Annual Average Estimates of the Number of Fires, Injuries, Deaths, and Property Loss Associated with Gas-Fueled Water Heaters, 1986-1991

Material First Ignited	Fires		Injuries		Deaths		Property Loss	
	Number	Percent	Number	Percent	Number	Percent	Thousand $	Percent
Total	9,844	100*	586	100	40	100*	87,420	100.0
Gasoline	**1,337**	**13.6**	**239**	**40.8**	**14**	**36.0**	**20,179**	**23.1**
Other Liquid	**624**	**6.3**	**77**	**13.1**	**3**	**7.9**	**6,160**	**7.1**
Fuel Gas	1,547	15.7	110	18.9	12	29.0	15,330	17.5
All Other	6,336	64.7	160	27.2	11	27.2	45,751	52.3

Information in "Bold" type represents gasoline and other flammable liquids

Source: CPSC/EPHA, from data obtained from the National Fire Protection Association and the U.S. Fire Administration

* Percentages do not total 100.0 due to independent rounding.

UNITED STATES GOVERNMENT

MEMORANDUM

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

Date: April 14, 1994

TO : Joseph Z. Fandey, ESEE

THROUGH: Robert T. Garrett, Acting Director ESEL

FROM : Albert Eugene Martin, ESEL

SUBJECT: Water heater test project.

INTRODUCTION

The Engineering Sciences Engineering Laboratory (ESEL) began in January 1993 to design engineering tests, as requested, to investigate the propagation of a vapor cloud from a gasoline spill. Tests of vapor cloud propogation began in September of 1993. ESEL also investigated the performance of a simple device that could prevent the ignition of a gasoline vapor cloud by the flame in the water heater.

APPARATUS AND PROCEDURES

Five water heater samples were received at ESEL. These were connected to water and fuel gas sources per the manufacturers' instruction. These were operated in the combustion test laboratory. The velocity of the exhaust gases was measured with one of the hot wire anemometers in this lab. A D.C. blower was fitted to the top of the exhaust stack. This permits air to be drawn through the water heater at the velocity created by the pilot fire or the burner as appropriate.

The gasoline vapor cloud propagation measurements were made in a test room in the Fire Lab at the National Institute of Standards and Technology (NIST). These tests were performed with ESEL equipment and by ESEL staff. The work was done in a room built with gypsum board walls and fitted with a blow out safety door. These equipments and fixtures are described in Appendix A.

A Rosemont Model 880 analyzer was procured for the tests of vapor cloud propagation. This unit is a Non Dispersive Infra Red (NDIR) gas analyzer set up to measure the percent of "Lower Explosive Limit" (LEL) of gasoline vapors. This LEL unit is calibrated, by Rosemont, so that the user, ESEL, could perform "span calibrations" from a mixture of propane and nitrogen flowed into the analyzer. The ESEL performed this calibration daily using concentrations of 1.79, 0.821 and zero percent propane in nitrogen. These concentrations are equivalent to 94.2, 43.2 and zero percent LEL of gasoline vapor. Additional equipment used in the fire lab test cell was the required pumps, valves, rotameters, gages, thermocouples and tubing connecting the test points to the analyzer.

The data from the analyzer and four thermocouples in the

cell were collected by a 286 computer. This permitted quick analysis of each day's test results.

Tests to measure the effect, if any, of a barrier around the base of the water heater were run using the Hood Test System in The Combustion Test Lab at ESEL. This facility measures the products of combustion of hydrocarbon fires at short intervals. These data are used to compute the mass of combustion components of interest including Carbon Dioxide, CO_2, and Carbon Monoxide, CO.

The water heater was connected to a fuel gas (methane) line and to water inlet and outlet lines. All operating parameters were set to manufacturers specifications. The water heater operation was controlled by using the thermostat setting. Measurement of CO and CO_2 concentrations were noted with and without the barrier. The effect of "blocking" the space between the heater and barrier was also measured.

RESULTS

Appendix A compiles the gasoline vapor cloud propagation tests. This presents graphics of each test showing the percent L.E.L versus time. Annotations are made for significant events in the test run. These data show that dangerous levels of gasoline vapor concentrations occur at the pilot light when 2000 ml, approximately 1/2 gallon, is spilled 18 inches from the centerline of a water heater sitting on the floor. This is believed to be the most common installation. When elevated six inches these data show that dangerous levels are not reached at the pilot light location.

With the water heater on the floor and a barrier, made of 14 inch wide aluminum flashing, placed around the base and taped to the floor the L.E.L. concentrations are reduced well below safe levels.

Appendix B reports the results of operating a water heater with and without the barrier. These data for CO and CO_2 concentrations are the same in each case.

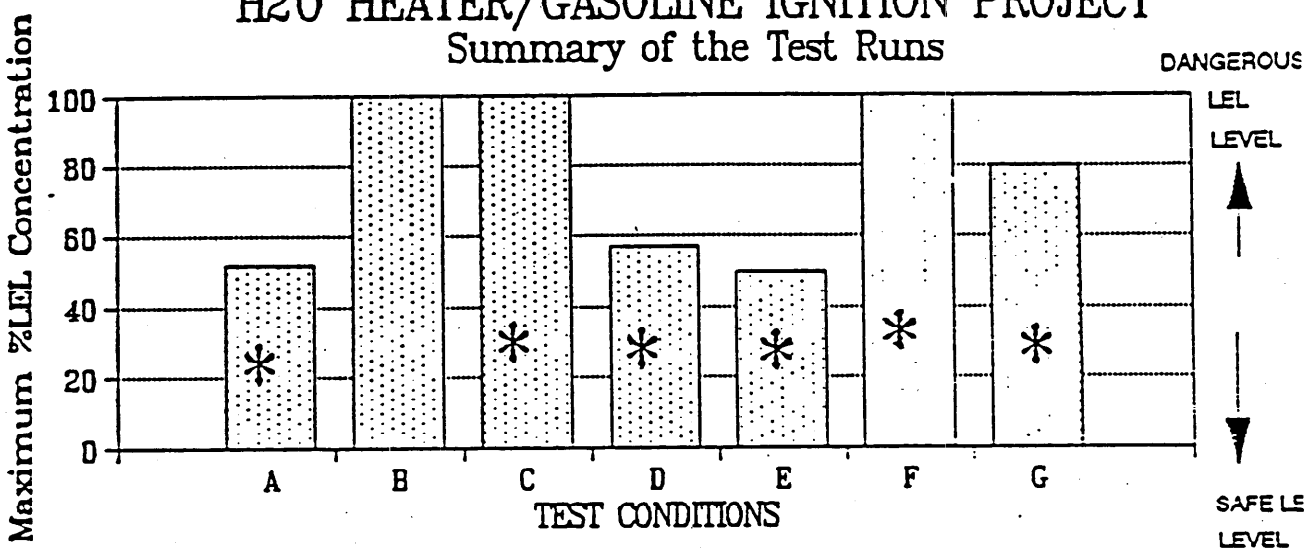
The work performed at ESEL shows that in those communities where water heaters are installed six inches or more above the floor the risk of ignition of spilled gasoline is minimal. These data also show that a simple 14 inch high barrier of light weight sheet metal taped to the floor prevents spilled gasoline vapors from reaching the flame in a water heater.

cc: George Sushinsky ESEL.

APPENDIX A

H2O HEATER/GASOLINE IGNITION PROJECT

Summary of the Test Runs



A: 6 in elevation / 2000 mL spill / Pilot cover off

B: On the floor / 2000 mL spill / Pilot cover on

C: On the floor / 2000 mL spill / Pilot cover on / Aluminum Flashing uncaulked to floor pan

D: On the floor / 2000 mL spill / Pilot cover on / ALuminum Flashing caulked to floor pan

E: On the floor / 2000 mL spill / Pilot cover on / ALuminum Flashing with 3 1/4" holes caulked to pan

F: On the floor /1 Gallon spill / Pilot cover on / Aluminum Flashing with 3 1/4" holes caulked to pan

G: On the floor / 1 Gallon spill / Pilot cover on / Aluminum Flashing without holes caulked to pan

* Forced air blown in the enclosed test chamber

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT

Summary of Test Results

All tests were performed with heater "C" at 18 in from the centerline of the heater to the point of gasoline spill.

* Forced air blown in the enclosed test chamber.

DATE	TEST CONDITIONS	RESULTS
10/28/93	450 mL of gasoline spilled; Sample line 2 is 2" off the floor, line 3=6" off the floor, line 4=bottom of the air inlet of heater. This arrangement has been used for the test runs through 11/12/93 am. Heater is on the floor	Sample line 1 (pilot) did not reach a dangerous LEL level. The maximum LEL level of 45% occurred around 400 sec (6.7 min) after the spill.
11/1/93	Heater is on the floor; 450 mL of gasoline spilled	Two test runs have been performed--the first run showed the pilot reached a max. of 85% LEL and the second 100%. Both reached max. values 1 or 2 min after the spill.
11/2/93	Heater is on the floor; 450 mL of gasoline spilled	NO DATA; Stack blower lacked power supply.
11/3/93 am	Heater is on the floor; 450 mL of gasoline spilled	Sample line 1 (pilot) reached 100% LEL 100 sec after the spill
11/3/93 pm	Heater is on the floor; 450 mL of gasoline spilled	Sample line 1 (pilot) reached 100% LEL 100 sec after the spill
11/4/93	Heater is raised 12" off the floor; 1000 mL of gasoline spilled	No Data for the morning run; Exhaust fan was on when testing was in progress. Afternoon run shows no indication of dangerous LEL levels.
11/8/93	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	NO DATA; Power failure occurred in the fire research building at NIST.
11/9/93 am	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	Sample line 2 reaches >100% LEL. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 1% to 26% over the course of 4600 sec (1 hr., 17 min).
11/9/93 pm	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	Sample line 2 reaches >100% LEL. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 1% to 15% over the course of 3500 sec (58 min).
11/12/93 am	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled;	Sample line 2 reaches >100% LEL @ 120 sec (2 min) after the spill. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 1% to 35% over the course of 2800 sec (47 min).

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT

Summary of Test Results

* Forced air blown in the enclosed test chamber.

