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# In-Flight Aircraft Seat Fire Extinguishing Tests (Cabin Hazard Measurements)

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December 1982

Final Report

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16. Abstract

This report describes the results of a test program designed to: (1) determine the amount of toxic decomposition byproducts from the use of Halon 1211 on large seat fires in an aircraft cabin while in flight; (2) compare relative hazard levels from the use of common aircraft hand-held extinguishers (Halon 1211, monoammonium phosphate, carbon dioxide, water) on large fires in an aircraft cabin while in flight; (3) compare the hazards from the hand-held extinguishers extinguishing a large aircraft seat fire to the hazards of an uncontrolled seat fire.

A series of nine tests was conducted during this project. Two tests each were conducted using Halon 1211, dry powder (monoammonium phosphate), water and $CO_2$ extinguishers, and one test in which the seat fire was allowed to burn uncontrolled.

Hazard level measurements were taken during all tests, they included heat, smoke, and toxic gas measurements.

It was concluded that Halon 1211 can be effectively and safely utilized to extinguish a severe seat fire in a transport passenger cabin.

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# METRIC CONVERSION FACTORS

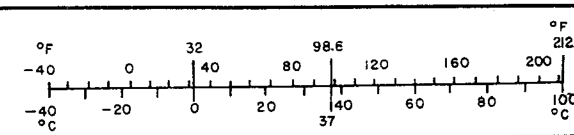
## Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.


## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



# PREFACE

The authors would like to acknowledge the assistance of Louis Brown, James Leach, Ross Glidewell, and Charles Cole in the varying activities of test equipment fabrication, instrumentation, and data analysis.

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# EXECUTIVE SUMMARY

The Federal Aviation Administration has requested that all Air Carrier aircraft have at least one Halon 1211 fire extinguisher on board. On July 29, 1980, Advisory Circular 20-42A was issued allowing the use of hand-held extinguishers in occupied areas of aircraft cabins. Questions arose about the effectiveness of hand-held extinguisher agents and the amount of toxic decomposition of the agents when used on large fires in an aircraft cabin.

This report describes the results of a test program designed to: (1) determine the amount of toxic decomposition by products from the use of Halon 1211 on large seat fires in an aircraft cabin while in-flight. (2) compare relative hazard levels from the use of common aircraft hand-held extinguishers (Halon 1211, monoammonium phosphate, carbon dioxide, water) on large fires in an aircraft cabin while in flight. (3) compare the hazards from the hand-held extinguishers extinguishing a large aircraft seat fire to the hazard of an uncontrolled seat fire.

A series of nine tests was conducted during this project. Two test each were conducted using Halon 1211, dry powder (monoammonium phosphate), water and $CO_2$ extinguishers, and one test in which the seat fire was allowed to burn uncontrolled.

Hazard level measurements were taken during all tests. They included heat, smoke, and toxic gas measurements.

It was concluded that Halon 1211 can be effectively and safely utilized to extinguish a severe seat fire in a transport passenger cabin.

# INTRODUCTION

## PURPOSE.

The main objectives of the test program were to: (1) determine the amount of toxic decomposition byproducts from the use of Halon 1211 on large seat fires in an aircraft cabin while in flight, (2) compare relative hazard levels from the use of common aircraft hand-held extinguishers (Halon 1211, monoammonium phosphate, carbon dioxide, water) on large fires in an aircraft cabin while in flight; (3) compare the hazards from the hand-held extinguishers extinguishing a large aircraft seat fire to the hazards of an uncontrolled seat fire.

## BACKGROUND.

On July 29, 1980, the Federal Aviation Administration (FAA) issued an advisory circular (AC-20-42A) concerning the use of hand-held fire extinguishers for use in aircraft. The FAA listed Halon 1211 (bromochlorodifluoromethane) as an acceptable aircraft extinguishing agent. Questions arose concerning the amount of toxic decomposition products that might be produced in an aircraft cabin if a Halon 1211 extinguisher was used in fighting a fire. This program was designed to answer those questions.

## TEST ARTICLE.

The C-133 full-scale cabin fire test article was used for the tests program (reference 1). The C-133 cabin was modified to simulate in-flight air ventilation conditions as shown in figures 1 and 2. The cabin was divided into two (2) sections by a galley partition. The test were conducted in the aft cabin section. Data were taken both forward and aft of the fire source in the aft cabin. Simulated in-flight airflow was supplied to both cabin sections.

These tests in which the seats were not extinguished by means of the hand-held extinguishers were terminated using an on-board total flood $CO_2$ system.

## FIRE EXTINGUISHER SYSTEM.

A remotely controlled system was designed and built for use with the hand-held extinguishers, which made it possible for the test fires to be extinguished without risk to personnel. As shown in figure 3, the apparatus consisted of two hand-held extinguishers mounted such that remotely actuated pneumatic pistons could depress their actuating handle, thus causing agent discharge. A closed-circuit video camera mounted on the apparatus provided a picture in the control room to monitor the fire and extinguishing process. A double axis camera mount was also remotely controlled to allow for camera/extinguisher rotation in both a vertical and horizontal plane. It was observed that fire extinguishment by the remotely-controlled apparatus took longer than when extinguishment was accomplished by an experienced person directly operating the extinguisher.

## INSTRUMENTATION.

Location of all instrumentation is shown in figure 4. Temperatures were measured using 24-gauge chromel/alumel (type K) thermocouples (reference 1). Smoke meters measured light transmission over a 1-foot distance (reference 1). Carbon dioxide

($CO_2$), carbon monoxide (CO), and Oxygen ($O_2$) levels were measured using Beckman Instrument Company's continuous process analyzers (reference 1). The acid and organic gases were collected and analyzed as follows.

ACID GAS COLLECTION. Absorption tubes were used to collect acid gas samples during the tests. This procedure was developed at the FAA Technical Center (formerly NAFEC) (reference 2) and modified to support full-scale fire tests (reference 3).

The absorption tube is glass lined, stainless steel, 16-1/2 centimeters long with a 4-millimeter inside diameter. It is packed to a depth of 14 centimeters with glass beads (3 millimeter diameter) which are held in place by a slice of teflon pressed into the tube at each end. The beads are rinse coated with a one molar sodium carbonate solution just prior to use, excess solution being blown from the tube by a syringe. The tubes are then sealed with plastic caps for protection. The absorption tubes are housed in an ice water solution in an aluminum box which is insulated with Kaowool™ board. The tubes are mounted horizontally in the box. They are held in place by water-tight bulkhead fittings. The outside ends extend just beyond the insulation and the plastic caps are removed before the test. The interior ends are attached to separate vacuum lines which pass through the bottom of the box and lead to the vacuum timing assembly.

The main vacuum line is "teed" to two solenoid valves, each connected to a 3-1/2 liter vacuum bottle. As one bottle is evacuated, the other draws a sample into an absorption tube. A 10-pole relay timer sequentially opens the solenoid valves (one every 30 seconds) joined to each absorption tube. This technique allows shorter sampling intervals and can handle a large number of samples.

The anion samples from the fire atmospheres are recovered for analysis by rinsing the absorption tubes with a 10-millimeter aliquot of 0.05 molar sodium carbonate solution dispensed by syringe. The syringe is adapted to the absorption tube with a female swagelok™ fitting to a female luer connector. The washings are collected in autosampler plastic cuvettes for subsequent analysis.

Acid Gas Analysis. Hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen bromide (HBr) and monoammonium phosphate were identified and quantitated by ion chromatography.

Anion concentrations are measured with a Dionex model 10 ion chromatograph. Potentiometric detectors are used for chloride and for fluoride (reference 4). A conductivity detector is used for phosphate and bromide anions (reference 5).

ORGANIC GAS COLLECTION. Absorption tubes were used to collect organic gas samples in the fire tests. This procedure was also developed at the FAA Technical Center and has been used during previous testing.

The tube is glass lined, stainless steel, 12 centimeters long, and packed with 30/60 mesh gas chromatograph grade porous Tenax™ adsorbent. The tubes are conditioned in the gas chromatograph prior to use and are sealed with parafilm. The tubes are ice jacketed by freezing in an inverted Ace-threed adapter.

Three automatic sampling stations are connected to a vacuum pump and solenoid/relay system for remotely starting and stopping the sampling process. The sampling station consists of an eight-port rotary valve with actuator, a fine metering valve, and assorted fittings, insulation, and electrical connectors. Eight ice-jacketed sample tubes are placed in each station after the fine metering valve is adjusted to draw 20 milliliters (ml) per minute. A remote automatic timer actuates the rotary valve every 30 seconds, to give eight 10 ml time averaged samples, for 4 minutes of coverage. Immediately after the test, the tubes are removed and stored in a freezer for subsequent analysis.

Organic Gas Analysis. The adsorbed organic gas sample tube is connected in a backflush mode to a Perkin-Elmer 3720 gas chromatograph equipped with flame ionization and nitrogen phosphorous detectors. Data is acquired on a Perkin-Elmer sigma 10B computer data station. A software program for the collection of raw data, calculation of quantities of identified gases and documentation is utilized.

## BIOLOGICAL TESTS.

Four laboratory rats were exposed in each test, two at station 650 at a height of 5 foot, 6 inches, and two at station 880 at a height of 5 foot 6 inches. The tests were of a relatively short duration and the rats were retrieved within 10 minutes. At the time of the tests, the rats were 3 to 5 weeks old and about 50 percent of their weight gain curve. They were kept until maturity (10 to 12 weeks).

## SCENARIO SELECTION.

The scenario selected was that of an automotive gasoline fire on a triple aircraft seat. Since a major purpose of the tests was to look at the decomposition of the extinguishing agent, and since the larger and hotter the fire, the more decomposition expected, it was felt that extinguishment of this type of fire would create the greatest hazard that would be encountered in an aircraft cabin during extinguishment of an in-flight fire.

The test was set up so that the agent was discharged directly at a burning triple aircraft passenger seat (see figure 2). The distance between the seat and extinguishers was approximately 6 feet. One quart of gasoline was used. This fuel was poured on the front surface of the triple seat which was directly exposed to the extinguishers.

# TEST DESCRIPTION AND RESULTS

A series of nine tests was conducted during this protect. Two tests each were conducted using Halon 1211, dry powder (monoammonium phosphate), water, and $CO_2$ extinguishers, and one test in which the seat fire was allowed to burn uncontrolled (see table 1). The following are the results of those tests.

## TABLE 1. LISTING OF TESTS CONDUCTED

| Test No. | Agent | Weight of Agent Discharged (lb) | Was Fire Extinguished |
|---|---|---|---|
| 1 | Halon 1211 | 2.35 | Yes |
| 2 | Halon 1211 | 3.1 | Yes |
| 3 | Dry Powder | 2.5 | Yes |
| 4 | Dry Powder | 2.5 | Yes |
| 5 | Water | 5 | No |
| 6 | Water | 5 | No |
| 7 | $CO_2$ | <10 | No |
| 8 | $CO_2$ | <10 | No |
| 9 | None | 0 | No |

## HALON 1211 TESTS.

Two Halon 1211 tests were conducted. In test No. 1, the seat fire burned for 15 seconds after ignition. This was due to a hesitation of the mechanical fire extinguisher mechanism. The seat fire was totally extinguished using less than one extinguisher. A total of 2.35 pounds of Halon 1211 was used. Figures 5 A, B and C and table 2 show the gas concentrations from test No. 1. The gas levels were very low, with some of the gases coming from the burning seats and not the agent decomposition. (This will be discussed in greater detail later in this report.)

In test No. 2 (Hazard levels are shown in figure 6 and table 2), the fire was not as easily extinguished. Extinguishment began 10 seconds after ignition. However a magazine ignited in the pocket of the seatback and this caused reignition of the seat fire two or three times before total extinguishment was obtained. Figure 7 shows a sequence of the extinguishing process, with final fire out occurring approximately 43 seconds after ignition. One full bottle (2.6 lbs. of agent), and 0.5 pounds of a second bottle were used.

The increase in time to begin extinguishing between test No. 1 and No. 2, (10 to 15 seconds) would account for the higher gas concentrations for test No. 1 and the reignition during test No. 2 would account for the slight rise in concentrations of HF and HCl late in test No. 2.

Figure 5A shows that the highest concentrations of decomposed agent was at the higher sampling station behind the seat, however, the highest concentration of neat agent was in the vicinity of the extinguisher.

## TEST 2. HALON 1211 TESTS

| Gas | Location | | Concentration PPM Test No. 1 Sample 1 | 2 | 3 | 4 | 5 | Test No. 2 Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HCl | Sta. 650 | 5'6" | 23 | 34 | 16 | 14 | 7 | 14 | 12 | 6 | 6 | - |
| | Sta. 650 | 3'6" | 4 | 10 | 12 | 7 | 5 | 22 | 15 | 7 | 15 | - |
| | Sta. 880 | 5'6" | 12 | 20 | 16 | 10 | 9 | 14 | 12 | 7 | 9 | - |
| HF | Sta. 650 | 5'6" | 5 | 12 | 5 | 4 | 3 | 14 | 11 | 4 | 3 | - |
| | Sta. 650 | 3'6" | 2 | 10 | 4 | 3 | 3 | 5 | 7 | 4 | 3 | |
| | Sta. 880 | 5'6" | 5 | 3 | 5 | 3 | 2 | 10 | 9 | 2 | 3 | - |
| HBr | Sta. 650 | 5'6" | - | 14.7 | 6.9 | - | - | 4.4 | 3.4 | - | - | - |
| | Sta. 650 | 3'6" | - | 5 4 | 9 | - | - | 0 | 2 | - | - | - |
| | Sta. 880 | 5'6" | - | 8.9 | 5 | - | - | 3.1 | 2.6 | - | - | - |
| HCN | Sta. 650 | 5'6" | | ZERO | | | | | | | | |
| | Sta. 650 | 3'6" | | | | | CONCENTRATION | | | | | |
| | Sta. 880 | 5'6" | | | | | | RECORDED | | | | |
| HALON | Sta. 650 | 5'6" | 112 | 290 | 480 | 384 | - | DATA | | | | |
| 1211 | Sta. 650 | 3'6" | - | 190 | 400 | 316 | 50 | | NOT | | | |
| | Sta. 880 | 5'6" | 451 | 935 | 1634 | 1072 | 260 | | | TAKEN | | |

Sample collection times are as follows:

No. 1- 0 to 30 sec.
No. 2- 30 to 60 sec.
No. 3- 60 to 90 sec.
No. 4- 90 to 120 sec.
No. 5- 120 to 150 sec.

DRY POWDER.

Two dry powder extinguishment tests were also conducted using monoammonium phosphate. In test No. 1, the left extinguisher failed to fire. The right extinguisher was fired 19 seconds after ignition of the seat fire. The hazard measurement of test No. 1 are shown in table 3 and figures 8 and 9. Two and 1/2 pounds of agent were used to completely extinguish the seat fire. In the second test, the fire did not spread from the right seat, and was less intense than in the previous test. Extinguishment began 10 seconds after ignition. Again, 2-1/2 pounds of agent was used to fully extinguish the seat. A peak concentration of 538 ppm of monoammonium phosphate was measured near the extinguisher.

TEST 3. DRY POWDER (MONOAMONIUM PHOSPHATE) TESTS

| | | | Concentration PPM | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Test No. 1 Sample | | | | | Test No. 2 Sample | | | | |
| Gas | Location | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| HCl | Sta. 650 | 5'6" | - | - | - | - | - | 0 | 7 | 4 | 2 | - |
| | Sta. 650 | 3'6" | 9 | 13 | 11 | 8 | - | 4 | 8 | 0 | 2 | - |
| | Sta. 880 | 5'6" | 9 | 26 | 13 | 11 | - | 0 | 7 | 0 | 2 | - |
| HF | Sta. 650 | 5'6" | - | - | - | - | - | 1 | 12 | 12 | 7 | - |
| | Sta. 650 | 3'6" | 1 | 1 | 1 | 1 | - | 1 | 7 | 12 | 9 | - |
| | Sta. 880 | 5'6" | 1 | 2 | 1 | 1 | - | 2 | 12 | 1 | 3 | - |
| HBr | Sta. 650 | 5'6" | .7 | 0 | .3 | - | - | - | .3 | - | - | - |
| | Sta. 650 | 3'6" | - | .5 | .3 | - | - | - | 0 | - | - | - |
| | Sta. 880 | 5'6" | .6 | 0 | .1 | - | - | 0 | 0 | - | - | - |
| HCN | Sta. 650 | 5'6" | | ZERO | | | | | | | | |
| | Sta. 650 | 3'6" | | | | | CONCENTRATION | | | | | |
| | Sta. 880 | 5'6" | | | | | | RECORDED | | | | |
| MONO- | Sta. 650 | 5'6" | .2 | 97 | 37 | - | - | - | 126 | - | - | - |
| AMMONIUM | Sta. 650 | 3'6" | - | 31 | 26 | - | - | - | 82 | - | - | - |
| PHOSPHATE | Sta. 880 | 5'6" | 21 | 538 | 160 | - | - | - | 110 | - | - | - |

Sample collection times are as follows:

No. 1- 0 to 30 sec.
No. 2- 30 to 60 sec.
No. 3- 60 to 90 sec.
No. 4- 90 to 120 sec.
No. 5- 120 to 150 sec.

WATER.

Two water extinguishment test were conducted. In each case, two full water extinguishers (1-1/2 quarts each) were used, and in both tests the fire could not be extinguished. Figure 10 shows a sequence during one of the tests. The hazards during a water extinguishment attempt are shown in figure 11. The water quickly knocked down the fire, but was unable to extinguish it. Hazard levels were very low, except for smoke and temperature. Flame spread on the seat was slow (due to water on the seat), but did occur to some degree. In both tests extinguishment of the seat fire was accomplished by using the aircraft total flooding $CO_2$ system.

CARBON DIOXIDE.

