −15 SEC DURATION T_0 + 21 MIN.
3 (B)	79	0	0	2	0	WOOL/NYLON, MUSLIN, URETHANE VONAR 3/PS, FIRE BARRIER EXTRA SYSTOLI AT 5 AND 8 MIN
4 (B)	79	0	1	25	0	KERMEL/WOOL, NONE, URETHANE NOM. III/LS200, FIRE BAR-FLOAT 5 SINGLE Ca's, 20 MULTIPLE Ca's S (EKG) Ti-26.7 MIN.
5 (B)	77	0	0	2	0	KERMEL/WOOL, NONE, URETHANE NOMEX III/LS200, FIRE BARRIER Ca's AT 15 MIN.
6 (B)	78	0	0	101	0	KERMEL/WOOL, NOMEX III, LS200/ PI FOAM, (LIGHTWEIGHT CUSHION)
7 (B)	79	0	0	0	0	100% WOOL, MUSLIN, PI FOAM FIRE RETARDANT CUSHION
8 (B)	78	0	1	50	1	100% WOOL, MUSLIN, PI FOAM/AIREX FIRE RET., CUSHION/FLOTATION Ti's AT 25 MIN., MULTIPLE Ca's AT 26 MIN., SINGLE CA's AT 5 to 8 MIN S(EKG) Ti-25 MIN., CA-31 MIN.

responses to the gases. Cardiac arrhythmias (Ca) are shown on a scale of 0 to 50, with 101 indicating unusable data resulting from excessive noise or broken sensors. A "0" on the scale indicates no arrhythmias and "50" indicates cardiac arrest (CA).

5.2 BASELINE CONFIGURATION

In the baseline tests both initial ignition sources resulted in complete burning of all cushion materials.

5.3 FIRE BLOCKING

The radiant panel melted/burned the urethane, hollowing out the right seat cushions, and lightly damaging the left seat back and bottom cushions. The fuel pan melted/burned the urethane, hollowing out the right seat bottom cushion completely and the left seat bottom cushion partially, leaving both right and left back cushions with minor if any damage.

5.4 ADVANCE MATERIALS

For the radiant panel advanced cushion tests, there was extensive polyimide shrinkage and charring on the right seat cushions with medium-to-light damage on the left seat cushions.

The fuel pan test extensively shrank/charred the polyimide on the right seat bottom cushion with medium-to-light damage to the left seat bottom cushion and no damage to either left or right back cushions.

SECTION 6
CONCLUSIONS

The energy sources, radiant panel at 10 watts/square centimeter and Jet A fuel, were severe flammability tests for each cushion configuration.

The fire barrier and advance material cushions exhibited superior fire resistance when compared to the baseline cushions while differences in burn damage between the fire barrier and advance material polyimide cushions were minimal. However, the polyimide cushions were marginally better with respect to temperatures above the seat, smoke density, and weight loss.

The fire barrier and advance material cushions showed fire resistant properties which could prevent propagation of a fire in an aircraft cabin.

It is therefore concluded that fire barrier and the advance material cushions tested are viable replacements for contemporary urethane cushions with respect to fire resistance of a passenger seat. Development of design configurations must consider weight impacts, material costs, and functional requirements.

SECTION 7
RECOMMENDATIONS

This program demonstrated the feasibility of improving the fire resistance of current passenger seat cushions by enveloping the polyurethane cushion with a protective fire barrier material or by using a polyimide foam cushion. The scope of the test program was too limited to establish a viable production configuration. Future programs should include burn testing of candidate cushsion configurations at various heat-flux levels.

It is recommended that NASA continue the polyimide optimization and characterization program. At the same time, as an interim configuration, the fire barrier concept should be optimized by NASA to create a viable end item.

REFERENCES

1. F. E. Duskin, K. J. Schutter, H. H. Speith, E. L. Trabold, "Study to Develop Improved Fire Resistant Aircraft Passenger Seat Materials", NASA CR No. 152408, September 1980.

2. H. H. Speith, J. G. Gaume, R. E. Luoto, D. M. Klinck, "Investigate a Combined Hazard Index Methodology for Ranking an Aircraft Cabin Interior Material for Combustion Hazards", Unpublished.

APPENDIX A
CUSHION TEST PHOTOS

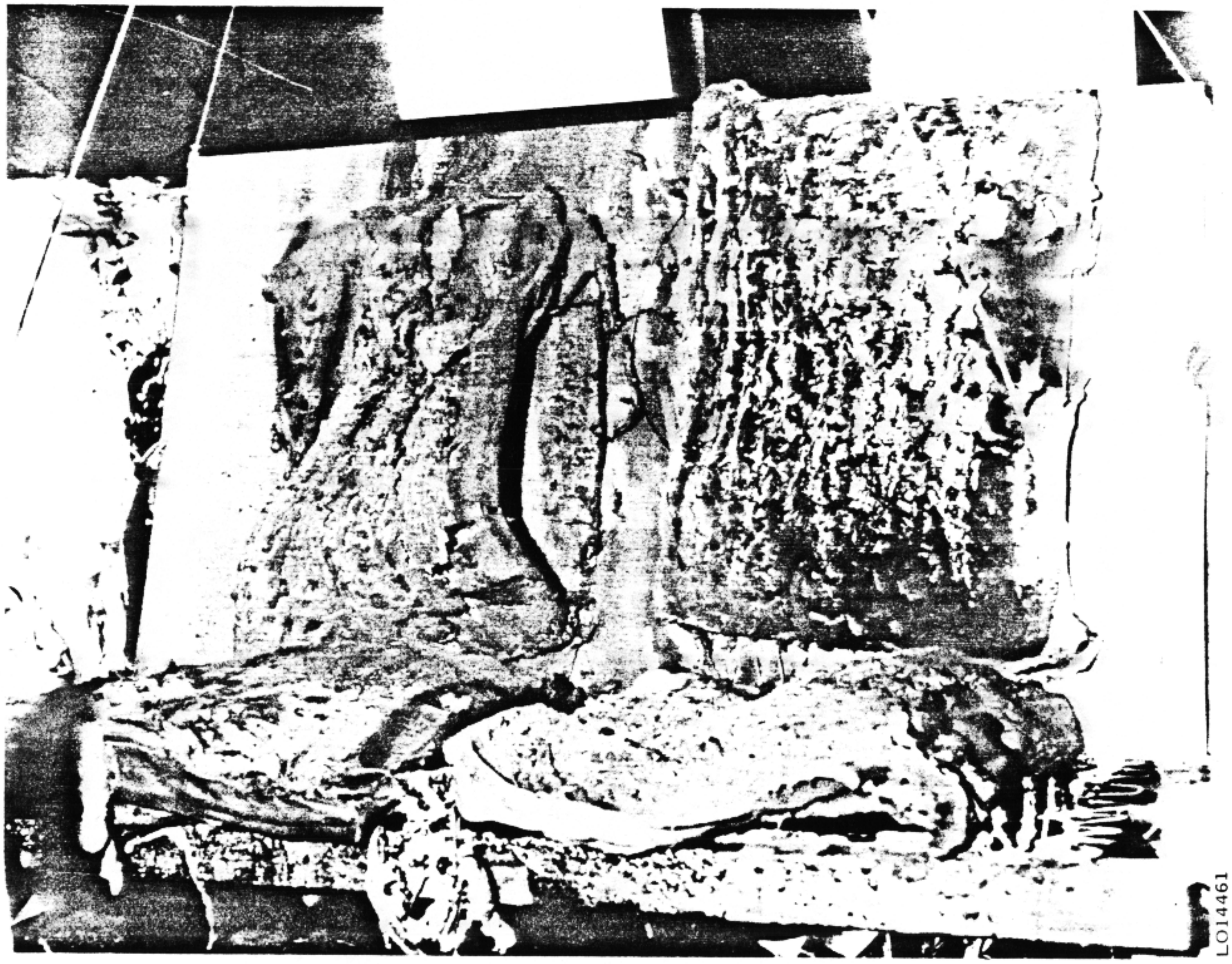


FIGURE A-1. CONFIGURATION 1 – RADIANT PANEL

- 90 PERCENT WOOL 10 PERCENT NYLON
- COTTON MUSLIN
- URETHANE FOAM

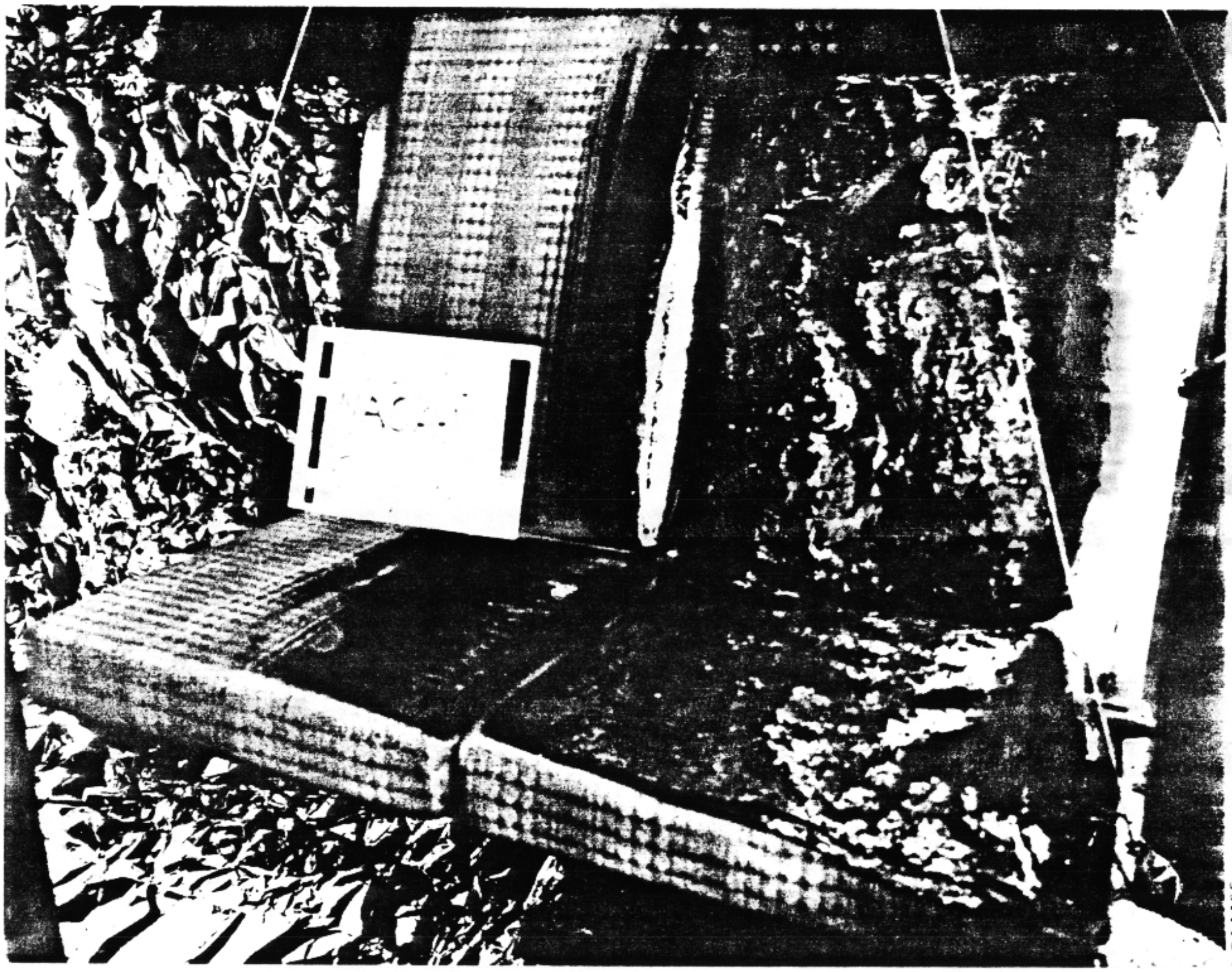


FIGURE A-2. CONFIGURATION 2 – RADIANT PANEL

- 90 PERCENT WOOL 10 PERCENT NYLON
- DURETTE BATTING
- NOMEX III
- URETHANE FOAM

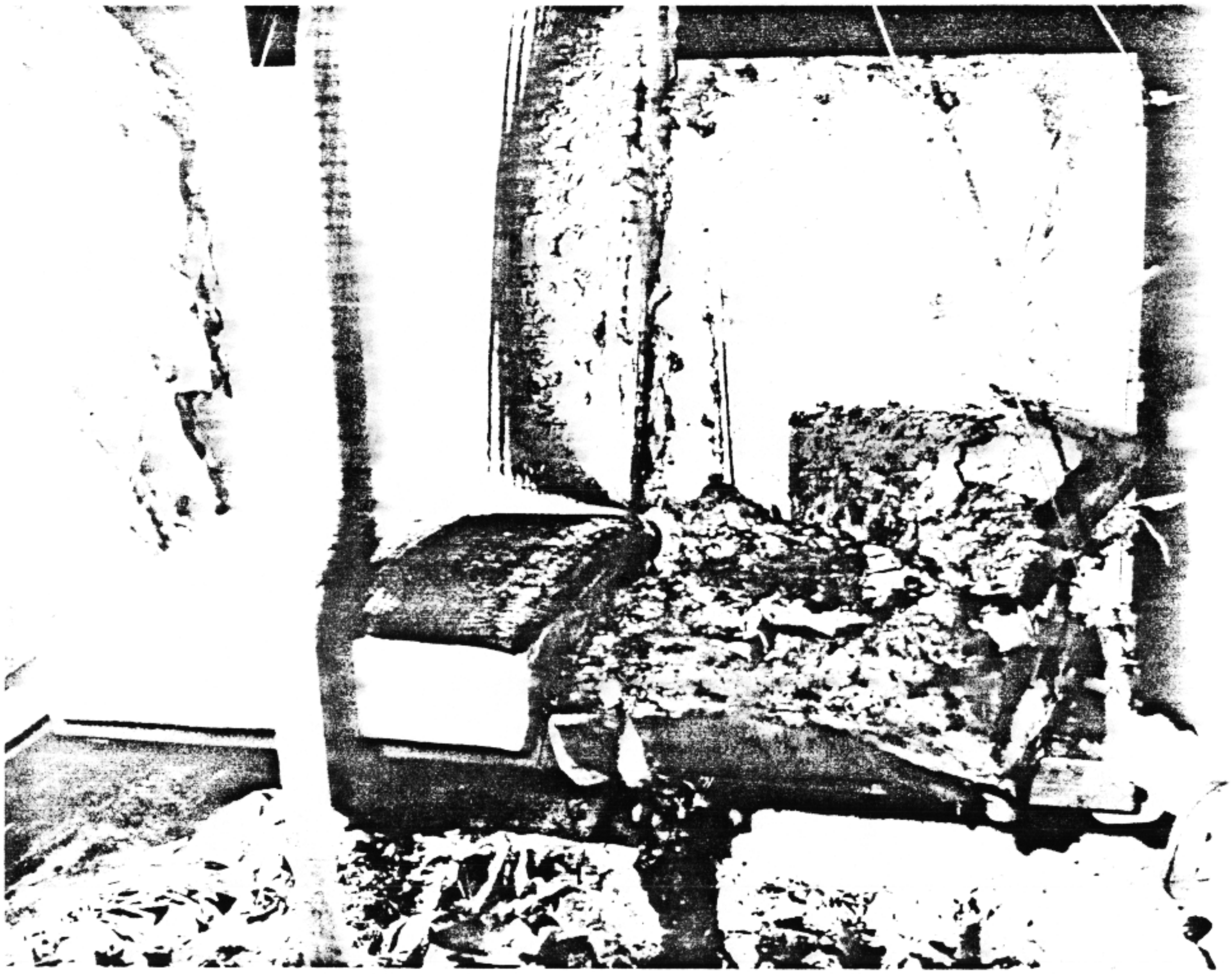

LO14470

FIGURE A-3. CONFIGURATION 3 – RADIANT PANEL

- 90 PERCENT WOOL 10 PERCENT NYLON
- VONAR 3/PS
- COTTON MUSLIN
- URETHANE FOAM

FIGURE A-4. CONFIGURATION 4 – RADIANT PANEL

- KERMEL/WOOL BLEND
- NOMEX III
- 1/2 IN. LS-200 NEOPRENE FOAM
- URETHANE FOAM
- AIREX FLOTATION FOAM

LO14481

FIGURE A-5. CONFIGURATION 5 – RADIANT PANEL

- KERMEL/WOOL BLEND
- NOMEX III
- 1/2 IN. LS-200 NEOPRENE FOAM
- URETHANE FOAM

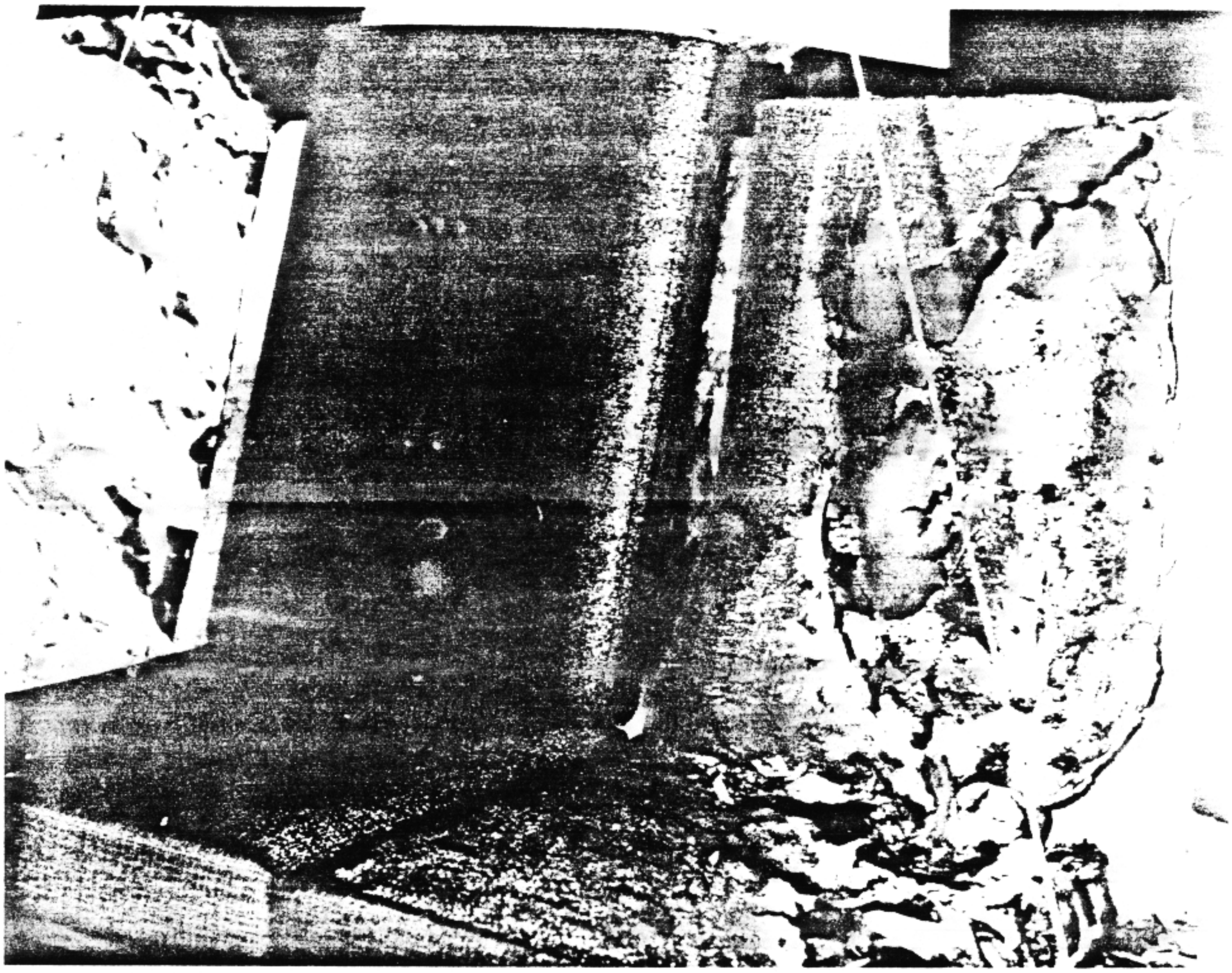
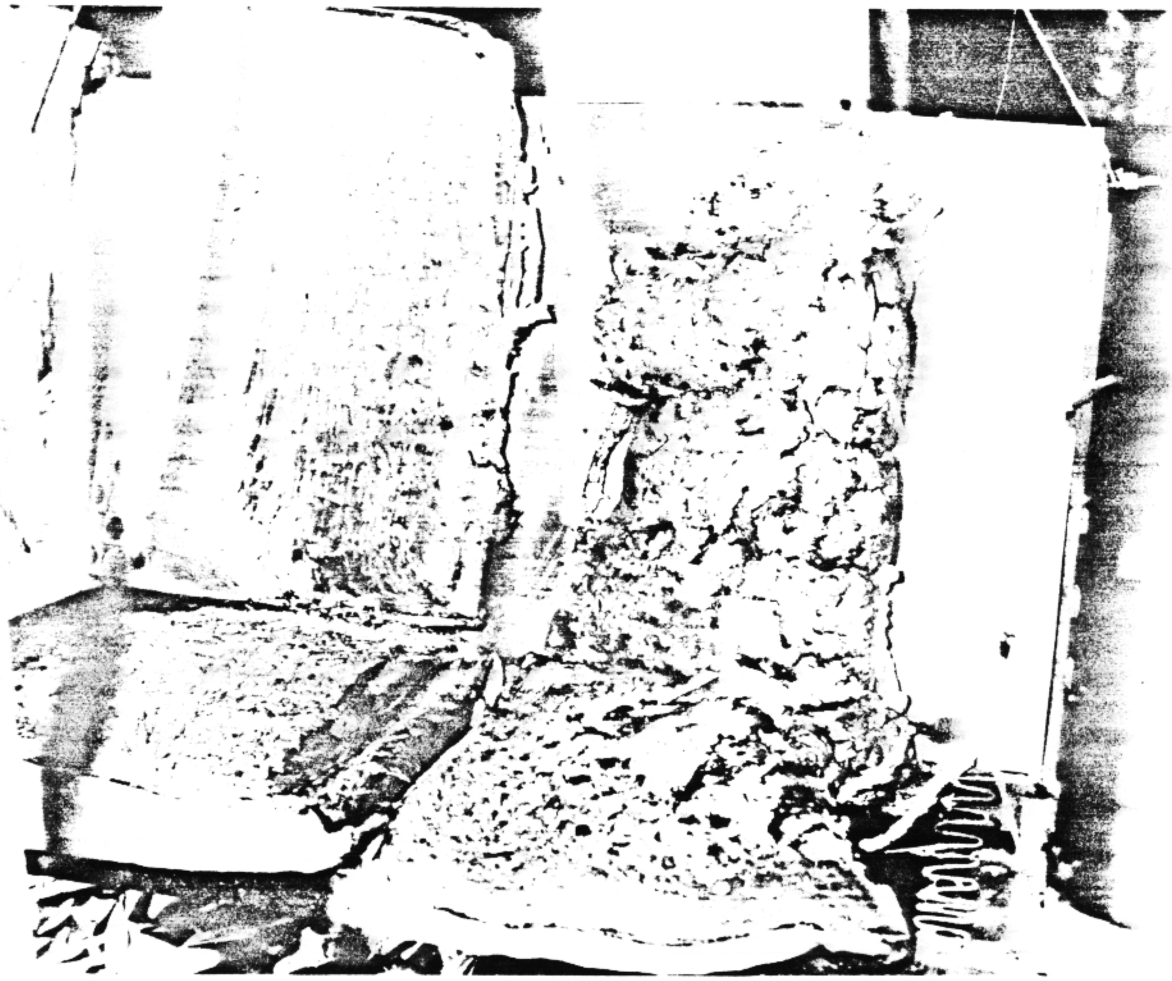