DATE	TEST CONDITIONS	RESULTS
11/12/93 pm	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled; sample line 2=3"off the floor, line 3=4.5" and line 4=6". This sample line arrangement has been maintained for the remainder of the test runs.	Sample line 2 reaches >100% LEL @ 40 sec after the spill. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 2% to 36% over the course of 3400 sec (56 min).
11/16/93	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample line 2 reaches >100% LEL @ 180 sec (3 min) after the spill. The LEL concentration @ the pilot never reached a dangerous level; the LEL concentration gradually rose from 17% to 25% over the course of 3000 sec (50 min).
11/17/93 am * A	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample line 2 reaches >100% LEL @ 180 sec (3 min) after the spill. The fan was pulsed (turned on/off) once @ 2300 sec (38 min) after the spill and turned on for 10 min @ 2400 sec (40 min). The LEL concentration @ the pilot did not reach a dangerous level, but reached a steady state of 52%.
11/17/93 pm * A	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample line 2 reaches >100% LEL @ 190 sec (3 min. 10 sec) after the spill. The fan was pulsed once @ 440 sec (7 min) after the spill and pulsed 10 times @ 950 sec (15.8 min). The LEL concentration @ the pilot did not reach a dangerous level, but reached a steady state of 52%.
11/18/93 am *	Water heater was raised 6 in above the floor pan; 2000 mL of gasoline was spilled	Sample lines 2 and 3 reach >100% LEL @ 166 sec and 168 sec, respectively. When the fan was pulsed (turned on/off) ten times, the hot wire anemometer read an air velocity of 459 ft/min and the pilot (line 1) concentration jumped from 7.4% to 45.7% LEL. The pilot never reached a dangerous LEL level.
11/18/93 pm B	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; pilot cover is ON the heater	Sample line 1 (pilot) reaches >100% LEL 62 sec after the spill. The pilot maintained its >100% LEL level for about 800 sec (13 min). At about 890 sec (15 min), the pilot LEL level dropped to about 73%.

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT
Summary of Test Results

* Forced air blown in the enclosed test chamber.

DATE	TEST CONDITIONS	RESULTS
11/19/93 pm *	Water heater was placed on the floor pan; pilot cover is ON the heater throughout the remainder of the tests; 2000 mL of gasoline was spilled; aluminum flashing is around the water heater, resting on the floor pan (flashing is not caulked)	Sample line 1 (pilot) reaches a maximum of about 61% LEL @ 2110 sec (35 min) after the gasoline spill. The liquid gasoline crept underneath the flashing. "Pulsing" (turning fan on/off) was performed to determine what sort of characteristics the sample line @ the pilot will exhibit. The pilot reached about 61% LEL after 2 sets of 10 pulses in 1 sec intervals. After every set of pulses, the hot wire anemometer read air velocities from 100 to 200 feet/min. It appears the pilot cover prevents some of the stronger vapor concentration from coming in.
11/22/93 am * C	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is around the water heater, resting on the floor pan (flashing is not caulked)	Sample line 1 (pilot) reaches >100% LEL @ 180 sec (3 min) after the spill. The fan was pulsed 10 times (turned on and off) from the time of the spill to the time when 100% LEL was reached. The liquid gasoline crept underneath the flashing. When the pilot reached >100% LEL, other sample lines were switched and observed. After about 6 min (360 sec) and 10 pulses, the pilot was at 91% LEL. 15 min after the spill, the fan was pulsed 10 times and the pilot reaches 74% LEL. Without the aid of the fan, the pilot does not reach dangerous LEL levels.
11/22/93 pm * D	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan.	Sample line 1 (pilot) reaches a maximum of about 57% LEL @ 880 sec (15 min) after the gasoline spill. The caulking prevented liquid gasoline from going underneath the flashing. "Pulsing" (turning fan on/off) was performed to determine what sort of characteristics the sample line @ the pilot will exhibit. The pilot reached a steady state of about 57% LEL after 6 sets of pulses: 2 sets of 8 pulses in 5 sec intervals, 2 sets of 8 pulses in 1 sec intervals, and 2 sets of 10 pulses in 1 sec intervals. After every set of pulses, the hot wire anemometer read air velocities from 100 to 200 feet/min.

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT
Summary of Test Results

* Forced air blown in the enclosed test chamber.

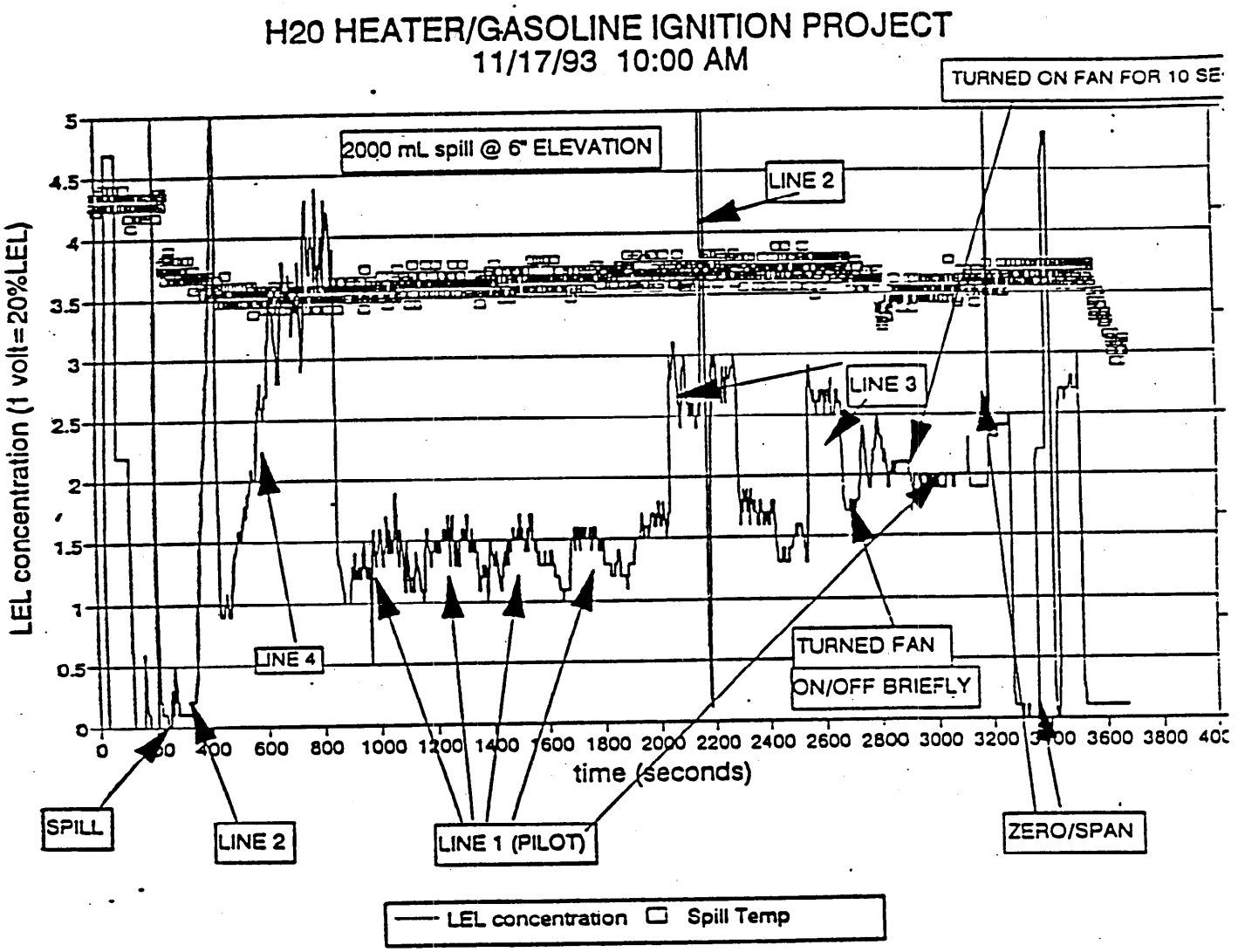
DATE	TEST CONDITIONS	RESULTS
11/23/93 pm * D	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan	Sample line 1 (pilot) reaches a maximum of about 57% LEL @ 1360 sec (23 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed to determine what sort of characteristics the sample line @ the pilot will exhibit. The pilot reached a steady state of about 57% LEL after 5 sets of pulses: 3 sets of 2 pulses in 1 sec intervals, a set of 6 pulses in 1 sec intervals, and a set of 5 pulses in 1 sec intervals. After every set of pulses, the hot wire anemometer read air velocities from 60 to 120 feet/min.
11/24/93 am *	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan	Sample line 1 (pilot) reaches a maximum of about 54% LEL @ 1890 sec (32 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed a few minutes after sample line 2 saturated (>100% LEL). 2½ minutes after the spill, sample line 2 (3" off the floor) saturated. The pilot reached a steady state of about 50% LEL after 7 sets of pulses: 2 sets of 5 pulses in 4 sec intervals, 2 sets of 8 pulses in 2 sec intervals, a set of 5 pulses in 2 sec intervals, and 2 sets of 10 pulses in 2 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.
11/30/93 am * E	Water heater was placed on the floor pan; 2000 mL of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing).	Sample line 1 (pilot) reaches a maximum of about 50% LEL @ 2640 sec (44 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed a few minutes after sample line 2 (3" off the floor) saturated (>100%). 2½ minutes after the spill, sample line 2 saturated. The pilot reached a steady state of about 50% LEL after 7 sets of pulses: 2 sets of 5 pulses in 4 sec intervals, 2 sets of 8 pulses in 2 sec intervals, a set of 5 pulses in 2 sec intervals, and 2 sets of 10 pulses in 2 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.

U.S. Consumer Product Safety Commission
Engineering Laboratory

WATER HEATER/GASOLINE IGNITION PROJECT
Summary of Test Results

* Forced air blown in the enclosed test chamber.