Two $CO_2$ hand-held extinguisher tests were conducted. Due to the inability of the remote control apparatus to fire the larger and much heavier $CO_2$ bottles, a technician with protective gear performed the attempted extinguishment in the aircraft. This gave the $CO_2$ an advantage over the other extinguishers, since the human reactions are much faster than those of the remote control apparatus. In both tests over 10 pounds of agent was used, and in both tests the fire was not extinguished (see figure 12). The $CO_2$ provided an initial knockdown of the flames, however the fire quickly reintensified. The hazard levels for the first $CO_2$ extinguishment test are shown in figure 13. Note that the hazard levels are on the rise during the second minute of the test (the curves showing only the first 60 seconds also increase during that period). The $CO_2$ extinguishing tests were the only extinguishment tests in which hydrogen cyanide was recorded. Both tests were terminated after approximately 2 minutes using the $CO_2$ total flooding system in the aircraft.

UNCONTROLLED SEAT FIRE.

One test was conducted in which no extinguishment was attempted. This was done in order to determine the hazards produced by the burning seat itself. Figure 14 are photographs of the seat during the test. The hazards measured are shown in figure 15. High levels of all the hazards were measured, particularly hydrogen chloride, temperature, CO, HCN, and smoke. These measurements were made using only one triple seat as a fire load. In a real situation the fire could quickly involve other seats and interior aircraft material, producing even greater hazard levels.

## ANALYSES OF DATA AND TEST RESULTS

VISUAL OBSERVATIONS.

All extinguishers tested reduced the hazard level buildup compared to the unextinguished seat fire. Both dry powder and Halon 1211 extinguishers were able to completely control the fires. However, the fires could not be extinguished with two water or $CO_2$ extinguishers. The water extinguishers slowed the burning rate of the seat to a greater degree than did the $CO_2$ extinguishers.

BIOLOGICAL TEST OBSERVATIONS.

The test rats survived all tests. They were kept for observation for 10 to 12 weeks. No ill effects were detected for any of the test rats during this observation period.

HAZARD LEVEL ANALYSIS.

The use of each of the hand-held extinguishers resulted in hazard levels, after initial flame knockdown, below the dangerous level. However when two water, or $CO_2$ extinguishers were used, and the seat fire was not completely extinguished, the seat fire reintensified after total agent discharge (and initial fire knockdown) with the hazards increasing towards a dangerous level. The Halon 1211 tests produced slightly more of the acid gases (HF, HCl, HBr) than did the dry powder; however, the dry powder produced more loss in visibility. The concentrations of acid gases produced by the decomposing 1211 and the burning seat was still far below the dangerous level (reference 6).

Table 4 compares the peak acid gas concentrations measured with the dangerous levels. Moreover, when extinguishment was completed using the Halon 1211 extinguisher, the acid gas concentrations disappeared within several minutes because of ventilation, diffusing and adsorption effects.

TABLE 4. PEAK CONCENTRATION - DANGEROUS CONCENTRATION

| | Peak Concentration Measured (PPM) | Dangerous * Concentration (PPM) |
|---|---|---|
| HCl | 34 | 1000-2000 |
| HF | 14 | 50-250 |
| HBr | 14.7 | 50-250 |
| 1211 | 1935 | 40,000 |
| MONOAMMONIUM PHOSPHATE | | |

* Reference 6

The main decomposition products of Halon 1211 (HF, HCl, HBr) are also by-products from the combustion of many aircraft interior materials. The seat foams and cloth coverings can produce high yields of HCl, the plastic components can produce HBr and the panel finishes high yields of HF. Since the tests conducted used only one set of triple seats, and no other interior materials, the hazard levels are not fully representative of a burning cabin. As shown in figure 15A, the major acid gas byproducts of the seat fire was HCl. Relatively little HF or HBr was produced by the seats.

In order to determine the amount of decomposition of 1211 during extinguishment of a seat fire, the quantity of gases produced by the burning materials must be subtracted from the total, thus leaving the 1211 byproducts. This is a rather difficult procedure, because of the time dependency of the gas concentrations. However, since the tests using extinguishers other than 1211 produce little or no HF or HBr, it can be assumed that almost all of the HF and HBr shown in table 2 are byproducts of the decomposing 1211. A large quantity of HCL can be produced by burning seats, as shown in figure 15A. Therefore the quantities of HCl shown in table 2 are that of both Halon 1211 and seat material decomposition. Figure 16 is an attempt to determine the amount of HCl due to the decomposing 1211. For each of the Halon 1211 and dry powder tests, a point having the peak concentration of HCl recorded for its X coordinate and the time of initial agent discharge for its Y coordinate, was plotted. A straight line was then used to connect the two Halon 1211 test points and likewise the dry powder test points. Assuming all of the HCl in the dry powder tests came from the decomposing seat material, and similar levels would be produced for a given seat burn time no matter what extinguishing agent was used, the vertical difference between the two lines between the HCl produced when 1211 was used to extinguish the seat and when dry powder was used shows that approximately 12 to 15 PPM of the HCl came from the decomposing 1211.

The data for the uncontrolled fire was for only one triple seat in an otherwise noncombustible interior. Fire in a fully furnished cabin would result in greater hazards and much ealier attainment of nonsurvivable levels. Figures 17 through 19 are an attempt to predict hazard levels for a fully furnished cabin, based on a previous fire test in the C-133 test article (reference 7) given an uncontrolled seat fire ignited on a single triple seat using gasoline. The predictions are made by using data from a test conducted in which six sets of triple seats were installed in the C-133 and a fire was ignited under one seat in a carry-on bag. In-flight conditions were simulated the same as for the extinguishing tests. Assuming that the majority of heat, prior to flashover, is produced by the seats, this six-seat test may be considered to represent a fully furnished cabin from a thermal standpoint. The buildup of the fire is much slower because of the carry-on bag ignition source, the time must be shifted to predict the results of a gas fire. Figure 18 attempts to do that. The temperature from a single triple seat test is plotted, then the temperature from the six-seat test is plotted. The curve from the six-seat test is then shifted to the left. This is done so that the rise in temperature from the six-seat carry-on bag test corresponds to the rise in temperature of the single seat gas test. This prediction indicates the flashover would occur approximately 90 to 100 seconds after ignition of a seat doused with 1 quart of gasoline, if the fire is left uncontrolled.

Figure 17 predicts temperatures in an adjacent cabin 40 feet from the initial fire. The temperatures are from the six-seat test using the new start time determined in figure 19. The arrow indicates the point at which all the seats are ablaze. Data after that point is affected by the fact that there are no more materials in the cabin to support combustion.

As stated earlier, the HF and HBr are produced mainly by the panels and thermoplastics. Since the large test used for extrapolation only consisted of seats, no prediction of HF or HBr could be made. However, since HCl comes primarily from the seats, figure 19 is the prediction of HCl for a full cabin.

## SUMMARY OF RESULTS

1. Acid gases and 1211 concentrations were below "dangerous" levels when a gasoline ignited seat fire, in a simulated in-flight aircraft, was extinguished with Halon 1211.

2. Acid gases and 1211 disappear due to ventilation, diffusion, and adsorption effects.

3. Halon 1211 and dry powder were more effective than $CO_2$ or water.

4. Uncontrolled gasoline ignited seat fire is predicted to flashover in 90 to 100 seconds.

5. All four extinguishers evaluated reduced the fire to some degree.

## CONCLUSIONS

1. Effective utilization of Halon 1211 to extinguish a severe seat fire in a transport passenger cabin is safe in terms of agent decomposition (HF, HCl, and HBr) and neat agent concentration.

3. Halon 1211, dry powder, $CO_2$ or water extinguishers can provide an initial reduction in A/C seat fire severity with little or no toxic gas by-products from the agent.

3. The hazards associated with an uncontrolled severe seat fire will quickly exceed those transient hazards associated with Halon 1211 extinguishment.

4. Because of the rapid buildup in cabin fire hazards, it is crucial to reduce the flaming of a large seat fire (or any cabin fire) as soon as possible, with whatever means available.

## REFERENCES


1. Hill, R. G., Johnson, G. R., Sarkos, C. P., Postcrash Fire Hazard Measurements in a Wide Body Aircraft Cabin, FAA/NAFEC Report No. FAA/NA-79-42, December 1979.

2. Spurgeon, J., and Feher, R., A Procedure for Determining Hydrogen Fluoride Concentrations as a Function of Time in a Combustion Atmosphere, NAFEC Data, Report No. 121, April 1976.

3. Guastavino, T. M., Speitel, L. C., and Filipczak, R. A., Methods of Collection and Analysis of Toxic Gases from Fire Testing of Aircraft Materials, Technical Note FAA 82102 June 1982.

4. Guastavino, T. M., Speitel, L. C., and Filipczak, R. A., The Pyrolysis Toxic Gas Analysis of Aircraft Interior Materials, FAA Technical Center Report No. DOT/FAA/CT-82/13, April 1982.

5. Speitel, L. C., Spurgeon, J. C., and Filipczak, R. A., Ion Chromatographic Analysis of Thermal Decomposition Products of Aircraft Interior Materials in Ion Chromatographic Analysis of Environmental Pollutants, Mulik, J. D., and Sawicki, E., Eds. (Ann Arbor Michigan, Ann Arbor Science Publishers, Inc. 1979).

6. Halon 1211 Fire Extinguishing Systems 1980, NFPA Standard 12B, November 20, 1980.

7. Hill, R. G., Aircraft Seat Blocking Layer Full-Scale Study, FAA Technical Center Report to be published.

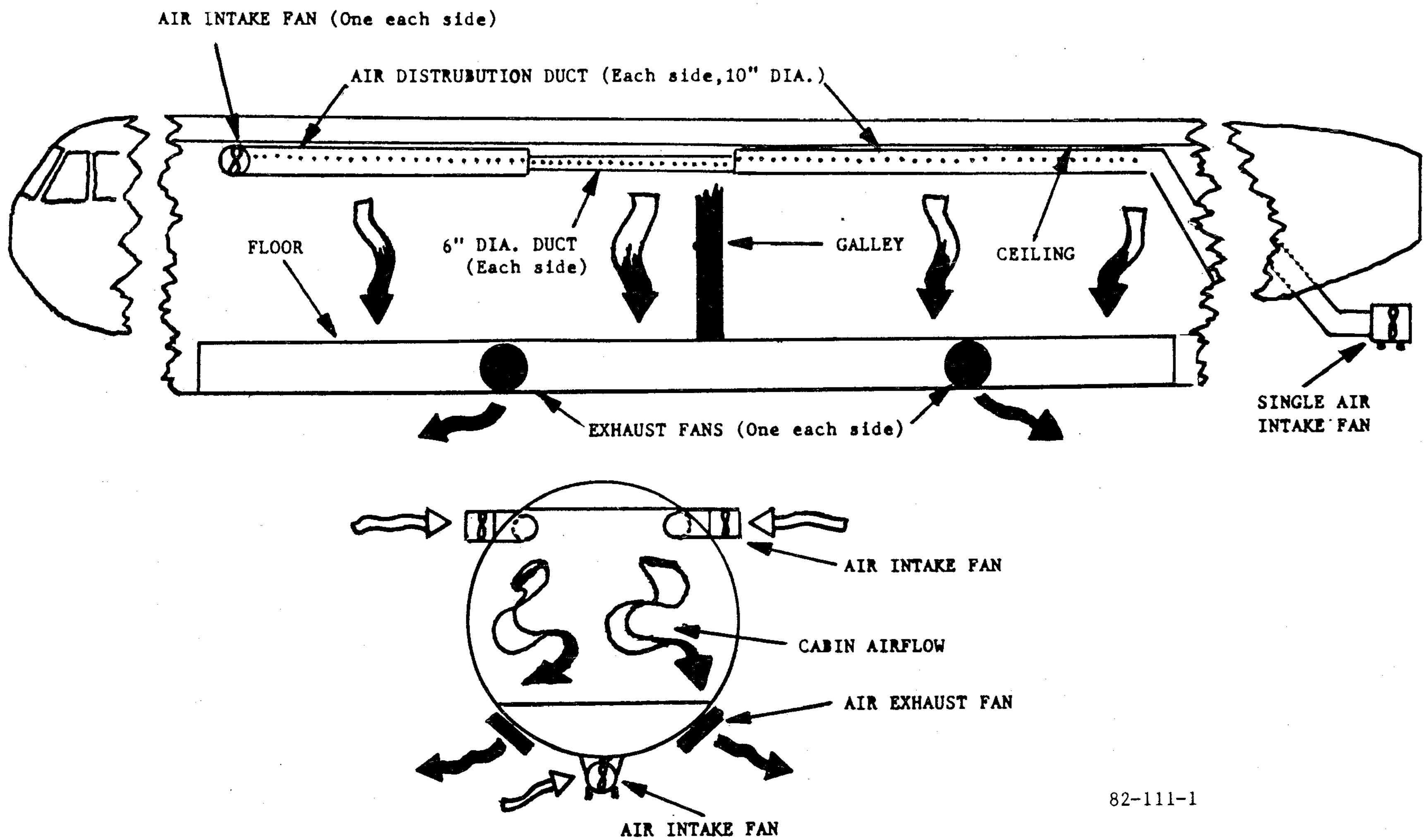



FIGURE 1. C-133 TEST ARTICLE CABIN AIR DISTRIBUTION SYSTEM

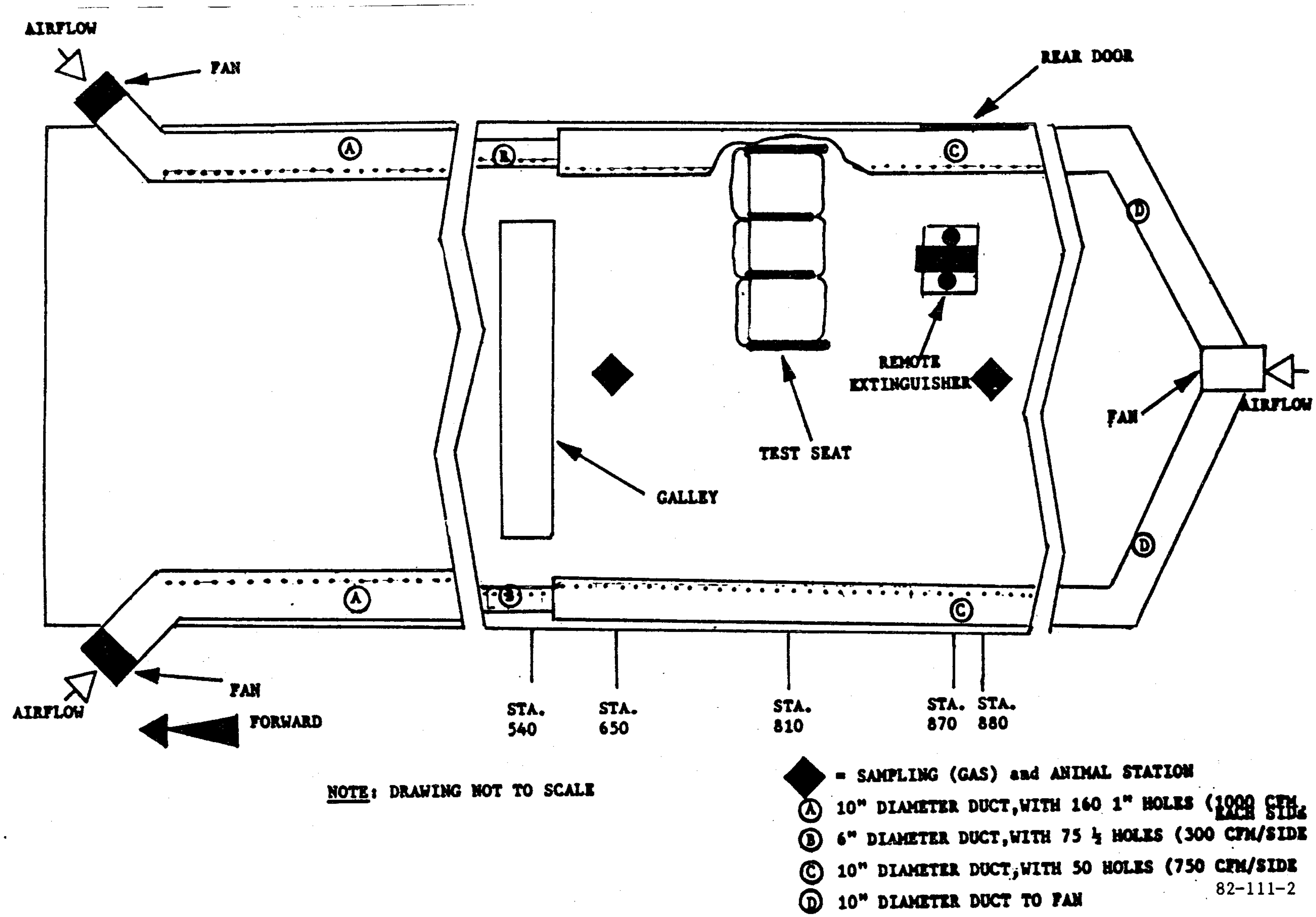
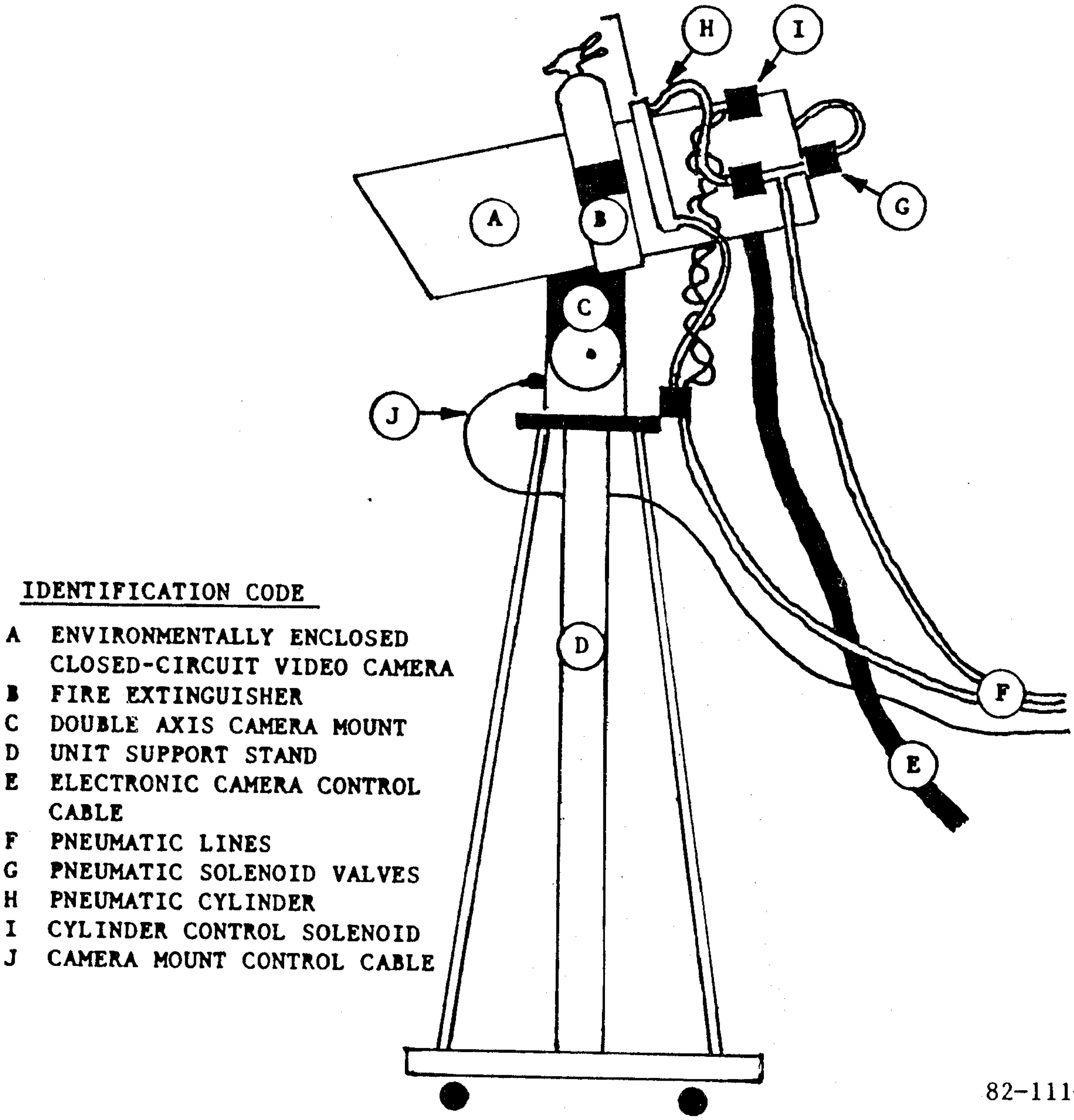