FIGURE A-6. CONFIGURATION 6 – RADIANT PANEL

- KERMEL/WOOL BLEND
- NOMEX III
- 1/2 IN. LS-200 NEOPRENE FOAM
- POLYIMIDE FOAM



LO14490

FIGURE A-7. CONFIGURATION 7 – RADIANT PANEL

- 100 PERCENT WOOL
- COTTON MUSLIN
- POLYIMIDE FOAM

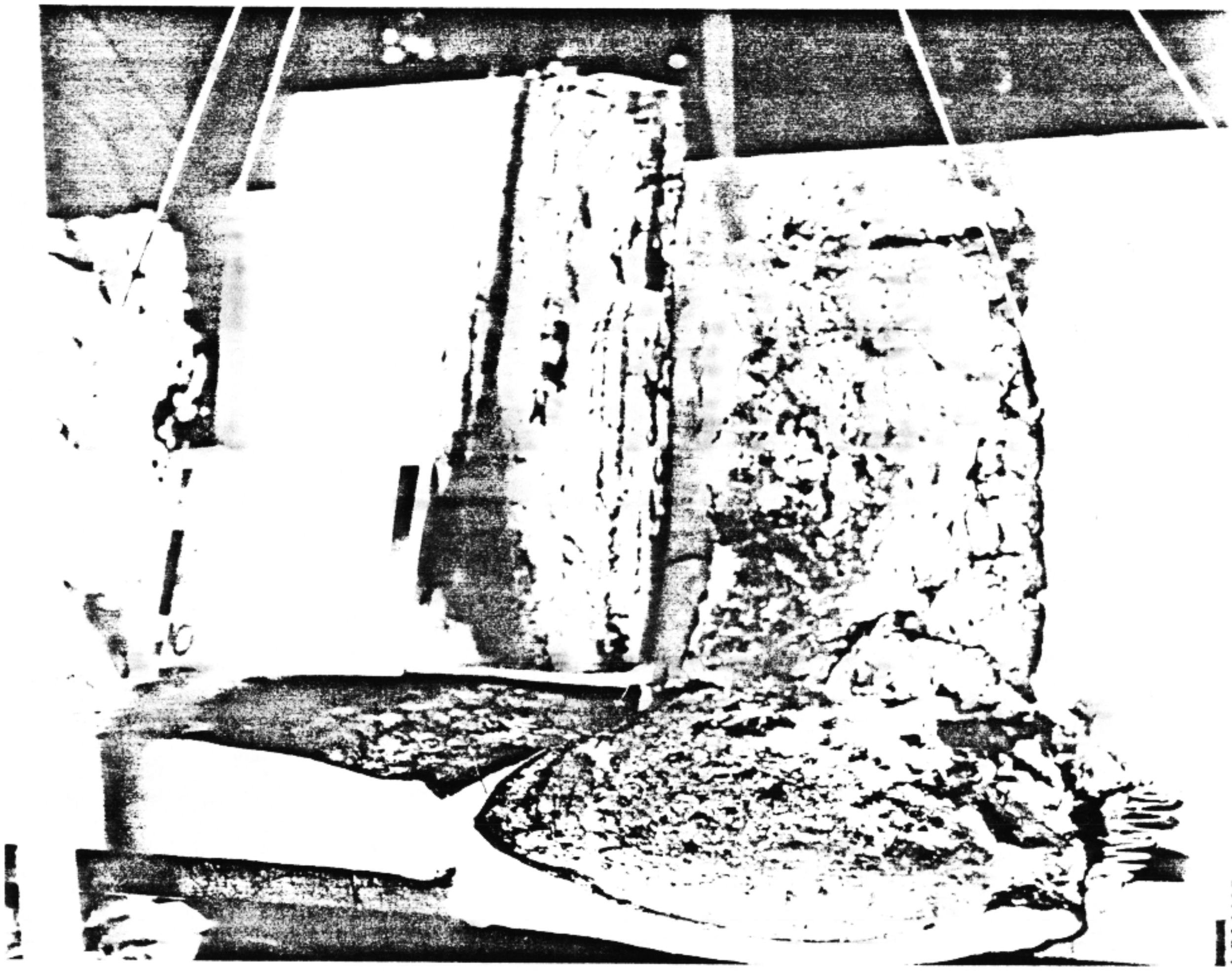


FIGURE A-8. CONFIGURATION 8 – RADIANT PANEL

- 100 PERCENT WOOL
- COTTON MUSLIN
- POLYIMIDE FOAM
- AIREX FLOTATION FOAM

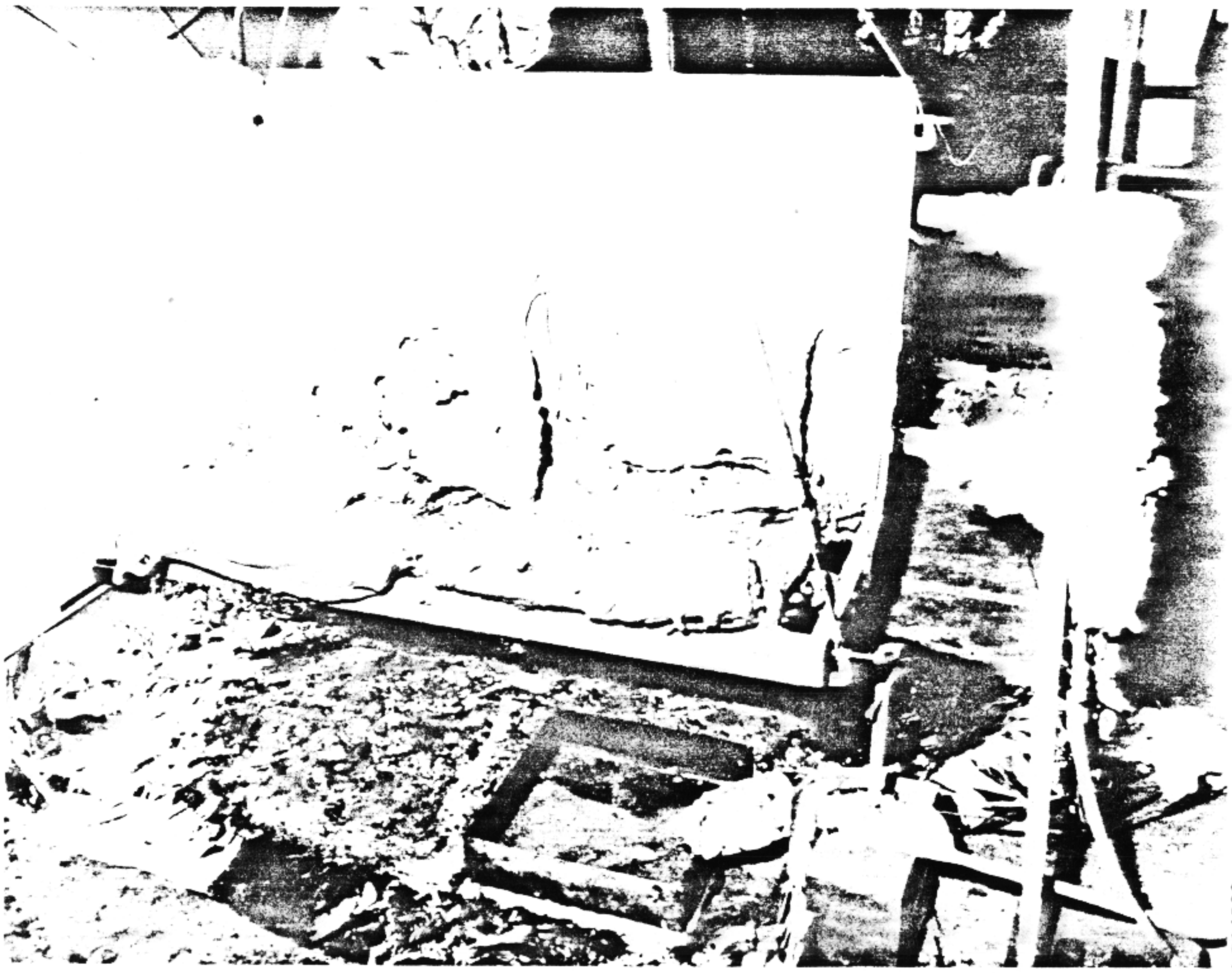


FIGURE A-9. CONFIGURATION 1 – FUEL PAN

- 90 PERCENT WOOL 10 PERCENT NYLON
- COTTON MUSLIN
- URETHANE FOAM

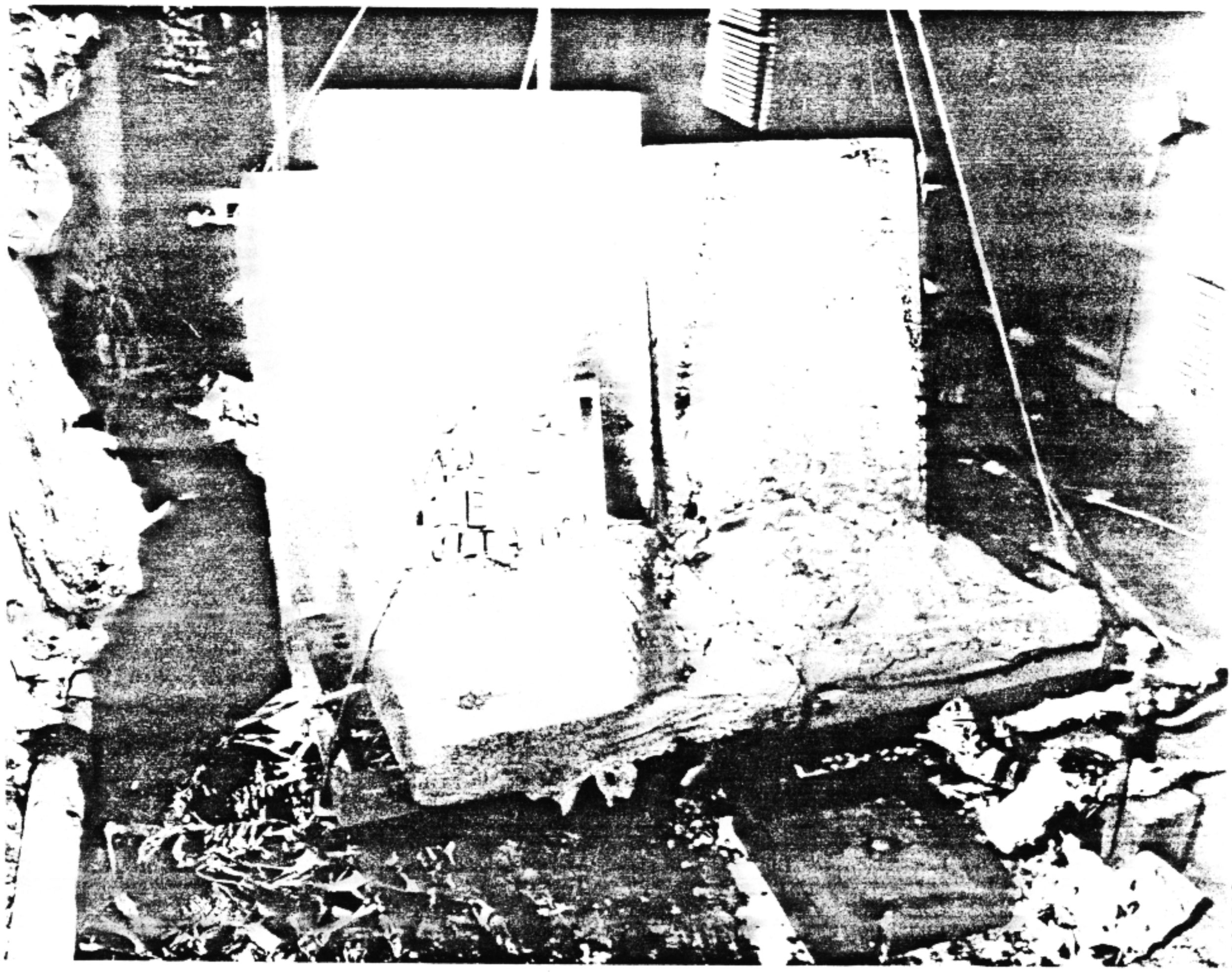


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FIGURE A-10. CONFIGURATION 2 – FUEL PAN

- 90 PERCENT WOOL 10 PERCENT NYLON
- DURETTE BATTING
- NOMEX III
- URETHANE FOAM

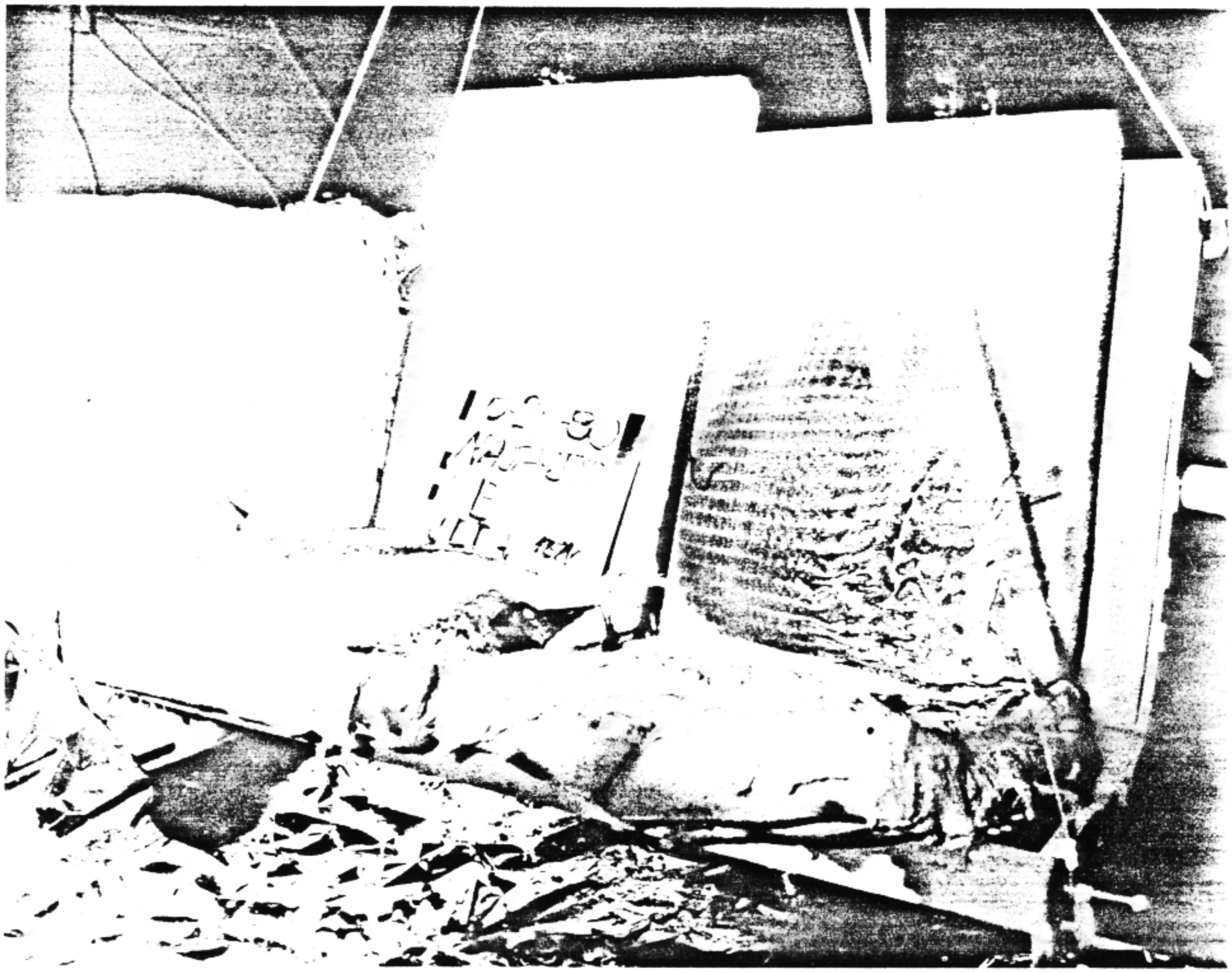

FIGURE A-11. CONFIGURATION 3 – FUEL PAN

- 90 PERCENT WOOL 10 PERCENT NYLON
- VONAR 3/PS
- COTTON MUSLIN
- URETHANE FOAM

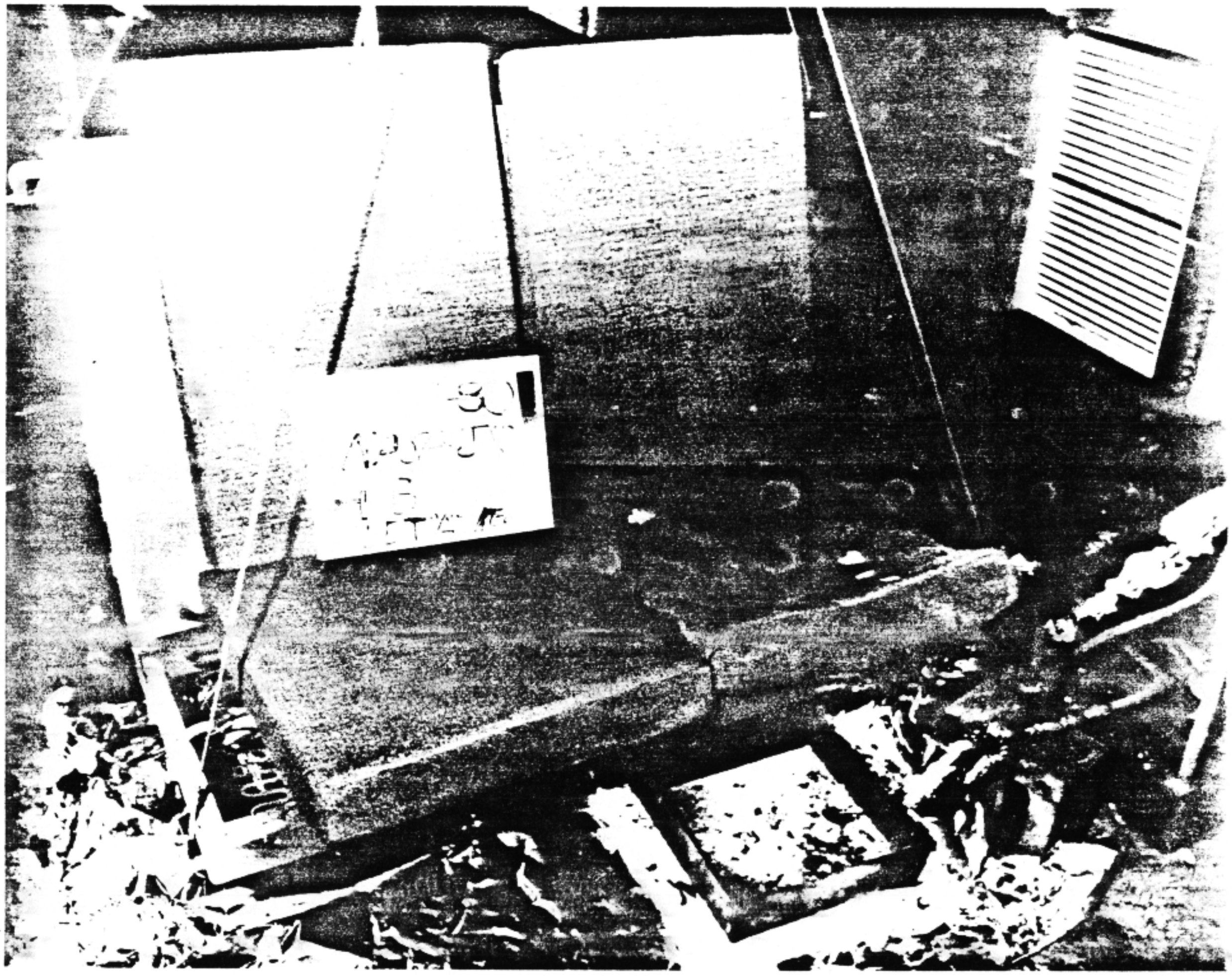

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FIGURE A-12. CONFIGURATION 4 – FUEL PAN

- KERMEL/WOOL BLEND
- NOMEX III
- 1/2 IN. LS-200 NEOPRENE FOAM
- URETHANE FOAM
- AIREX FLOTATION FOAM

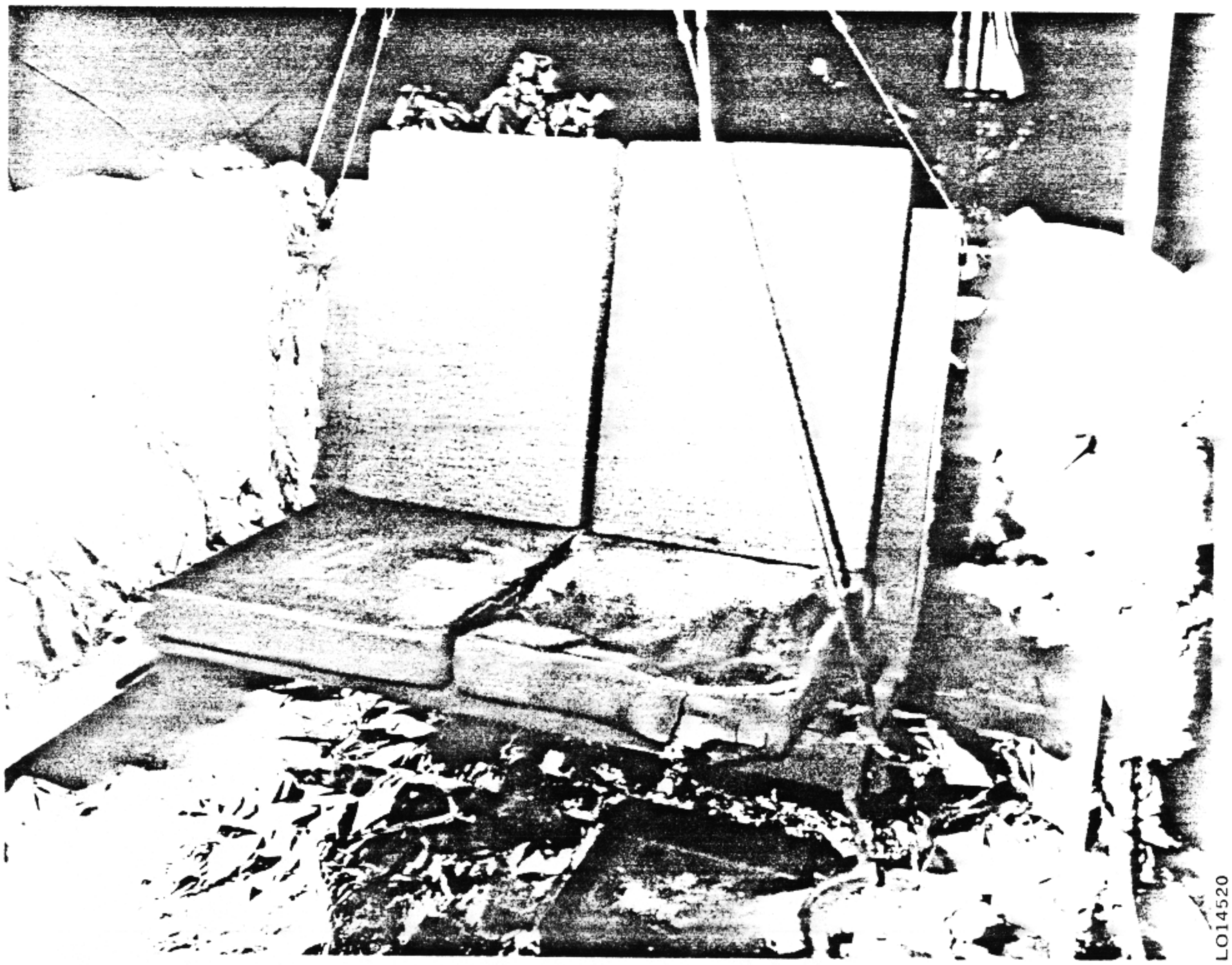
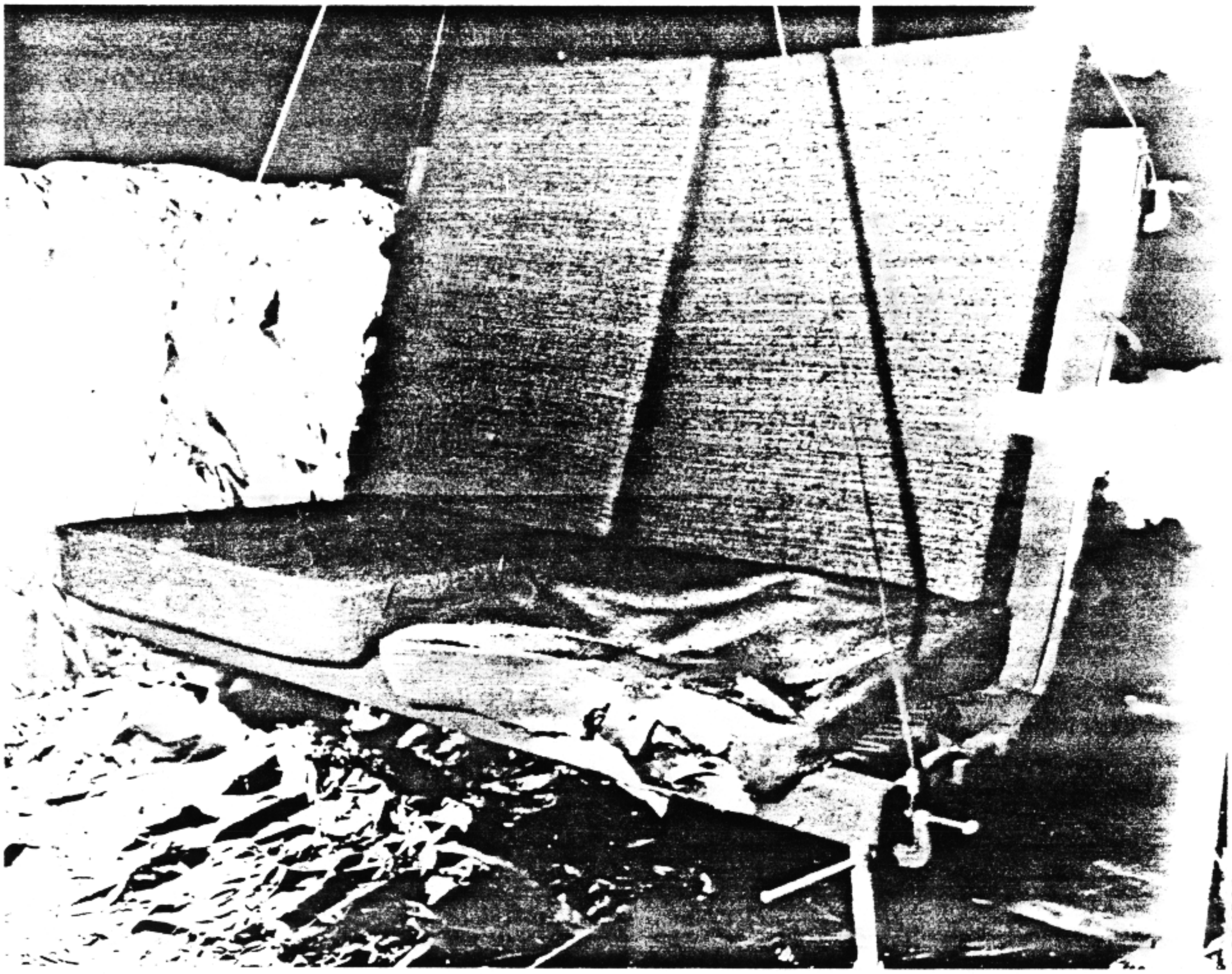


FIGURE A-13. CONFIGURATION 5 – FUEL PAN

- KERMEL/WOOL BLEND
- NOMEX III
- 1/2 IN. LS-200 NEOPRENE FOAM
- URETHANE FOAM



LO14525

FIGURE A-14. CONFIGURATION 6 – FUEL PAN

- KERMEL/WOOL BLEND
- NOMEX III
- 1/2 IN. LS-200 NEOPRENE FOAM
- POLYIMIDE FOAM

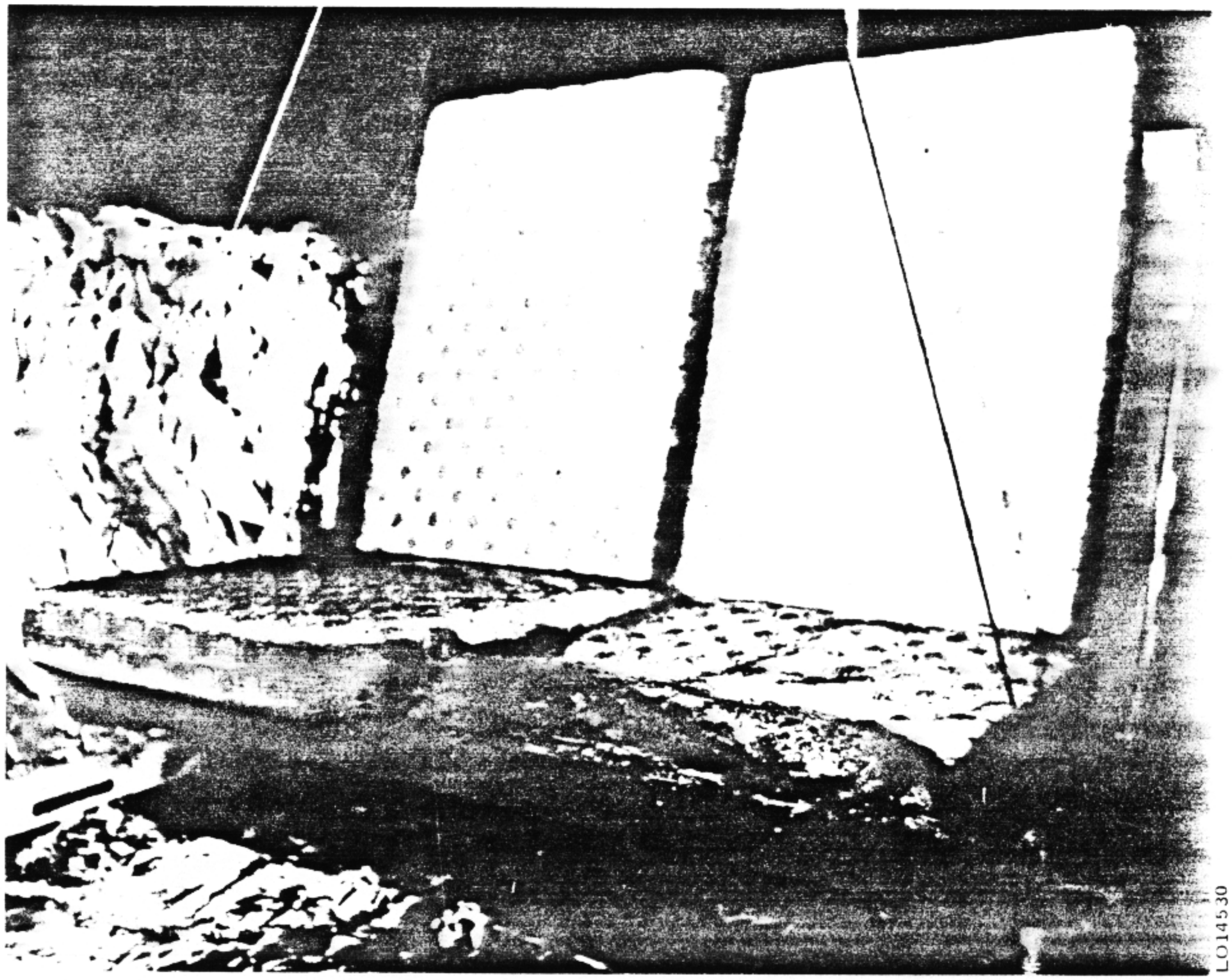


FIGURE A-15. CONFIGURATION 7 – FUEL PAN

- 100 PERCENT WOOL
- COTTON MUSLIN
- POLYIMIDE FOAM

FIGURE A-16. CONFIGURATION 8 – FUEL PAN

- 100 PERCENT WOOL
- COTTON MUSLIN
- POLYIMIDE FOAM
- AIREX FLOTATION FOAM

APPENDIX B
GAS ANALYSIS REPORT

(REPRINT OF DOUGLAS REPORT MDC J1856)

Copy number　　　　　　　　Report number　MDC-J1856

ENGINEERING REPORT

GAS ANALYSIS FOR NASA SEAT TESTS

Revision date　　　　　　　　Revision letter

Issue date　1-12-81　　Contract number

Prepared by P. T. Lally

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DOUGLAS AIRCRAFT COMPANY

MCDONNELL DOUGLAS CORPORATION

ABSTRACT

Eight types of possible aircraft seat cushions were tested in the MDC Cabin Fire Simulator to compare their fire characteristics. Two sets of seat cushions were used in each test. Each type was subjected to two tests, first using a radiant panel to ignite one side of the seat cushions, and then using a flat pan filled with Jet A fuel as a fire source.

