NUREG/CR-2377
SAND81-7160
RP

Test and Criteria for Fire Protection Of Cable Penetrations

Sandia Project Officer: L. J. Klamerus

October 1981

Prepared for
Sandia National Laboratories
Albuquerque, NM 87185
Operated by
Sandia Corporation
for the
U. S. Department of Energy

Work Performed under Sandia Contract No. 13-7331
Funded by
Division of Engineering Technology
Office of Nuclear Reactor Research
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555
Under Interagency Agreement DOE 40-550-75
NRC FIN No. A1010

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Report To
NUCLEAR REGULATORY COMMISSION
Sandia Laboratories
Albuquerque, New Mexico 87185

Contract #13-7331

Tests & Criteria for Fire Protection of Cable Penetrations

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June 1981
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ABSTRACT

A series of experiments are described which evaluate the effects of test furnace pressure differential and excess pyrolyzates on the fire resistance of cable penetrations installed in fire resistive walls. It is shown that the measured fire resistance of penetrations can be strongly influenced by the pressure difference between the test furnace and the unexposed face of the penetration, and, to a lesser degree, by the presence or absence of excess pyrolyzates. Methods for the local introduction of excess pyrolyzates into a fire test furnace are discussed.

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1. INTRODUCTION

This report is concerned with the test method and criteria used to evaluate the fire resistance of cable penetrations which are installed in fire resistive building elements (e.g., walls and floor/ceiling assemblies). The fire resistance of cable penetrations used in nuclear power generation facilities in the United States are of primary interest here, although this discussion also applies to less critical installations.

The fire induced failure of a cable penetration within an operating nuclear power generation facility has many possible ramifications. These range from simple fire extension beyond a barrier located in a noncritical area of the facility to interference with reactor control functions. The seriousness of the event is clearly dependent upon the location of the fire within the facility and the number and types of functions that are interrupted. The main point is that a cable penetration failure in an operating nuclear power facility could produce substantial ill effects.

The concept of providing compartmentation in order to limit fire damage has been widely employed for many years. The general goal, of course, is to limit the amount of damage sustained by a structure in a given fire event. In order to achieve this goal, physical barriers are erected which will contain fire of a given severity for a specified period of time. Given the present inability to theoretically predict the fire resistance of complex building elements, it is necessary to conduct large scale fire tests for this purpose. As such, the ultimate success of the fire resistive element to fulfill its fire protection function is dependent to a large degree, upon the accuracy with which the test method models the "real" fire event and upon the criteria used to evaluate the resultant test performance.

This report describes three experiments designed to assess the effects of furnace pressure and excess pyrolyzates on the post-flashover fire performance of barrier assemblies that contain cable penetrations. The effects of the parameters are evaluated for penetrations that have a range of fire resistance. It will be shown that the fire resistance of penetrations is primarily dependent upon the pressure difference between the test furnace and the unexposed face of the penetration and, to a lesser degree, on the presence or absence of excess pyrolyzates.

2. DESCRIPTION OF EXPERIMENTAL EQUIPMENT

The large scale vertical furnace used in these experiments is shown in Fig. 1. It consists of a reinforced concrete frame lined with refractory material. The furnace opening is 3.66 m (12 ft-0 in) wide and 3.35 m (11 ft-0 in) high. The furnace is fired by 44 burners using natural gas fuel. The burners can be operated in either a premixed or diffusion mode. During these experiments the burners were operated in a premixed mode. The 44 burners are arranged so that the furnace temperature can be maintained in accordance with the standard temperature-time curve as specified by ASTM Designation E-119. The internal furnace temperature and pressure, the fuel gas flow rate and pressure, and the temperature at various locations on the specimen were measured. All data was recorded and stored by a 100 channel digital data acquisition system.

Furnace temperatures were measured by two sets of nine, Type K thermocouples. One set had their elements encased in 12 mm (1/2 in) standard pipe size inconel sheaths and met ASTM Specifications for this test. The second set of nine Type K thermocouples had their elements encased in 6 mm (1/4 in) o.d. stainless steel tubes packed with MgO. These thermocouples have a much faster response time than the ASTM E-119 thermocouples described above and are used to improve the accuracy of furnace control. The two sets of thermocouples protruded a minimum of 0.3 m (12 in) into the combustion space and can be adjusted to to the required 0.15 m (6 in) from the specimen face. The specific thermocouple placement within the furnace is designated in Fig. 1.

The furnace is equipped with four steel stacks lined with a refractory insulation material. Each stack has an inside diameter of .36 m (14 in) and extends 6.1 m (20 ft) above the top of the furnace. Each stack is equipped with a manually controlled damper*. The internal furnace pressure is determined by the damper opening.

The furnace door assembly, which functions as a specimen holder, is shown in Fig. 2. The door is a steel frame of heavily reinforced 0.38 m, 19.45 kg (15 in, 42.9 lb) "I" beams. It has a horizontal opening of 3.68 m (12 ft-1 in) and a maximum vertical opening 3.05 m (10 ft-0 in). The width of the door is fixed but its height can be adjusted to provide a net opening of 2.13-3.05 m (7 ft-10 in). The bottom of the frame on which the specimen rests consists of a steel "I" beam covered with fire bricks. Specimens are held in the frame by brackets which bolt along the perimeter of the door frame. Although the door frame is designed to allow loading of the specimen, no load was applied during the experiments described here. The entire door frame is mounted on an overhead monorail to permit the specimen to be housed in a protected bay prior to the experiment.