FIGURE 2. REMOTE EXTINGUISHER INTERIOR ARRANGEMENT




82-111-3

FIGURE 3. REMOTELY CONTROLLED EXTINGUISHING AGENT TEST APPARATUS

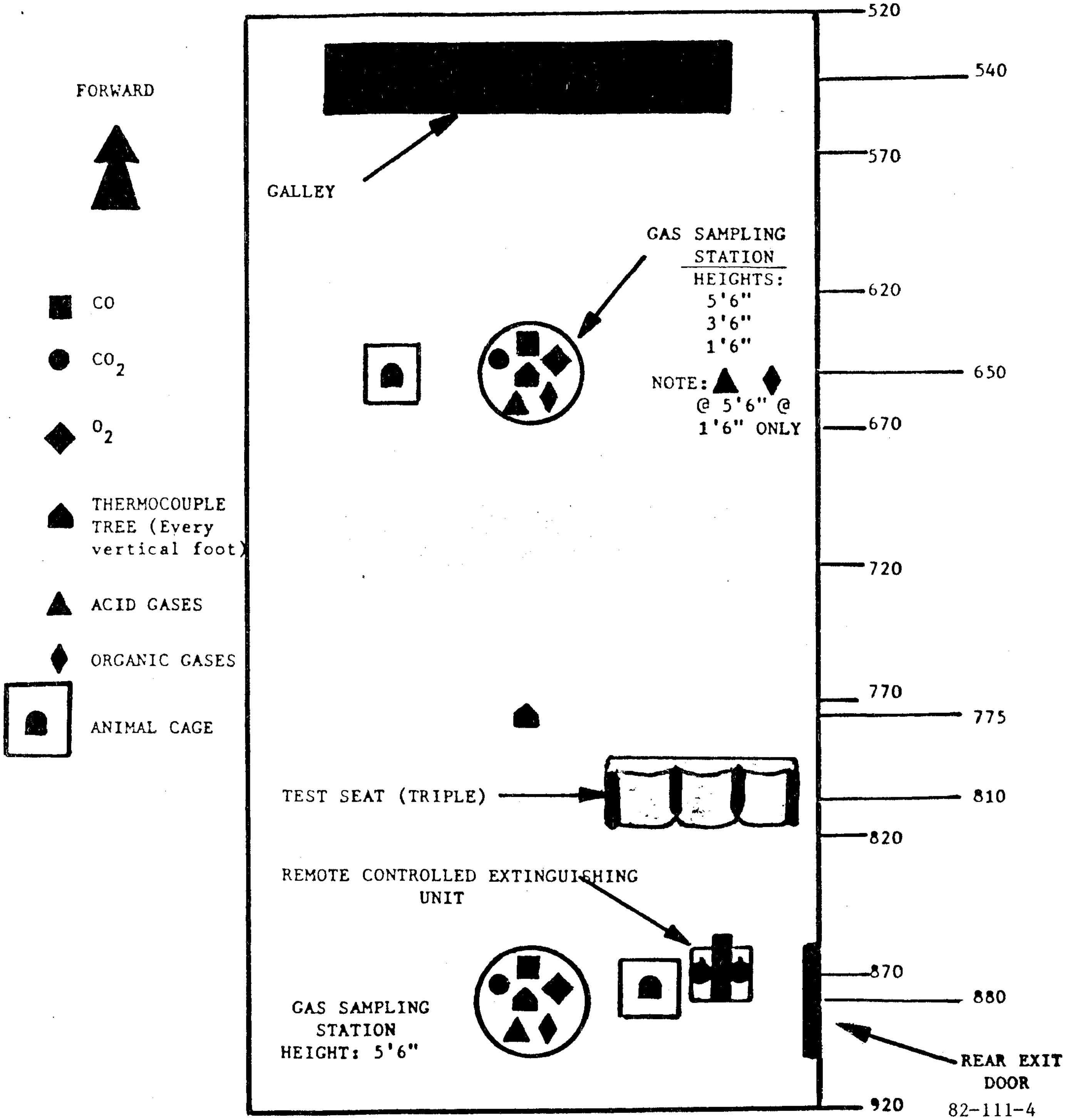



FIGURE 4. EQUIPMENT POSITION DIAGRAM FOR TEST ARTICLE

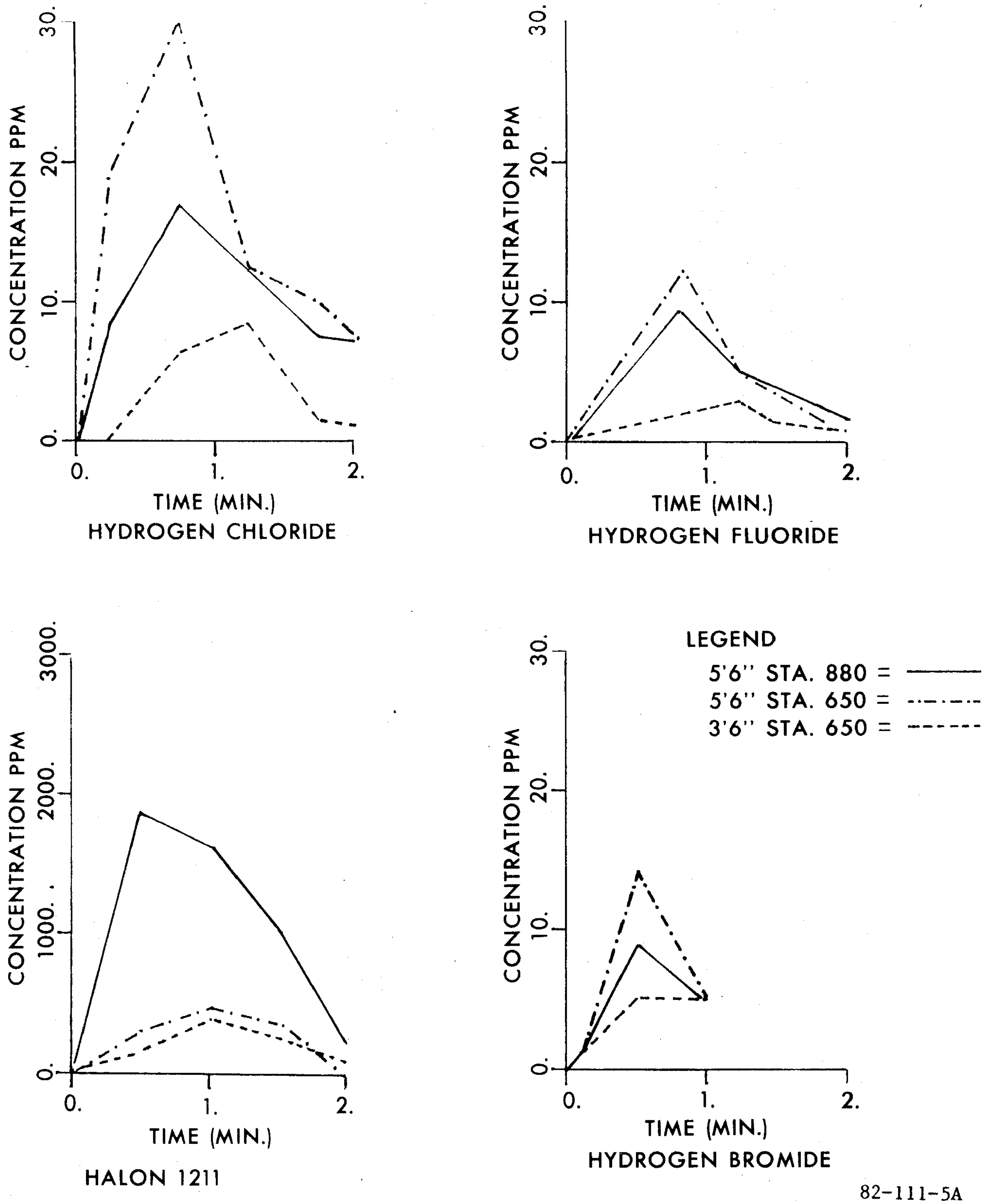



FIGURE 5. GAS CONCENTRATIONS FROM HAZARD LEVEL MEASUREMENTS HALON 1211 TEST NUMBER ONE (1 of 3 SHEETS)

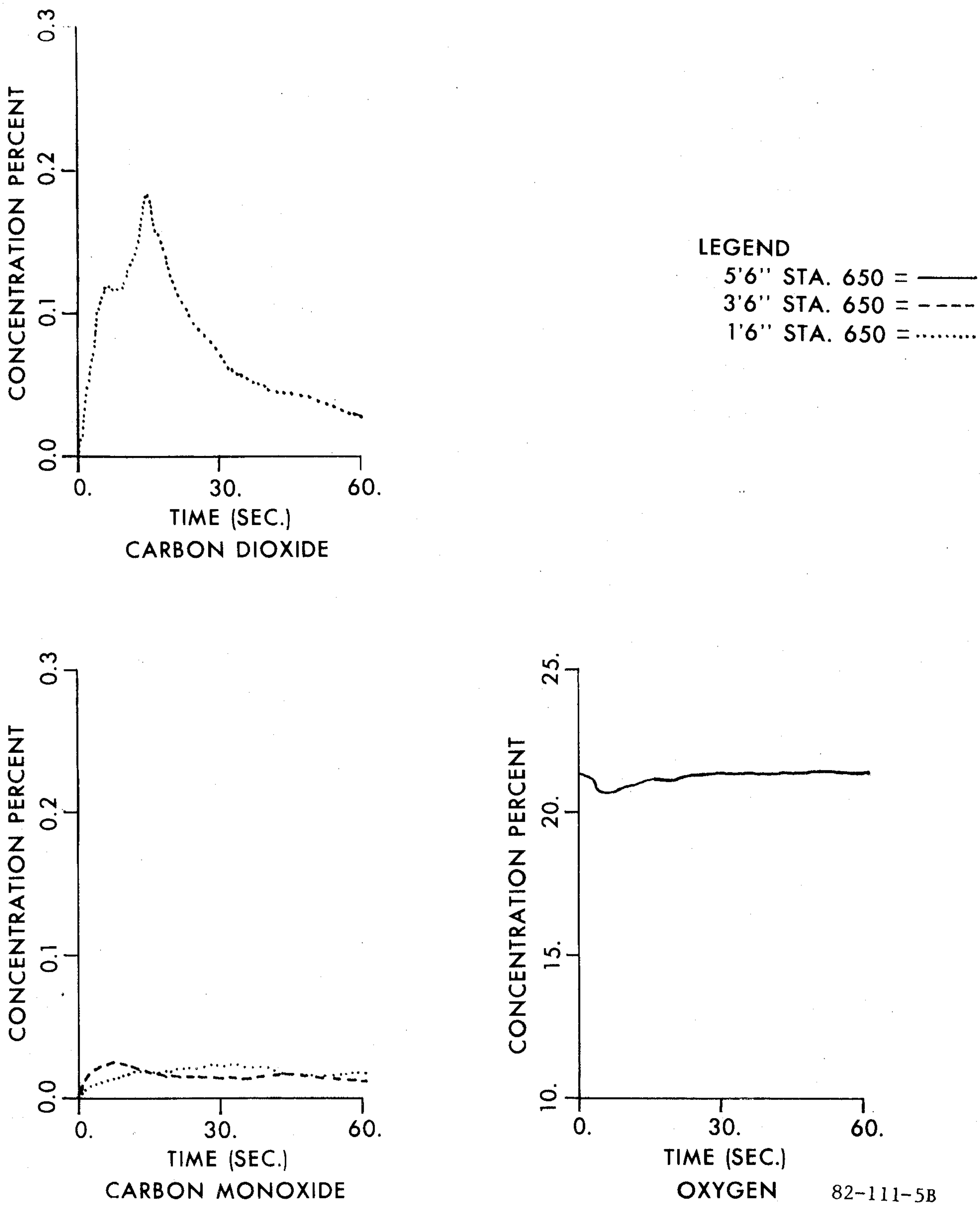
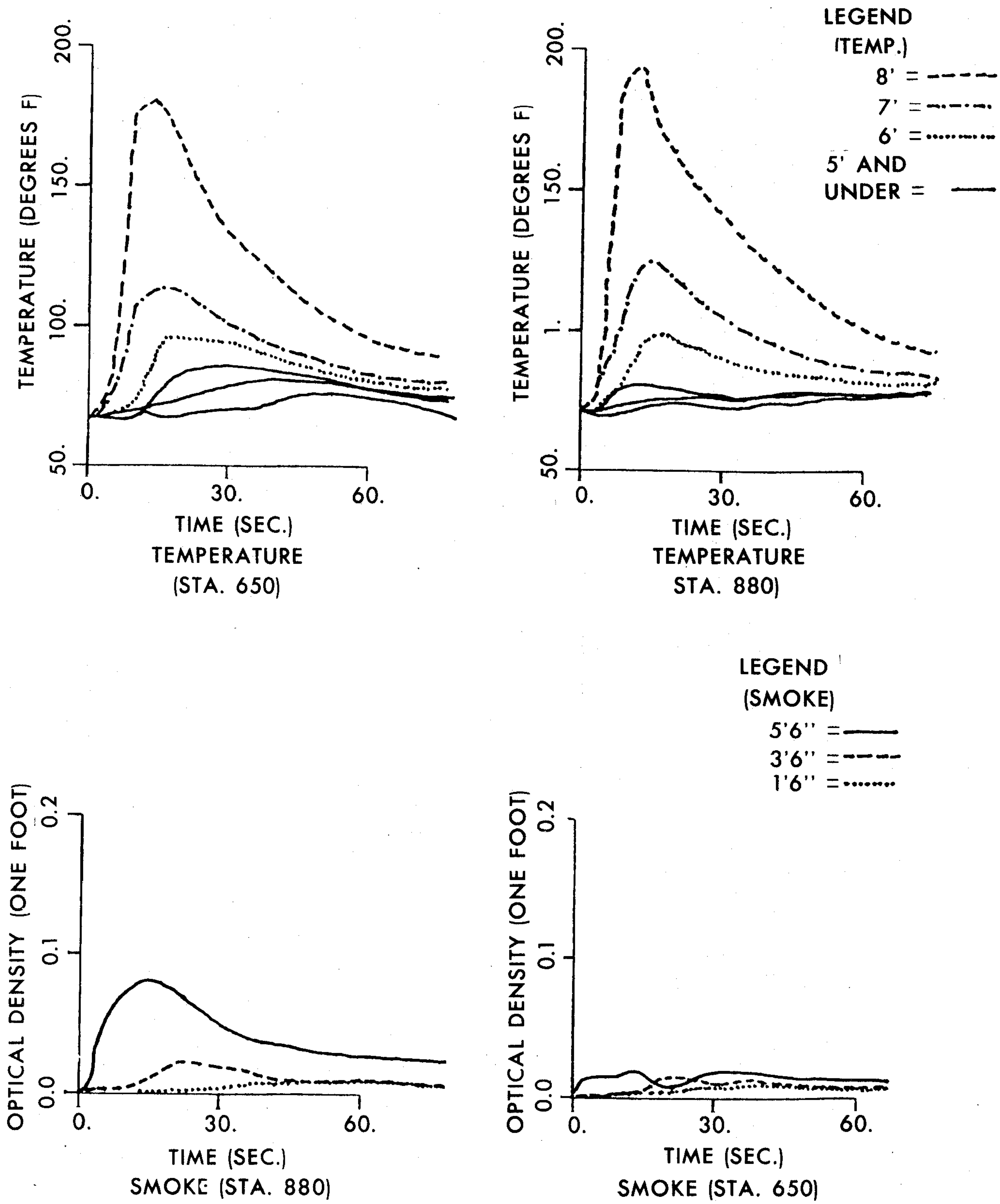