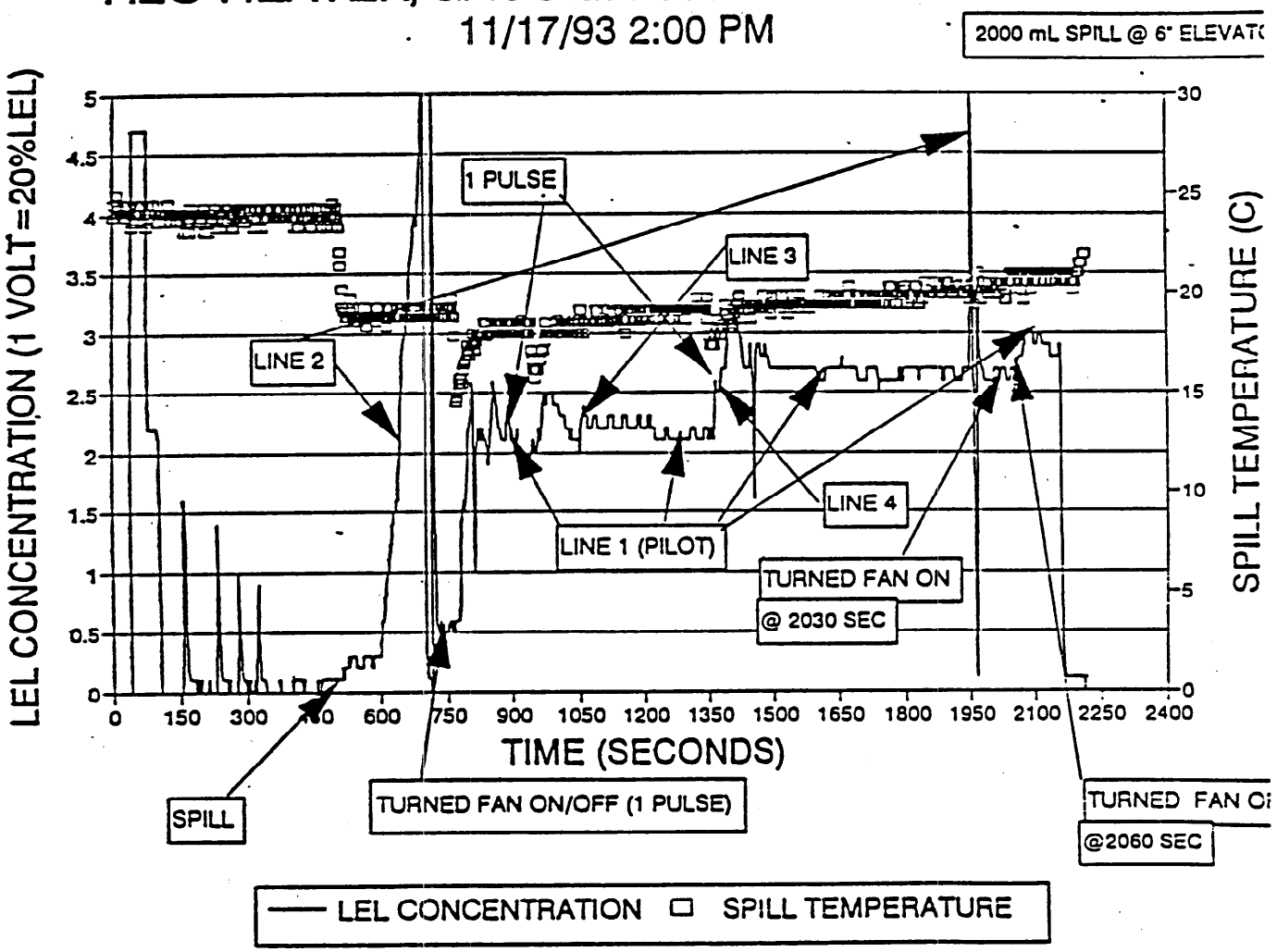
DATE	TEST CONDITIONS	RESULTS
11/30/93 pm * F	Water heater was placed on the floor pan; 1 gallon of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing).	Sample line 1 (pilot) reaches over 100% LEL @ 940 sec (16 min) after the gasoline spill. Periodic "pulsing" (turning fan on/off) was performed every min or 30 sec., three minutes after sample line 2 (3" from the floor) saturated (>100% LEL). The pilot reached over 100% LEL after 9 sets of 5 pulses in 2 sec intervals, with the exception of the first set which was 5 pulses in 4 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.
12/1/93 am * G	Water heater was placed on the floor pan; 1 gallon of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing) that have been covered up with aluminum tape.	Sample line 1 (pilot) reaches a maximum of about 70% LEL @ 2160 sec (36 min) after the gasoline spill. Periodic "pulsing" (turning fan on/off) was performed every 2 min or 1 min, 3½ minutes after sample line 2 (3" off the floor) saturated (>100% LEL). The pilot reached a steady state of about 70% LEL after 19 sets of 5 pulses in 2 sec intervals, with the exception of the first set which was 5 pulses in 4 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.
12/1/93 pm *	Water heater was placed on the floor pan; 1 gallon of gasoline was spilled; aluminum flashing is caulked to the floor pan and has 3 ¼ inch diameter holes (spaced approximately 120° apart around the flashing).	Sample line 1 (pilot) reaches a maximum of about 80% LEL @ 2290 sec (38 min) after the gasoline spill. "Pulsing" (turning fan on/off) was performed a few minutes after sample line 2 (3" off the floor) saturated(>100% LEL). 2½ minutes after the spill, sample line 2 saturated. The pilot reached a steady state of about 82% LEL after 7 sets of pulses: 2 sets of 5 pulses in 4 sec intervals, 2 sets of 8 pulses in 2 sec intervals, a set of 5 pulses in 2 sec intervals, and 2 sets of 10 pulses in 2 sec intervals. After every set of pulses, the hot wire anemometer read air velocities over 200 feet/min.


H20 HEATER/GASOLINE IGNITION PROJECT
11/17/93 10:00 AM
TURNED ON FAN FOR 10 SE
2000 mL spill @ 6" ELEVATION
LINE 2
LINE 3
LINE 4
TURNED FAN
ON/OFF BRIEFLY
SPILL
LINE 2
LINE 1 (PILOT)
ZERO/SPAN
LEL concentration (1 volt=20%LEL)
time (seconds)
LEL concentration
Spill Temp