Concentrations of carbon monoxide, carbon dioxide, oxygen, hydrocarbons, and acid gases were measured for each test. Smoke density measurements were also obtained at nine locations throughout the chamber.

KEYWORD DESCRIPTORS

Gas analysis, fire sources, Cabin fire, aircraft seats, Cabin Fire Simulator, smoke density, acid gases.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTINUED)

I

INTRODUCTION

Over the period of 10/15/80 to 10/30/80, Interiors Engineering conducted tests in the Cabin Fire Simulator Facility at McDonnell Douglas Astronautics Company (A3) under contract to NASA. In these tests, eight different seat cushion materials were tested using a radiant panel at 10 watts/cm^2 heat flux as a fire source, and then duplicate cushions were tested using a fuel pan filled with 1 liter of Jet A fuel as a fuel source. One test was run with just a fuel pan filled with 1 liter of Jet A fuel to obtain a baseline for the fuel pan tests. The eight different seat cushion materials are listed in Table I.

TABLE I

CUSHION MATERIALS

TEST NUMBER	UPHOLSTERY	FIRE BLOCKING	CUSHION REINFORCEMENT	CUSHION
#1,#1B	90% Wool, 10% Nylon	None	Cotton Muslin	Urethane
#2,#2B	90% Wool, 10% Nylon	Durette Batt	Nomex 111	Urethane
#3,#3B	90% Wool, 10% Nylon	Vonar	Cotton Muslin	Urethane
#4,#4B	Kermel/Wool Blend	Nomex 111/1/2" Neoprene	None	Urethane/Airex Core
#5,#5B	Kermel/Wool Blend	Nomex 111 1/2" Neoprene	None	Urethane
#6,#6B	Kermel/Wool Blend	None	Nomex 111	1/2" Neoprene/Polyimide
#7,#7B	100% Wool	None	Cotton Muslin	Polyimide
#8,#8B	100% Wool	None	Cotton Muslin	Polyimide/Airex Core

II

PROCEDURE

Figure 1 shows the experimental set-up of the Cabin Fire Simulator. The sampling lines for the real time gas analysis were approximately 30 feet long. A heated Teflon line was used for the hydrocarbon sample. The analyzers were all preceded by particulate filters and an in-line filter filled with calcium sulfate and zinc powder (to remove moisture and acid gases). The carbon dioxide was sampled at a flow rate of 1 liter per minute using an MSA Lira Model 303 infrared analyzer with a range of 0-3.5%, and an approximate full-scale response time of 30 seconds. The carbon monoxide was sampled at a flow rate of 1 liter per minute using an MSA Lira Model 303 infrared analyzer with a range of 0-10% and a response time of approximately 30 seconds. The oxygen was sampled at a flow rate of 2 liters per minute using an MSA Model 802 magnetic oxygen analyzer with a range of 0-25% and an approximate response time of 45 seconds. The hydrocarbon concentration was sampled at 2 liters per minute using a Beckman Model 865 infrared analyzer with a range of 0-10% and a response time of 5 seconds.

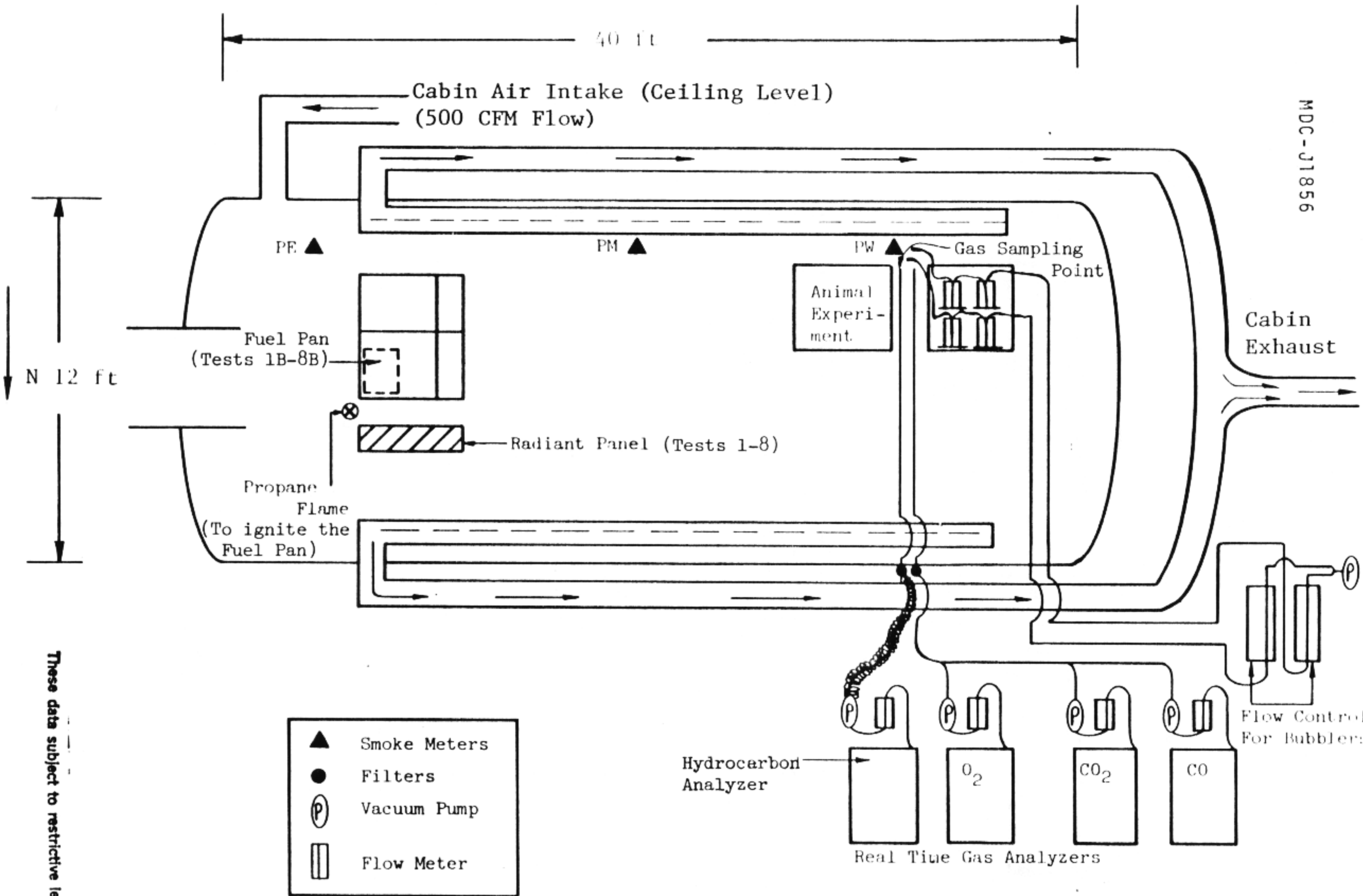

FIGURE 1. EXPERIMENTAL SET-UP OF THE CABIN FIRE SIMULATOR

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Acid gas samples were collected in two sets of bubblers containing 0.1N NaOH. The flow rate through the bubblers was controlled at 1.0 liter per minute and the bubblers were run for the first 10 minutes of each test. The concentration of hydrogen cyanide (HCN) was determined by analyzing the bubbler solution colorimetrically using the pyridine/pyrazoline method. The concentration of hydrogen chloride (HCl) was determined by a potentiometric titration with silver nitrate. The concentration of hydrogen fluoride (HF) was determined by using a fluoride specific electrode.

Smoke density measurements were made using Weston Model 594 photocells with a 36 cm light path length. The smoke meters were calibrated to read in percent transmittance of light. The nine photometers were located in groups of three at the west end, middle, and east end of the chamber and were designated PW, PM and PE, respectively. At each location, the smoke meters 1, 2, and 3 are located 6 feet, 3 feet, and 1 foot off the floor, respectively.

The flow through the chamber was maintained at approximately 500 cubic feet per minute, with the exhaust located at floor level along the length of each side of the chamber and the air addition down the center of the ceiling. Each test lasted 30 minutes, with the radiant panel being turned on at 20 seconds and off at 320 seconds for tests 1 through 8. For the fuel pan tests 1B through 8B, time zero corresponds to the ignition of the fuel pan.

III

RESULTS

The acid gas results are listed in Table II. The gas concentrations and smoke density measurements from tests 1 - 8 (radiant panel)are shown in Figures 2 thru 17. The gas concentrations and smoke density measurements from the fuel pan baseline test are shown in Figures 18 and 19, respectively. The gas concentrations from tests 1B - 8B (fuel pan) are shown in Figures 20-35.

The first 100 seconds of real time data for test 6B was lost due to a computer failure.

The upper east photometer (PE1) was not operational for the fuel pan baseline (test B) or for tests 2B and 3B.

TABLE II

ACID GAS RESULTS*

TEST NUMBER	CONCENTRATION OF HF (PPM)	CONCENTRATION OF HCl (PPM)	CONCENTRATION OF HCN (PPM)
TEST #1	33	< 15	< .27
TEST #2	8.1	< 15	< .27
TEST #3	< 5	< 15	< .27
TEST #4	5.5	< 15	.30
TEST #5	< 5	< 15	< .27
TEST #6	< 5	< 15	< .27
TEST #7	19	< 15	< .27
TEST #8	21	< 15	< .27
FUEL PAN ONLY	< 5	< 15	< .27
TEST #1B	39	< 15	.63
TEST #2B	8.5	< 15	< .27
TEST #3B	< 5	< 15	.32
TEST #4B	< 5	< 15	< .27
TEST #5B	< 5	< 15	< .27
TEST #6B	< 5	< 15	< .27
TEST #7B	< 5	< 15	< .27
TEST #8B	< 5	< 15	.56

*Concentrations listed are an average concentration for the first 10 minutes of each test.

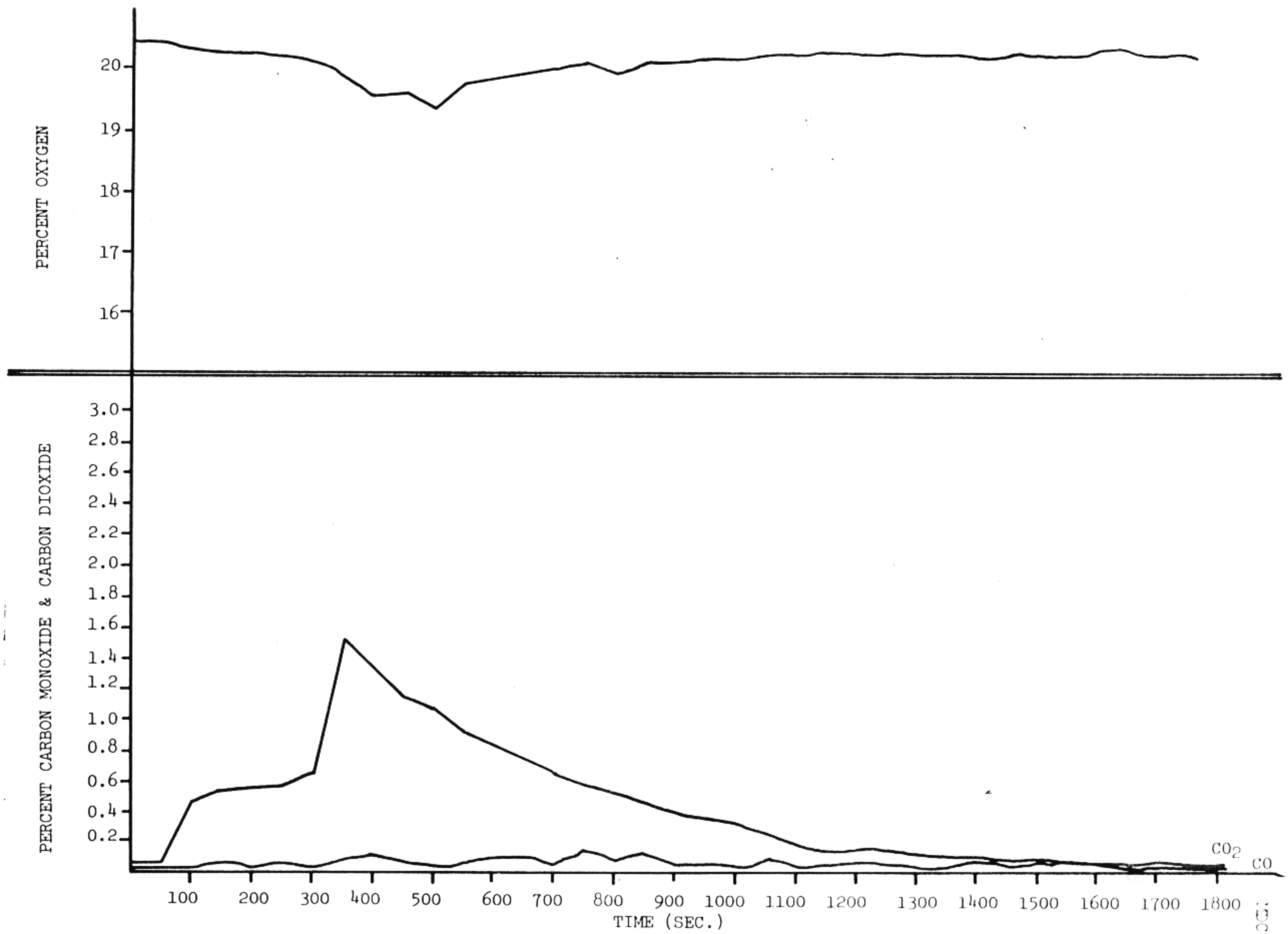

FIGURE 2. GAS CONCENTRATIONS FROM TEST 1

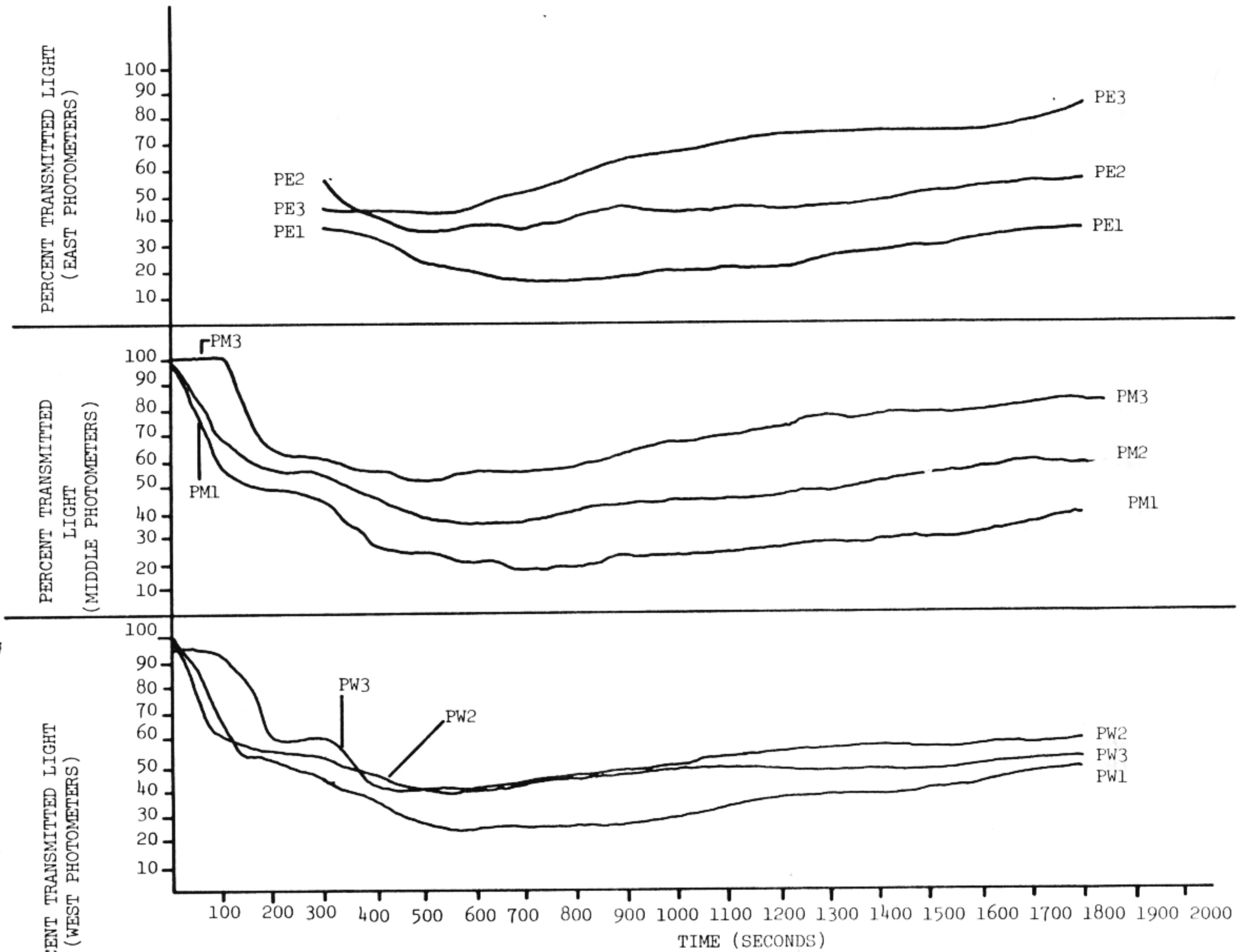

FIGURE 3. SMOKE METER READINGS FROM TEST 1

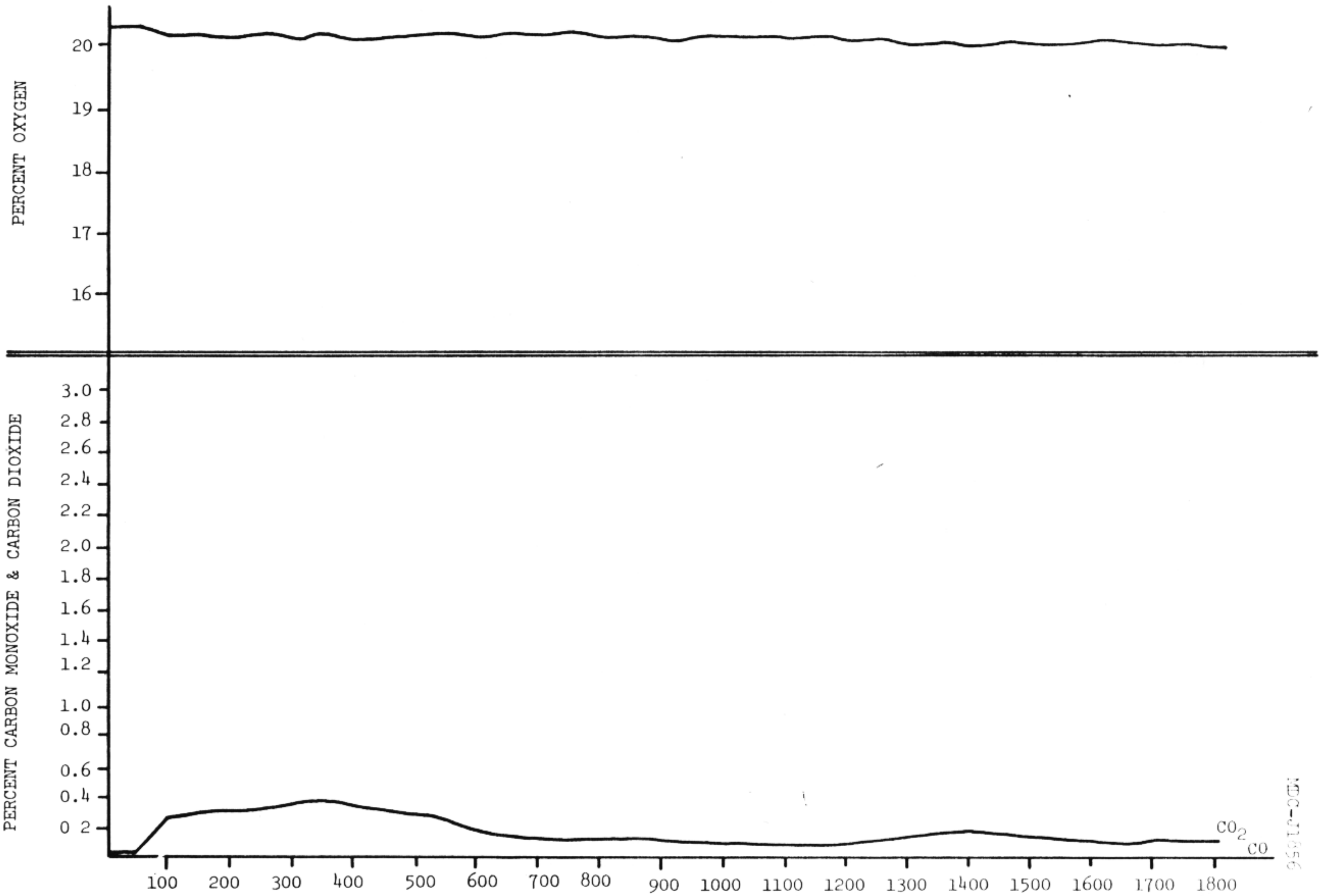

FIGURE 4. GAS CONCENTRATIONS FROM TEST 2

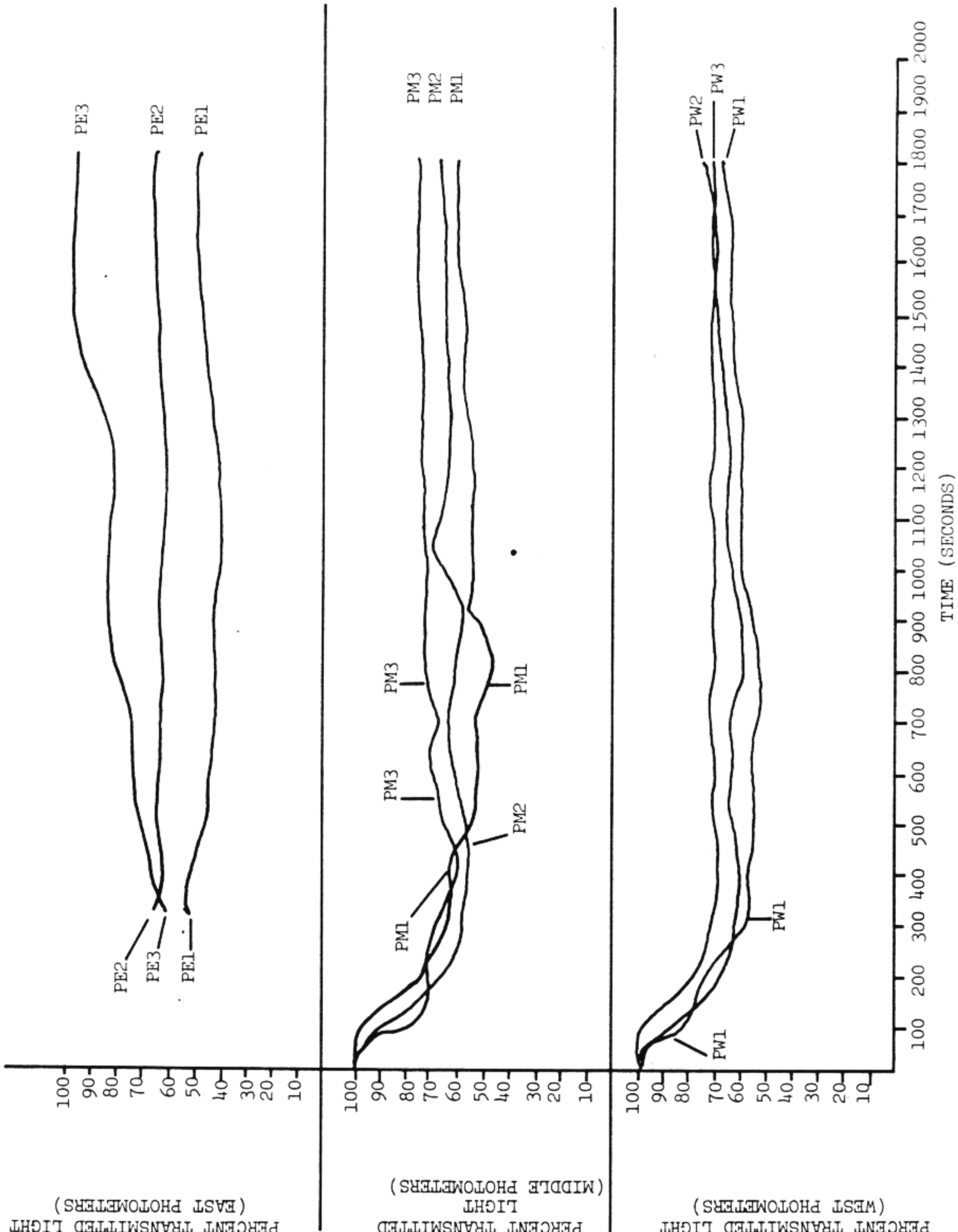

FIGURE 5. SMOKE METER READINGS FROM TEST 2

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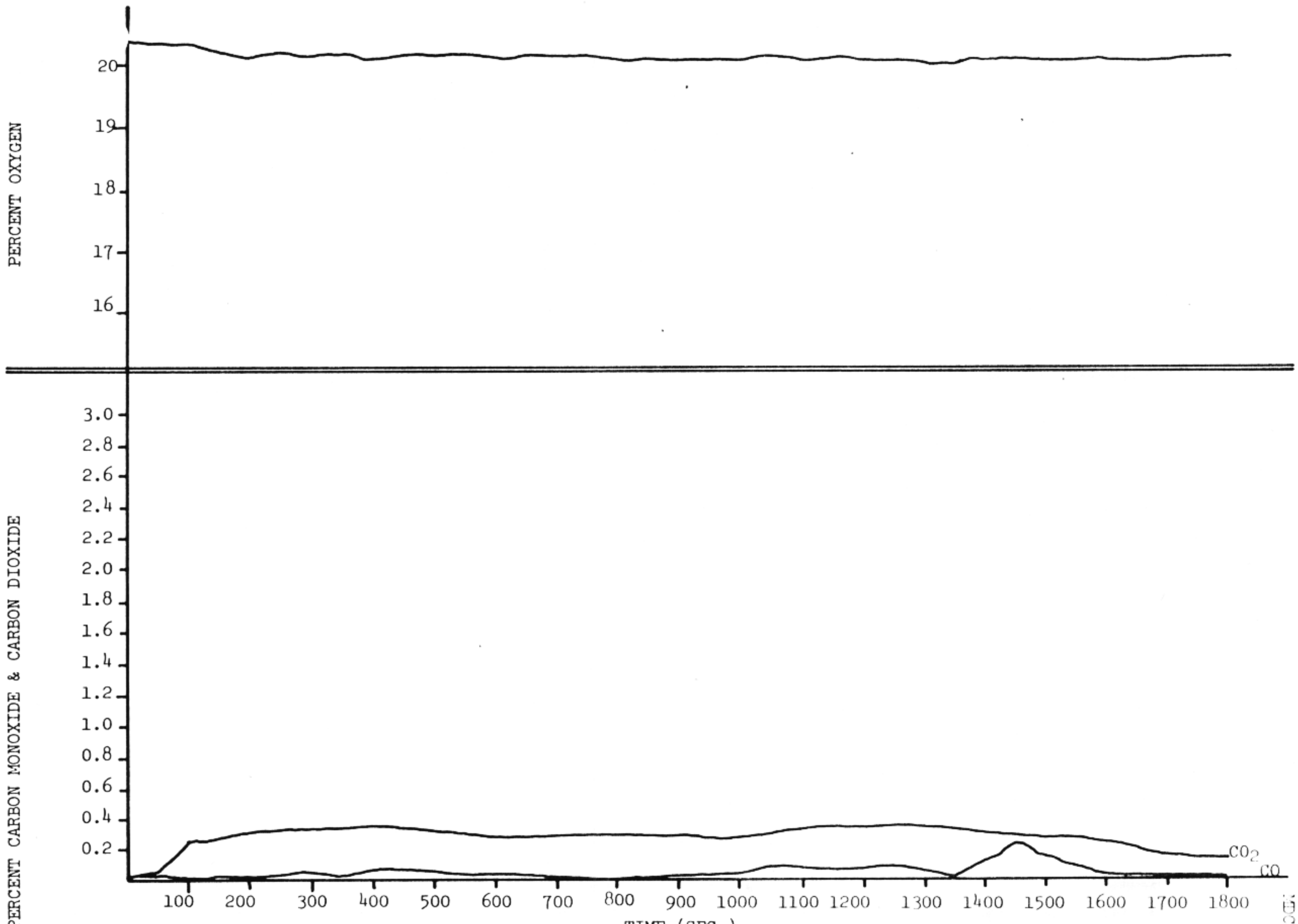