FIGURE 5. GAS CONCENTRATIONS FROM HAZARD LEVEL MEASUREMENTS HALON 1211 TEST NUMBER ONE (2 of 3 SHEETS)




82-111-5C

FIGURE 5. GAS CONCENTRATIONS FROM HAZARD LEVEL MEASUREMENTS HALON 1211 TEST NUMBER ONE (3 of 3 SHEETS)

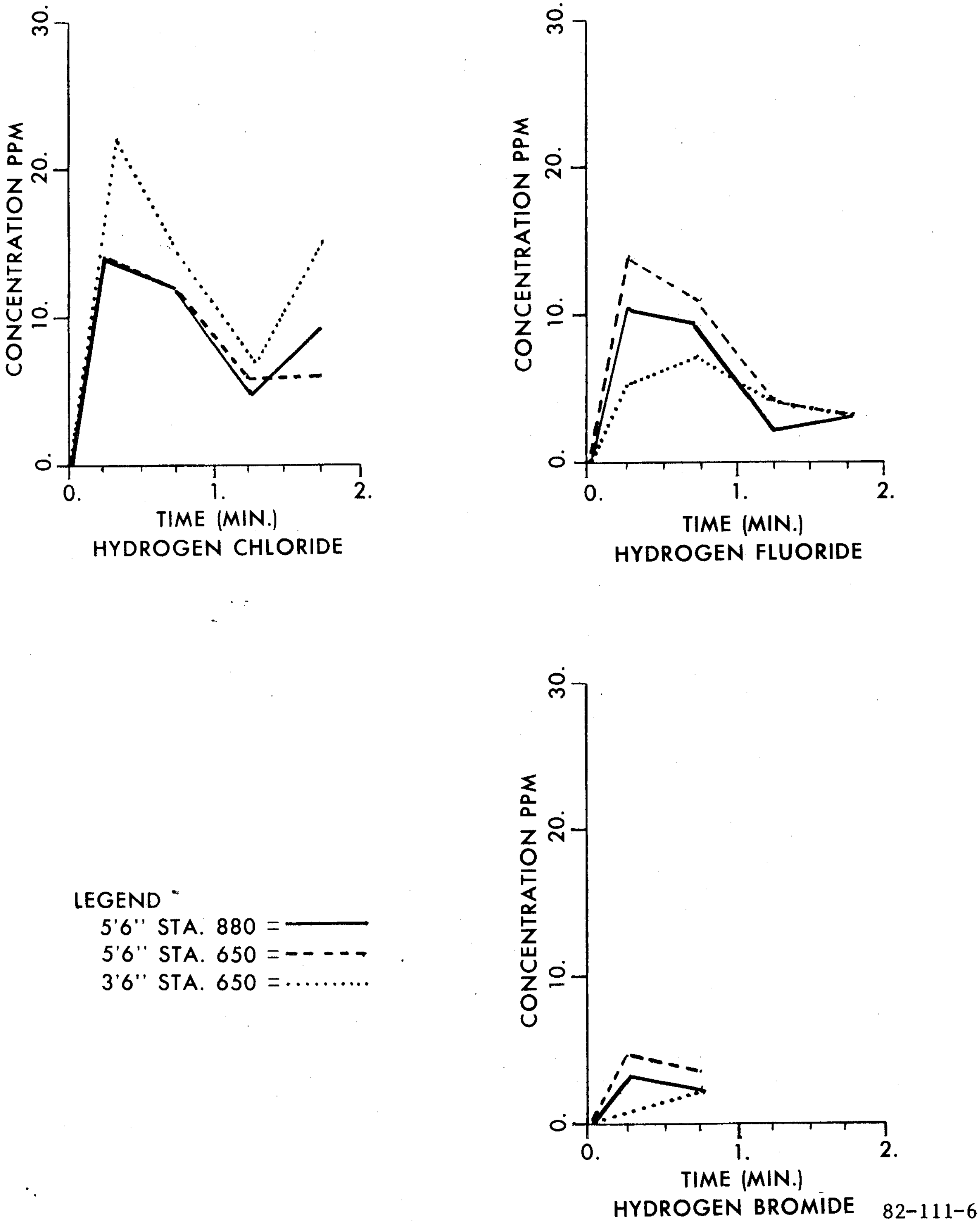
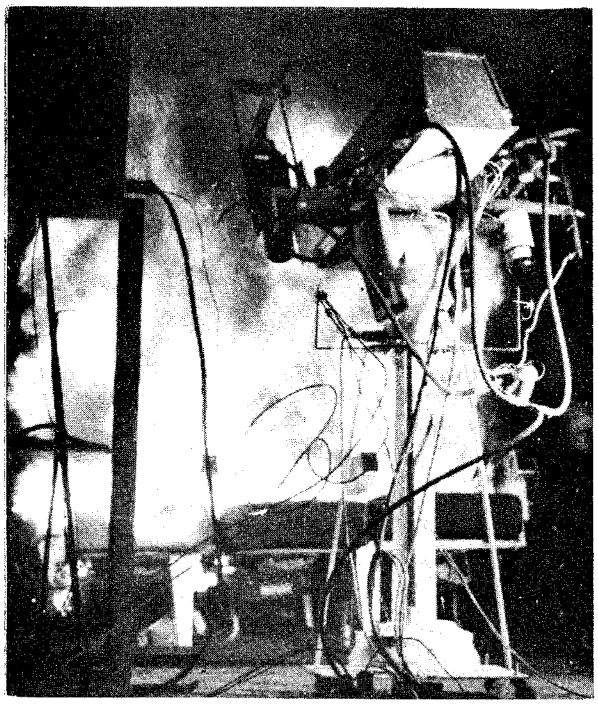
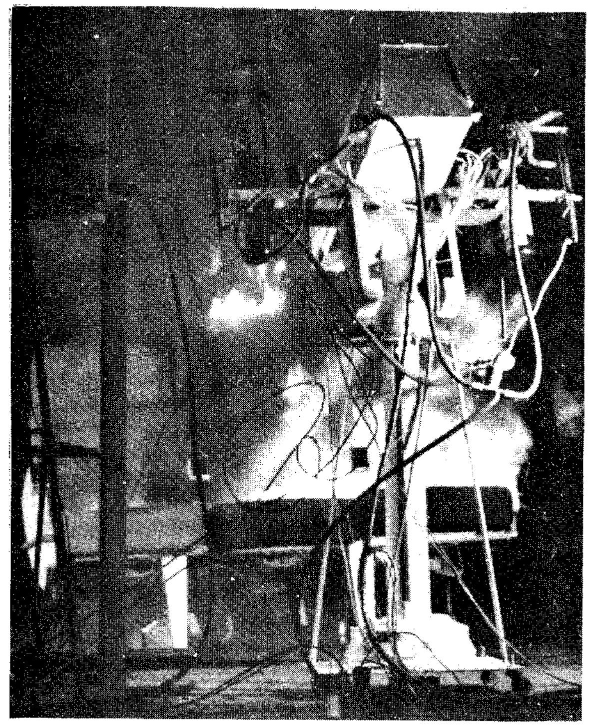


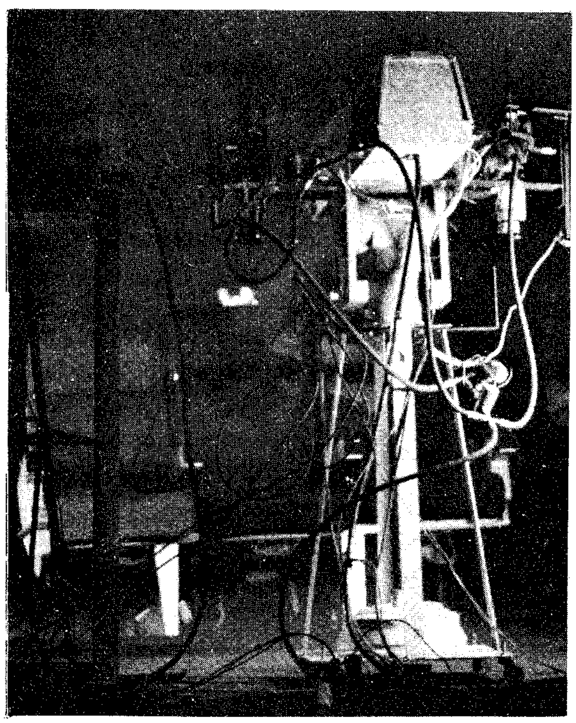

FIGURE 6. GAS CONCENTRATIONS FROM HALON 1211 TEST NUMBER TWO



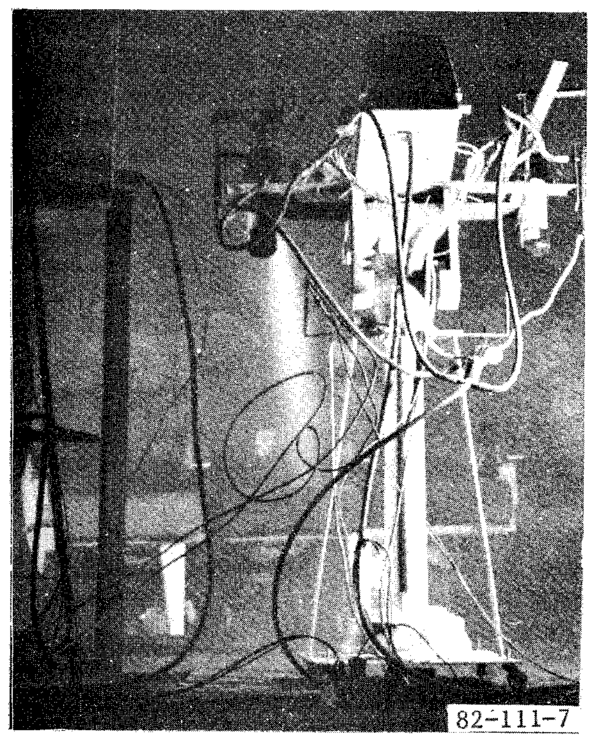
AGENT DISCHARGE
TIME(From ignition): 10 SECONDS



TIME: 12 SECONDS



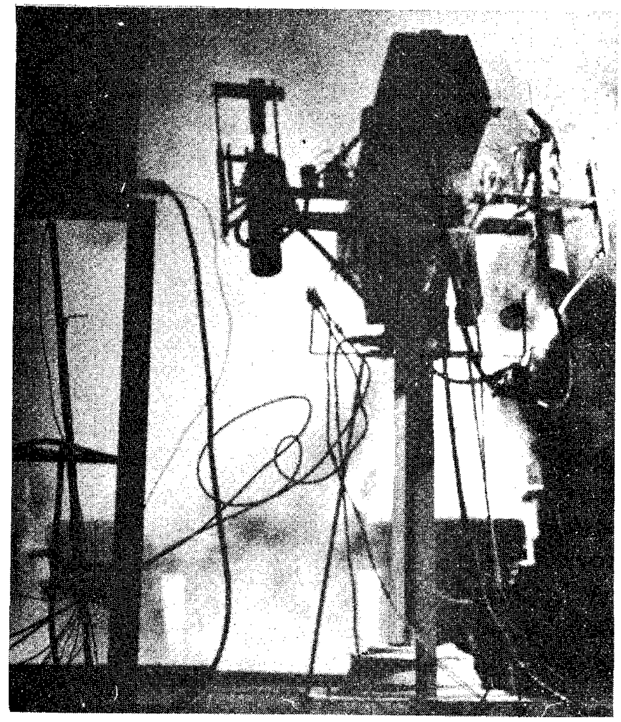
TIME: 18 SECONDS



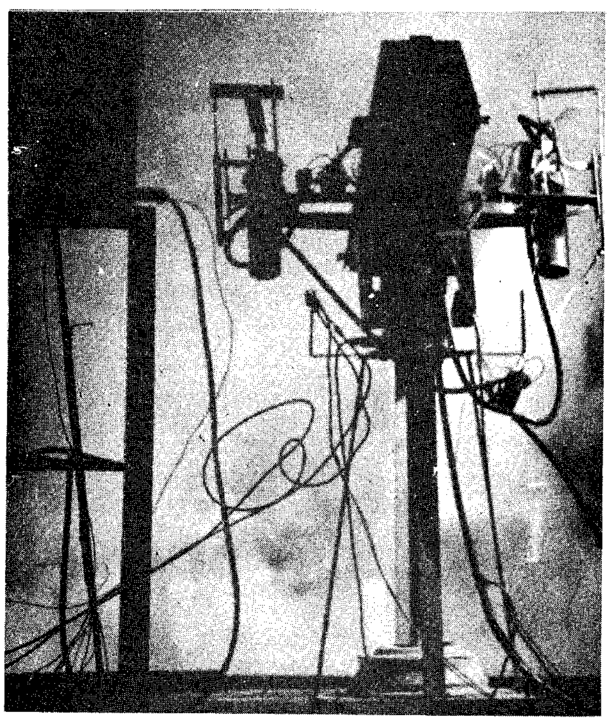

TIME: 42 SECONDS

FIGURE 7. SEQUENTIAL PHOTOGRAGHS OF HALON TEST NUMBER TWO

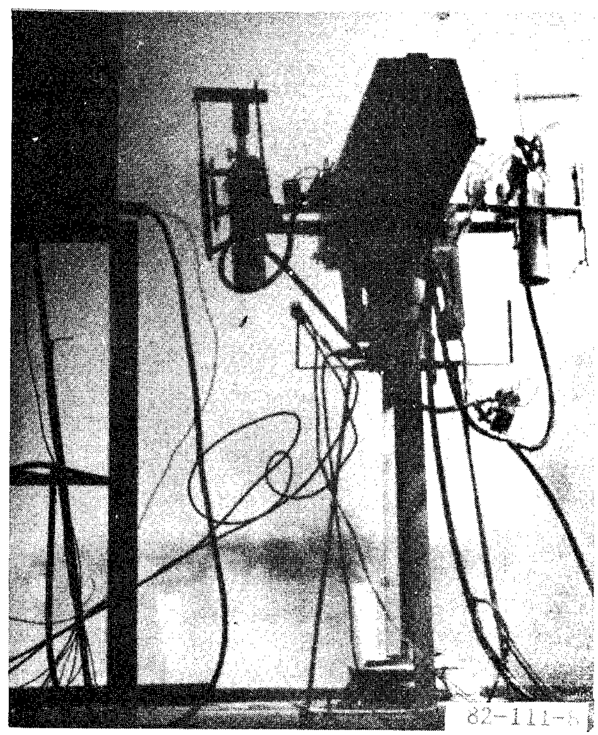
TIME: 19 SECONDS after ignition
(AGENT DISCHARGE)



TIME: 23 SECONDS after ignition



TIME: 25 SECONDS after ignition



TIME: 29 SECONDS after ignition

FIGURE 8. SEQUENTIAL PHOTOGRAPHS OF DRY CHEMICAL TEST NO. 1

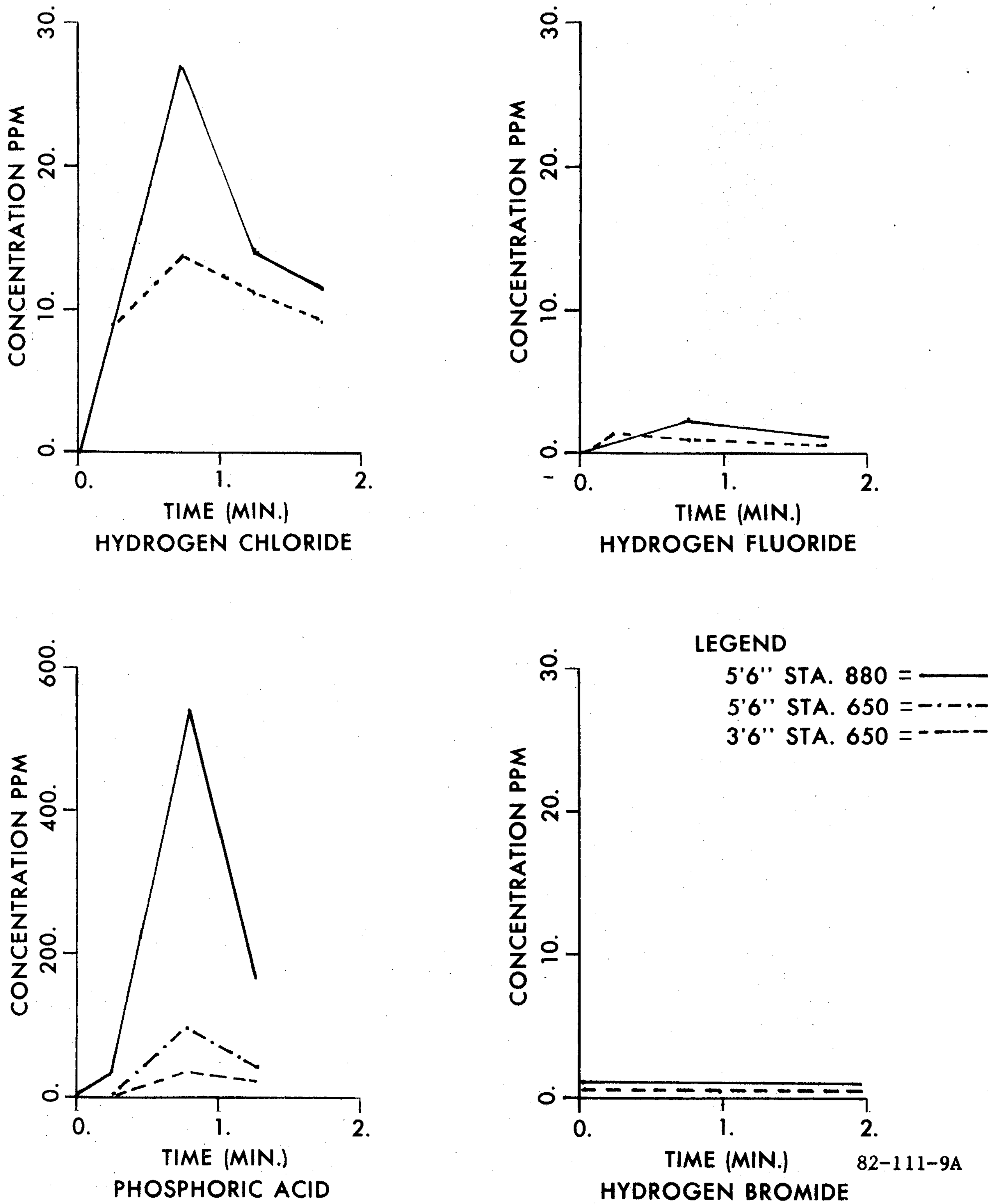



FIGURE 9. HAZARD LEVEL MEASUREMENTS, DRY CHEMICAL TEST NUMBER ONE (1 of 3 SHEETS)