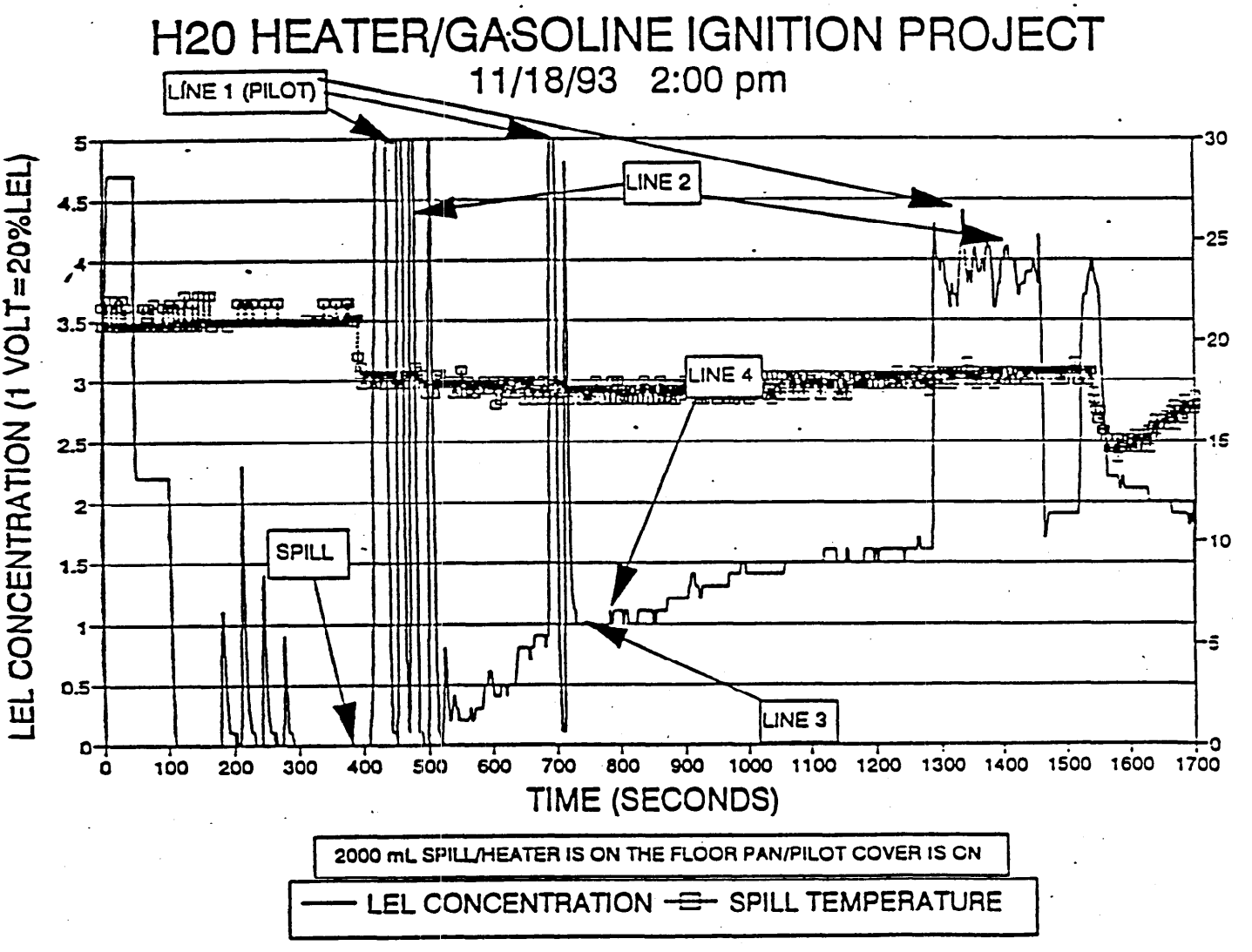
A

H2O HEATER/GASOLINE IGNITION PROJECT

11/17/93 2:00 PM



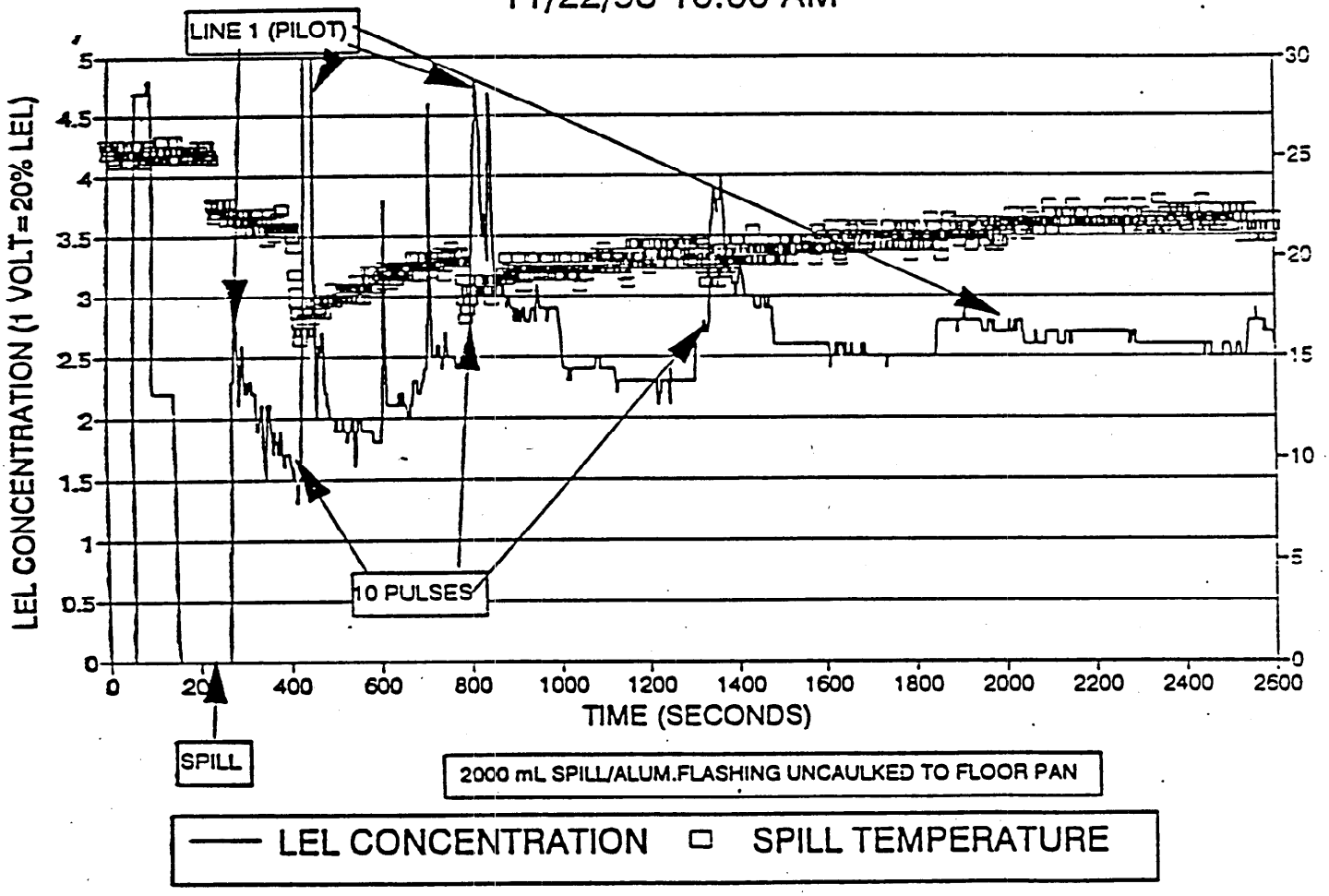
A


H20 HEATER/GASOLINE IGNITION PROJECT
11/18/93 2:00 pm
LINE 1 (PILOT)
LINE 2
LINE 3
LINE 4
SPILL
LEL CONCENTRATION (1 VOLT=20%LEL)
TIME (SECONDS)
2000 mL SPILL/HEATER IS ON THE FLOOR PAN/PILOT COVER IS ON
LEL CONCENTRATION
SPILL TEMPERATURE

B

H20 HEATER/GASOLINE IGNITION PROJECT

11/22/93 10:00 AM



C

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

VOTE SHEET

DATE: NOV 29 1994

TO : The Commission
Sadye E. Dunn, Secretary

FROM : Eric A. Rubel, General Counsel EAR
Stephen Lemberg, Asst. General Counsel
Harleigh Ewell, Attorney, GCRA (Ext. 2217) HE

SUBJECT: Options for Gas-Fired Water Heaters Concerning Ignition of Flammable Vapors

This vote sheet concerns the staff's latest briefing package on options for Commission action to address the risk that gas-fired water heaters will ignite vapors from flammable liquids that are present in the home. Please indicate your vote on the following options.

I. ISSUE AN ADVANCE NOTICE OF PROPOSED RULEMAKING ("ANPR") (a draft ANPR is at Tab N of the briefing package). If voting for this option, please check the action below.

____ 1. APPROVE THE DRAFT FEDERAL REGISTER NOTICE WITHOUT CHANGE.

____ 2. PUBLISH THE DRAFT FEDERAL REGISTER NOTICE WITH CHANGES (please specify).

____ 3. OTHER (please specify).

_____ (Signature) _____ (Date)

II. DO NOT ISSUE AN ANPR FOR THIS PRODUCT AT THIS TIME.

_____ (Signature) _____ (Date)

NOTE: This document has not been reviewed or accepted by the Commission.
Initial rh Date 11/29/94

CPSA 6 (b)(1) Cleared
11/29/94
No Mfr./Privileges or Products Identified

III. WORK WITH INDUSTRY TO DEVELOP A PERFORMANCE STANDARD FOR GAS-FIRED WATER HEATERS, TO BE ISSUED AS A VOLUNTARY STANDARD AND ADOPTED BY THE INDUSTRY AS SOON AS POSSIBLE.

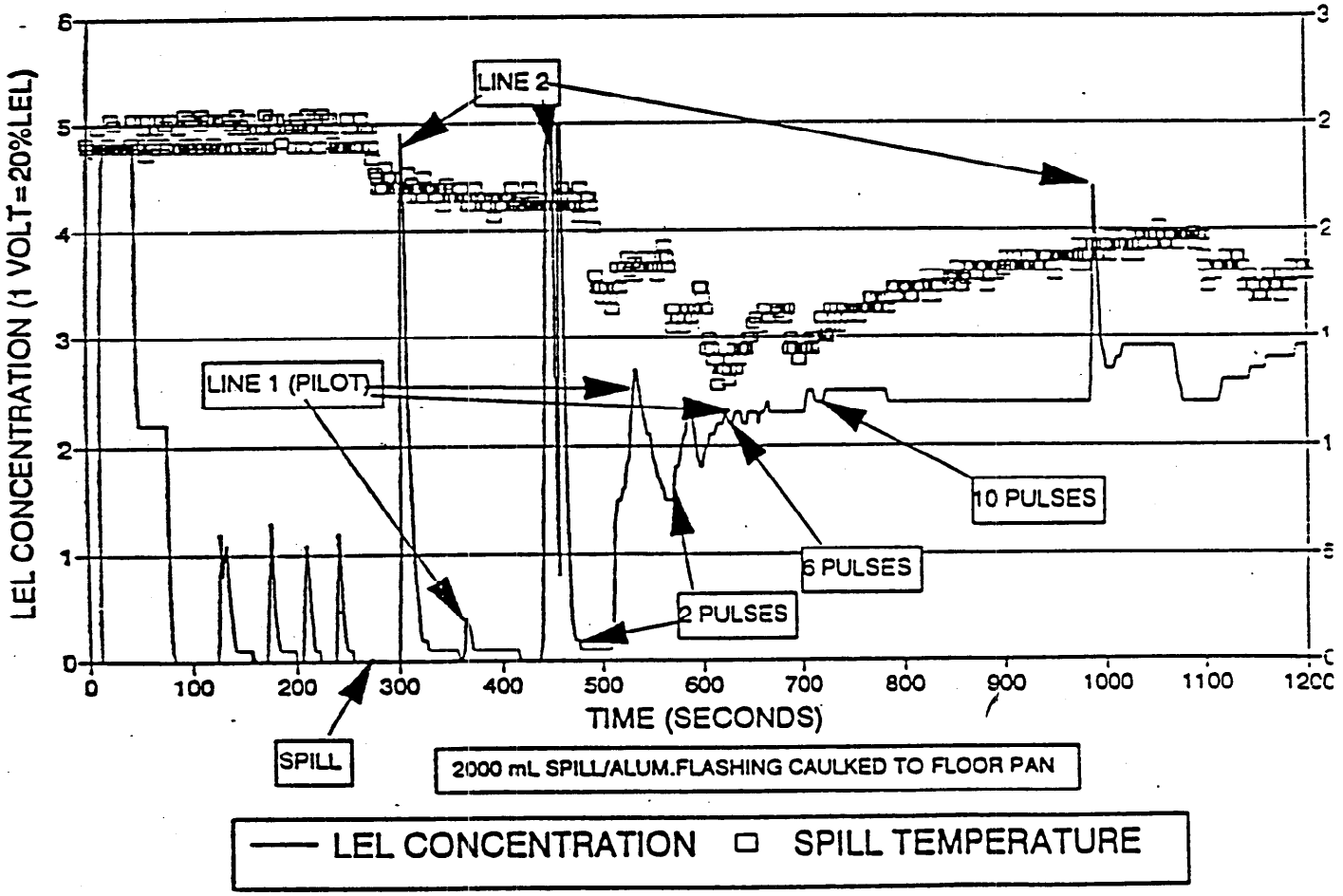
_____ (Signature) _____ (Date)

IV. TAKE OTHER ACTION (please specify).

_____ (Signature) _____ (Date)

Comments/Instructions:

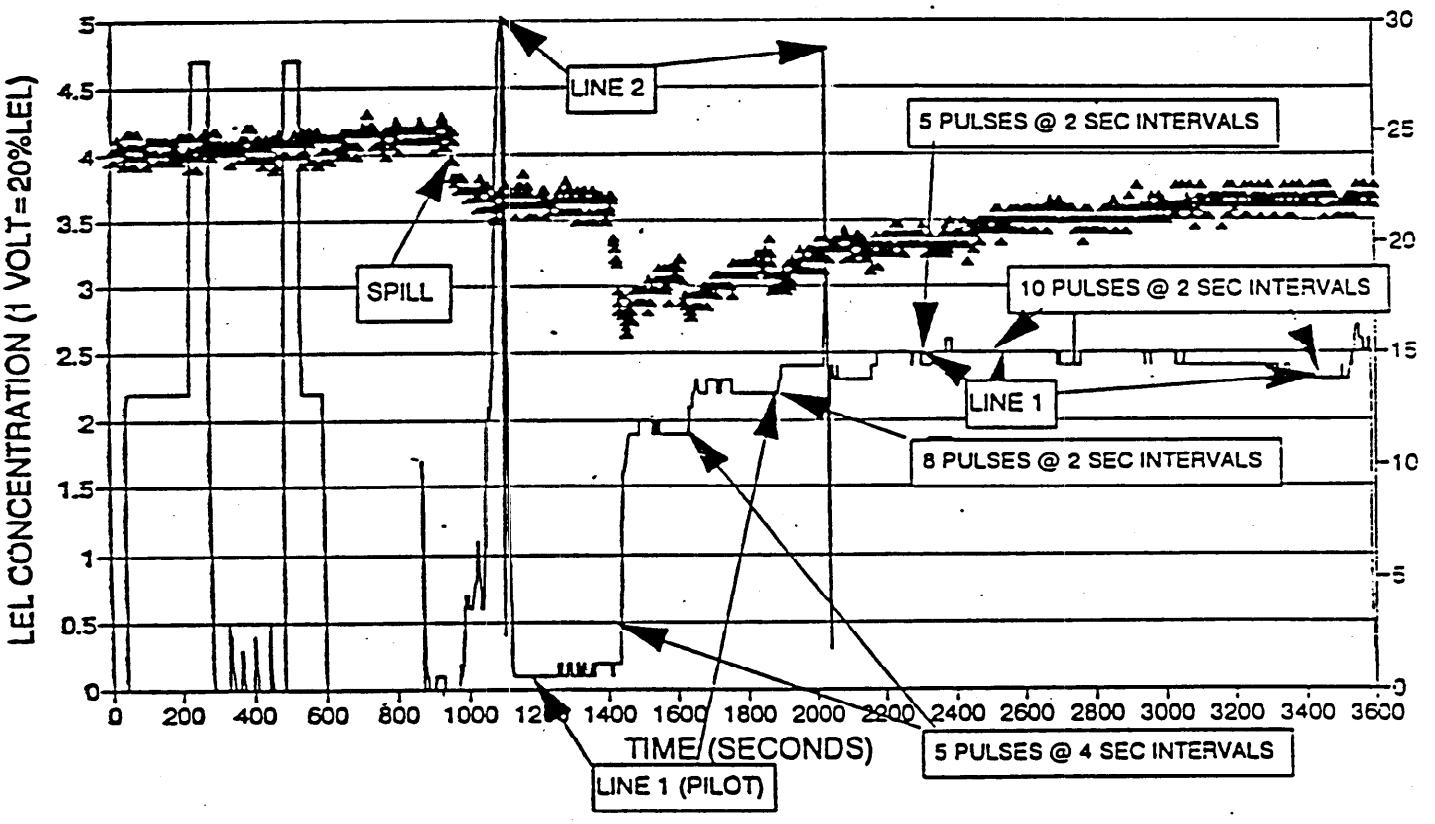
H20 HEATER/GASOLINE IGNITION PROJECT
11/22/93 2:00 PM



D

H20 HEATER/GASOLINE IGNITION PROJECT

11/30/93 9:00 AM



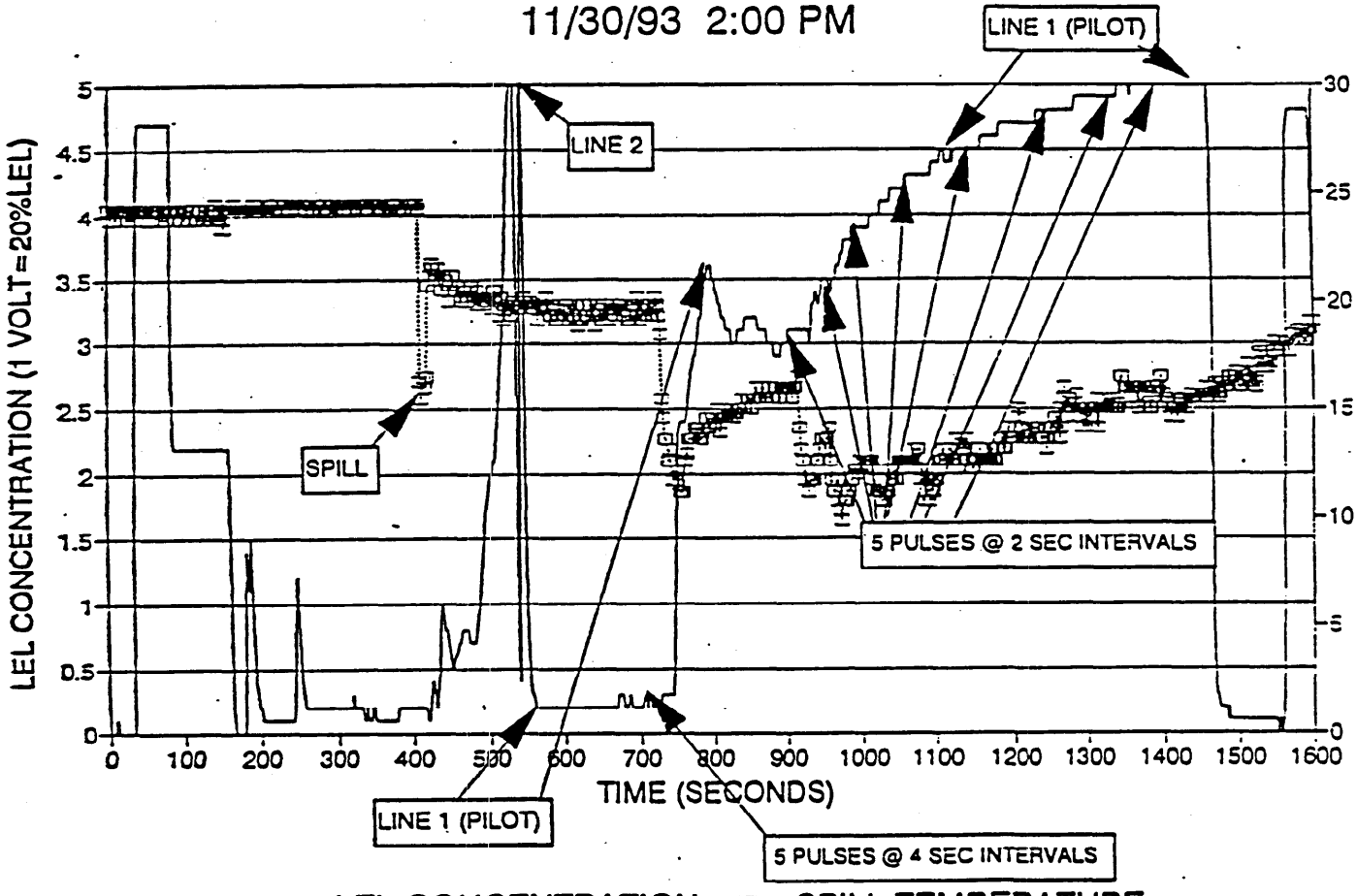
—— LEL CONCENTRATION ▲ SPILL TEMPERATURE

2000 mL SPILL/ALUM.FLASHING CAULKED/3 1/4" HOLES EQUALLY SPACED AROUND FLASHING

E

H20 HEATER/GASOLINE IGNITION PROJECT

11/30/93 2:00 PM



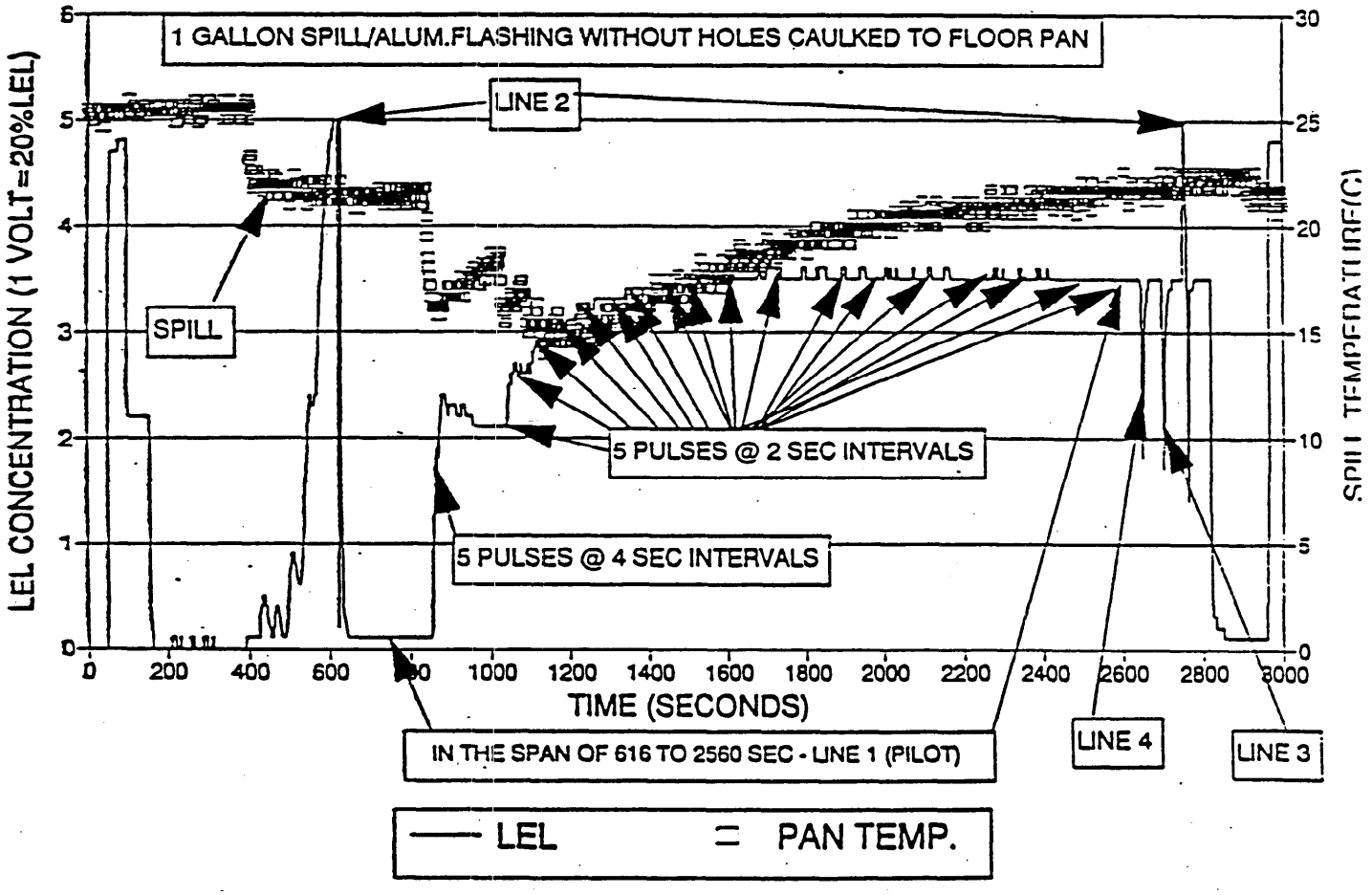