FIGURE 6. GAS CONCENTRATIONS FROM TEST 3

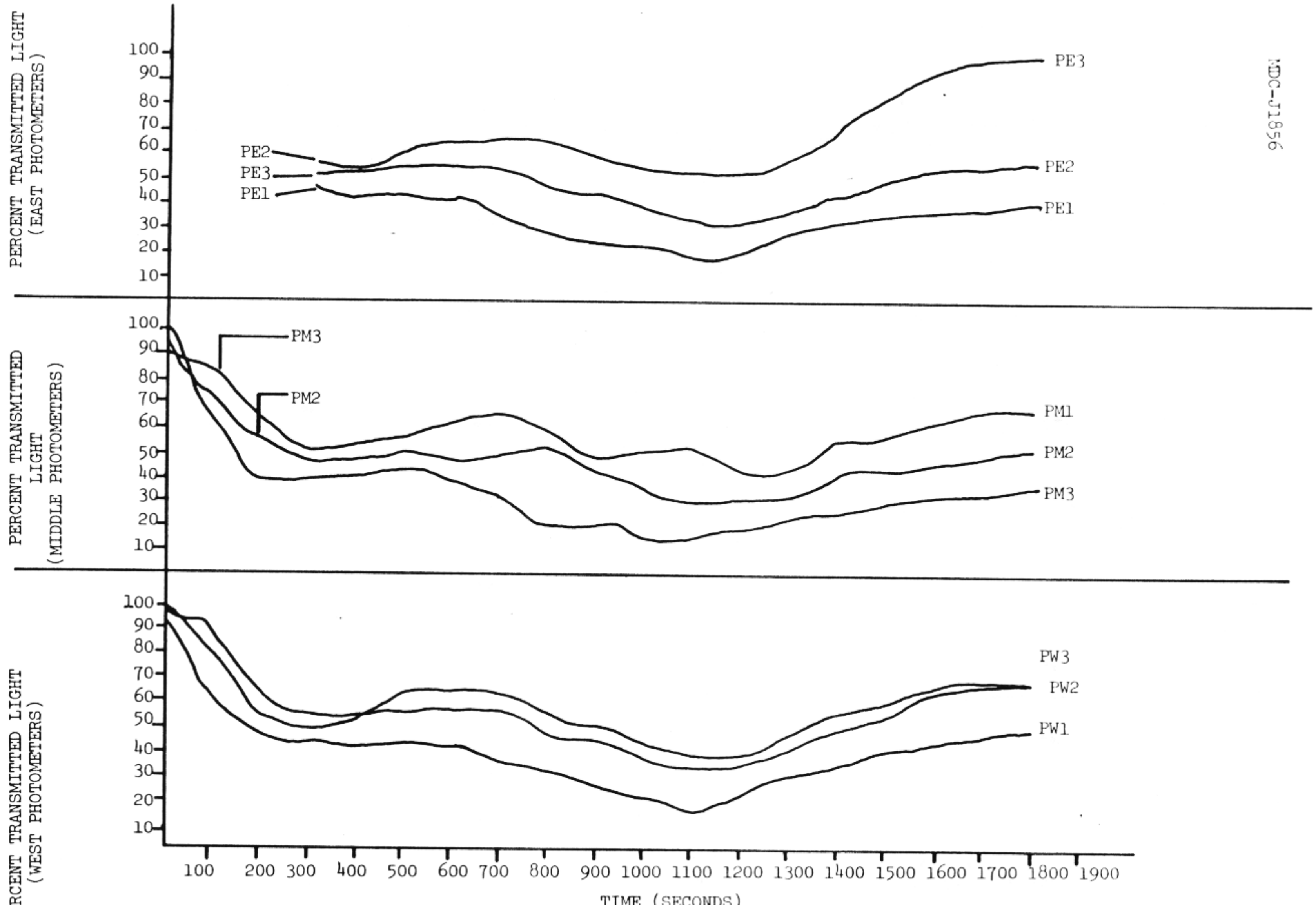

FIGURE 7. SMOKE METER READINGS FROM TEST 3

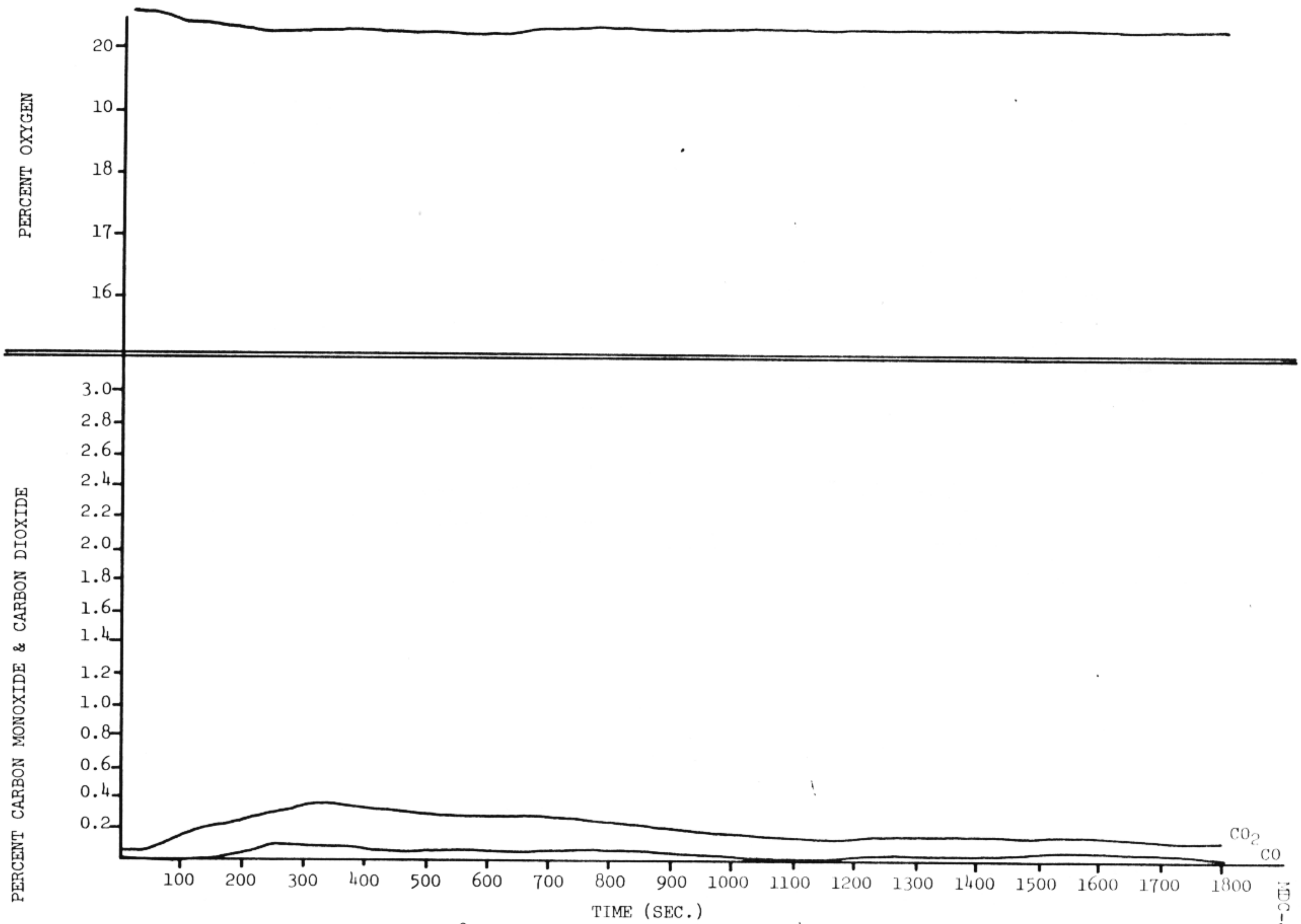

FIGURE 8. GAS CONCENTRATIONS FROM TEST 4

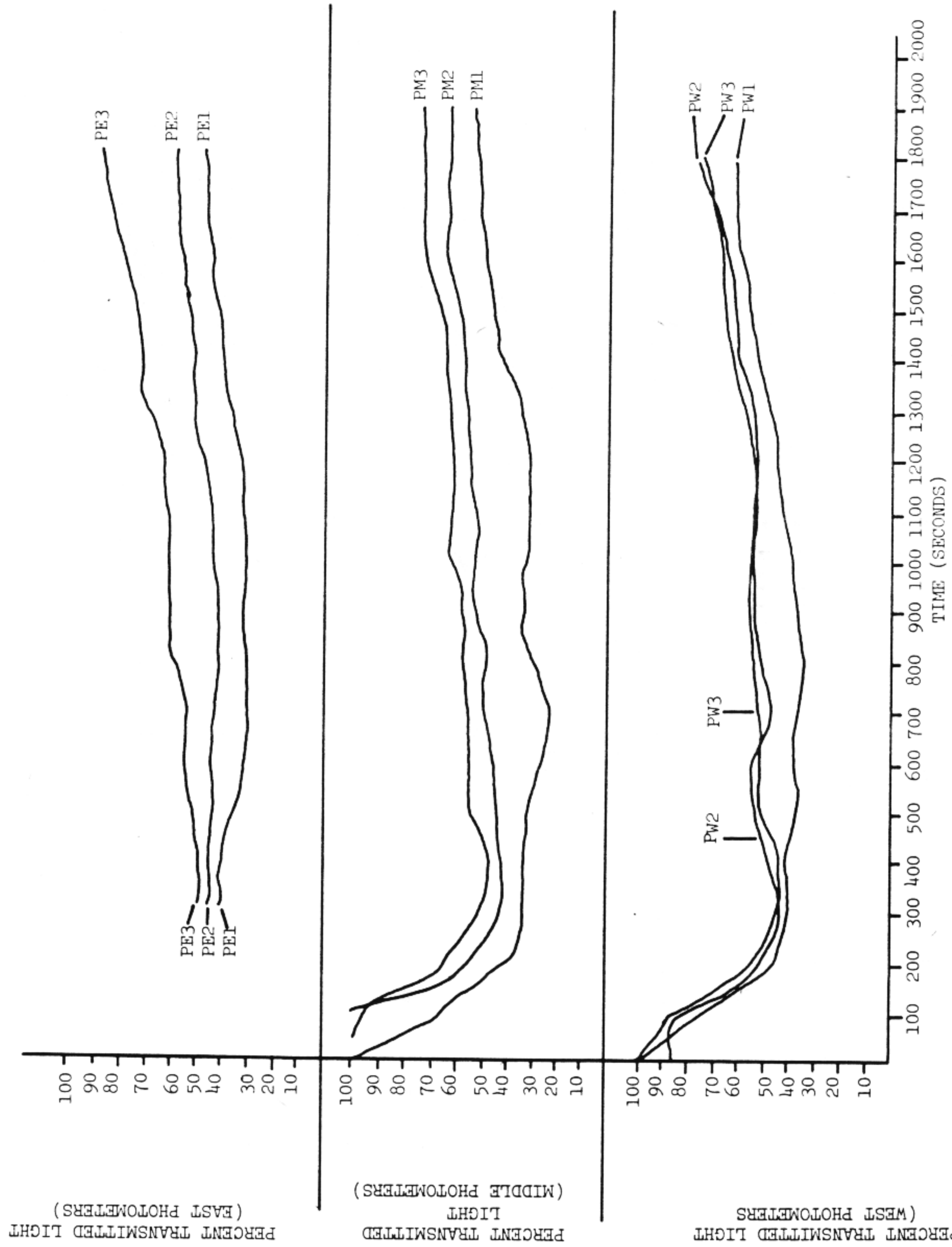

FIGURE 9. SMOKE METER READINGS FROM TEST 4

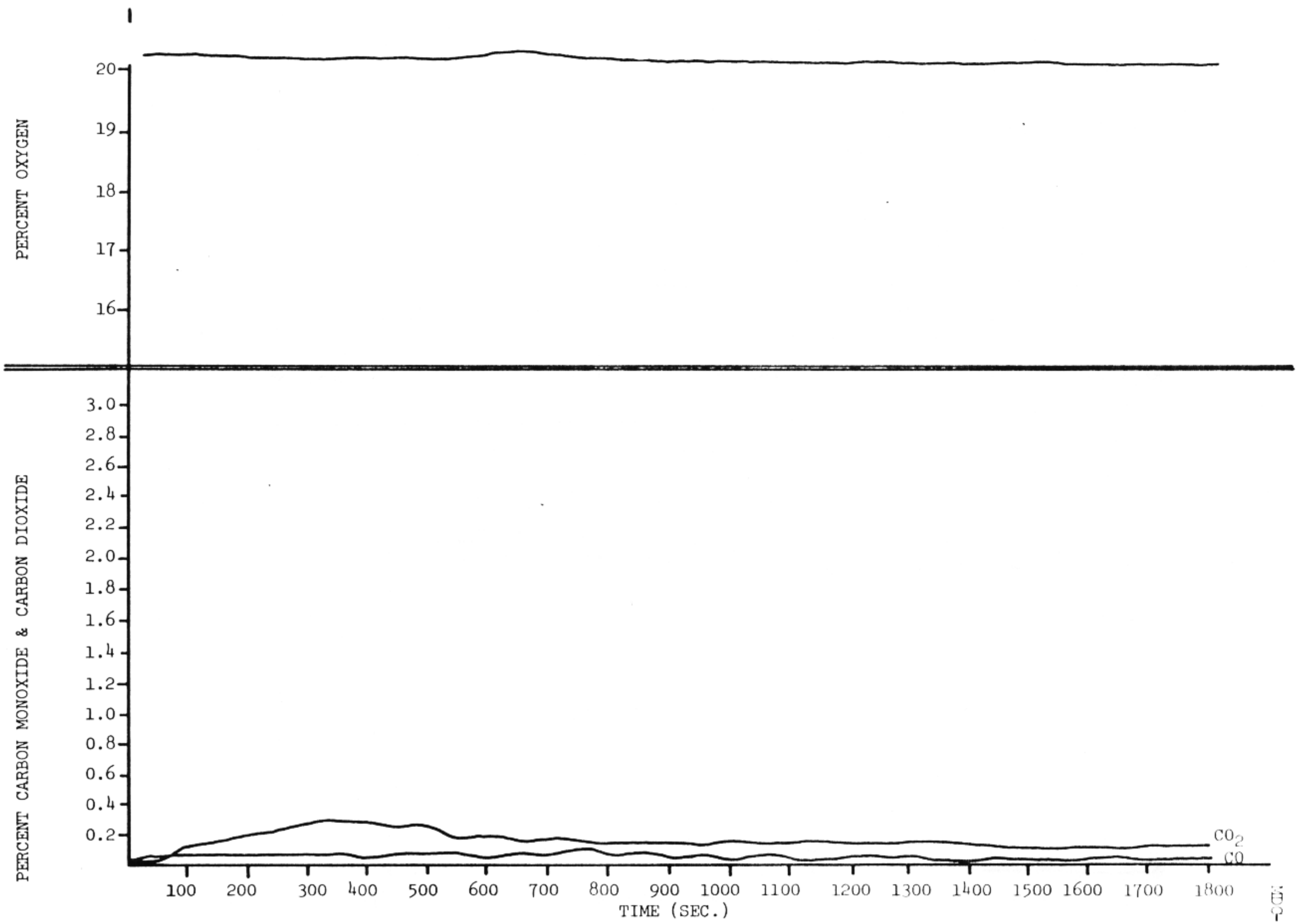

FIGURE 10. GAS CONCENTRATIONS FROM TEST 5

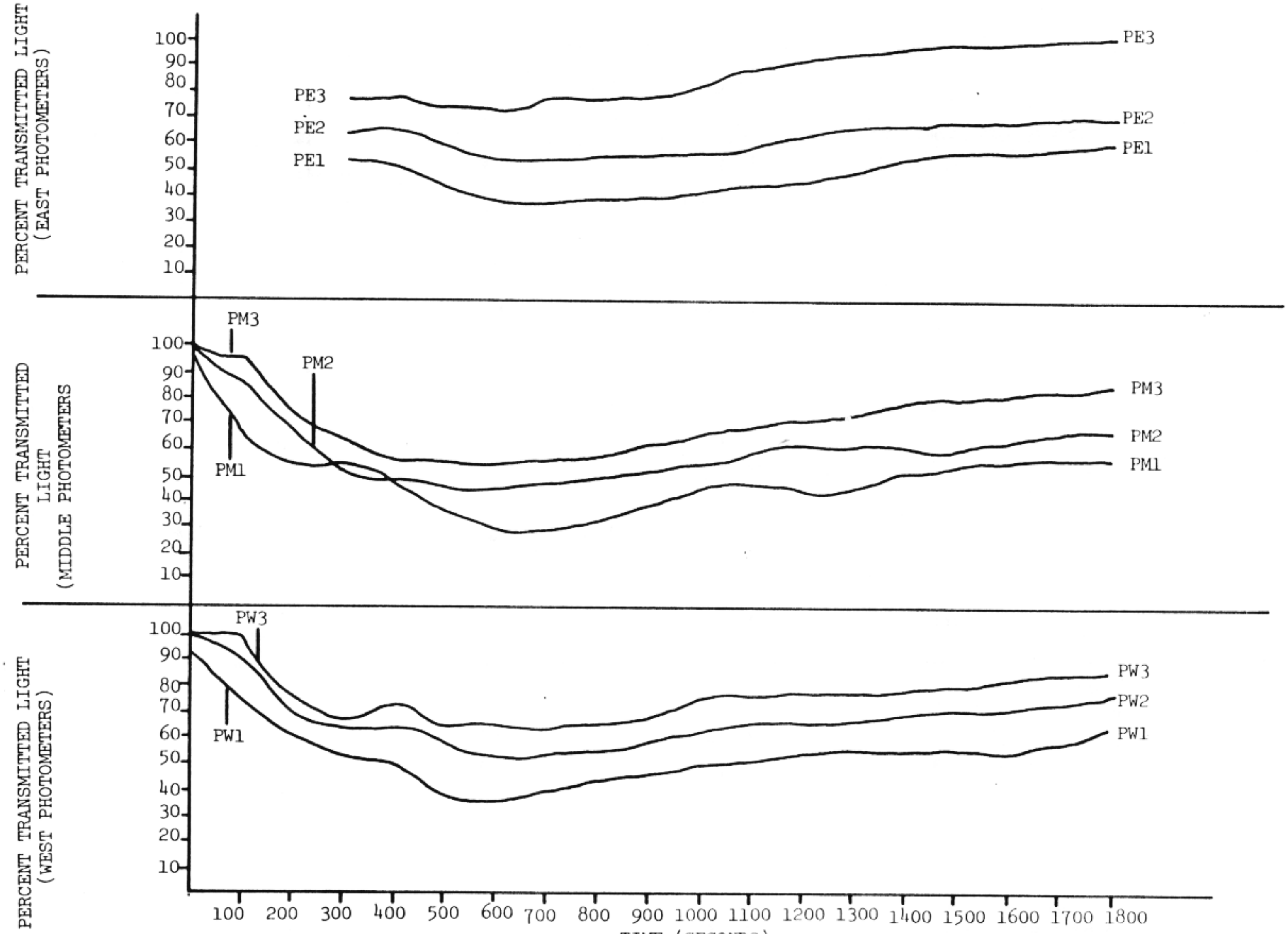

FIGURE 11. SMOKE METER READINGS FROM TEST 5

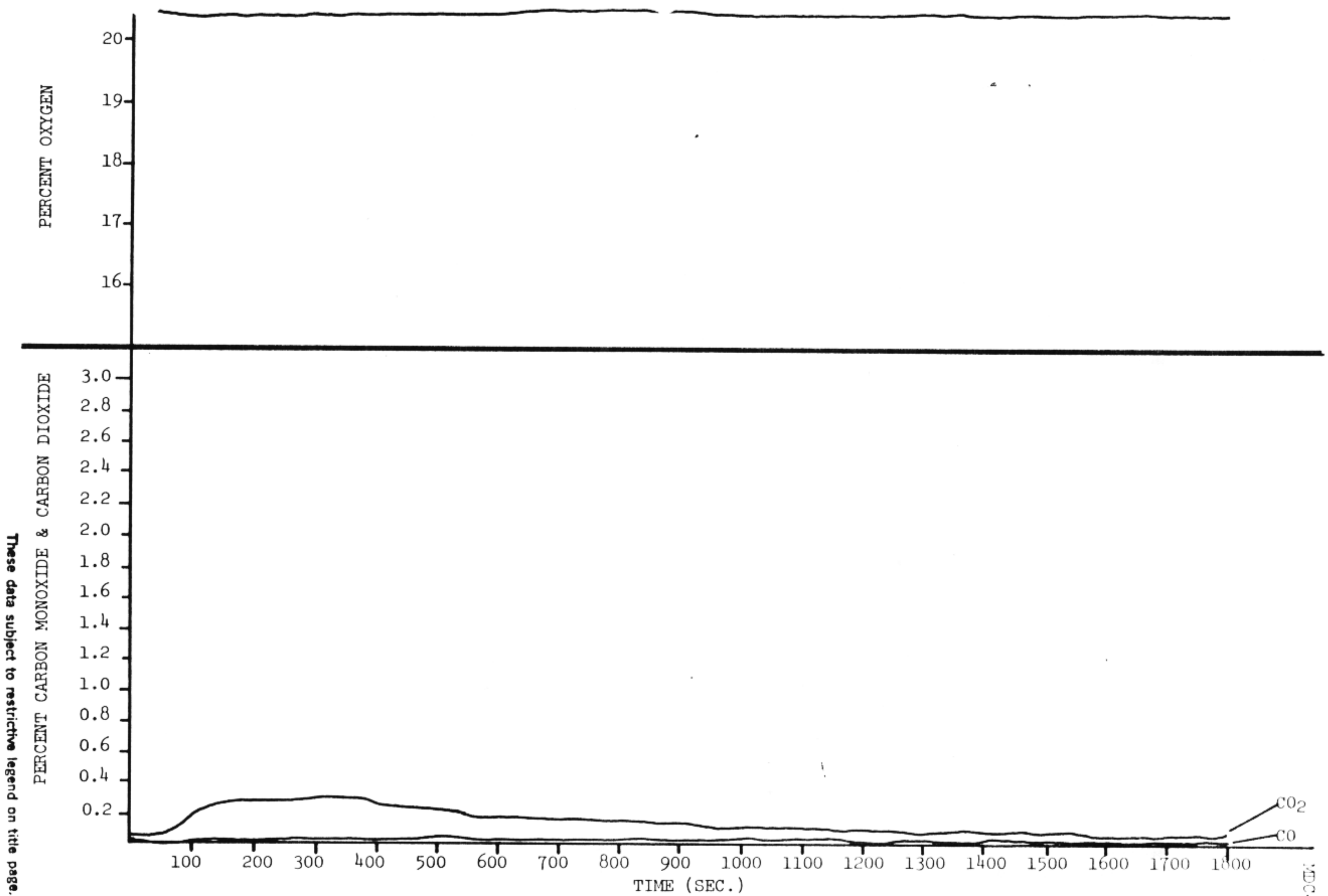

FIGURE 12. GAS CONCENTRATIONS FROM TEST 6

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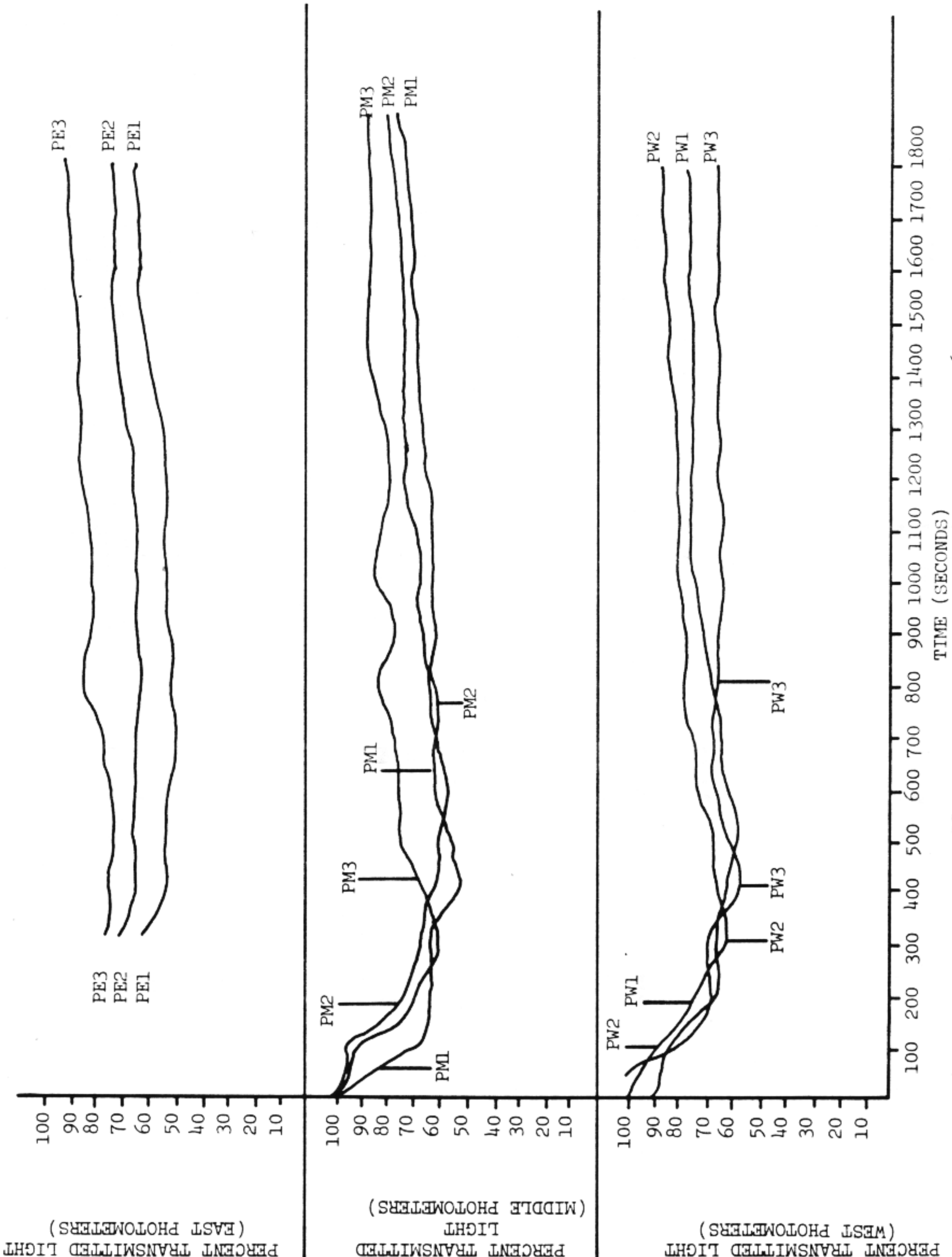