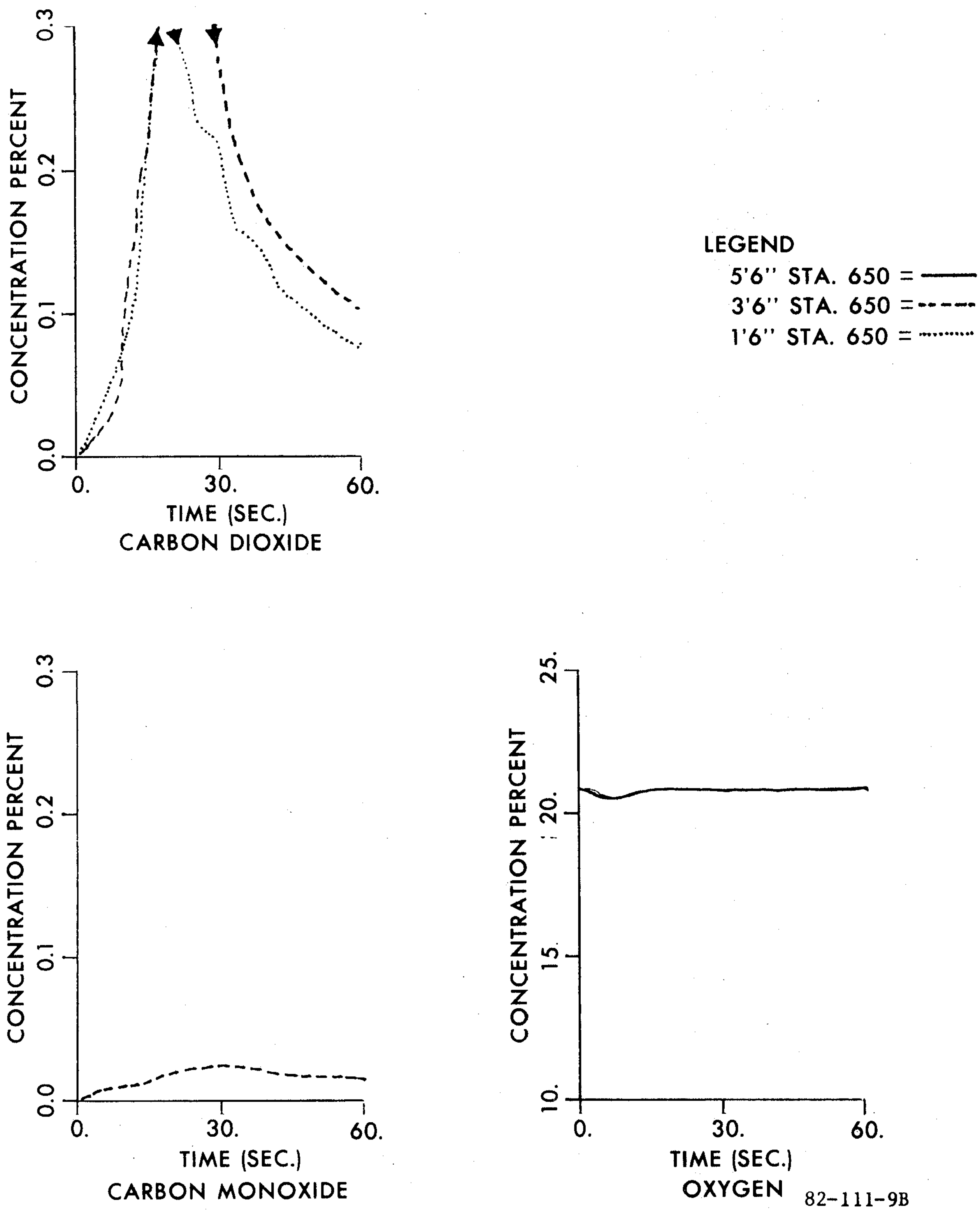



FIGURE 9. HAZARD LEVEL MEASUREMENTS, DRY CHEMICAL TEST NUMBER ONE (2 of 3 SHEETS)

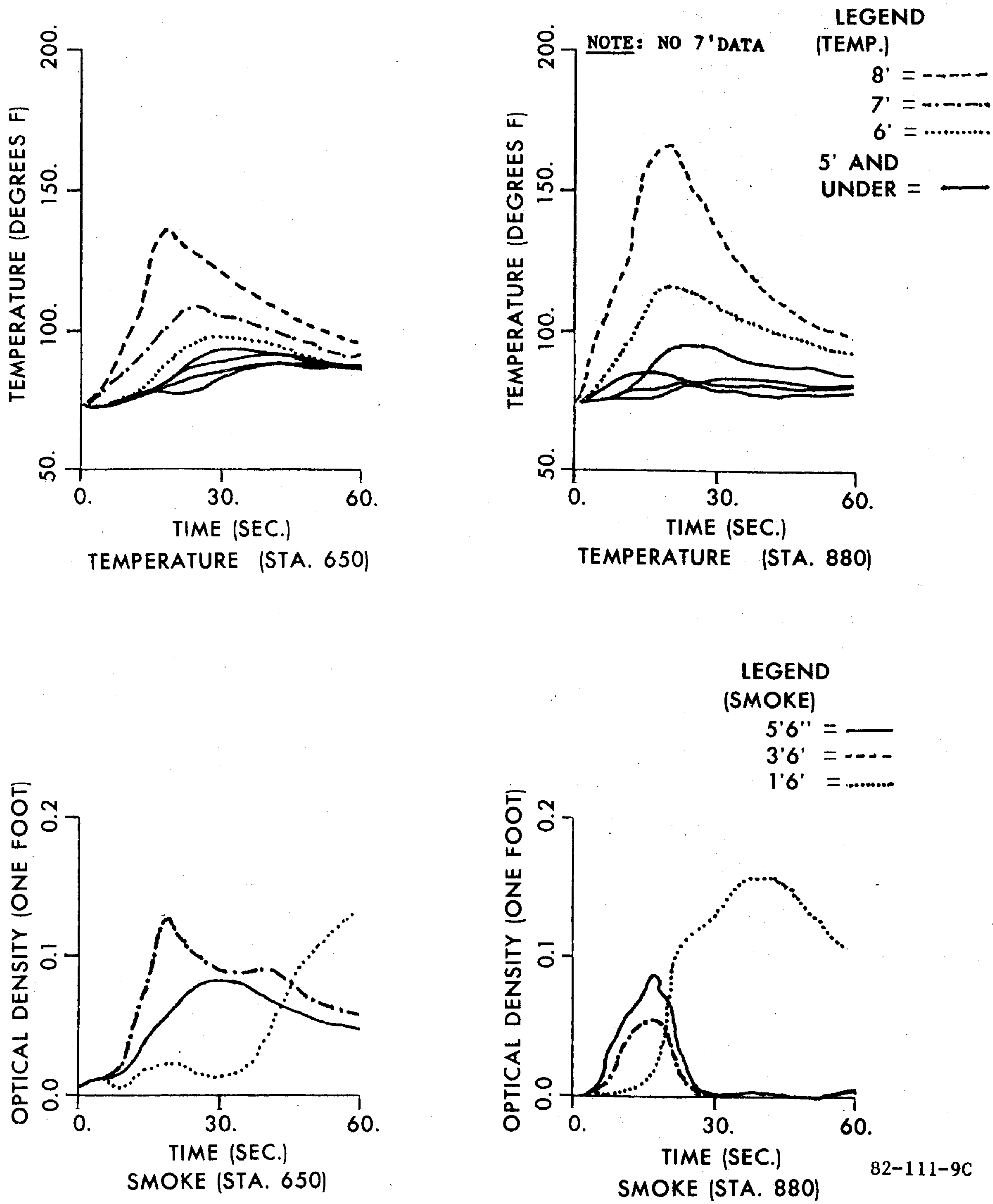
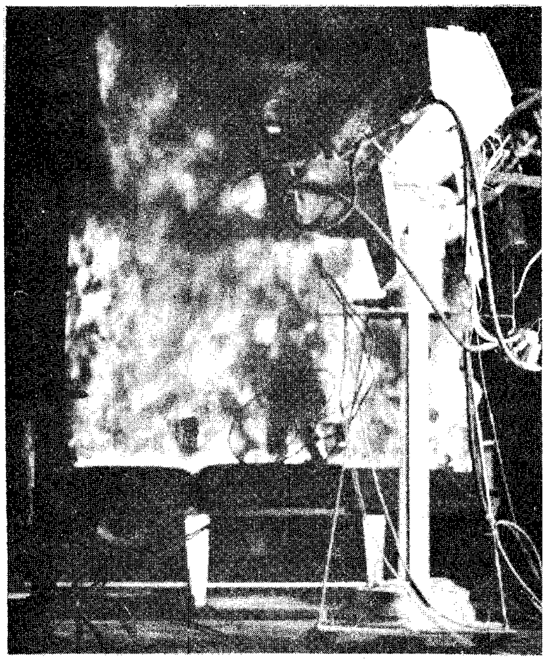
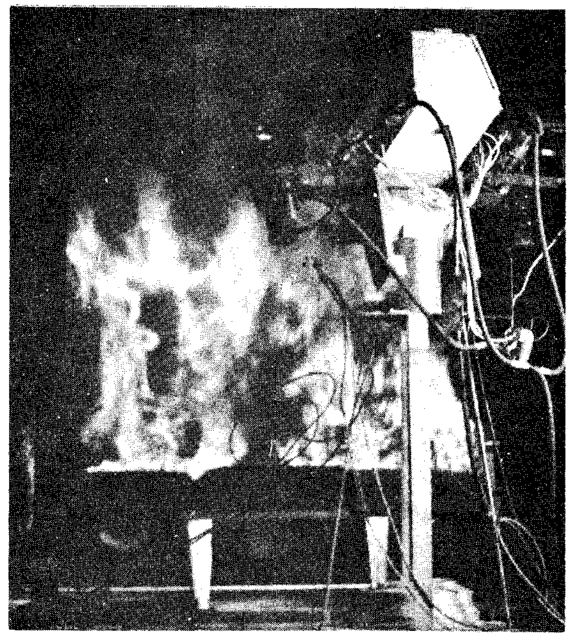


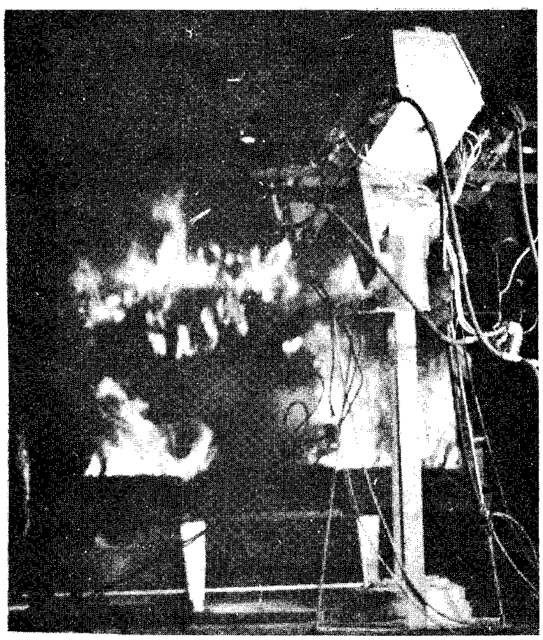

FIGURE 9. HAZARD LEVEL MEASUREMENTS, DRY CHEMICAL TEST NUMBER ONE (3 of 3 SHEETS)



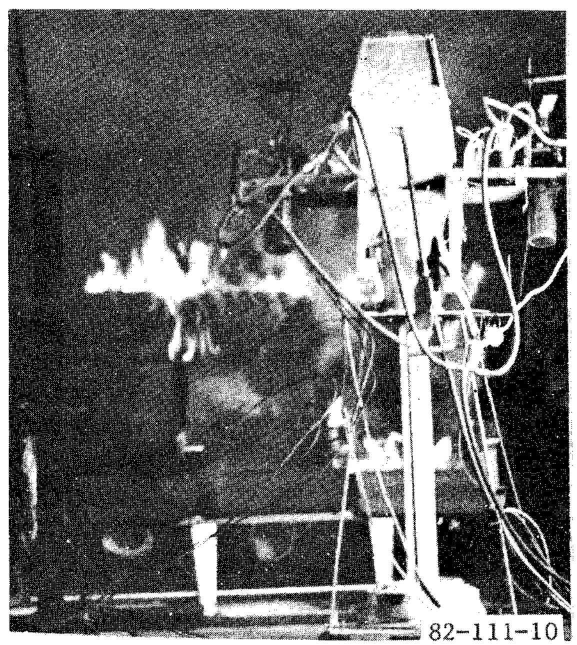
TIME: 10 SECONDS after ignition
(AGENT DISCHARGE)



TIME: 12 SECONDS after ignition



TIME: 14 SECONDS after ignition




TIME: 16 SECONDS after ignition

FIGURE 10. SEQUENTIAL PHOTOGRAPHS OF WATER TEST NO. 1

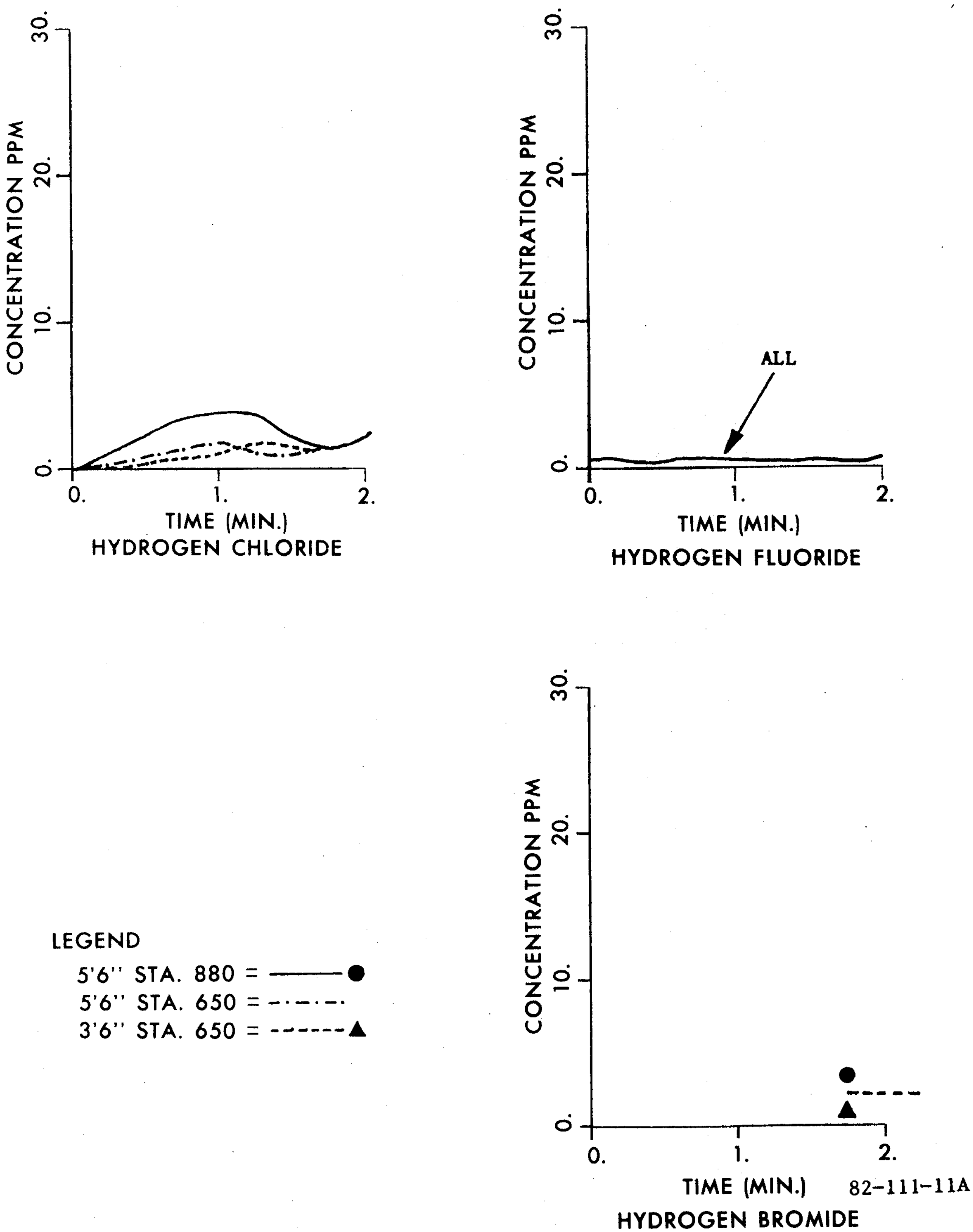



FIGURE 11. HAZARD LEVEL MEASUREMENTS, WATER TEST NUMBER ONE (1 fo 3 SHEETS)