—— LEL CONCENTRATION —≡— SPILL TEMPERATURE

1 GALLON SPILL/ALUM. FLASHING WITH 3 1/4" HOLES CAULKED TO FLOOR PAN

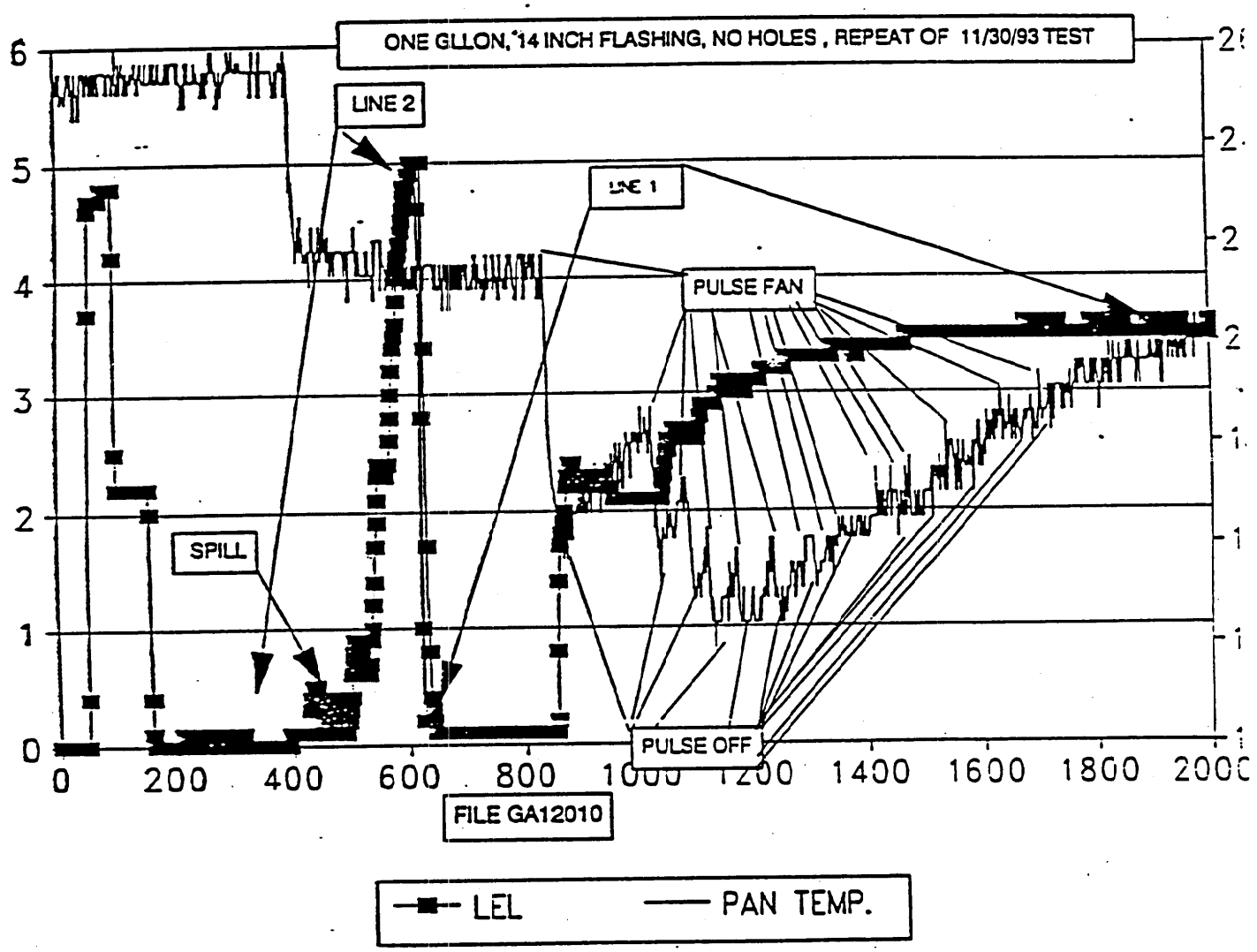
F

H20 HEATER/GASOLINE IGNITION PROJECT

12/1/93 10:00 am

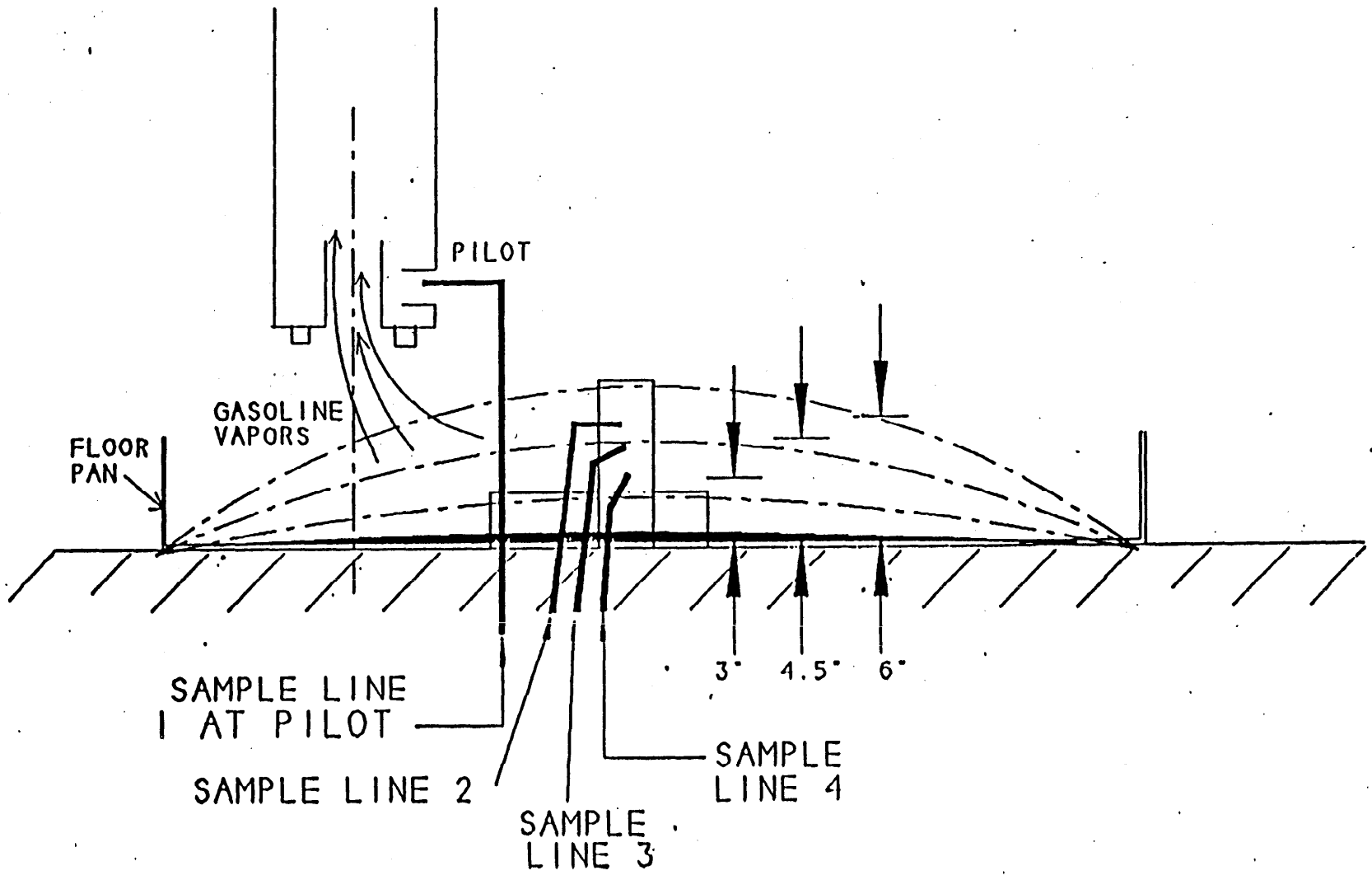


G


ONE GLLON, 14 INCH FLASHING, NO HOLES , REPEAT OF 11/30/93 TEST
LINE 2
LINE 1
PULSE FAN
SPILL
PULSE OFF
FILE GA12010
LEL
PAN TEMP.
0
1
2
3
4
5
6
0
200
400
600
800
1400
1600
1800