FIGURE 13. SMOKE METER READINGS FROM TEST 6

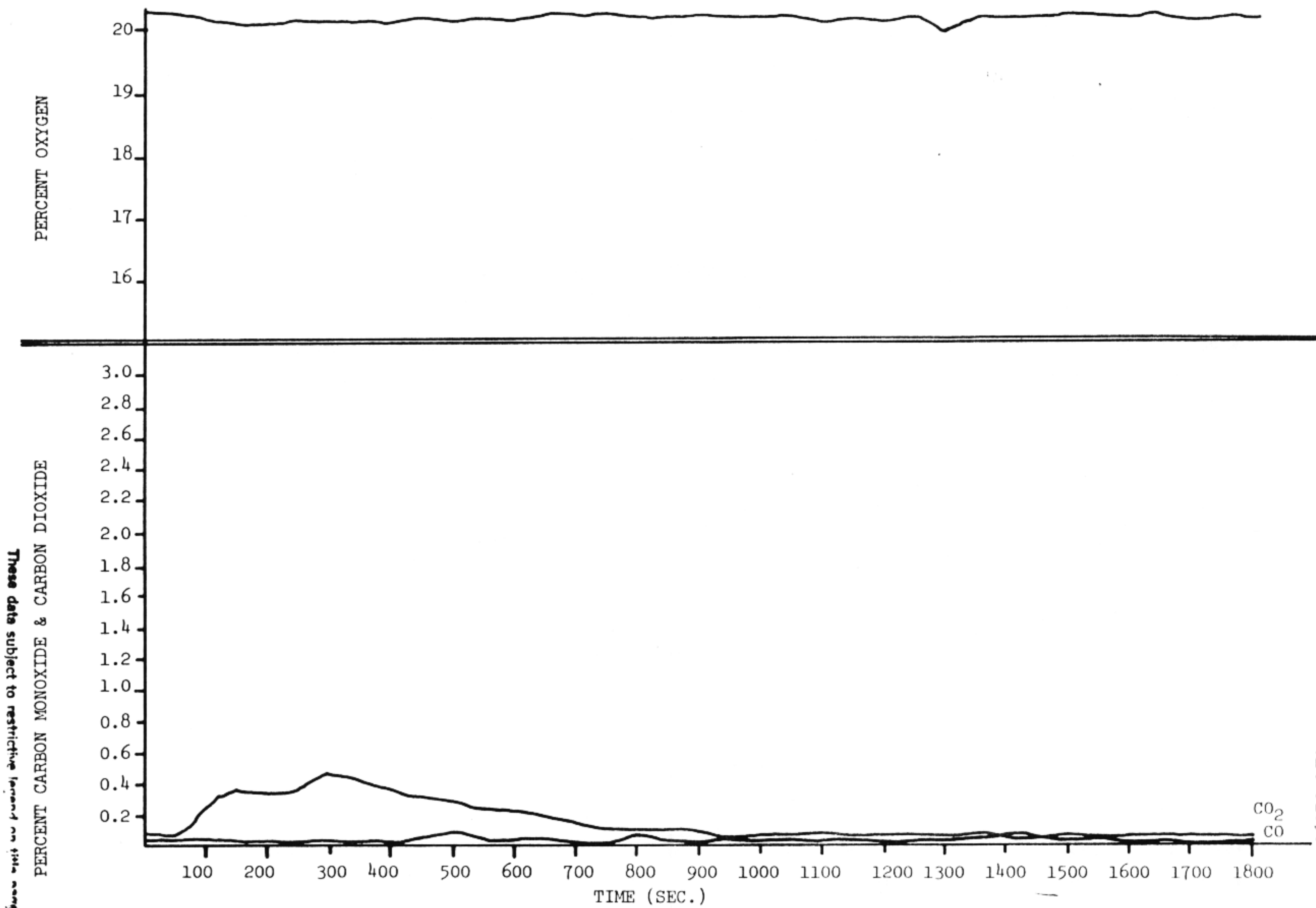

FIGURE 14. GAS CONCENTRATIONS FROM TEST 7

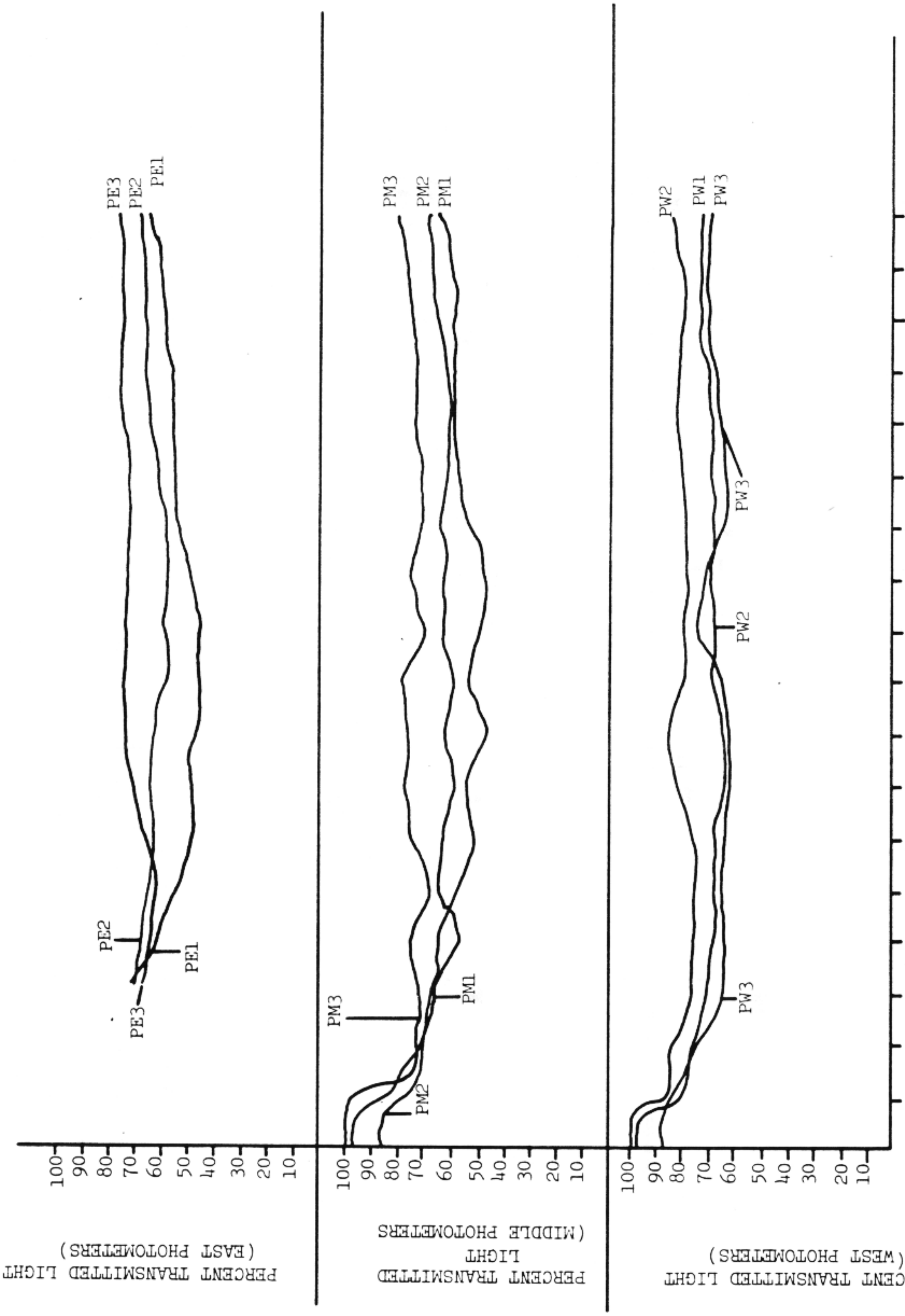

FIGURE 15. SMOKE METER READINGS FROM TEST 7

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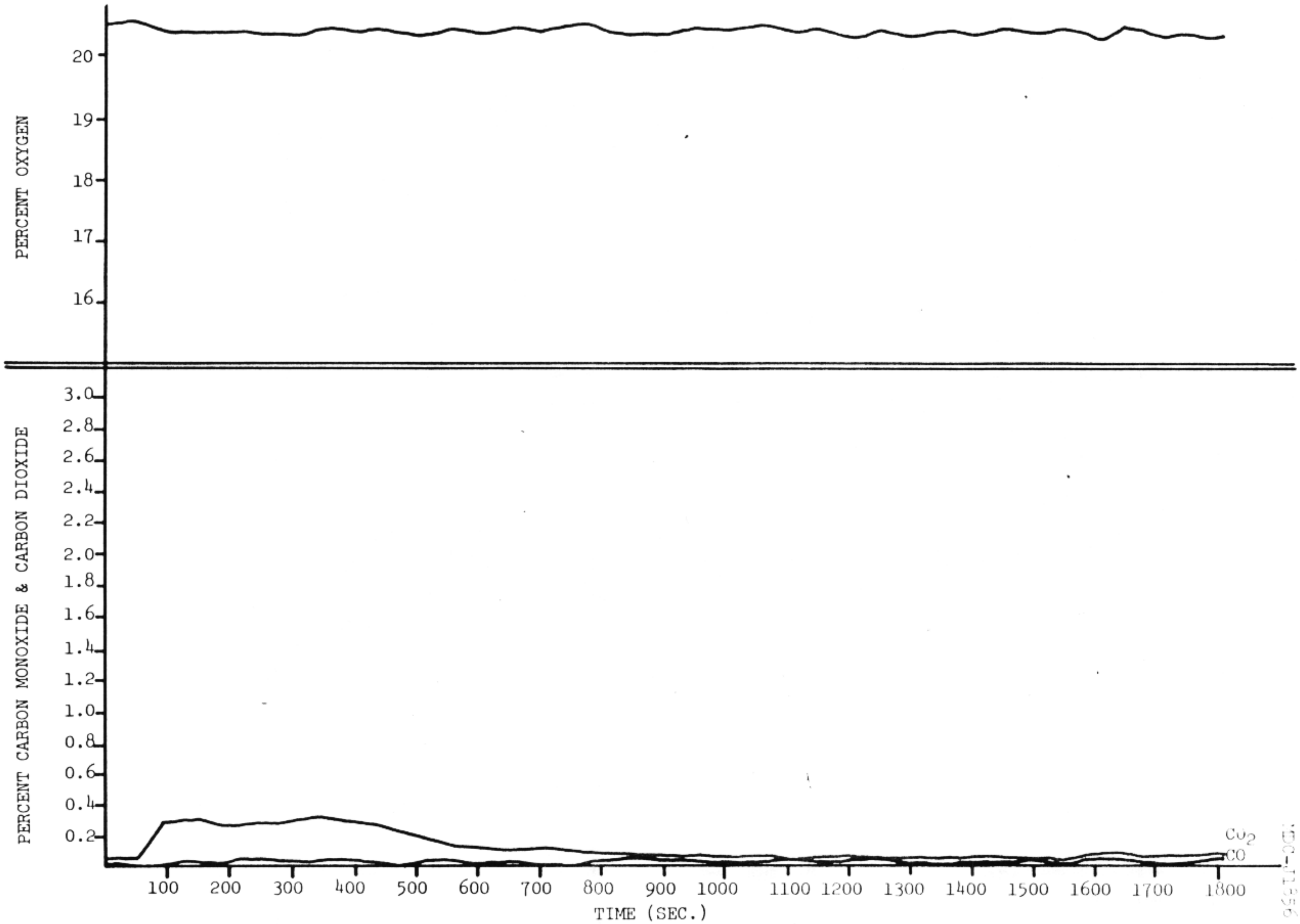

FIGURE 16. GAS CONCENTRATIONS FROM TEST 8

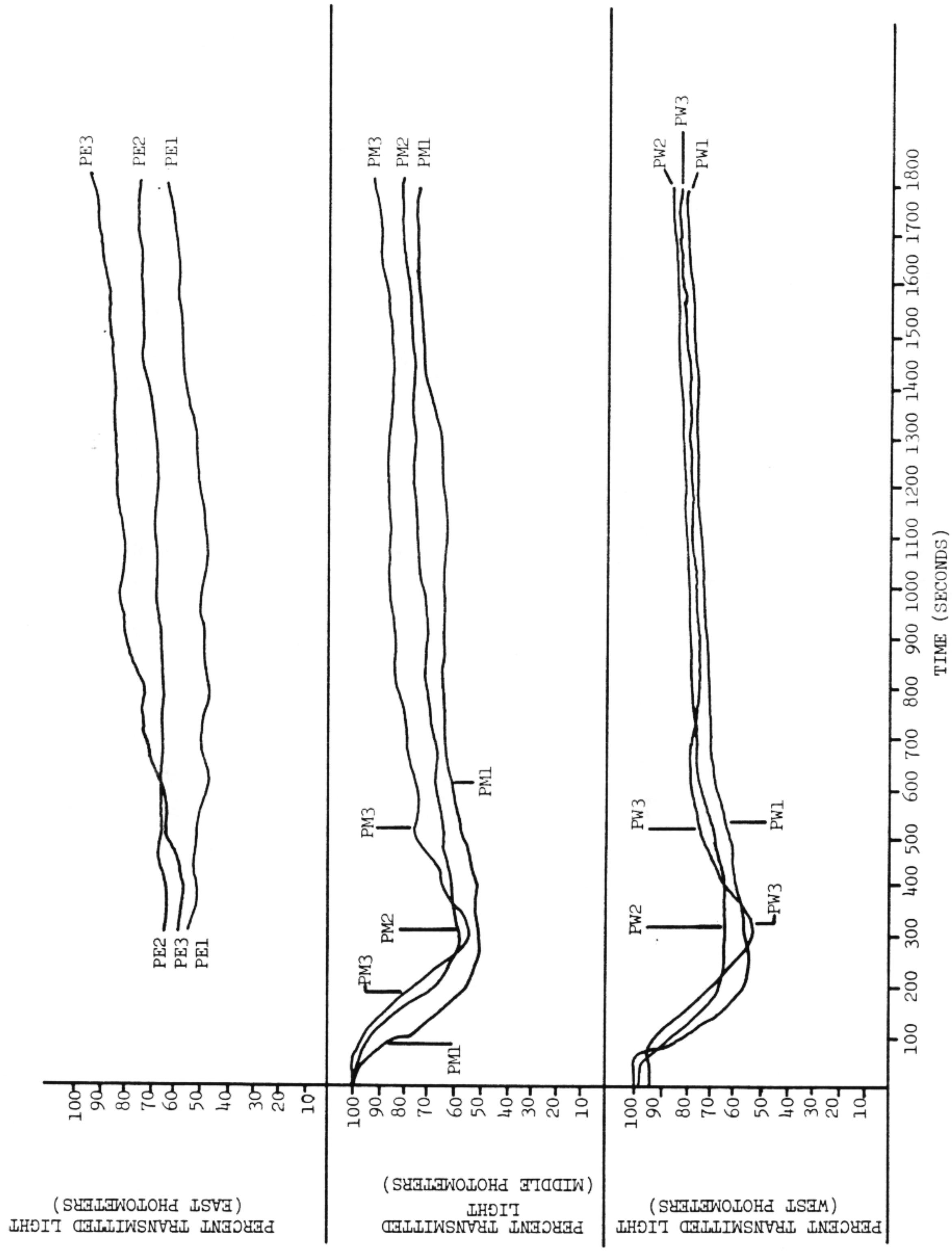

FIGURE 17. SMOKE METER READINGS FROM TEST 8

These data subject to restrictive legend on title page.

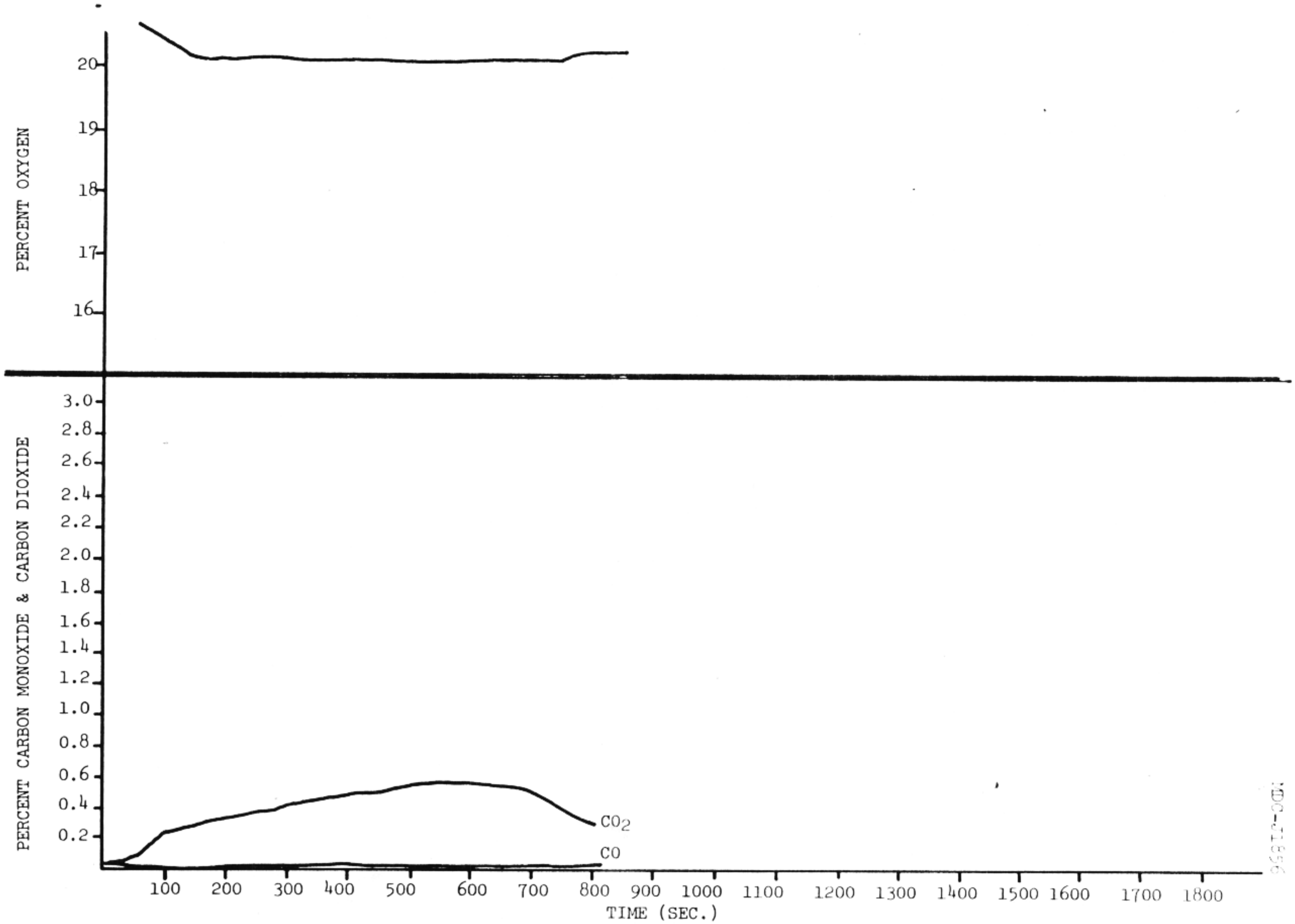

FIGURE 18. GAS CONCENTRATIONS FROM FUEL PAN BASELINE

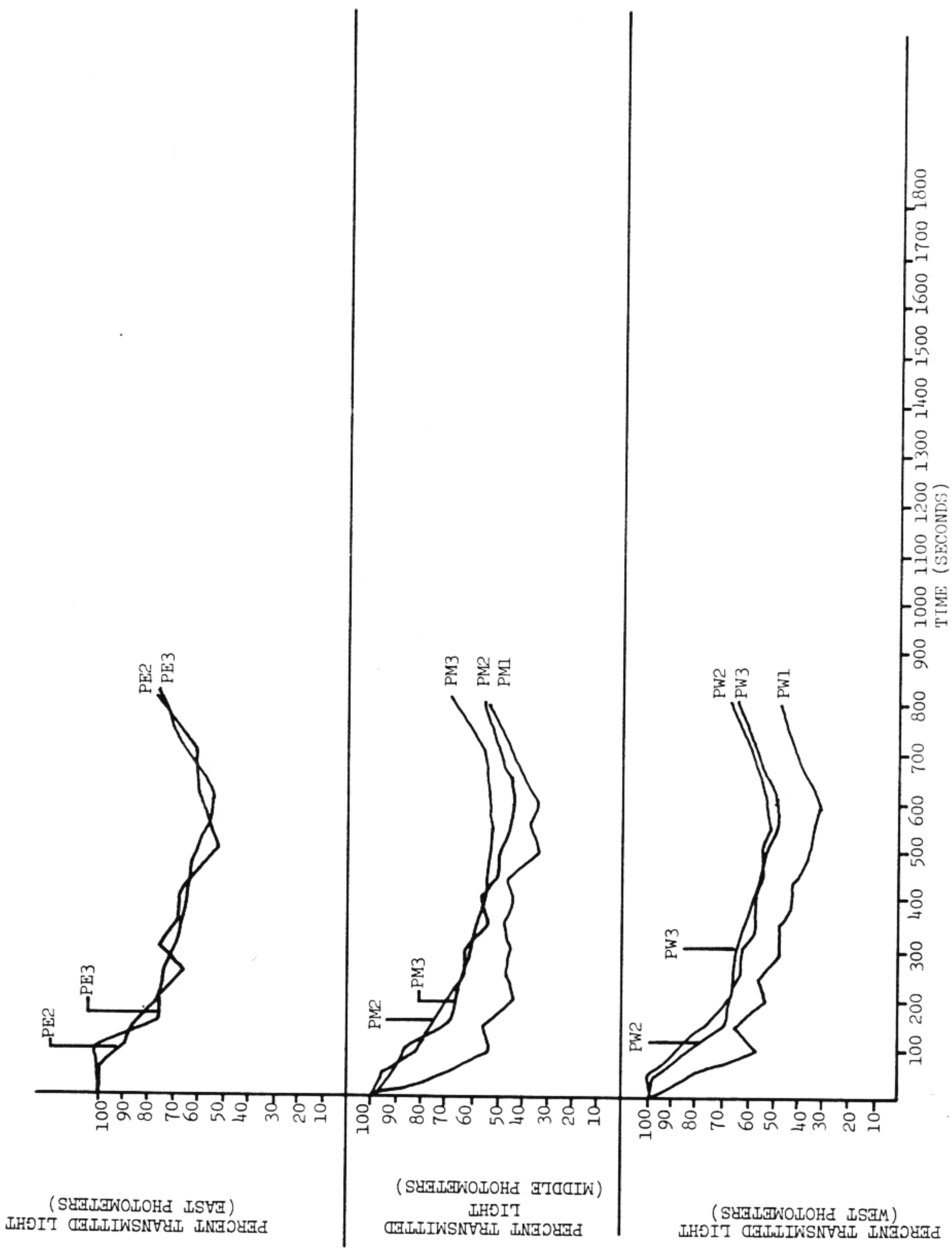

FIGURE 19. SMOKE METER READINGS FROM TEST B (FUEL PAN BASELINE)

These data subject to restrictive legend on title page.