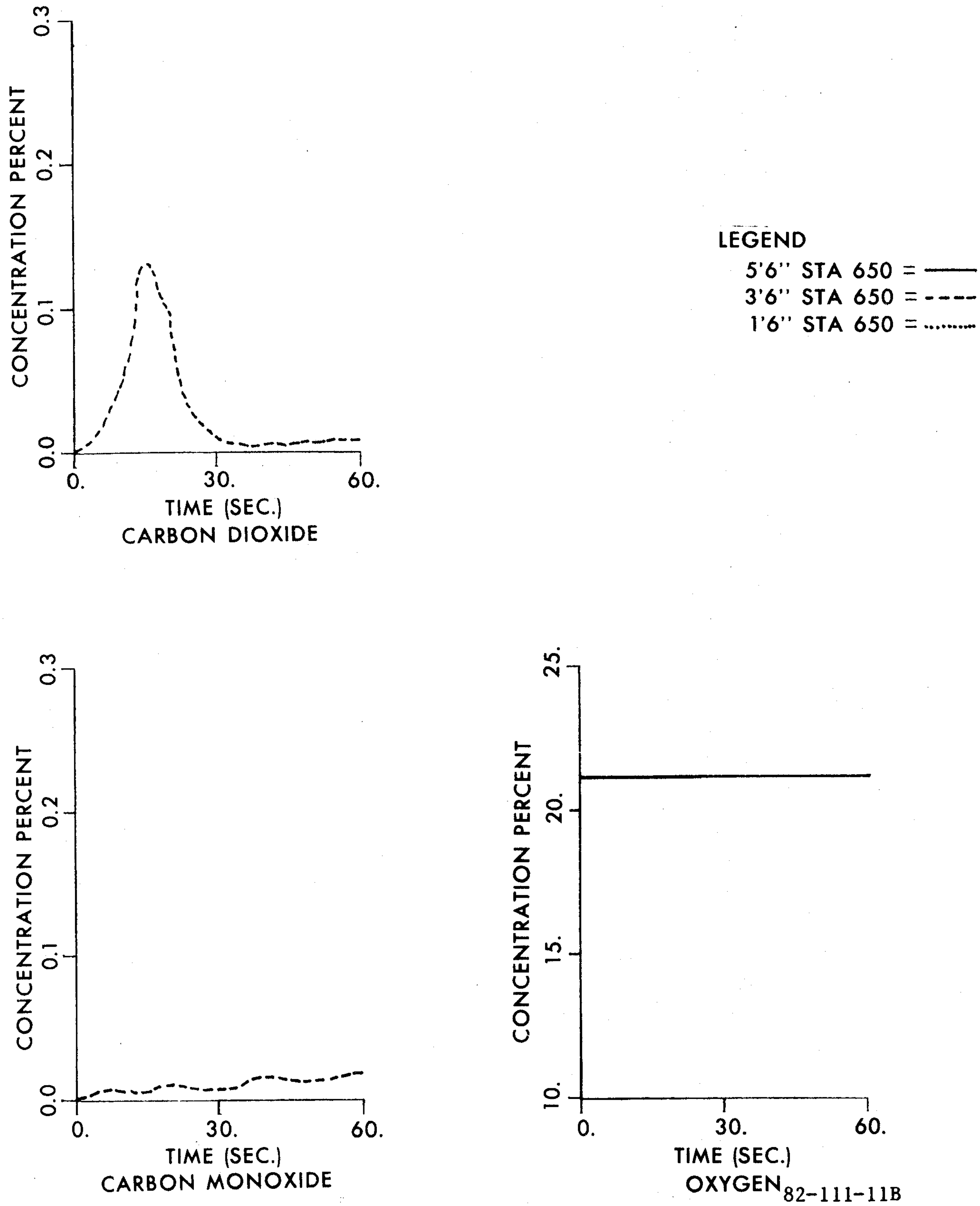



FIGURE 11. HAZARD LEVEL MEASUREMENTS, WATER TEST NUMBER ONE (2 fo 3 SHEETS)

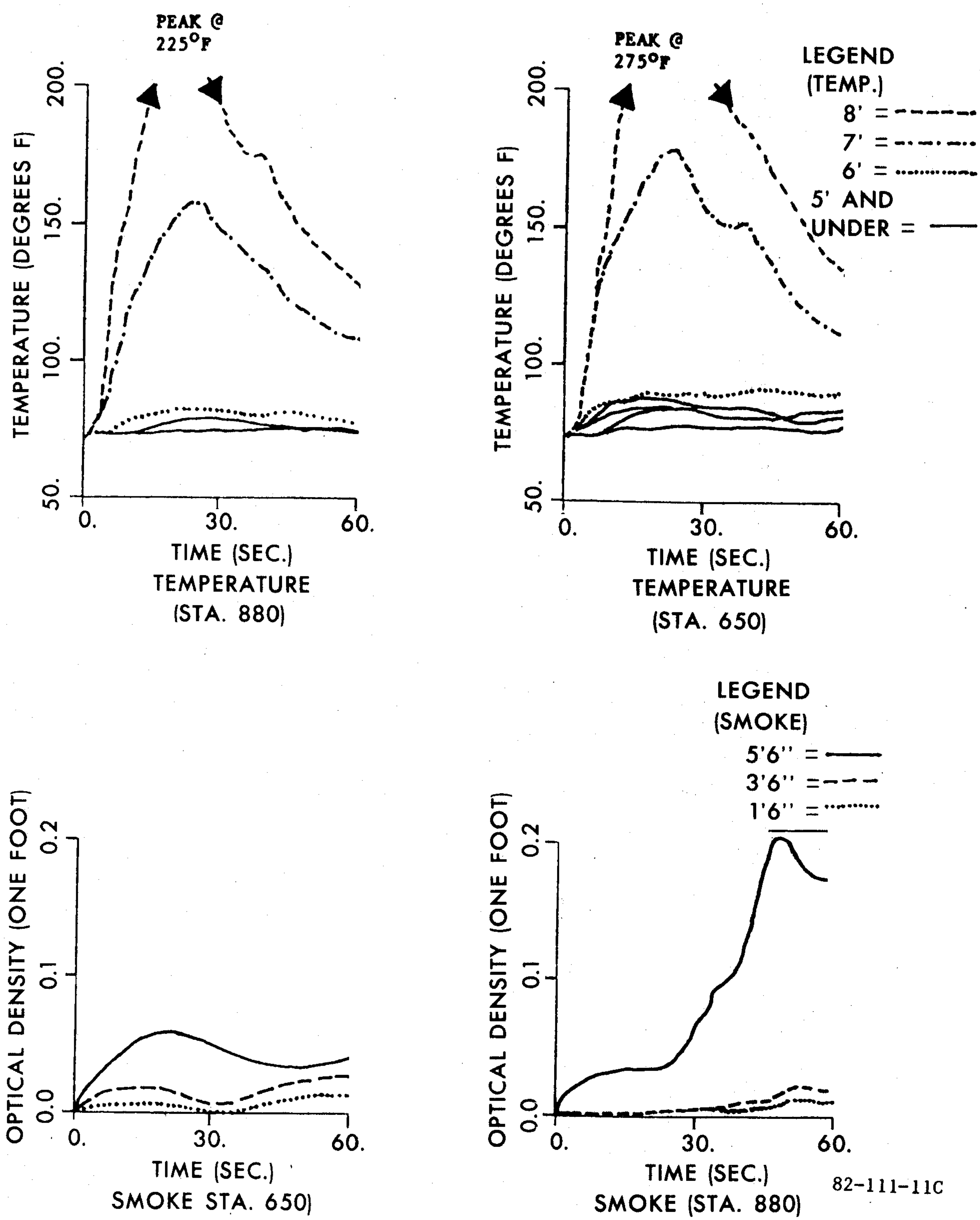
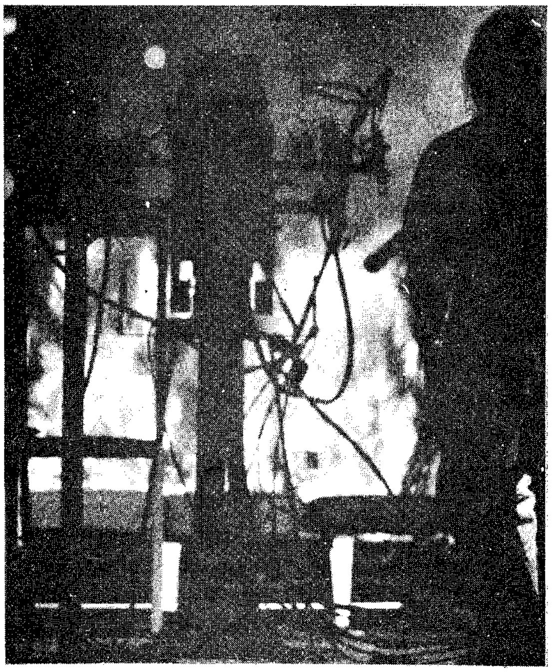
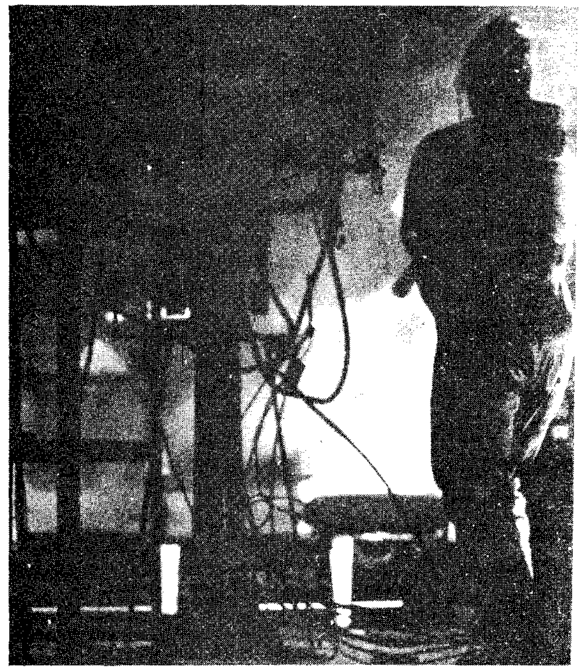


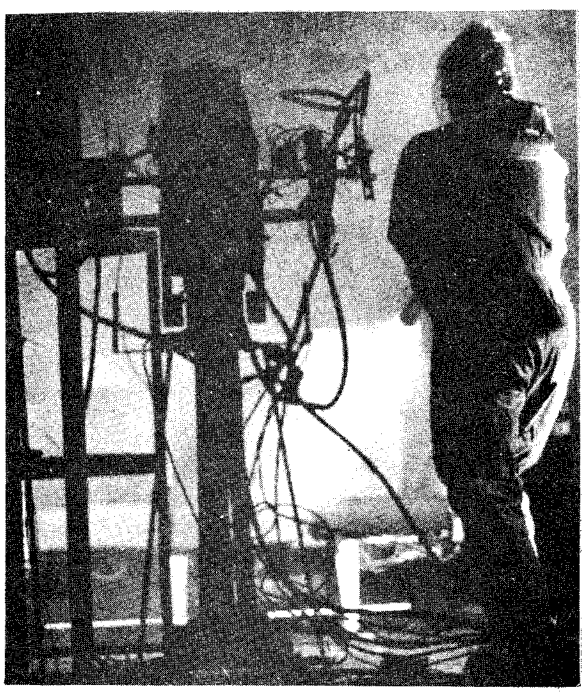

FIGURE 11. HAZARD LEVEL MEASUREMENTS, WATER TEST NUMBER ONE (3 fo 3 SHEETS)



TIME: 10 SECONDS after ignition
(AGENT DISCHARGE)



TIME: 16 SECONDS after ignition



TIME: 20 SECONDS after ignition


TIME: 46 SECONDS after ignition

FIGURE 12. SEQUENTIAL PHOTOGRAPHS OF CO2 TEST NO. 1

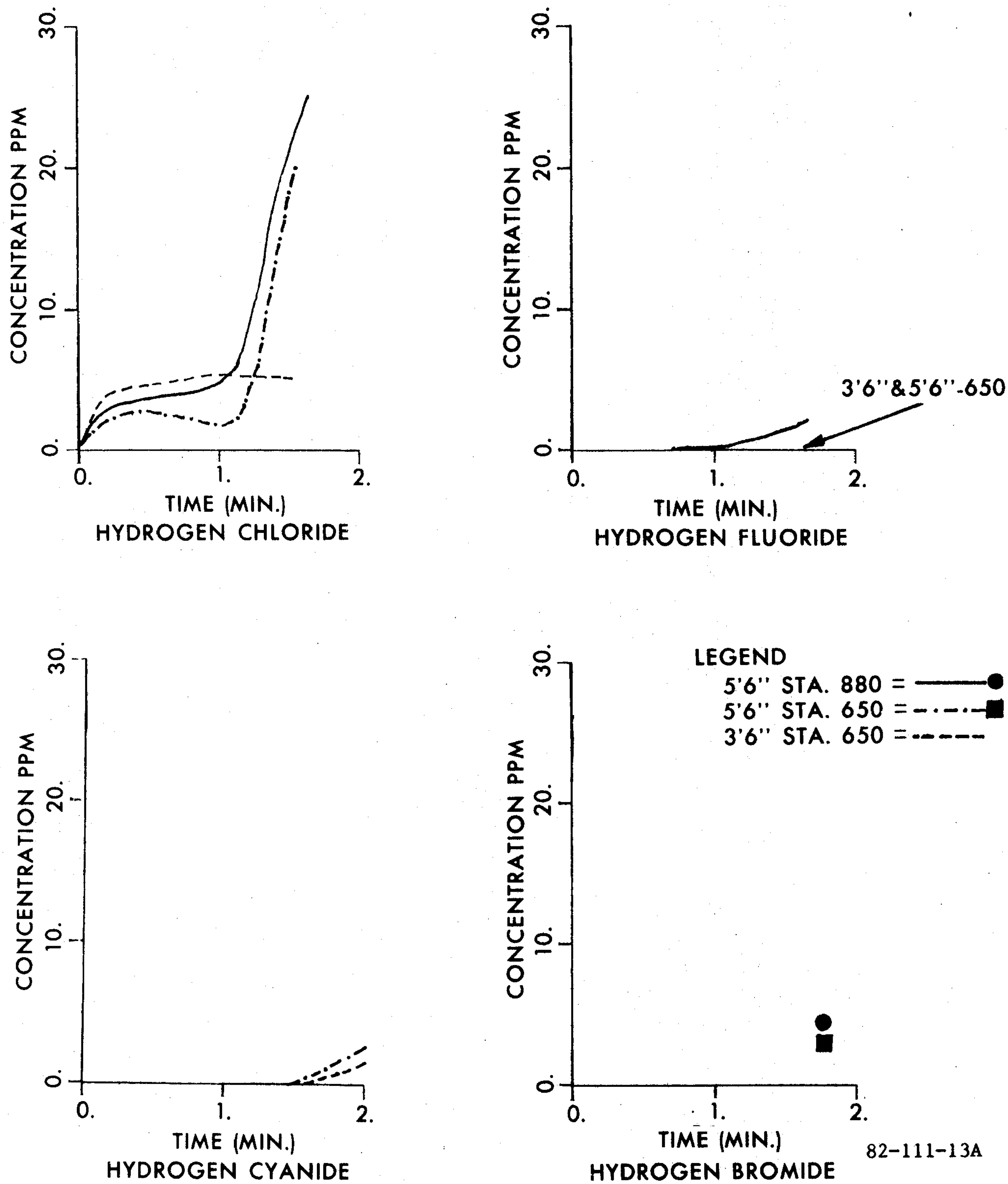



FIGURE 13. HAZARD LEVEL MEASUREMENTS, $CO_2$ TEST NUMBER ONE (1 of 3 SHEETS)

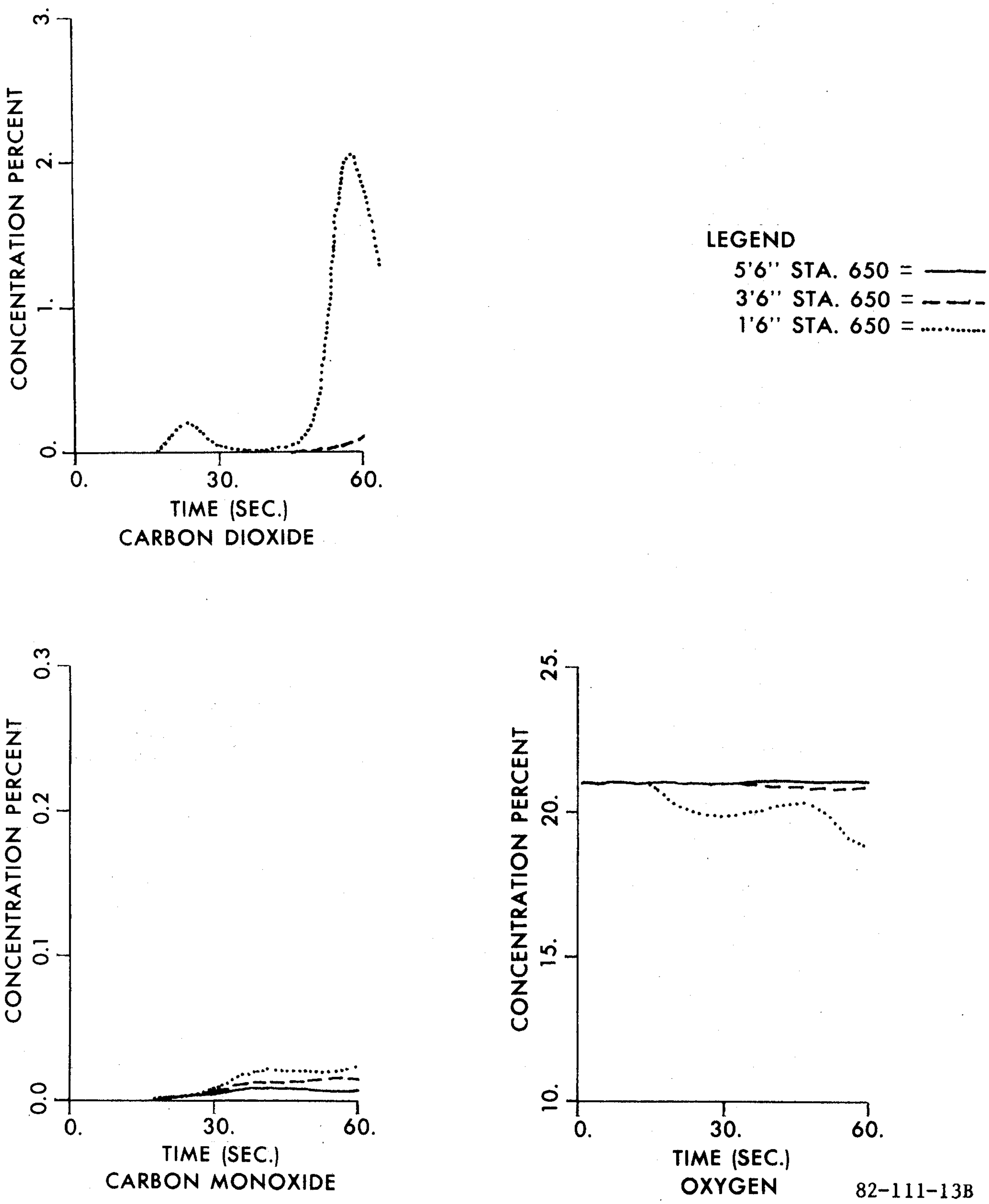



FIGURE 13. HAZARD LEVEL MEASUREMENTS, $CO_2$ TEST NUMBER ONE (2 of 3 SHEETS)