H

FIGURE 1 | SIDE VIEW OF H20 HEATER PROJECT TEST SETUP



LIQUID GASOLINE IS SHOWN IN THE SOLID SHADED MENISCUS

NOT DRAWN TO SCALE

FIGURE 2 SIDE VIEW OF H20 HEATER-GASOLINE IGNITION PROJECT TEST SETUP

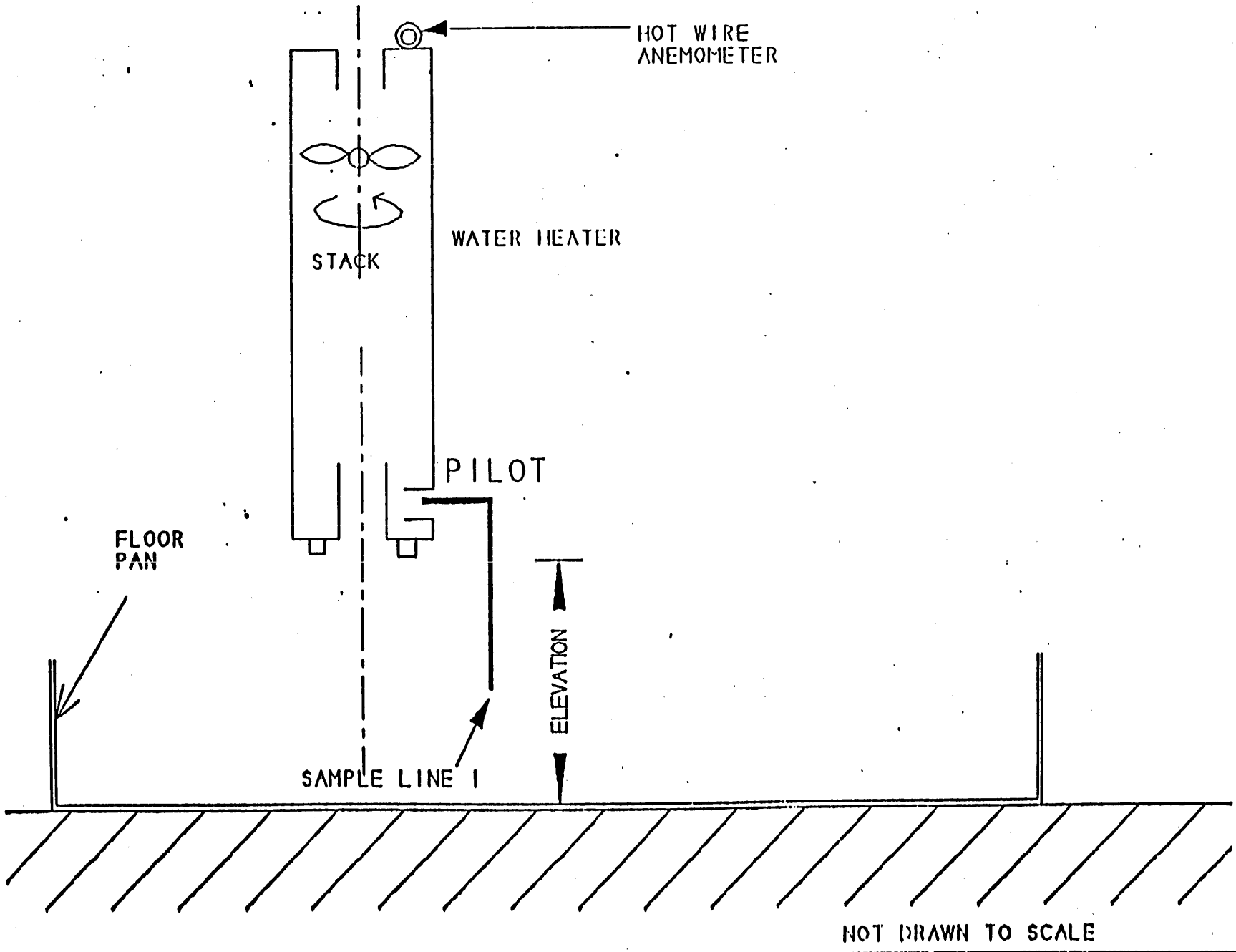
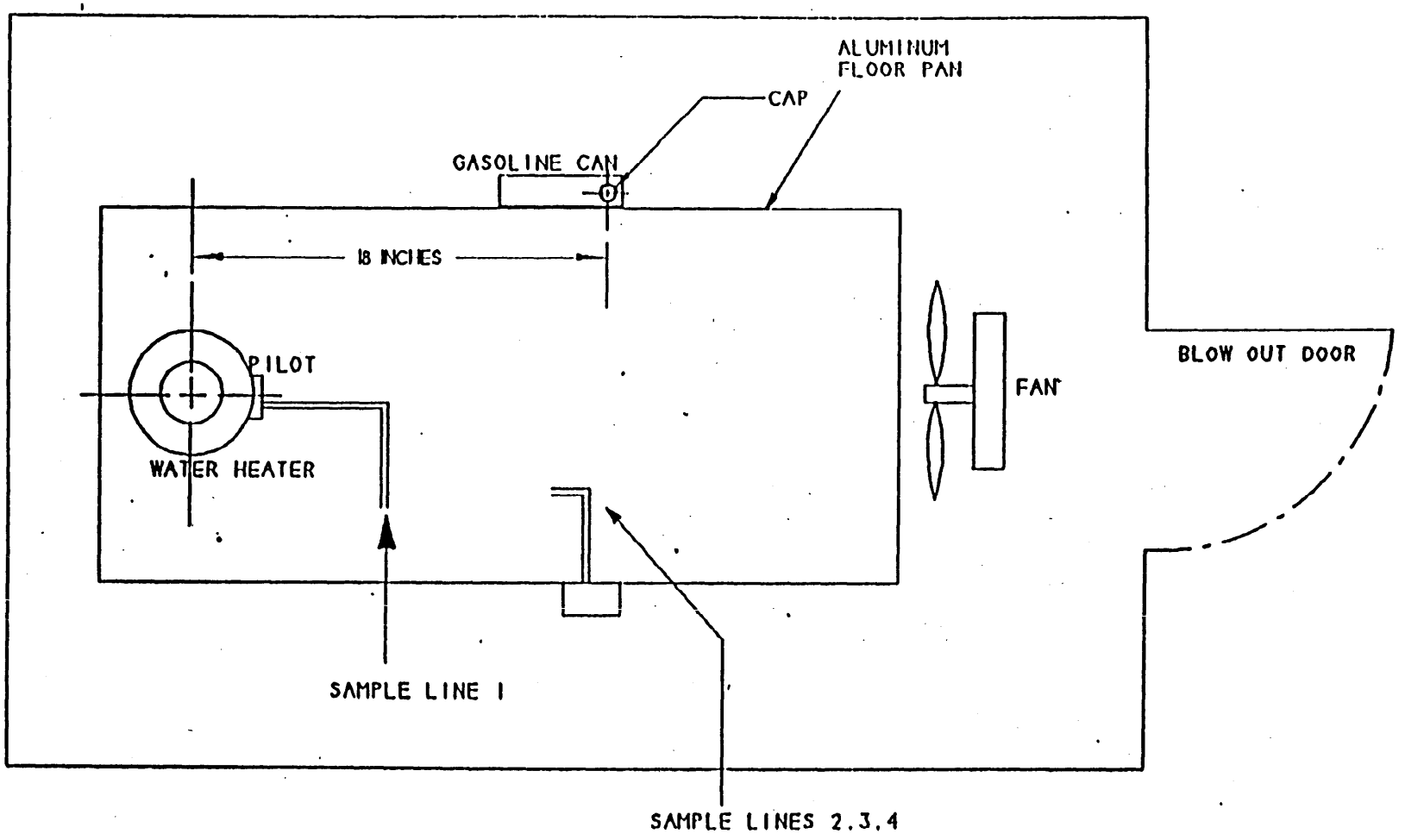
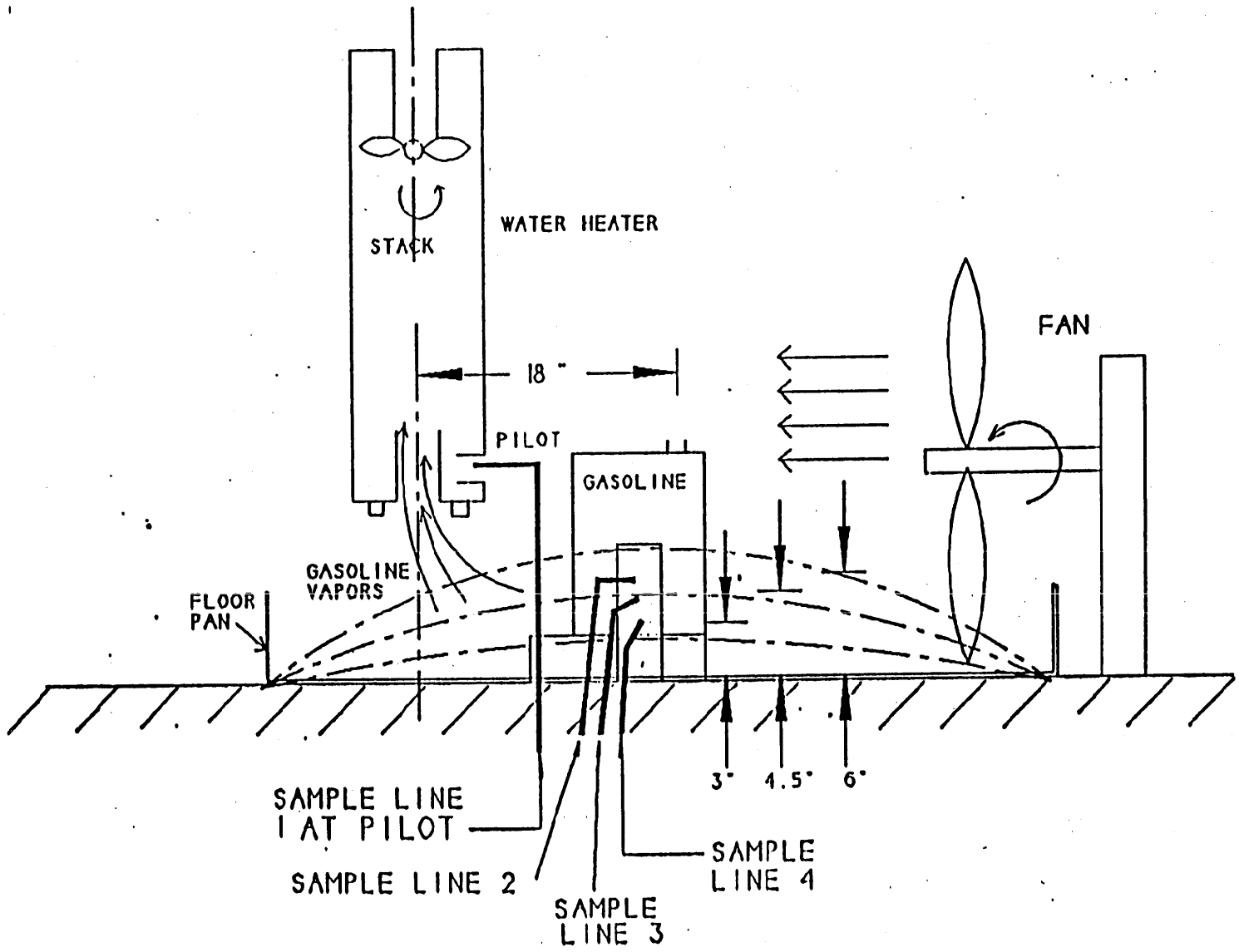


FIGURE 3 | FLOOR PLAN OF 1120 HEATER-GASOLINE IGNITION TEST SETUP



NOT DRAWN TO SCALE.

FIGURE 4 | SIDE VIEW OF 1120 HEATER-GASOLINE IGNITION TEST SETUP



NOT DRAWN TO SCALE

FIGURE 5 H20 HEATER-GASOLINE IGNITION TEST SETUP

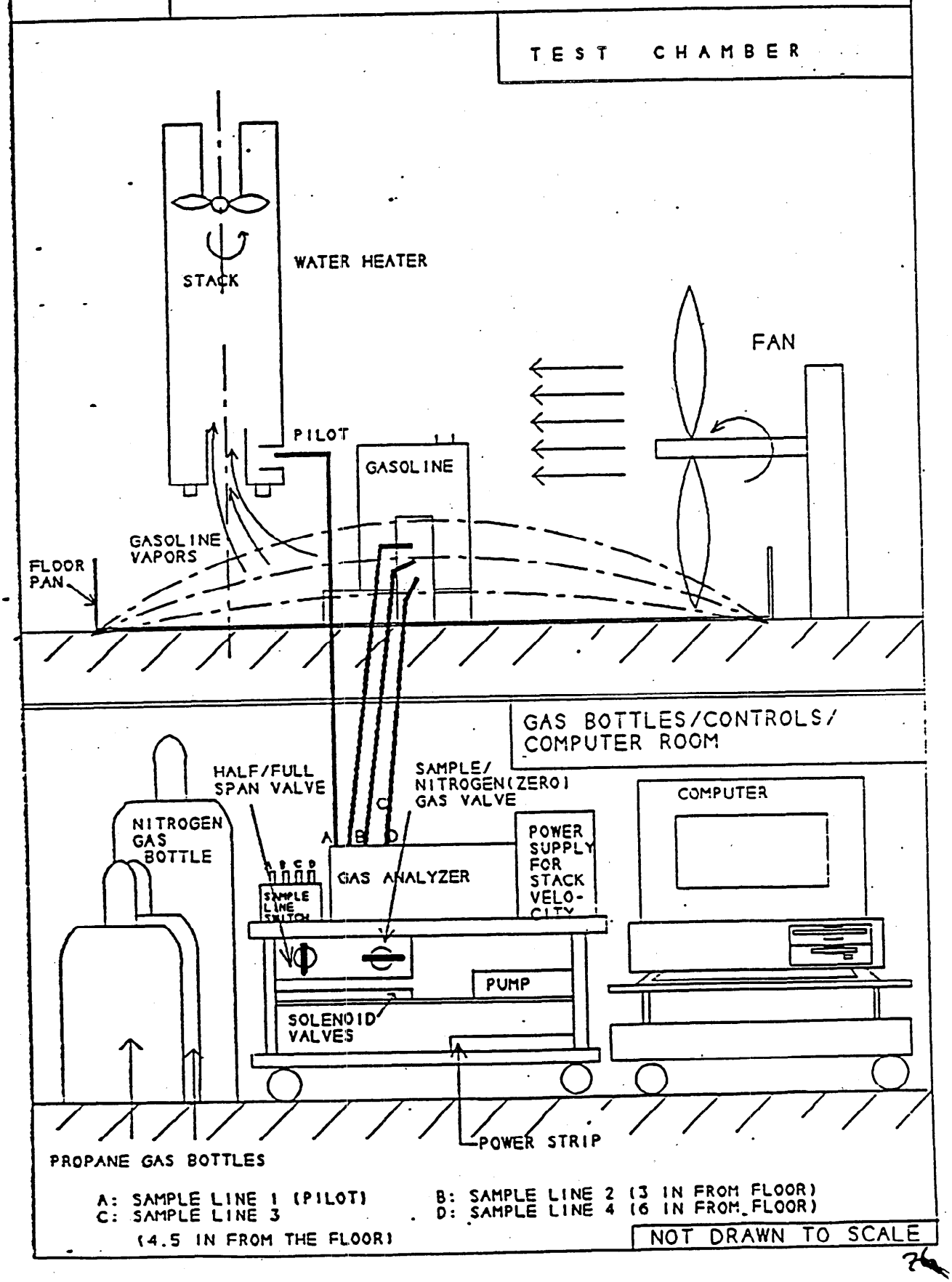


Photo 1
NIST (National Institute of Standards and Technology) fire research building where the water heater/gasoline ignition tests were performed.