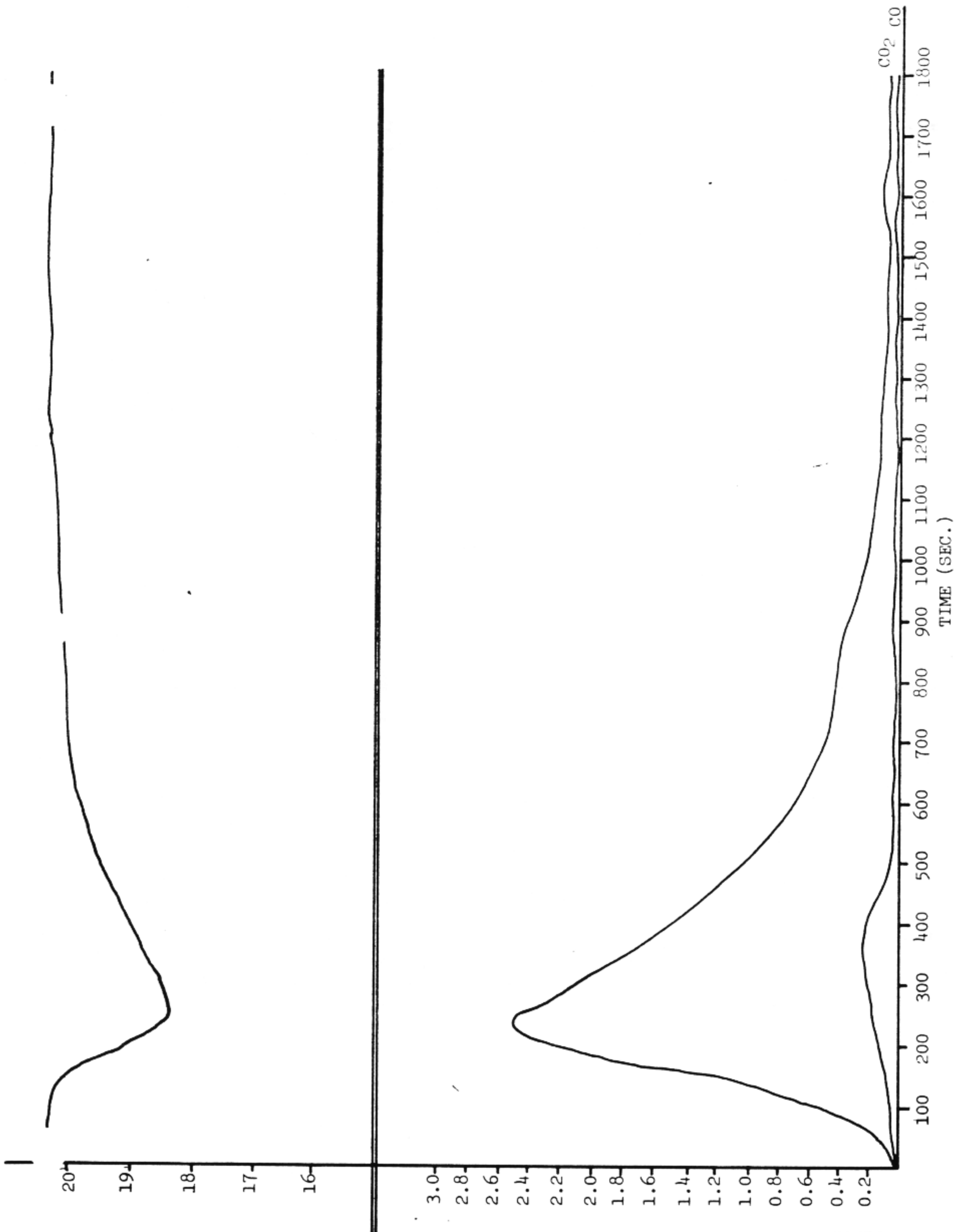

FIGURE 20. GAS CONCENTRATIONS FROM TEST 1B

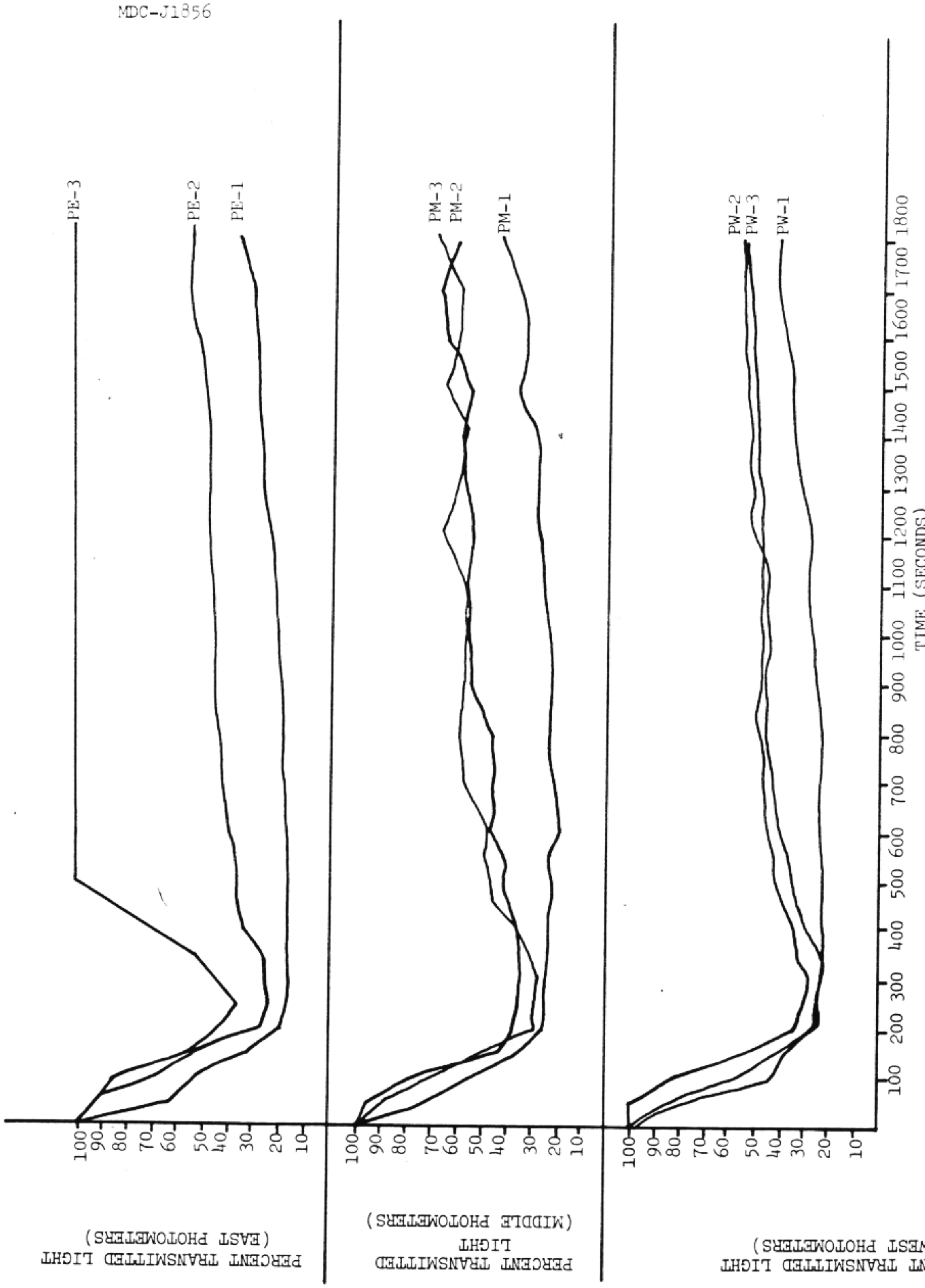

FIGURE 21. SMOKE METER READINGS FROM TEST 1B

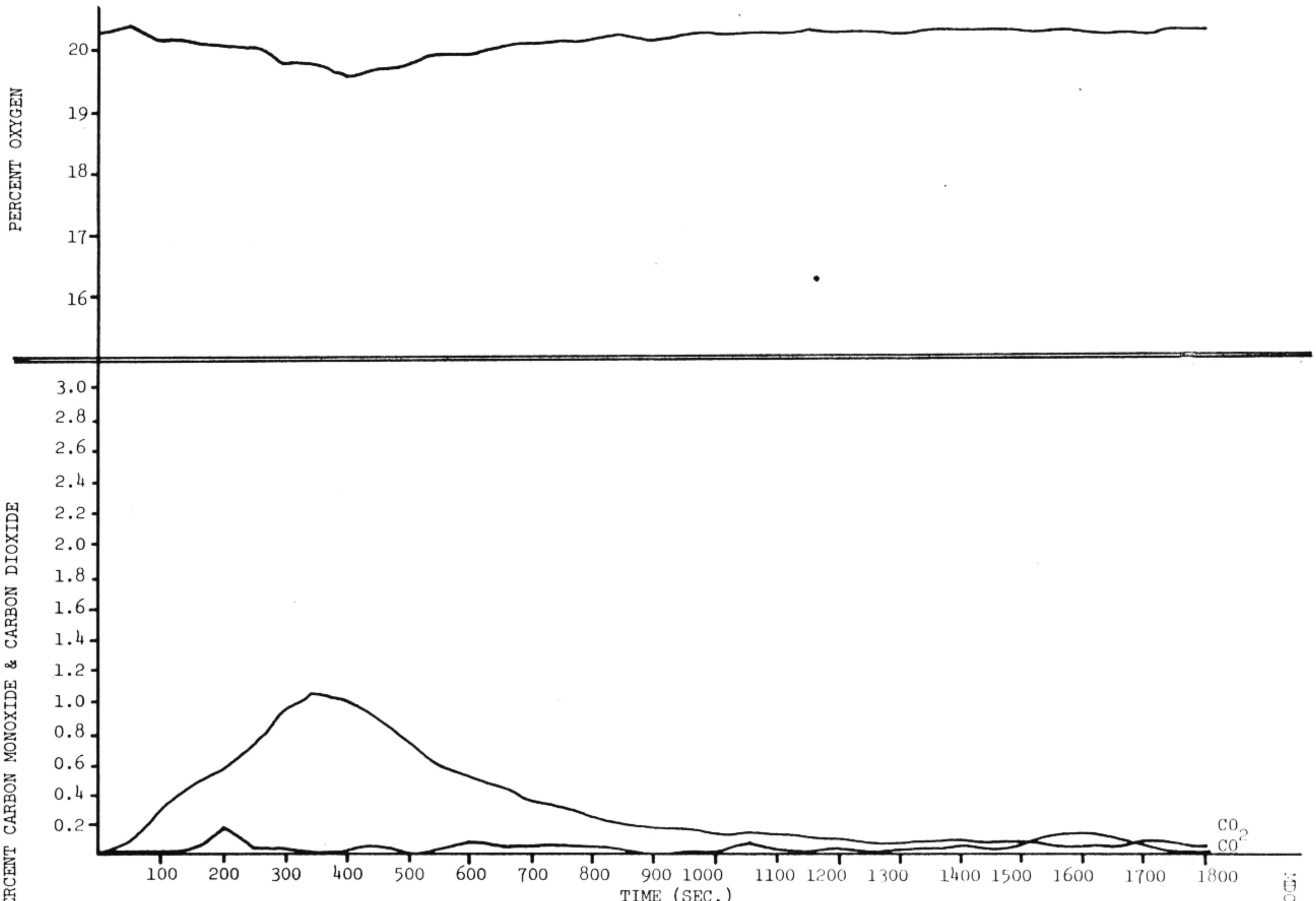

FIGURE 22. GAS CONCENTRATIONS FROM TEST 2B.