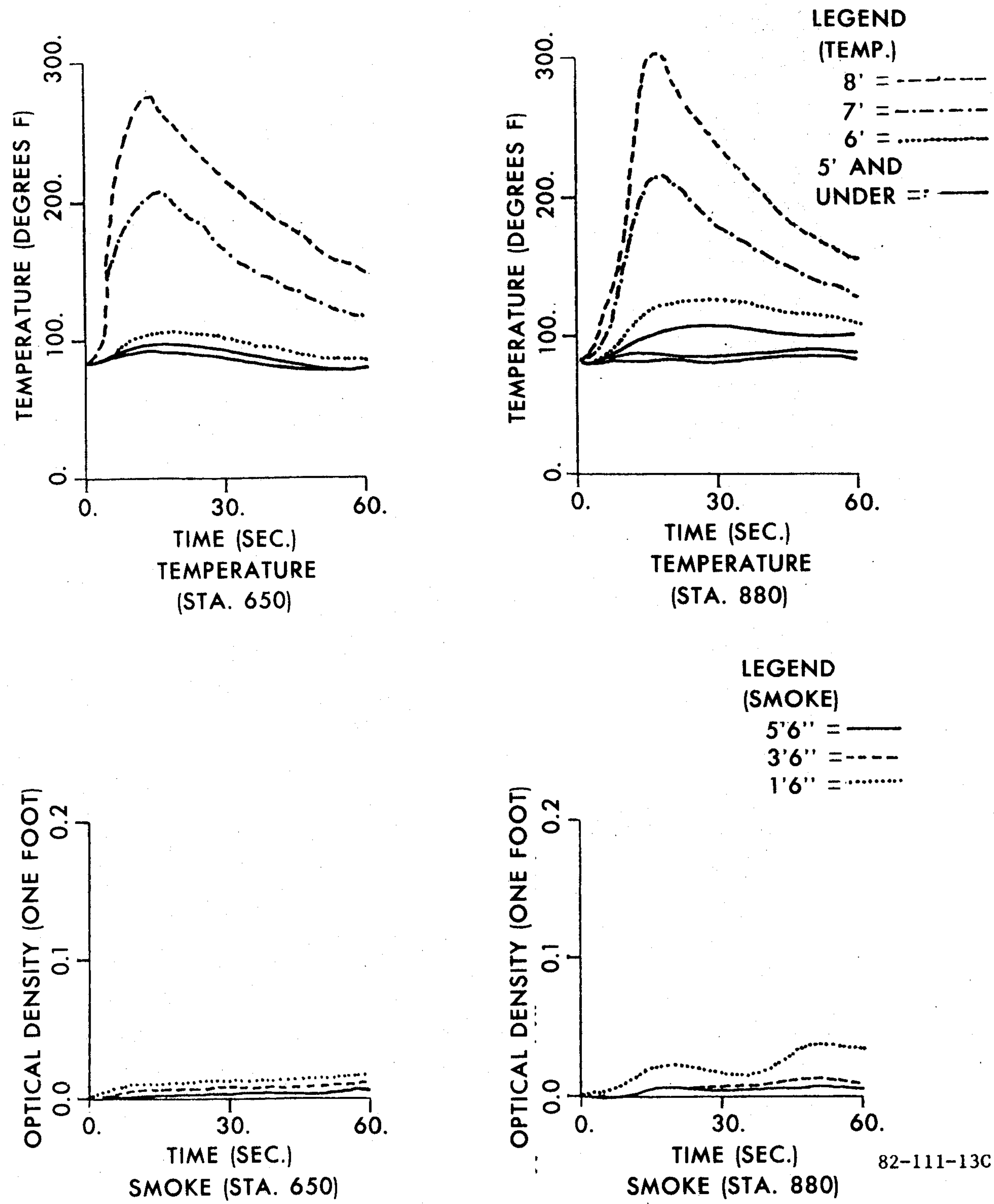
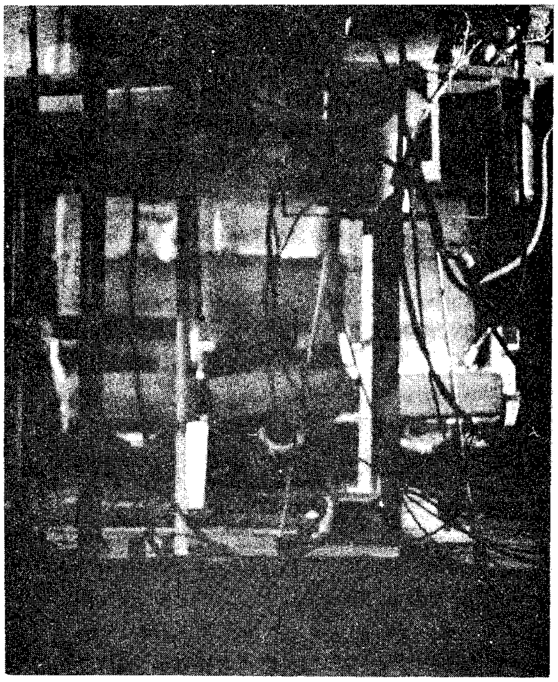
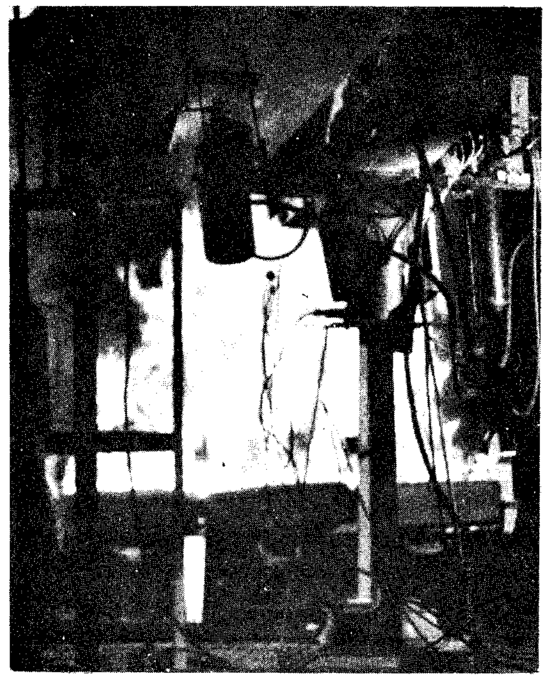


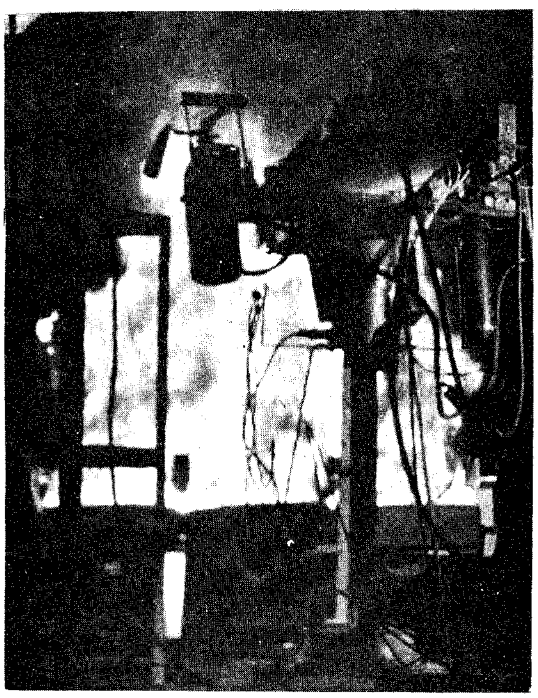

FIGURE 13. HAZARD LEVEL MEASUREMENTS, $CO_2$ TEST NUMBER ONE
(3 of 3 SHEETS)



TIME: ZERO (Ignition)



TIME: 4 SECONDS after ignition



TIME: 8 SECONDS after ignition


TIME: 30 SECONDS after ignition

FIGURE 14. SEQUENTIAL PHOTOGRAPHS OF UNCONTROLLED SEAT FIRE

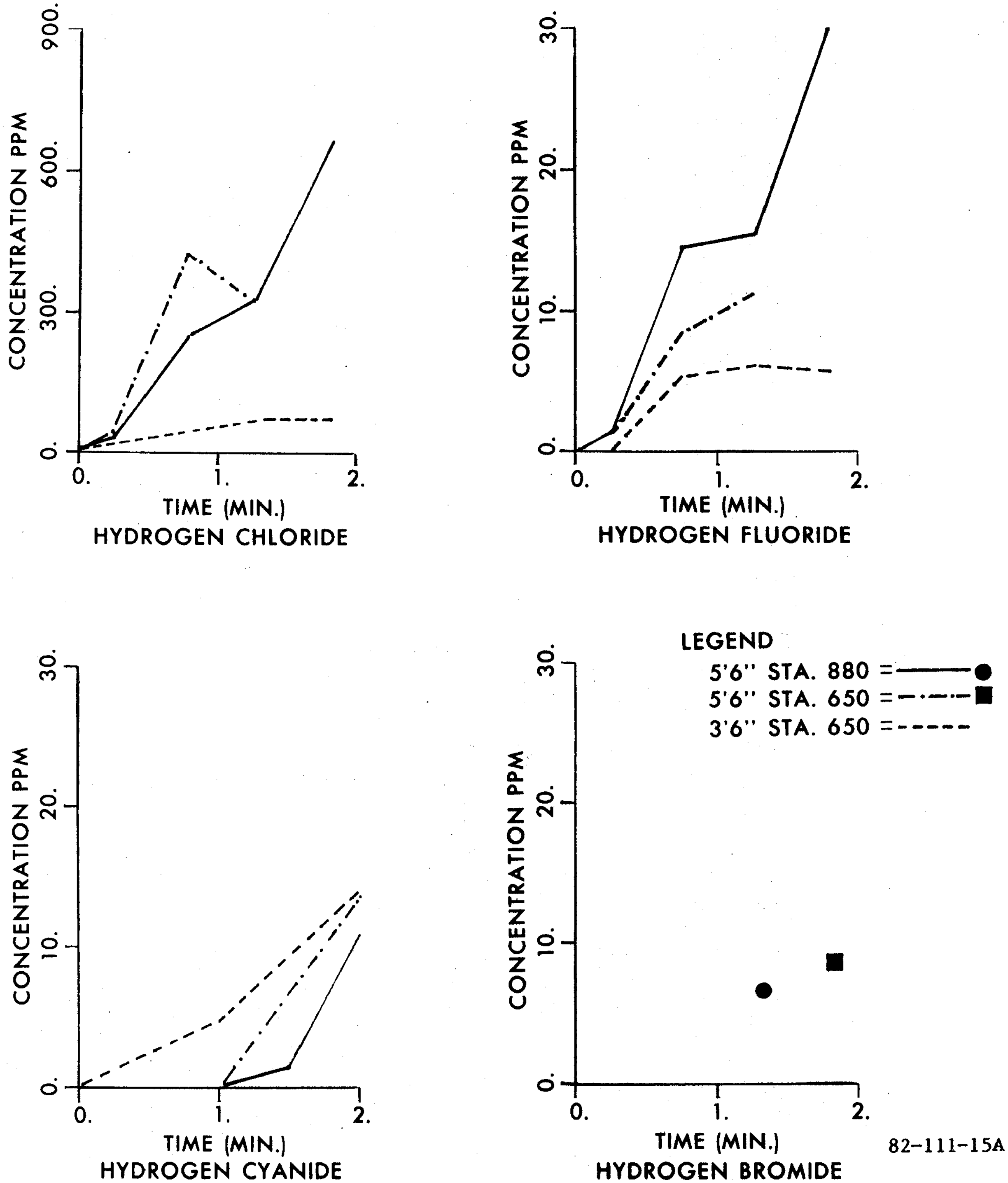



FIGURE 15. HAZARD LEVEL MEASUREMENTS, UNCONTROLLED SEAT FIRE (1 of 3 SHEETS)

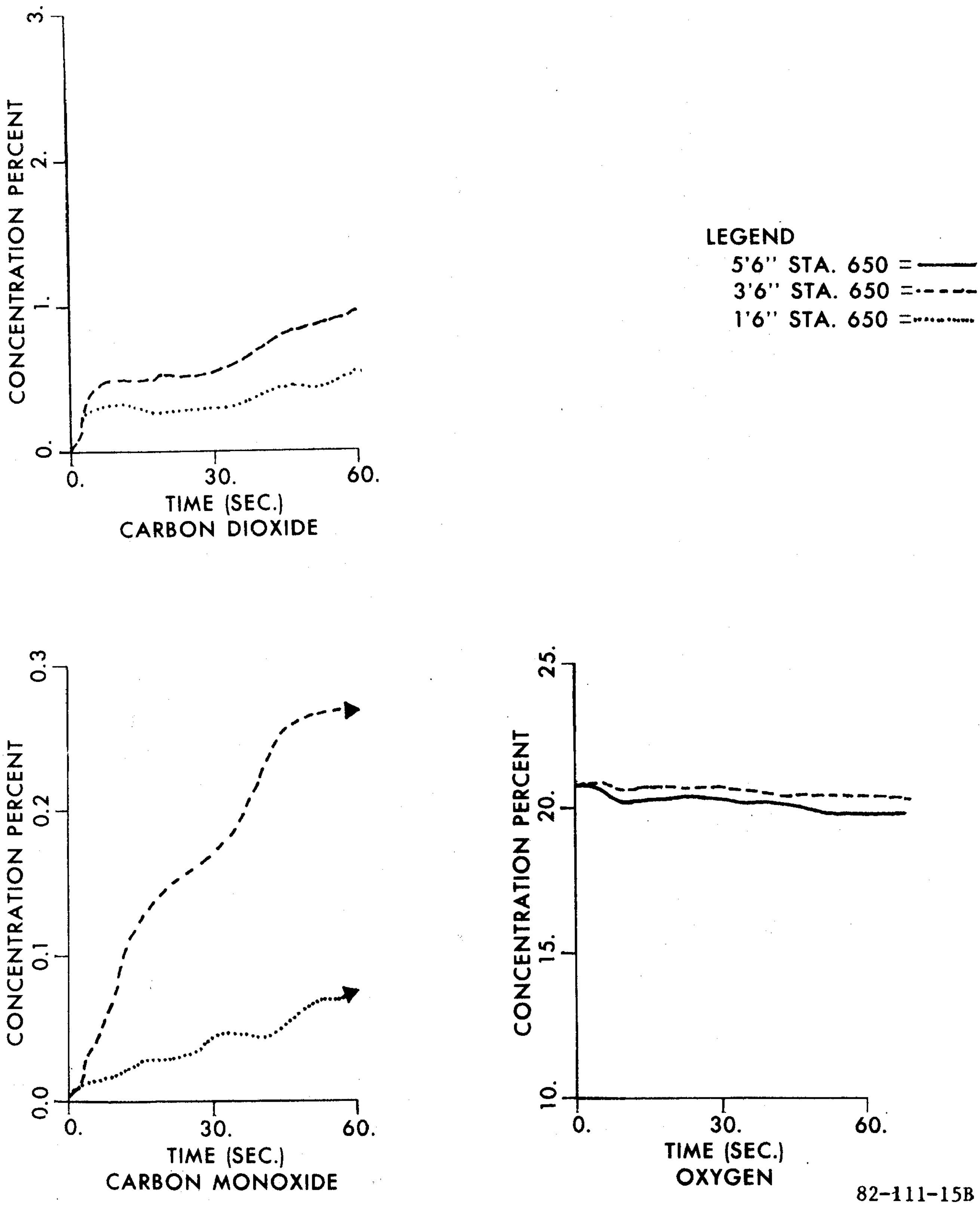



FIGURE 15. HAZARD LEVEL MEASUREMENTS, UNCONTROLLED SEAT FIRE (2 of 3 SHEETS)