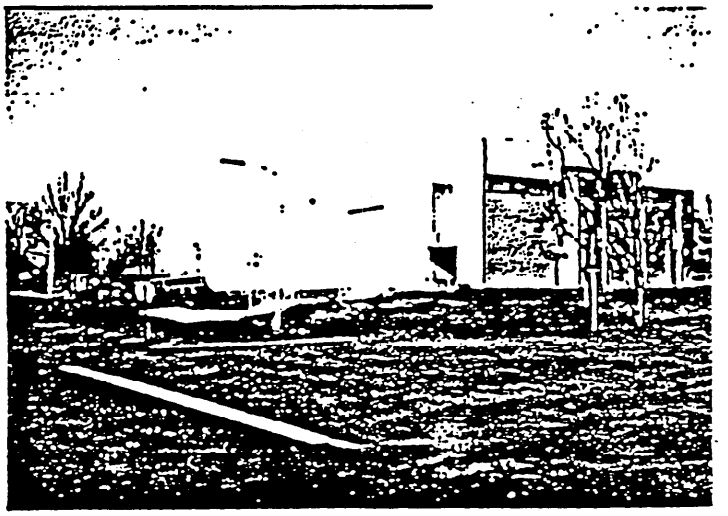


Photo 2
Close up of NIST's fire research building.

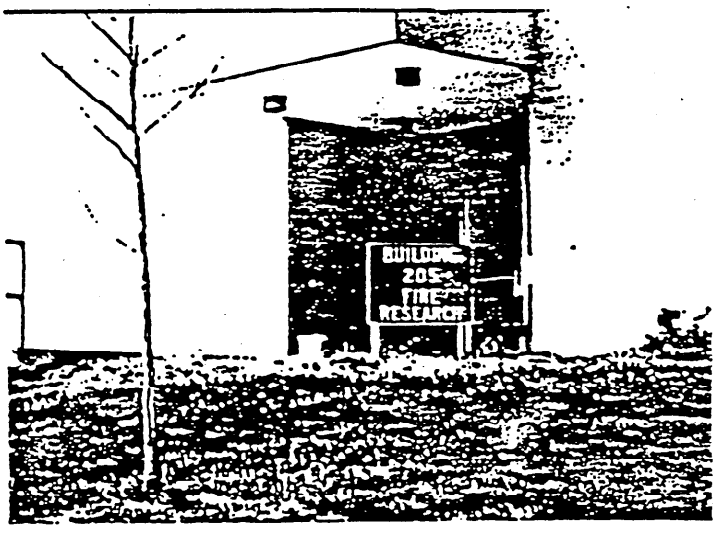


Photo 3
Close up of blow out door latch mechanism.

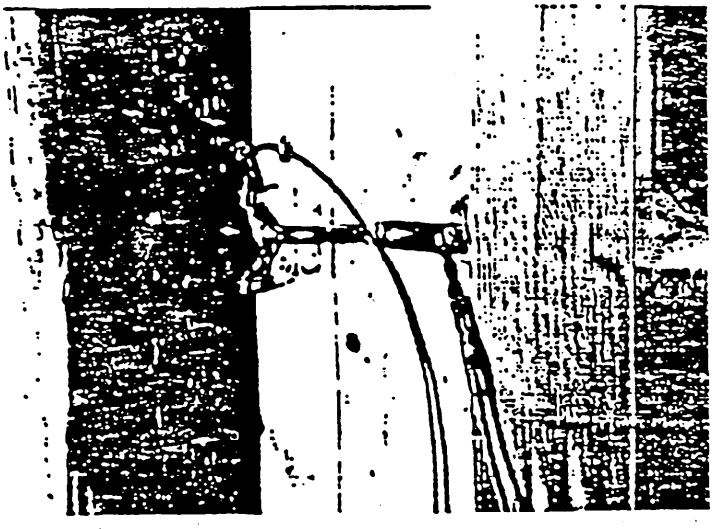


Photo 4
Blow out door

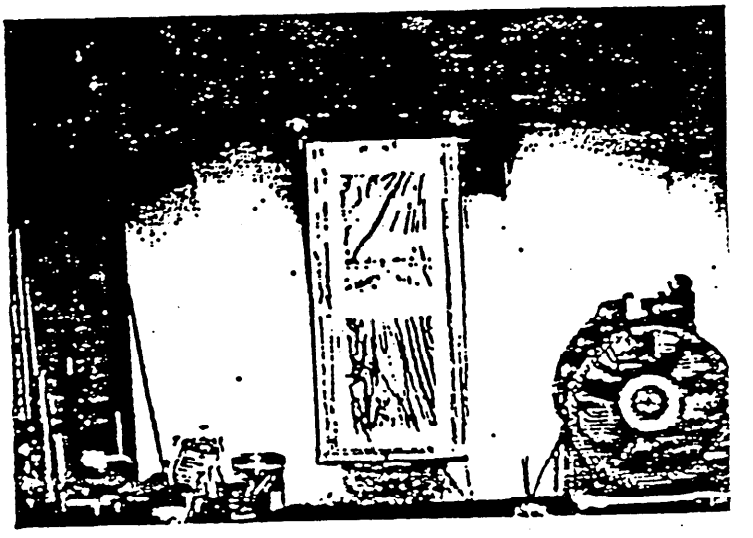


Photo 5
Overall view of the test chamber

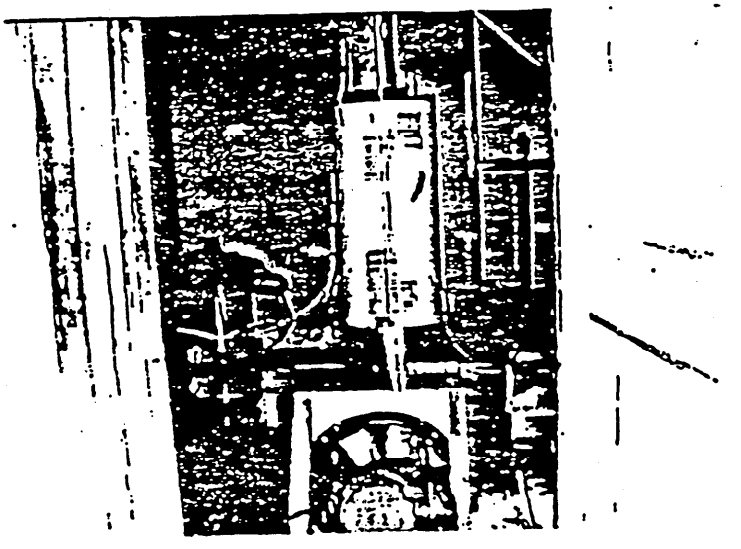


Photo 6
Close up of test setup. Sample lines, hot wire anemometer, and aluminum flashing are shown.

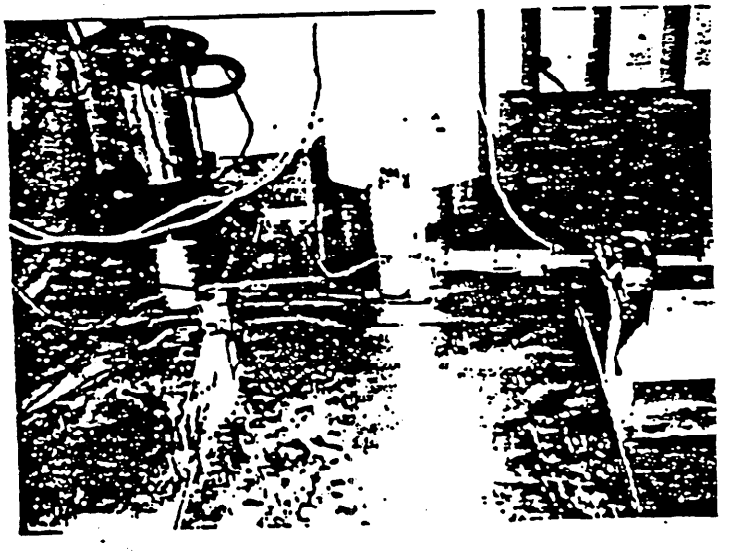


Photo 7
Sample lines "running" to the control room through the wall.

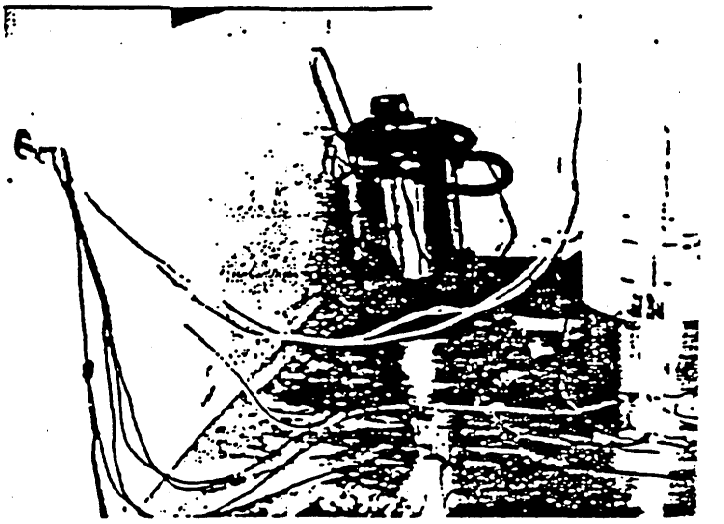


Photo 8
Aluminum flashing is caulked to the floor pan.

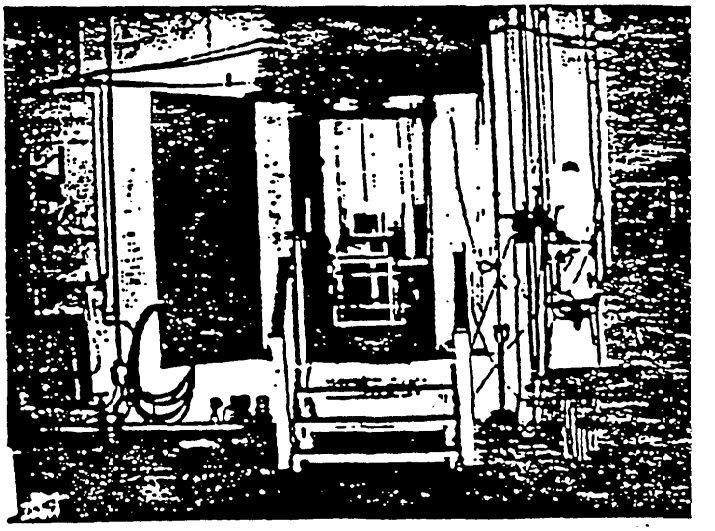



Photo 9
Overall view of the control room.