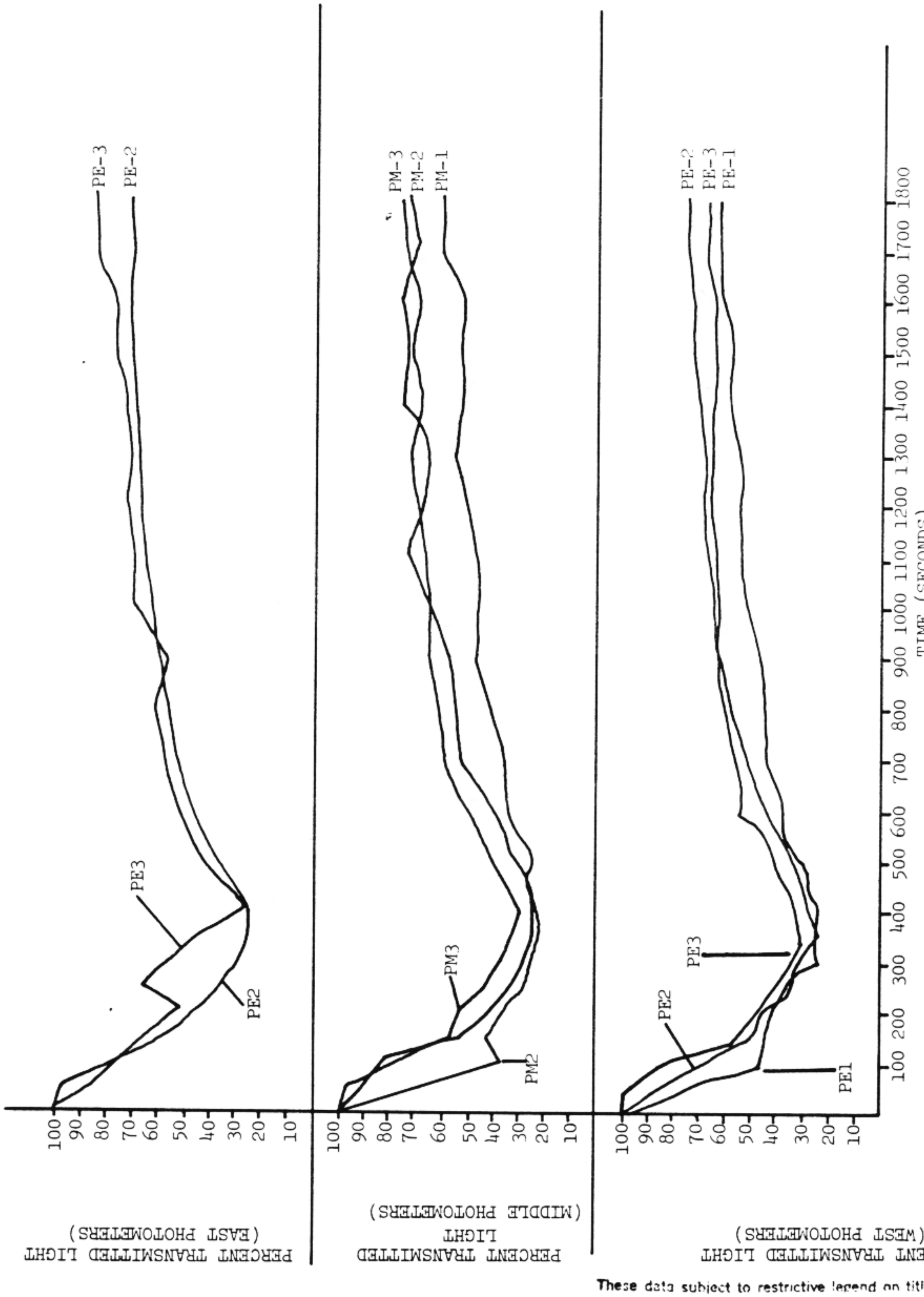

FIGURE 23. SMOKE METER READINGS FROM TEST 2B

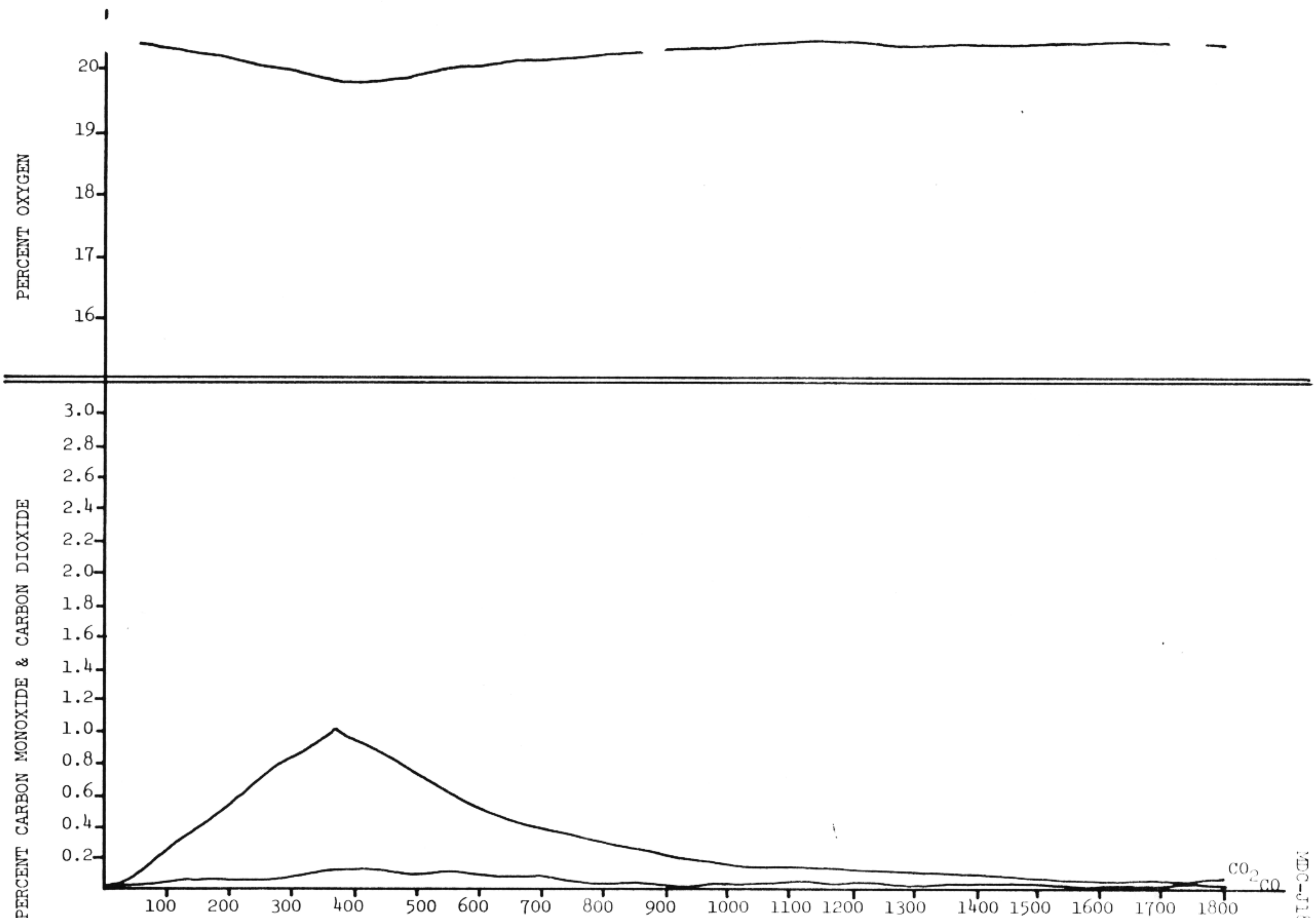

FIGURE 24. GAS CONCENTRATIONS FROM TEST 3B

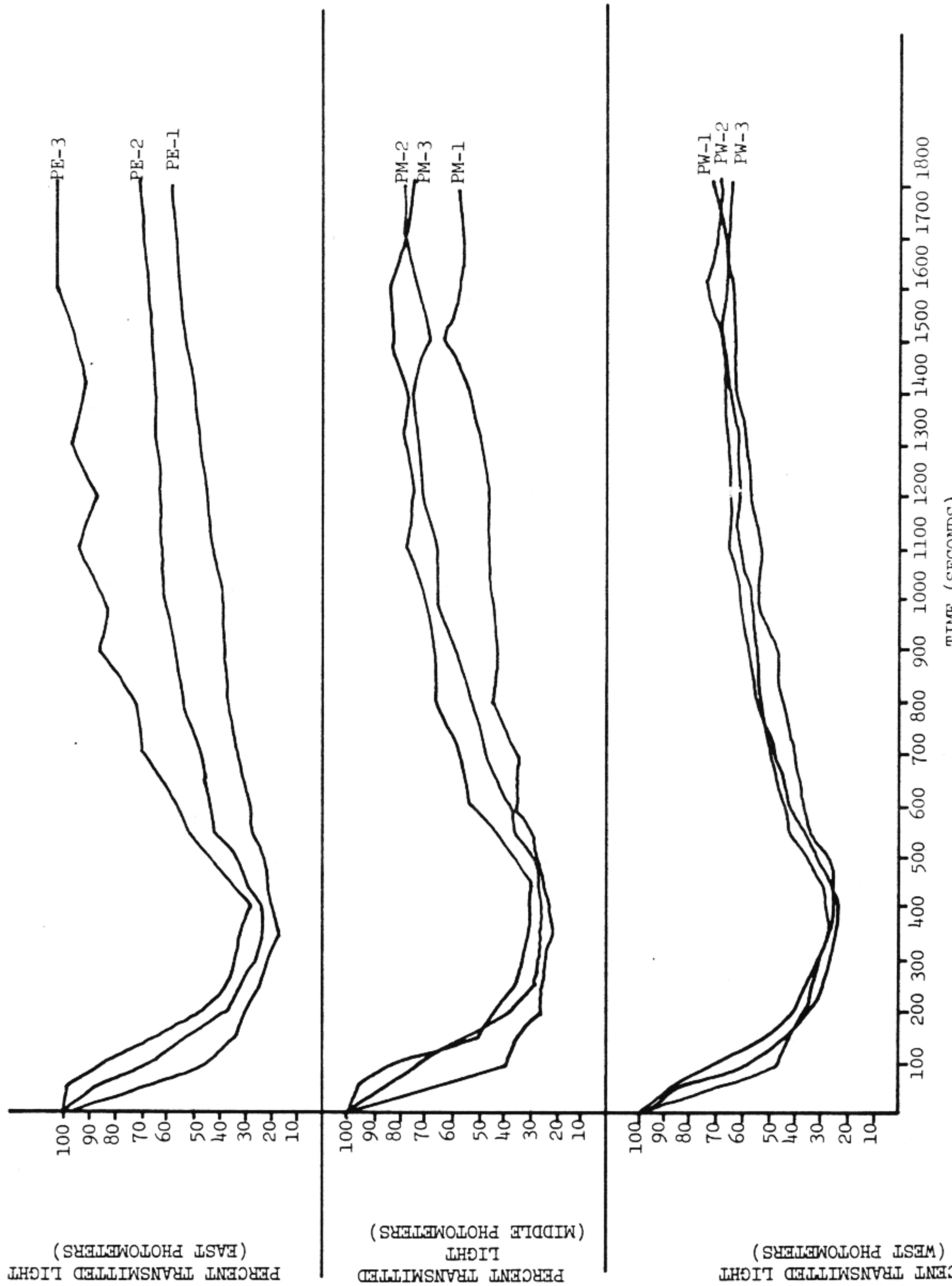

FIGURE 25. SMOKE METER READINGS FROM TEST 3B

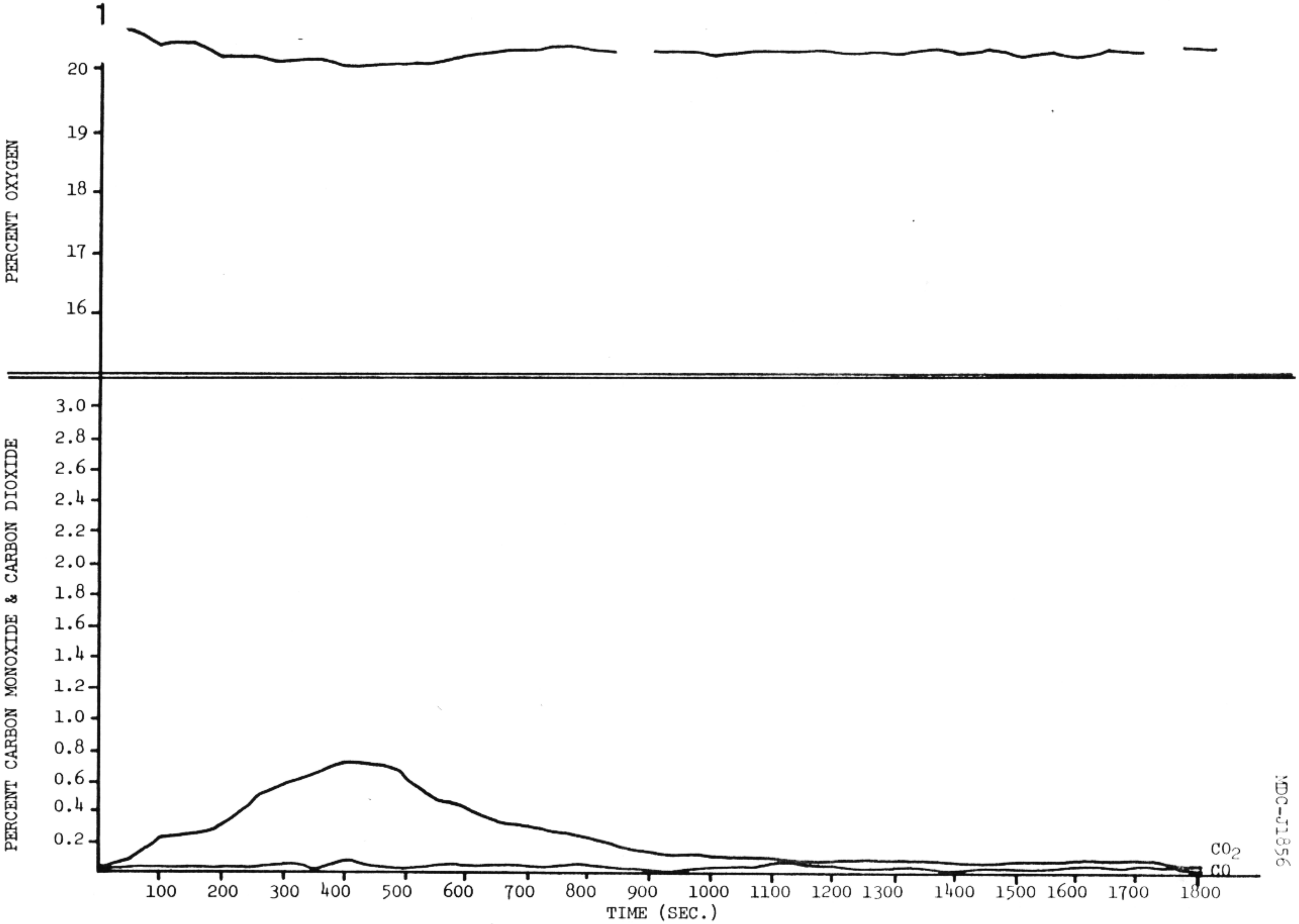

FIGURE 26. GAS CONCENTRATIONS FROM TEST 4B

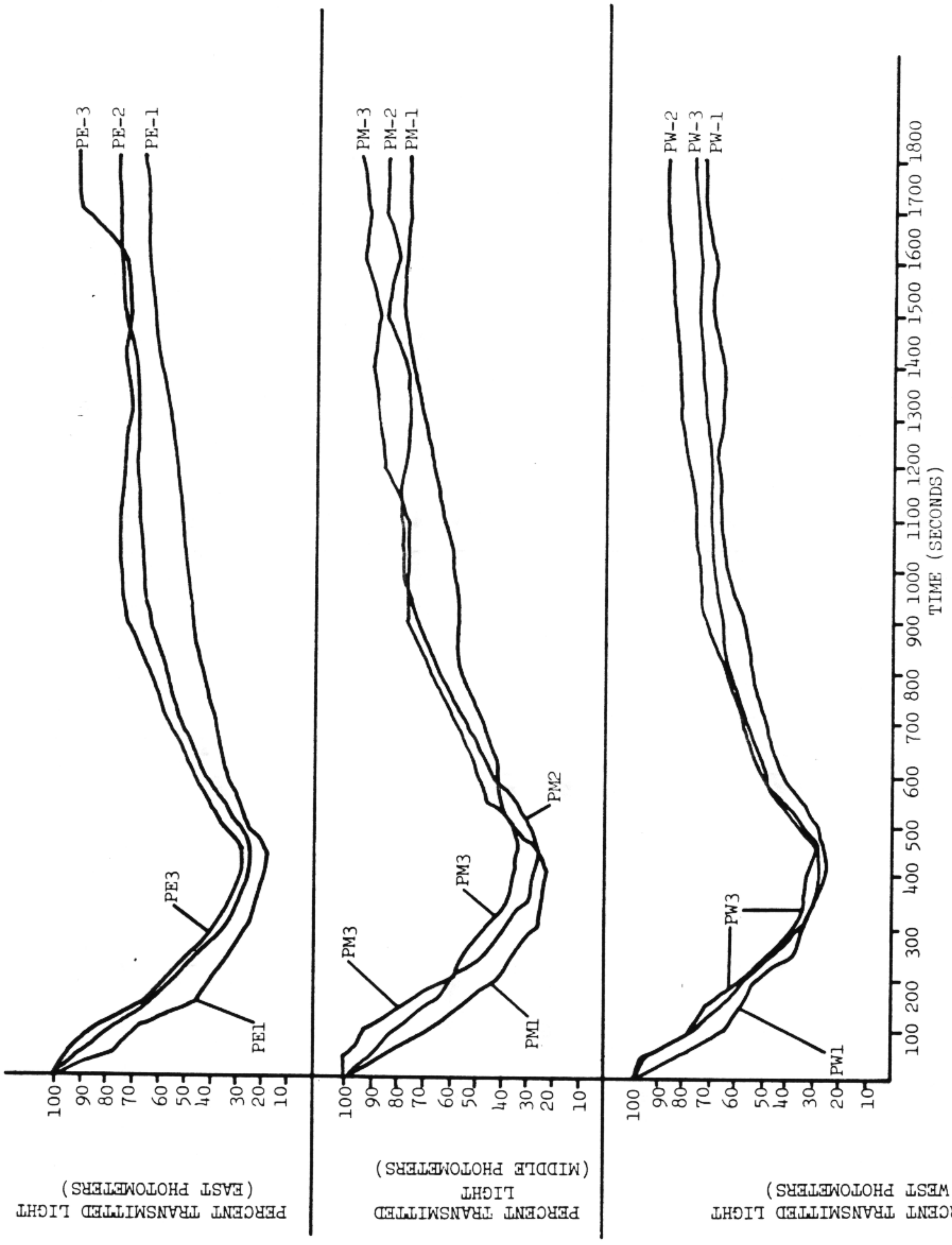

FIGURE 27. SMOKE METER READINGS FROM TEST 4B

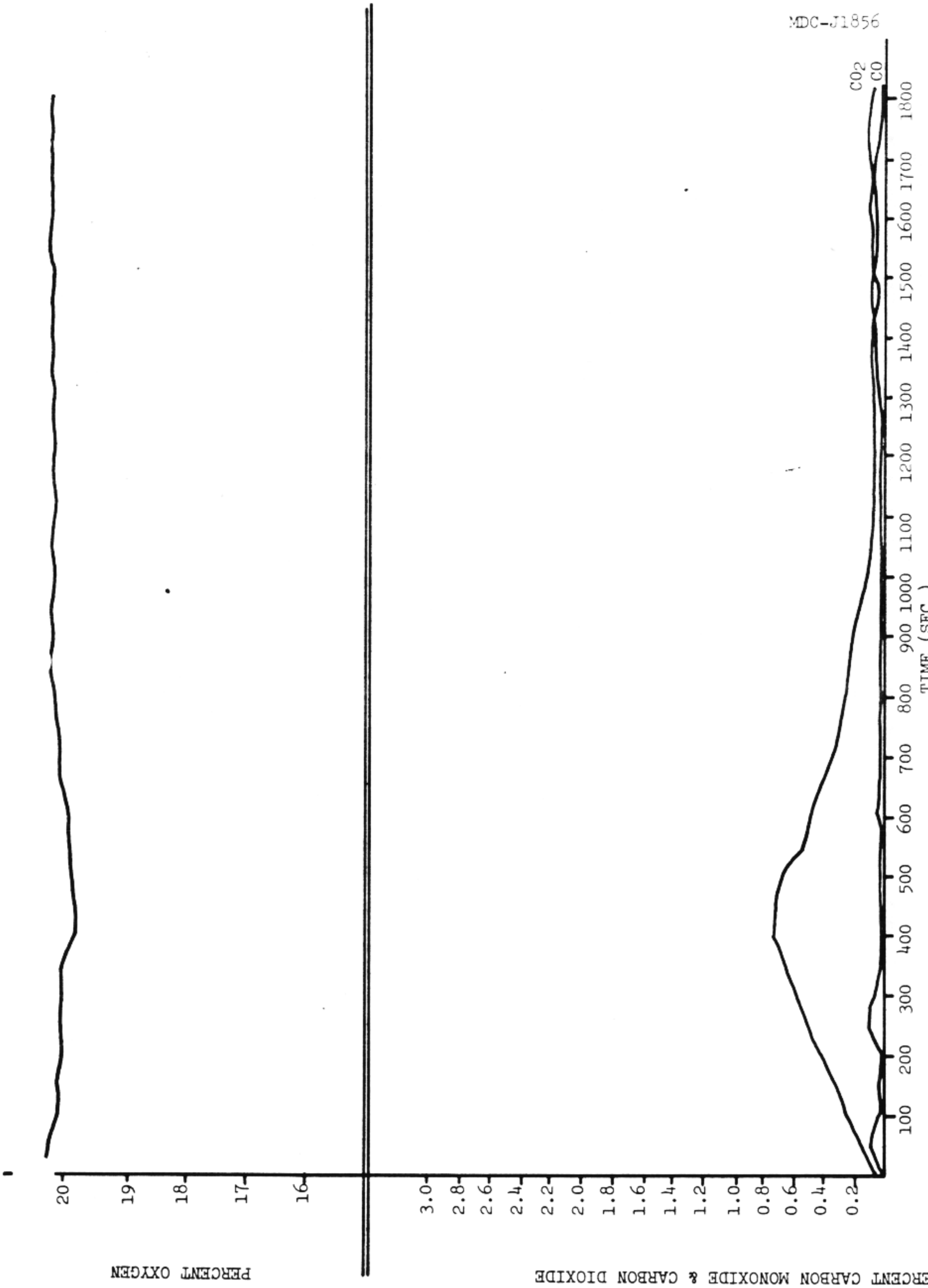

FIGURE 28. GAS CONCENTRATIONS FROM TEST 5B

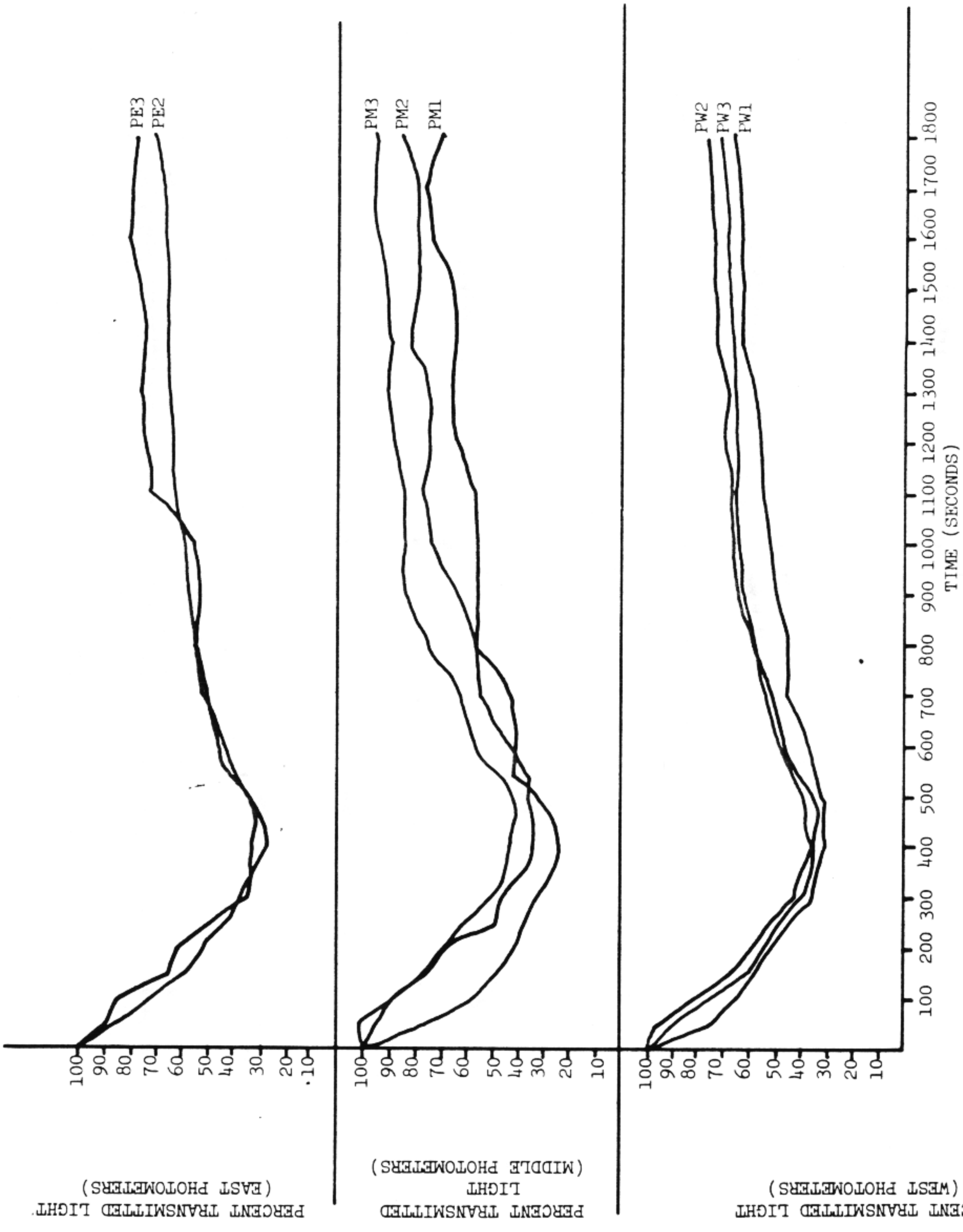

FIGURE 29. SMOKE METER READINGS FROM TEST 5B

These data subject to restrictive legend on title page.