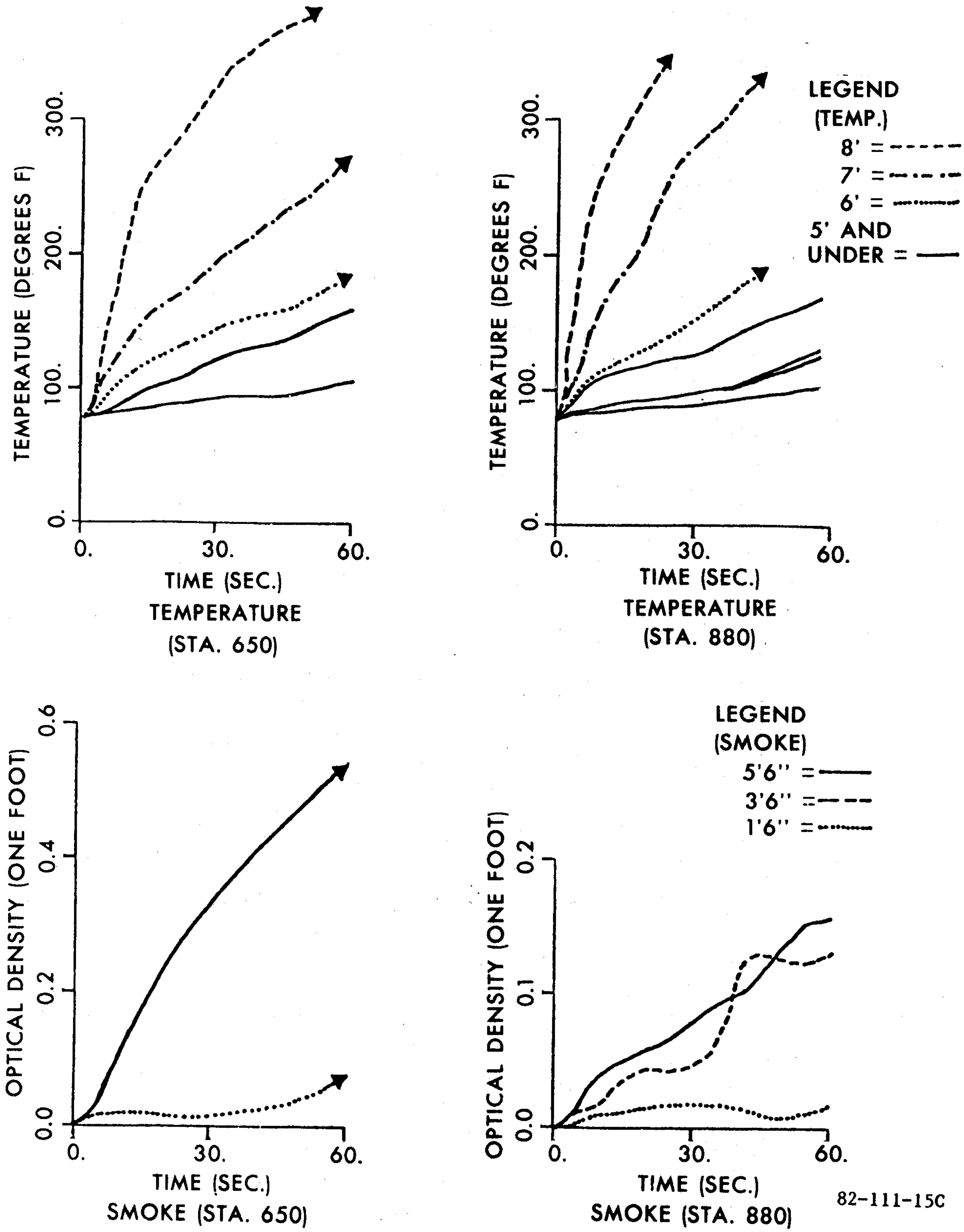



FIGURE 15. HAZARD LEVEL MEASUREMENTS, UNCONTROLLED SEAT FIRE (3 of 3 SHEETS)

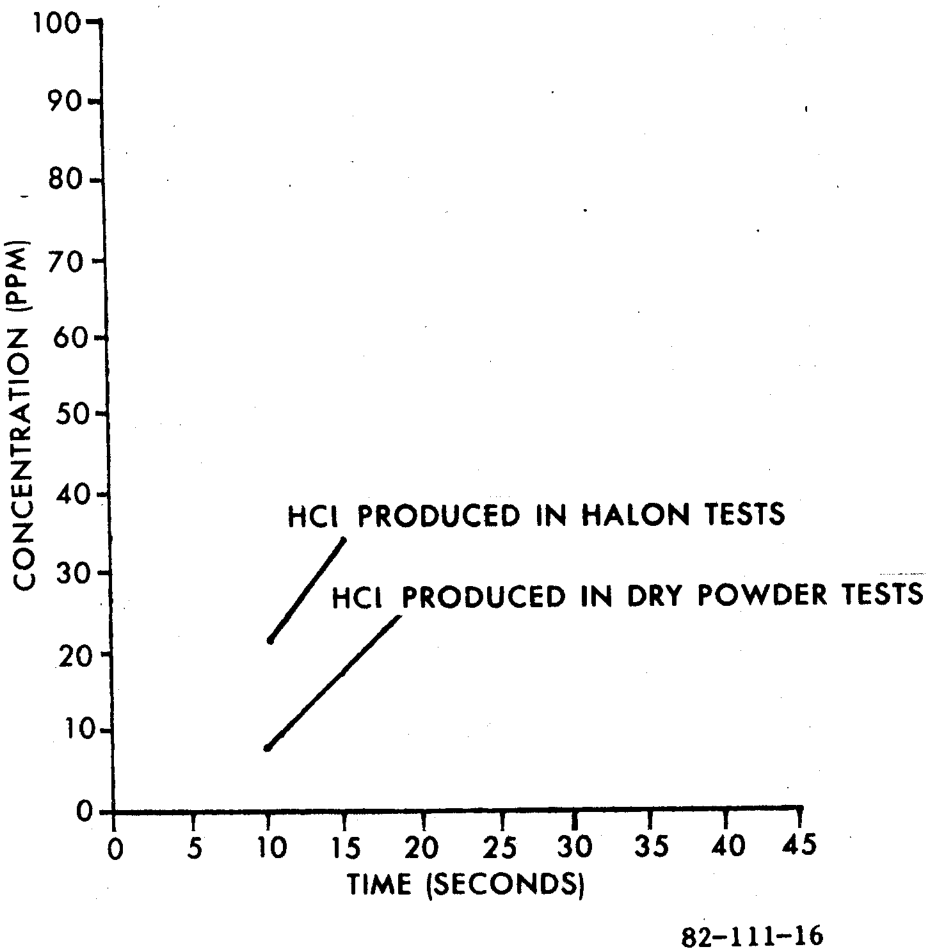



FIGURE 16. HCl PRODUCED DUE TO DECOMPOSED 1211 AND SEATS

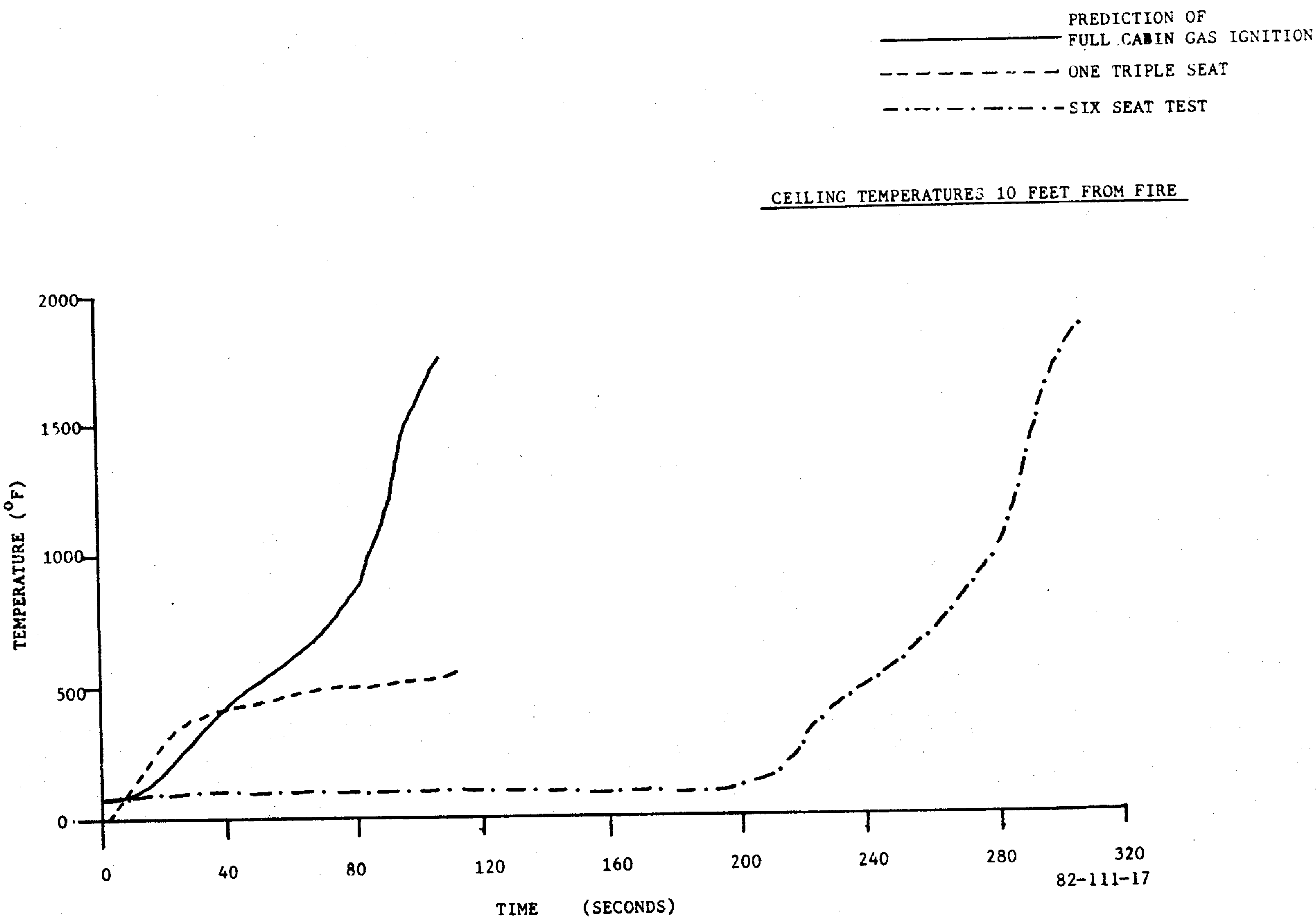



FIGURE 17. TEMPERATURE FOR ONE TRIPLE SEAT AND PREDICTED TEMPERATURE FOR FULL CABIN

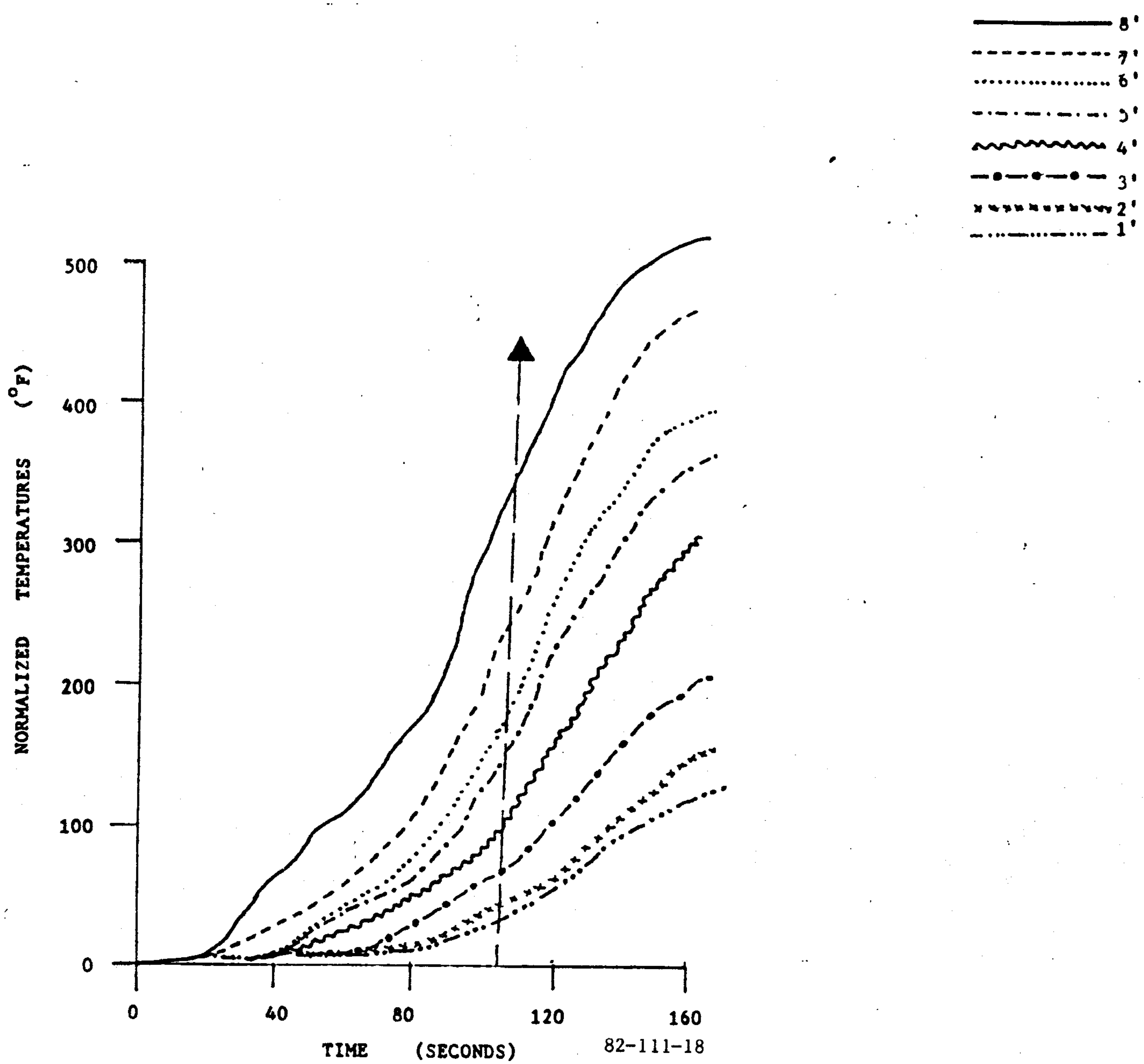



FIGURE 18. PREDICTED TEMPERATURES IN ADJACENT CABIN 40 FEET FROM FIRE, SEPARATED BY PARTITION

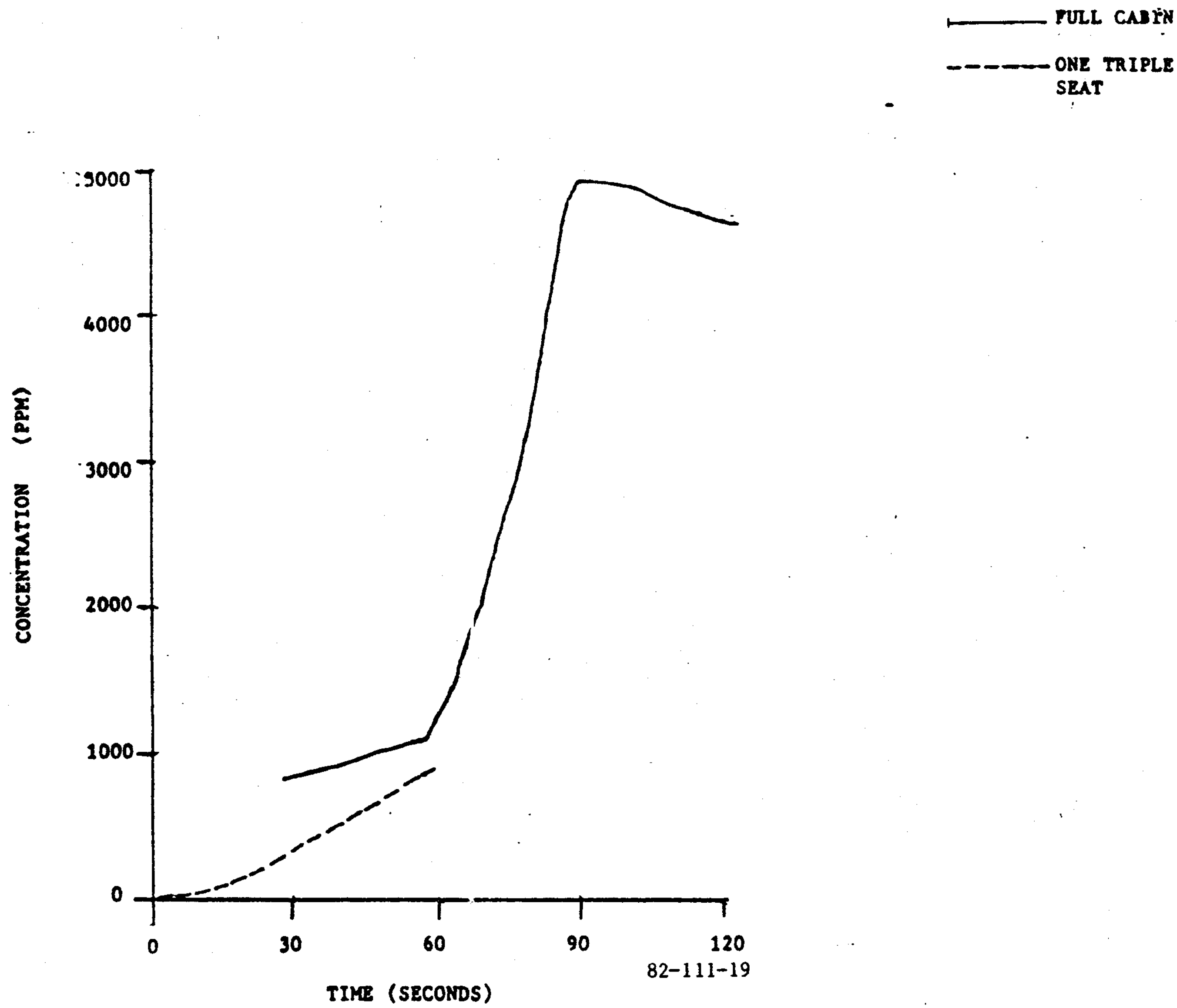



FIGURE 19. HCl FOR ONE TRIPLE SEAT AND PREDICTED HCL FOR FULL CABIN