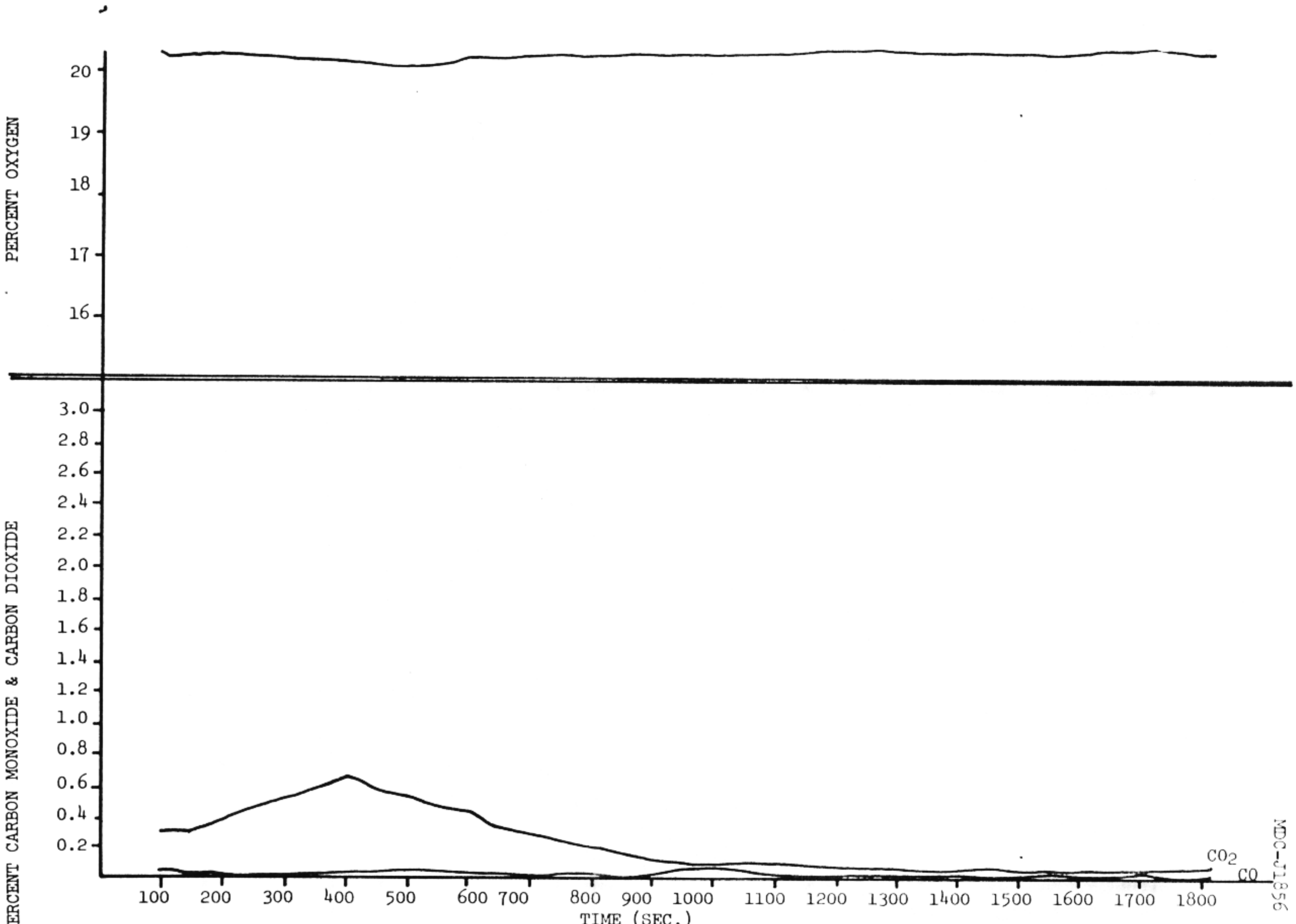

FIGURE 30. GAS CONCENTRATIONS FROM TEST 6B

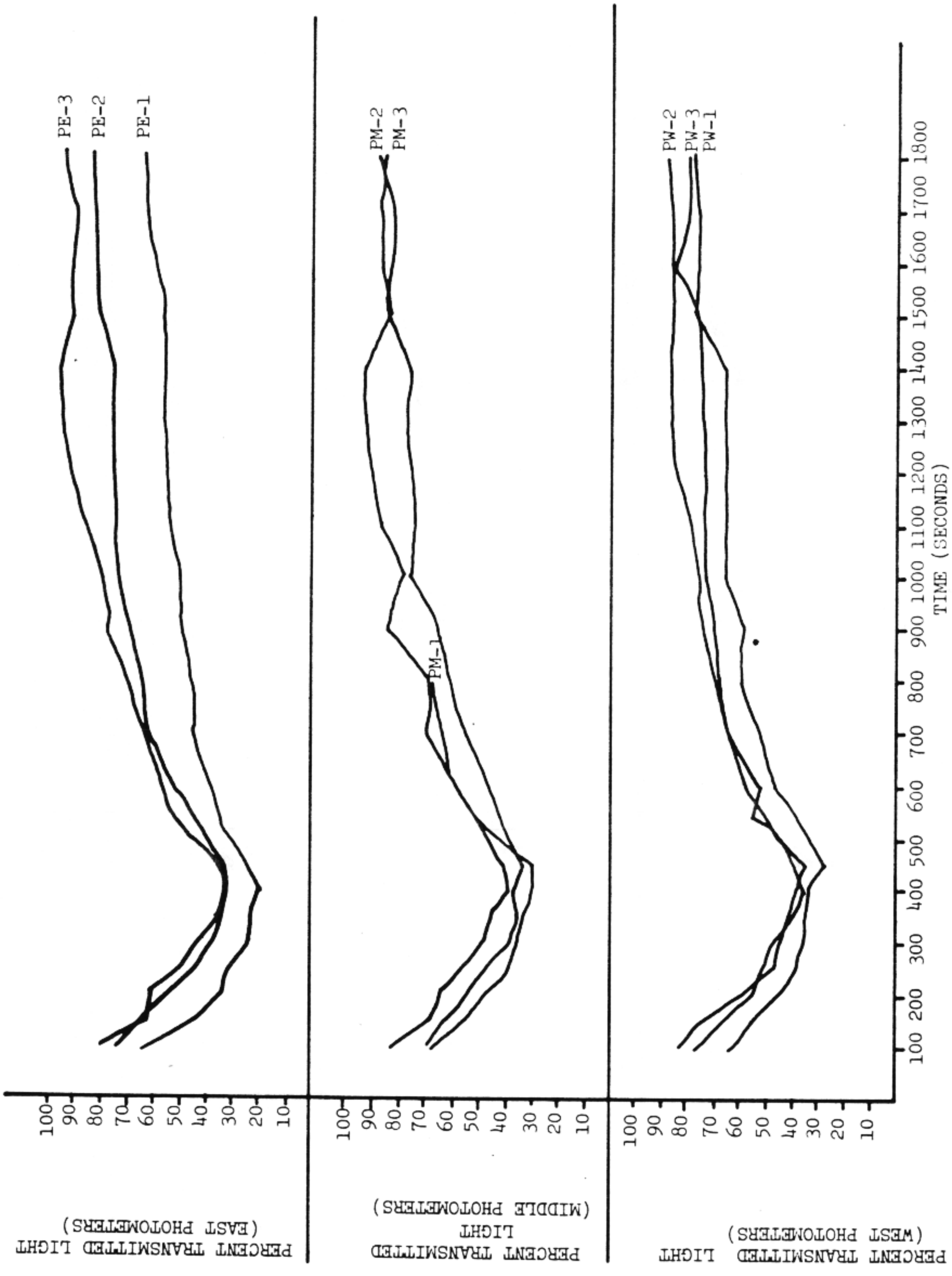

FIGURE 31. SMOKE METER READINGS FROM TEST 6B

These data subject to restrictive legend on title page

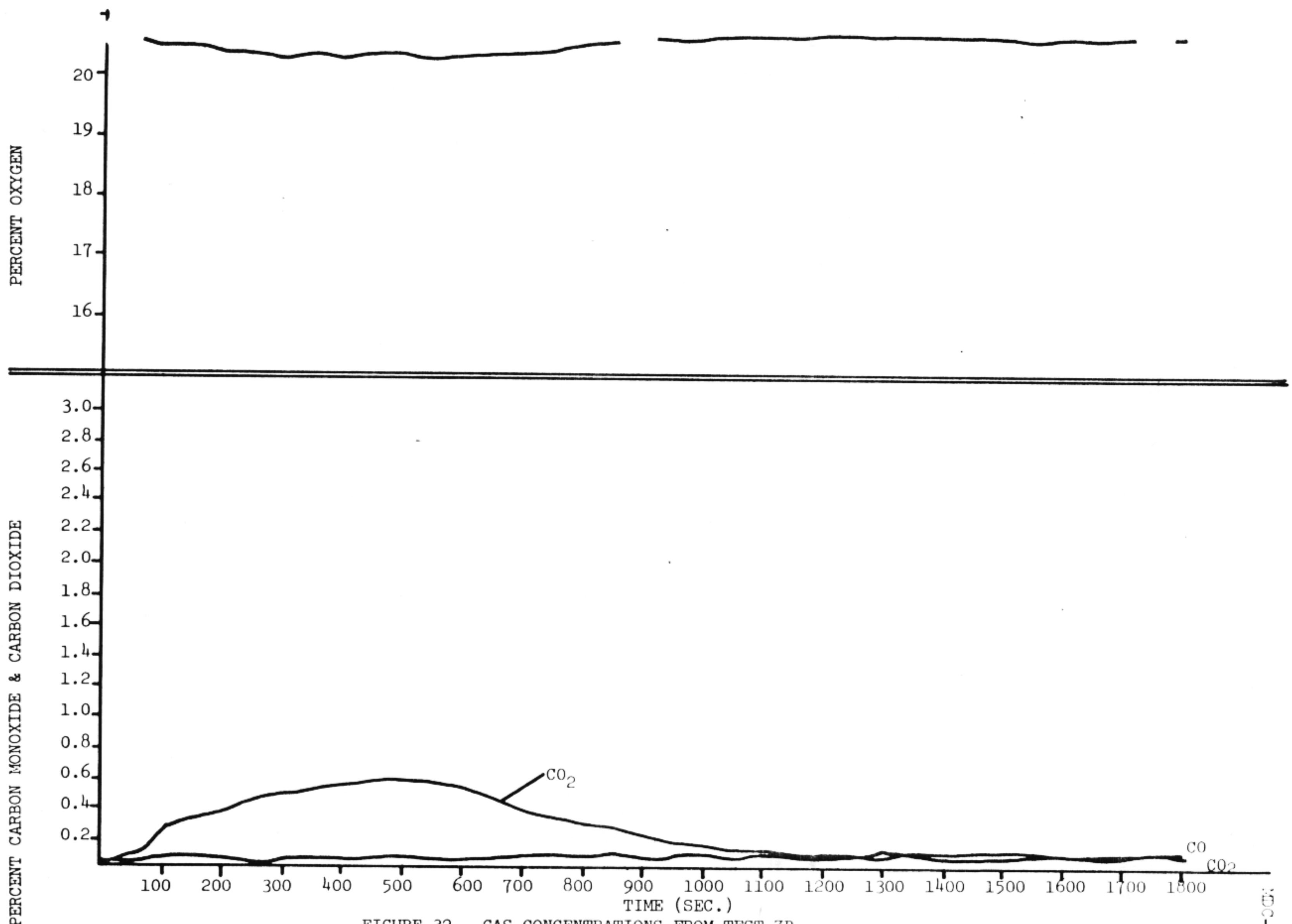

FIGURE 32. GAS CONCENTRATIONS FROM TEST 7B

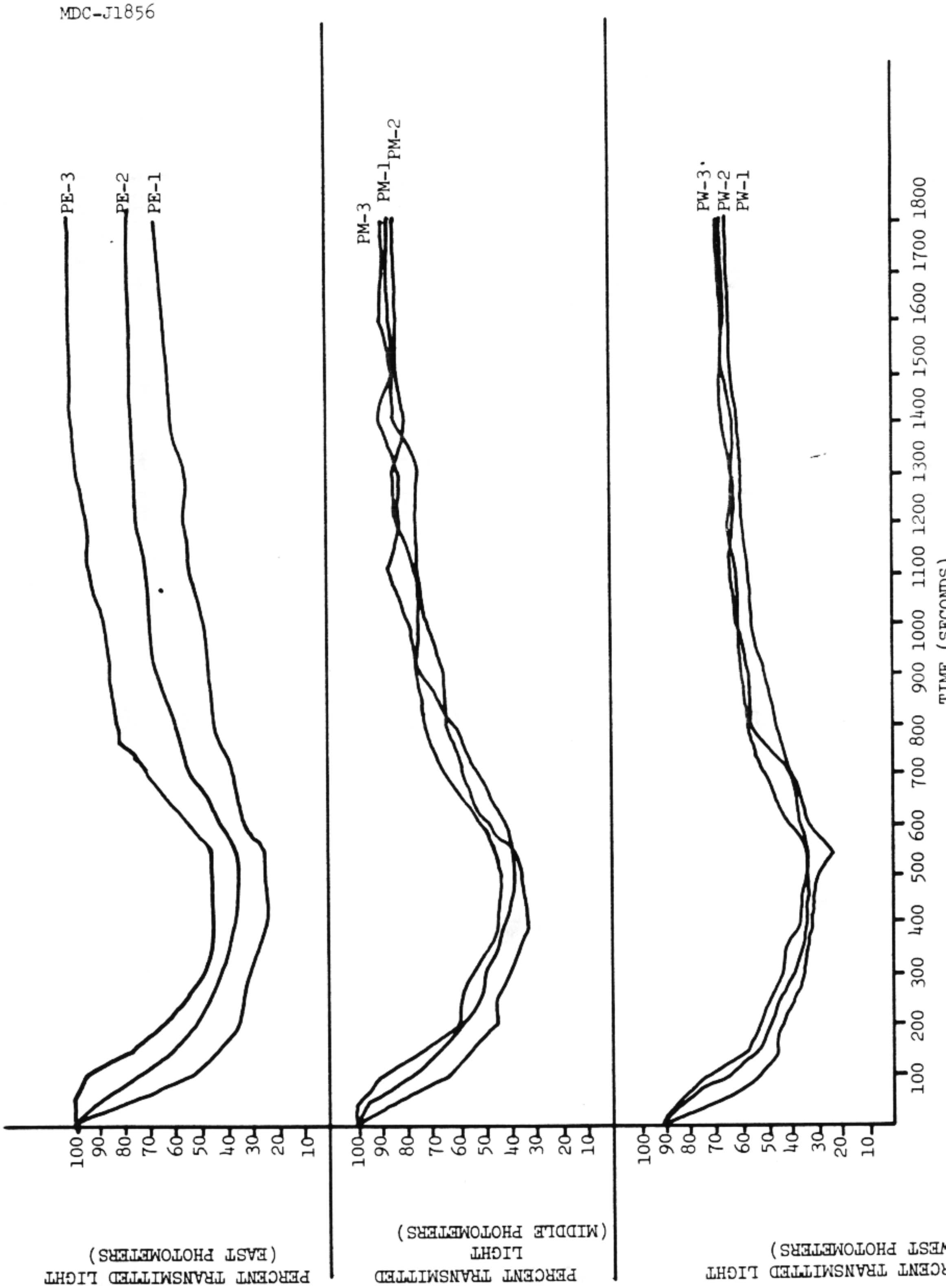

FIGURE 33. SMOKE METER READINGS FROM TEST 7B

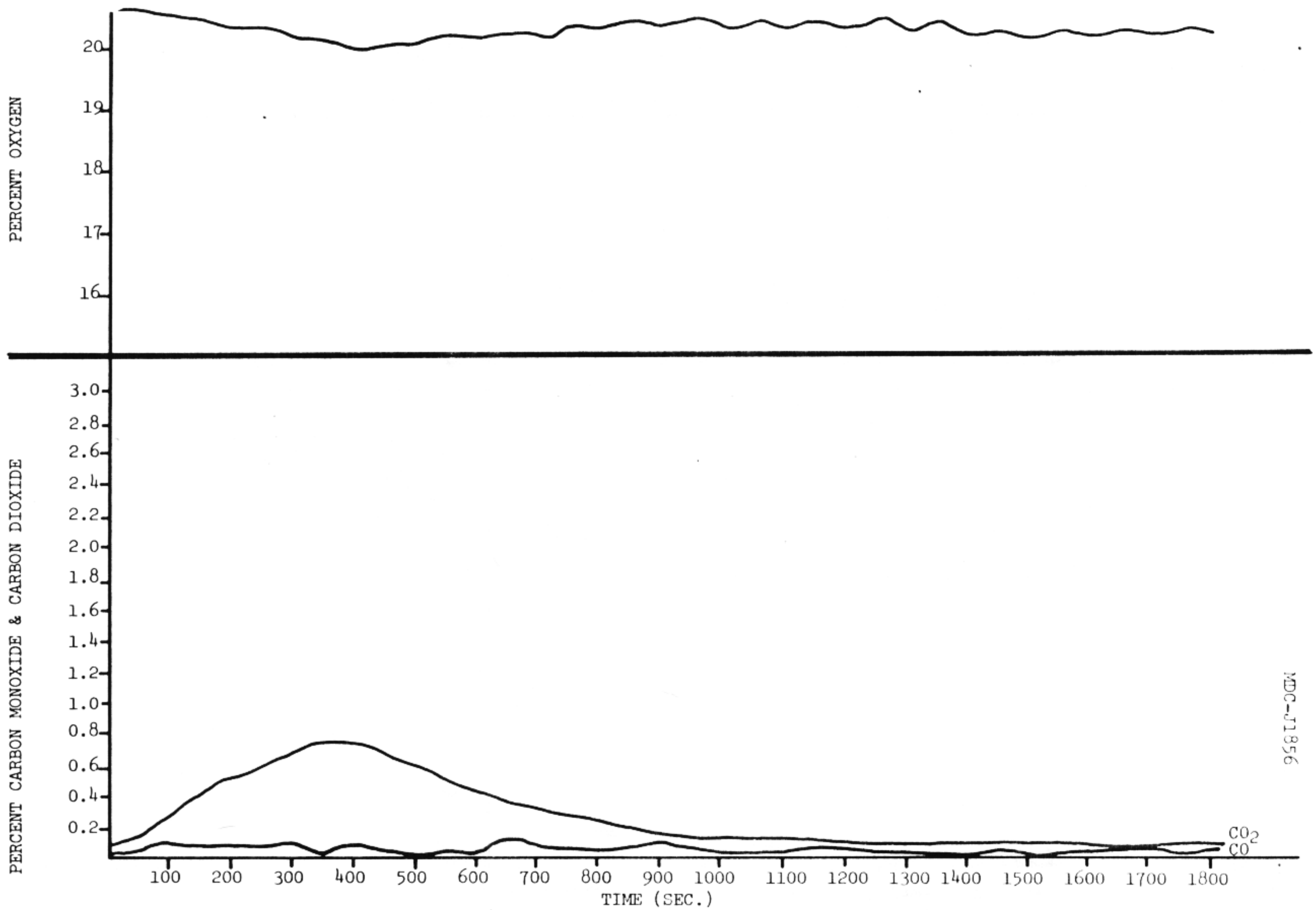

FIGURE 34. GAS CONCENTRATIONS FROM TEST 8B

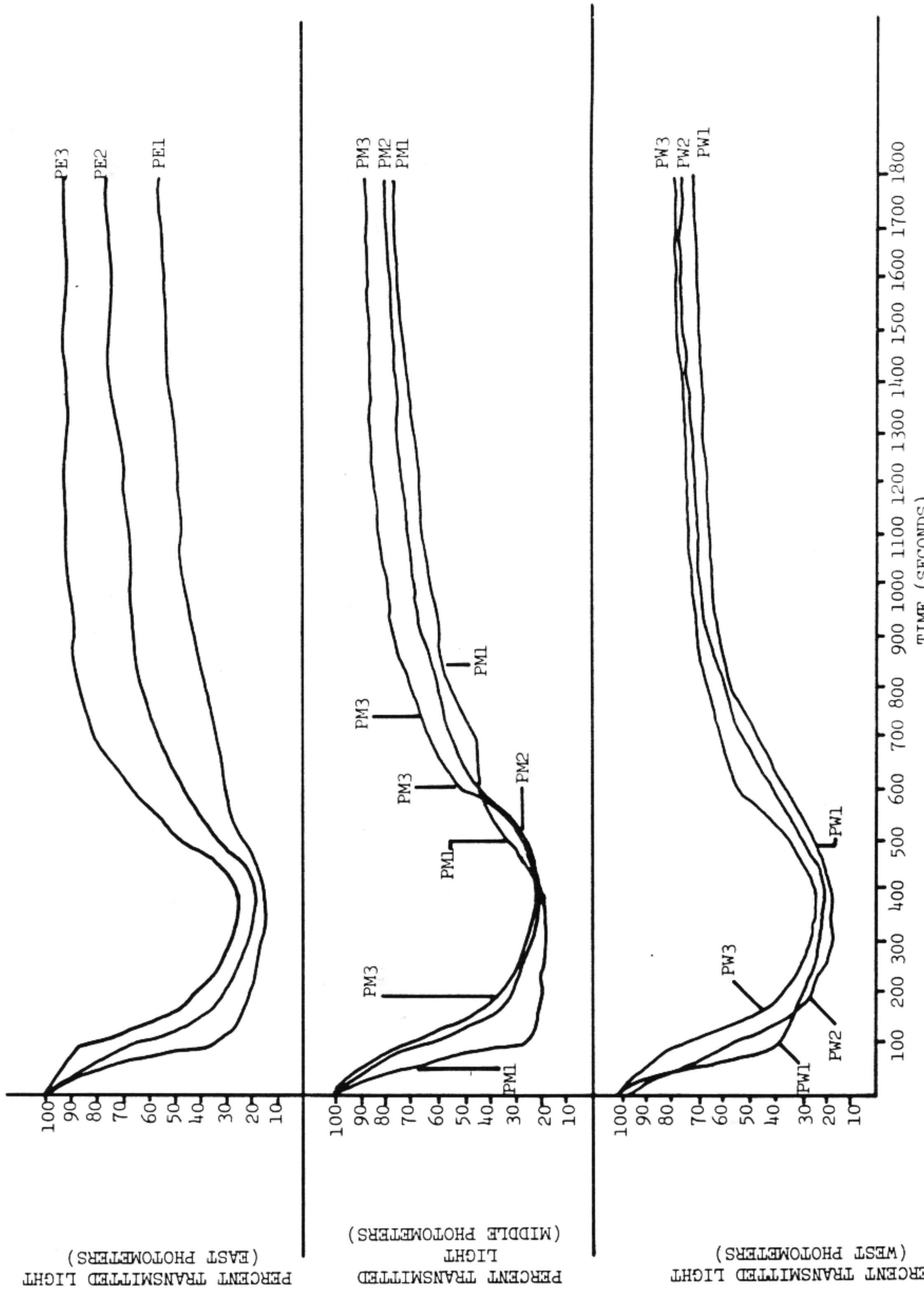

FIGURE 35. SMOKE METER READINGS FROM TEST 8B

IV

DISCUSSION

No measurable amounts of hydrocarbons were detected in any of the tests. The hydrocarbon detector used would probably not record any concentrations below several thousand parts per million.

A malfunction in the carbon monoxide analyzer caused readings below 0.1% to be inaccurate due to excessive electronic noise in the analyzer signal.

Smoke density measurements from the east photometers were substantially interfered with during the first 5 minutes of tests 1 - 8 by light emitted from the radiant panel.

No measurable concentrations of hydrogen chloride were observed in any of the tests. The method used to analyze for HCl would not show concentrations below approximately 15 parts per million.

V

CONCLUSIONS

This report summarizes data gathered by Materials & Process Engineering from the seat tests conducted for NASA by Interiors Engineering from 10/15/80 - 10/30/80. The gas concentrations and smoke density measurements from each test will be used in a comparison of the eight different cushion materials and the two different types of fire sources used.

APPENDIX C
NASA-JSC FLAMMABILITY TESTING OF AIRCRAFT SEATS

APPENDIX C
NASA-JSC FLAMMABILITY TESTING OF AIRCRAFT SEATS

INTRODUCTION

In 1976, a program was undertaken by Douglas Aircraft Company under Contract NAS 2-9337 entitled, "Study to Develop Improved Fire Resistant Aircraft Passenger Seat Materials" – Phase I. The purpose of the program was to screen and test candidate seat materials for flammability, heat release, smoke generation, and toxic products in order to establish a baseline or data base for the advanced materials to be tested in Phase II.

Solar Turbines International, under contracts NAS 9-14718, NAS 9-14050, and NAS 9-15484, has developed and characterized a lightweight, fire-retardant, high-resilient, low-smoke-emitting, and low-toxicity-polyimide foam for seat cushions.

Douglas was awarded Contract NAS 9-16062 for the full-scale flammability testing of aircraft seat prototypes consisting of contemporary and advanced materials. Eight seat design configurations were tested in the Douglas Aircraft Company cabin simulator. Concurrent with these tests, NASA Ames Research Center contracted Southwest Research Institute (SwRI) to perform flammability tests on the same seat configurations under similar conditions. Fairchild-Burns, Inc. built the seats for the Douglas and SwRI program and for the subsequent JSC tests in the 737 fuselage. Both the Douglas and SwRI tests have been completed. Douglas' observations of the tests resulted in the selection of the two configurations that performed the best for the comparable tests in the JSC 737.

TEST PROGRAM

Objectives

The purpose of the JSC seat flammability tests was to obtain data which could be compared to those obtained by Douglas and SwRI on the same seat configurations under similar test conditions. In addition, the involvement of the PSU, wall and ceiling panels were observed. Specific objectives were: (1) measure temperatures in the cabin, heat flux, and propagation rates across the configured materials; (2) analyze products of combustion for specific gases; (3) observe the animals exposed to the test atmosphere for signs of incapacitation; and (4) measure the loss of visibility due to the smoke produced during the test.

Test Parameters

The tests were conducted in the 56-foot length of the 737 fuselage. Each configuration was evaluated as one set of two seats placed side by side. Two configurations, designated No. 7 and No. 5, were tested. These configurations are described below in "Test Articles." The ignition source was one liter of Jet A 1 aviation fuel in a 12- by 12-inch pan placed under the window seat. The air flow through the fuselage was 500 cubic feet per minute. Auxiliary cabin materials included ceiling and wall panels, and a mockup PSU. For toxicity evaluation, three test animals were placed in each of two cages located as shown in Figure C-1. Five minutes into the test, the six animals were dropped out of the test chamber. One additional animal, which was in a cage equipped for special behavioral studies, remained in the test area for 20 minutes after ignition. This animal was monitored for behavior for 20 minutes before the test to provide a baseline for the test behavior. Gas analyses were performed automatically at the site for CO_2, CO, O_2, and total hydrocarbons. For hydrogen cyanide, hydrogen fluoride, and hydrogen chloride, samples were collected in the glass microimpinger bubblers with 0.1 molar sodium hydroxide and tested later in the chemistry laboratory.

Instrumentation in the test area consisted of thermocouples located as shown in Figure C-1. Figure C-2 shows the positioning of thermocouples and calorimeters on the seat cushions and backrests. Figure C-3 shows the location of the cameras.

Color movies, stills, and video tapes were made of the tests.

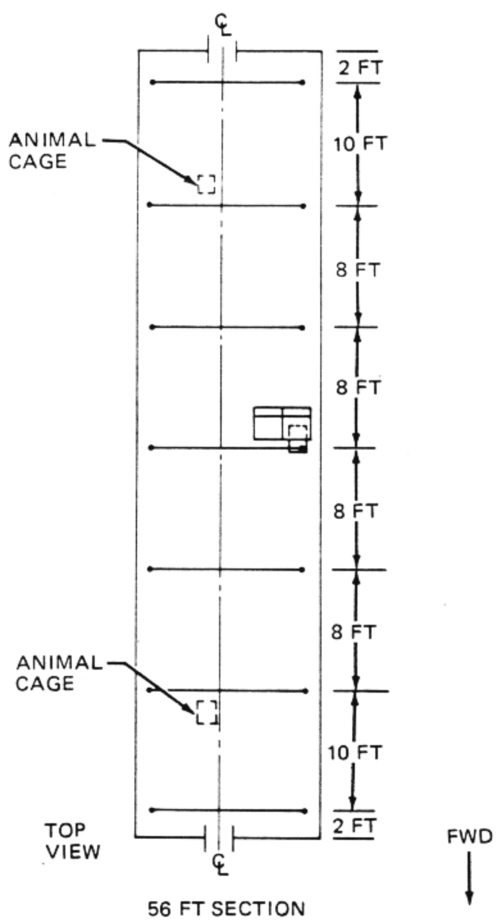

FIGURE C-1. THERMOCOUPLE LOCATIONS FUEL PAN AND ANIMAL CAGES

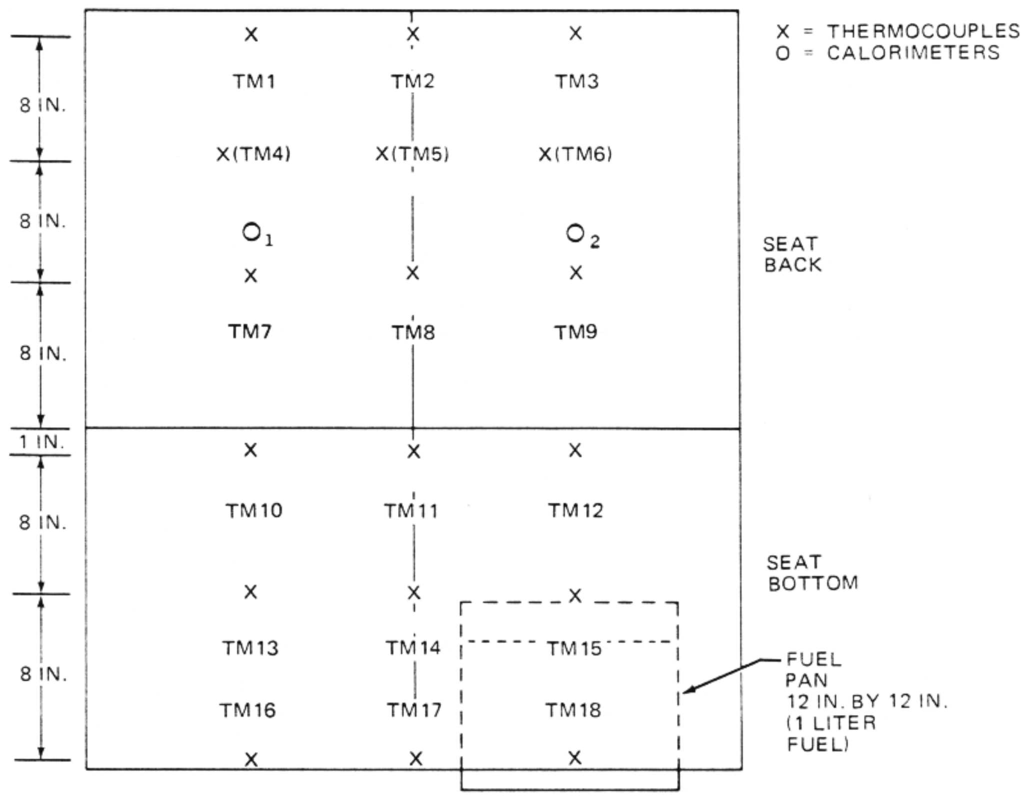

FIGURE C-2. THERMOCOUPLE AND CALORIMETER LOCATIONS

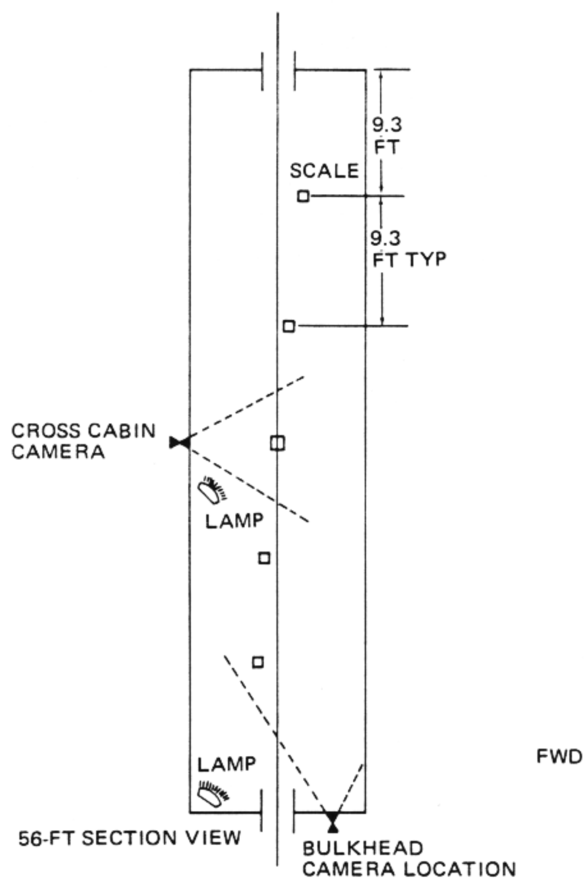

FIGURE C-3. CAMERA LOCATIONS

Test Articles

The two configurations selected as the more fire resistant of the eight tested by Douglas were constructed as follows: Configuration No. 7 was tested first. The seat and backrest consisted of polyimide foam upholstered with No. 3177 Sedellia Blue 100 percent wool. The foam was covered with fire-retardant, cotton muslin ticking. Configuration No. 5 was tested ten days later under the same test parameters and conditions. The cushioning for the seat and backrest consisted of a layer of polyurethane foam sandwiched between two 1/2-inch layers of LS-200 neoprene foam, covered with nomex III ticking. The cushion assembly was upholstered with Kermel wool blend. In the test area, PSU, wall, and ceiling panels of the Boeing 747 type were installed. These panels were composed of nomex honeycomb with epoxy fiberglass cover sheets. The PSU mockup was fabricated from No. 9600 Lexan polycarbonate.

TEST RESULTS

Test No. 1 (Configuration No. 7)

The seats were weighed before the tests and weights recorded as follows:

Aisle seat	= 1 lb 7 oz	Window seat	= 1 lb 9 oz
Aisle seat backrest	= 1 lb 6-1/2 oz	Window seat backrest	= 1 lb 5-1/2 oz

The fuel was ignited by a propane igniter and the flame rose up over the front edge of the seat almost to the top of the seat backrest. The fire burned for approximately 17 minutes. Five minutes into the test, the six animal specimens were removed from the chamber for evaluation. There was relatively little visual obscuration due to smoke evolution. What smoke was evident came principally from the Jet A 1 fuel. Post-test inspection showed the only damage was to the front edge of the cushion over the fuel pan. Here the upholstery burned away and the polyimide foam was charred. However, the foam did not ignite. There was no propagation of the fire from one seat to the other and neither back was affected.

The weights after the test were:

Aisle seat	= 1 lb 5 oz	Window seat	= 1 lb 2 oz
Aisle seat backrest	= 1 lb 6 oz	Window seat backrest	= 1 lb 5 oz

The weight losses were:

Aisle seat	= 2 oz (8.7%)	Window seat	= 7 oz (28%)
Aisle seat backrest	= 1/2 oz (2.2%)	Window seat backrest	= 1/2 oz (2.3%)

The 8.7 percent loss to the aisle seat was apparently due to the damage to the upholstery between the aisle and window seat cushions and to a loss of moisture from the wool. The loss of weight of the seat backrests was most likely due to moisture loss alone.

The temperatures at various times during the test are recorded in Table C-1. The highest temperature measured was 1372°F, recorded from the thermocouple TM 18 positioned at the edge of the window seat above the fuel pan. The two calorimeters, one positioned on the middle of each seat backrest cushion, showed no rise. This was apparently due to the very good insulative properties of the polyimide foam.

The six animals, consisting of male Sprague-Dawley rats, were exposed to the fire atmosphere for 5 minutes. They survived the test and showed no gross toxic effects during the one week post-test observation period. The single operant animal in the specially equipped shock escape cage showed no change in performance from baseline control levels. The results of the analyses of the combustion gases are shown in Table C-2.

TABLE C-1

TEMPERATURE (°F) AT VARIOUS TIMES AFTER FUEL IGNITION

THERMO-COUPLE IDENTIFY	MINUTES														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TM1	104	116	127	135	141	147	151	200	147	144	140	136	132		
TM2	114	125	143	151	165	174	193	181	174	164	157	152	147		
TM3	121	139	161	180	182	186	190	193	194	188	176	170	163		
TM4	109	121	136	141	148	151	153	172	150	147	139	137	133		
TM5	108	125	141	151	161	169	185	219	176	168	164	157	151		
TM6	151	151	181	197	204	206	210	203	200	185	174	169	160		
TM7	114	127	143	150	156	157	160	161	185	148	140	136	133		
TM8	121	135	147	164	185	200	209	209	193	182	176	168	160		
TM9	124	140	161	189	190	196	204	204	200	192	182	176	169		
TM10	97	105	114	121	125	127	125	128	125	128	123	117	116		
TM11	106	113	121	132	135	136	147	184	157	160	129	127	124		
TM12	101	112	123	132	135	135	136	133	136	137	132	127	125		
TM13	105	110	123	127	133	136	140	139	136	136	132	131	131		
TM14	105	117	132	140	148	150	151	165	148	155	151	165	186		
TM15	109	118	153	208	159	160	161	163	177	208	238	260	276		
TM16	140	155	174	200	222	237	235	226	222	218	239	190	182		
TM17	656	887	1140	1217	1071	1134	961	731	579	501	424	366	300		
TM18	222	370	730	1372	1232	965	1153	887	801	699	625	532	430		

HIGHEST READING 1372°F   TEST START 9:56:57   FINISH 10:16:36

TC TM18 (4 MINUTES INTO TEST)   PREPARED BY RM WALKER   DATE ______

TABLE C-2

COMBUSTION GAS ANALYSES

OFFGASSED PRODUCT	POLYIMIDE FOAM	NEOPRENE/POLYURETHANE FOAM
CARBON MONOXIDE (ppm)	69	376
LIGHT HYDROCARBONS (ppm)	143	417
CARBON DIOXIDE (%)	0.24	0.29
OXYGEN (%) MINIMUM LEVEL	20.3	20.4
HYDROGEN CYANIDE (%)	20	45
HYDROGEN FLUORIDE (%)	42*	22
HYDROGEN CHLORIDE (%)	105	330

*DUE PRIMARILY TO RESIDUAL FROM PREVIOUS TESTS AND INCOMPLETE PURGING AND FLUSHING OF LINES.

Test No. 2 (Configuration No. 5)

The pretest weights of the seats were as follows:

Aisle seat	= 3 lb 9 oz	Window seat	= 3 lb 9 oz
Aisle seat backrest	= 3 lb 6 oz	Window seat backrest	= 3 lb 14 oz

As noted under "Test Articles," the test parameters were the same as those followed for Test No. 1, i.e., the PSU mockup, wall and ceiling panels, animals, fuel pan, instrumentation, etc. were configured the same as in Test No. 7. The fire from the fuel pan burned up over the edge of the window seat and continued to burn for a total of approximately 30 minutes. After approximately 14 minutes, the flames were confined to a small area of the fuel pan apparently where the Fiberfrax wicking held more of the fuel. These small, flickering latent flames did not come close to impinging on the seats. Approximately four minutes into the test, smoke obscured the seats and the obscuration remained until approximately the ten-minute mark. The visibility in the area of the fuel pan and the edges of the seat cushions was fairly good and some burning of the window seat cushion was observed. This was more evident after the ten-minute mark when some of the smoke cleared apparently due to the ventilation of the cabin. There was no evidence of the seat burning when the fire no longer impinged on the seat. Posttest inspection showed extensive damage to the window seat cushion, some damage to the adjacent aisle seat cushion, and damage to the sidewall including burnthrough of an area 8 inches in diameter. The seat back cushion of the window seat was also slightly damaged. The Kermel wool blend used for the seat covers showed very good fire resistance. The test animals, as in Test No. 1, showed no apparent adverse effects from the exposure to the fire environment.

The weights of the cushions after the test were:

Aisle seat cushion	= 3 lb 4-1/2 oz	Window seat cushion	= 1 lb 11 oz
Aisle seat back cushion	= 3 lb 5 oz	Window seat back cushion	= 3 lb 8 oz

The weight losses were:

Aisle seat cushion	= 4.5 oz (7.9%)	Window seat cushion	= 1 lb 14 oz (52.6%)
Aisle seat back cushion	= 1 oz (1.85%)	Window seat back cushion	= 3 lb 6 oz (9.7%)

The temperatures at various times during the test are recorded in Table C-3.

The highest temperature recorded was 907°F measured at thermocouple TM18 positioned at the edge of the window seat above the fuel pan.

The results of the analyses of the combustion gases are shown in Table C-2.

CONCLUSIONS

The polyimide seat cushions did not ignite and therefore did not propagate a fire and they evolved very little smoke.

Polyurethane foam cushions ignited when impinged by a flame and burned completely with the evolution of much smoke.

The polyurethane-LS200 neoprene seat ignited and burned. Much smoke was generated but no fire was generated.

The 100 percent wool upholstery burned in the impingement area.

The Kermel wool resisted the fire and provided an effective fire barrier.

TABLE C-3

TEMPERATURE (^{o}F) AT VARIOUS TIMES AFTER FUEL IGNITION

THERMO-COUPLE IDENTITY	MINUTES																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TM1	91	100	105	112	114	117	123	127	133	129	128	125	125	125	123	123	123	124	123	121	121	121	118	118
TM2	102	108	116	125	131	139	139	144	144	144	140	139	139	140	139	137	140	140	137	136	137	137	136	135
TM3	114	121	131	144	150	157	161	157	156	157	155	159	156	155	153	153	152	150	150	143	147	147	144	141
TM4	96	101	109	117	118	118	124	127	129	127	127	125	127	127	127	125	125	127	127	125	127	125	124	123
TM5	105	114	123	133	140	145	147	150	148	145	141	141	144	147	145	144	147	150	150	148	150	150	147	145
TM6	123	129	140	153	157	164	165	168	161	161	161	161	163	164	163	164	165	168	165	164	165	164	161	159
TM7	98	106	114	123	127	129	132	137	143	132	132	132	133	135	131	131	131	132	132	131	132	132	131	131
TM8	125	136	150	159	166	174	165	172	164	163	163	157	163	165	161	164	168	172	169	169	172	170	169	168
TM9	108	116	125	137	145	150	151	151	151	152	153	153	155	159	160	161	165	170	172	173	176	177	176	176
TM10	89	93	100	104	109	116	118	123	121	123	124	123	123	123	120	120	118	118	117	116	116	114	114	114
TM11	91	96	102	108	114	121	123	129	132	137	139	139	139	137	137	139	140	140	147	150	153	160	168	178
TM12	93	97	102	110	116	120	145	148	150	159	161	165	169	174	181	190	208	226	242	251	261	268	269	270
TM13	101	105	113	121	128	140	139	144	141	139	139	136	135	133	129	128	125	128	128	129	135	136	139	143
TM14	96	100	103	116	129	145	153	157	163	168	173	184	203	234	268	295	314	340	373	393	407	428	434	432
TM15	108	114	124	131	143	160	176	186	223	268	326	389	490	534	575	614	636	634	665	694	667	633	564	490
TM16	164	156	217	239	239	257	250	256	249	238	230	222	218	212	206	203	201	203	200	198	201	201	203	201
TM17	135	180	258	324	313	304	304	319	328	329	330	337	359	378	395	410	432	452	459	464	460	460	452	442
TM18	189	196	201	233	243	256	306	335	374	422	451	540	638	731	817	862	898	907	881	838	829	814	751	668

HIGHEST READING__________ TEST START 9:55:21 FINISH 10:19:28

TC_____ MIN_____ SEC_____ PREPARED BY R. M. WALKER DATE 8 JANUARY 1981