The error limits of the temperatures measurements are functions of the thermocouple alloy, the analog to digital converter accuracy, and radiation effects. All temperatures were measured with thermocouples fabricated from standard grade Type K, chromel-alumel wire. The error limits of this alloy combination, as supplied by the manufacturer, are the greater of either +− 2.2°C or +− 0.75% of the indicated temperature. The digital to analog converter and the thermocouple linearization circuitry used have an accuracy of 1°C. At 1000°C, the maximum error is +− 8.5°C. Thus the error limits can be bracketed between +− 3.5-8.5°C.

Additional temperature measurement errors can result from radiation effects associated with the bare bead thermocouple configuration utilized during these experiments. Radiation errors of this type have been investigated by Newman and Croce**. The radiation errors decrease as the gas flow velocity (rate of aspiration) across the thermocouple bead increases. At gas flow rates in excess of approximately 7 m/sec., radiation errors are negligible. First order calculations of the gas velocity across the thermocouple beads mounted in the open penetrations during these experiments indicate that for a pressure differential of 5-10 Pa, the lower

*The manual control of the dampers has recently been changed to an electrical control, but for these experiments the manual control damper was used.

**Newman, J.S. and Croce, P.A., "A Simple Aspirated Thermocouple for Use in Fires," Journal of Fire & Flammability, 10, p. 326, October 1979.

penetrations would experience a gas flow velocity of approximately 3-4 m/sec., while the upper penetrations would encounter flow rates of about 5.4-7.6 m/sec. Thus the radiation induced errors at the center of the penetrations are minor. Due to uncertainties in the flow field conditions on the unexposed face of the test walls above the penetrations, calculations of radiation induced errors at these locations were not made. Errors in the differential pressure measurements, using the Validyne DP-45 transducer employed during these experiments, are on the order of +− 1.25 pascals.

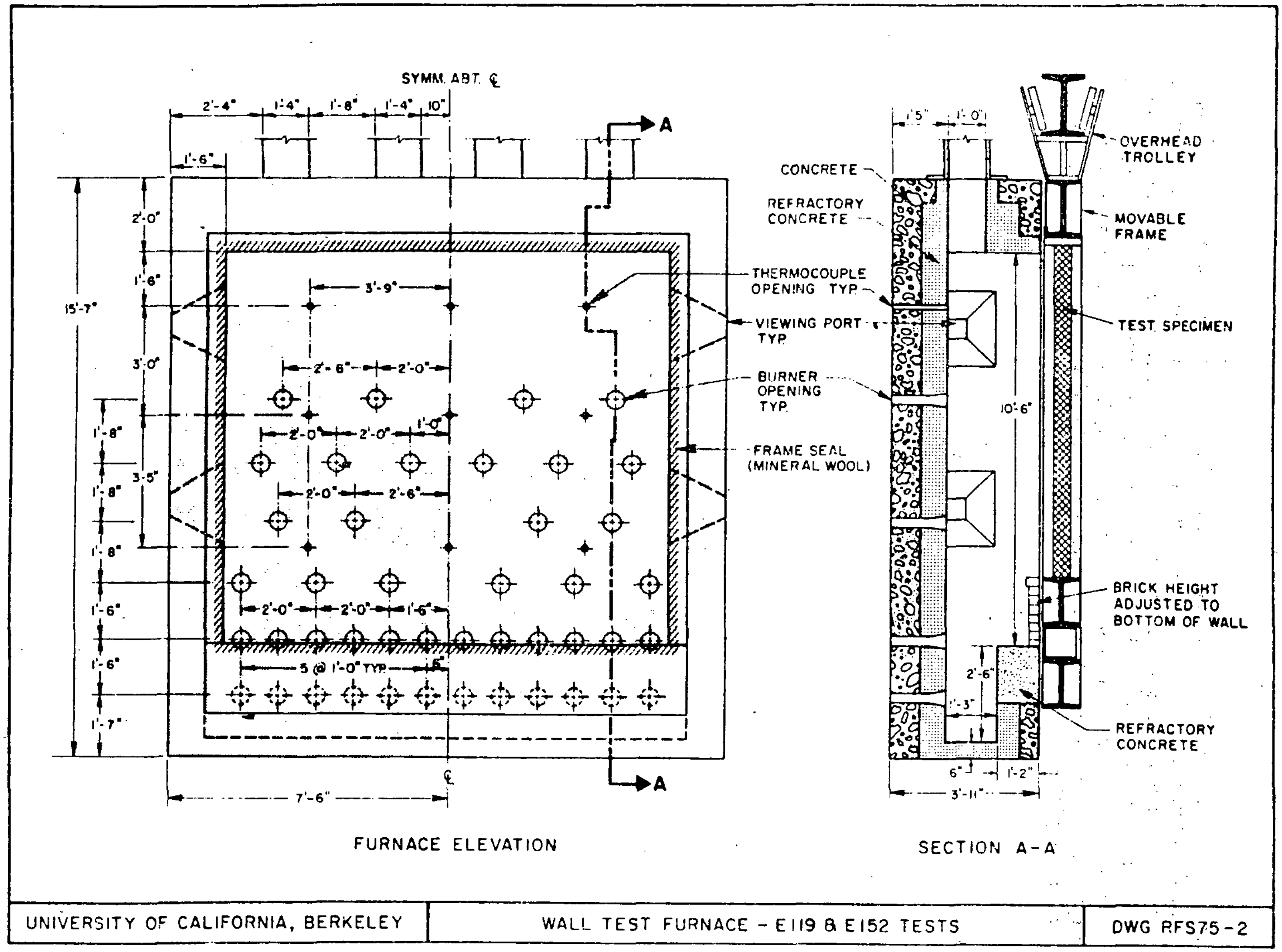


FIGURE 1: FIRE TEST FURNACE

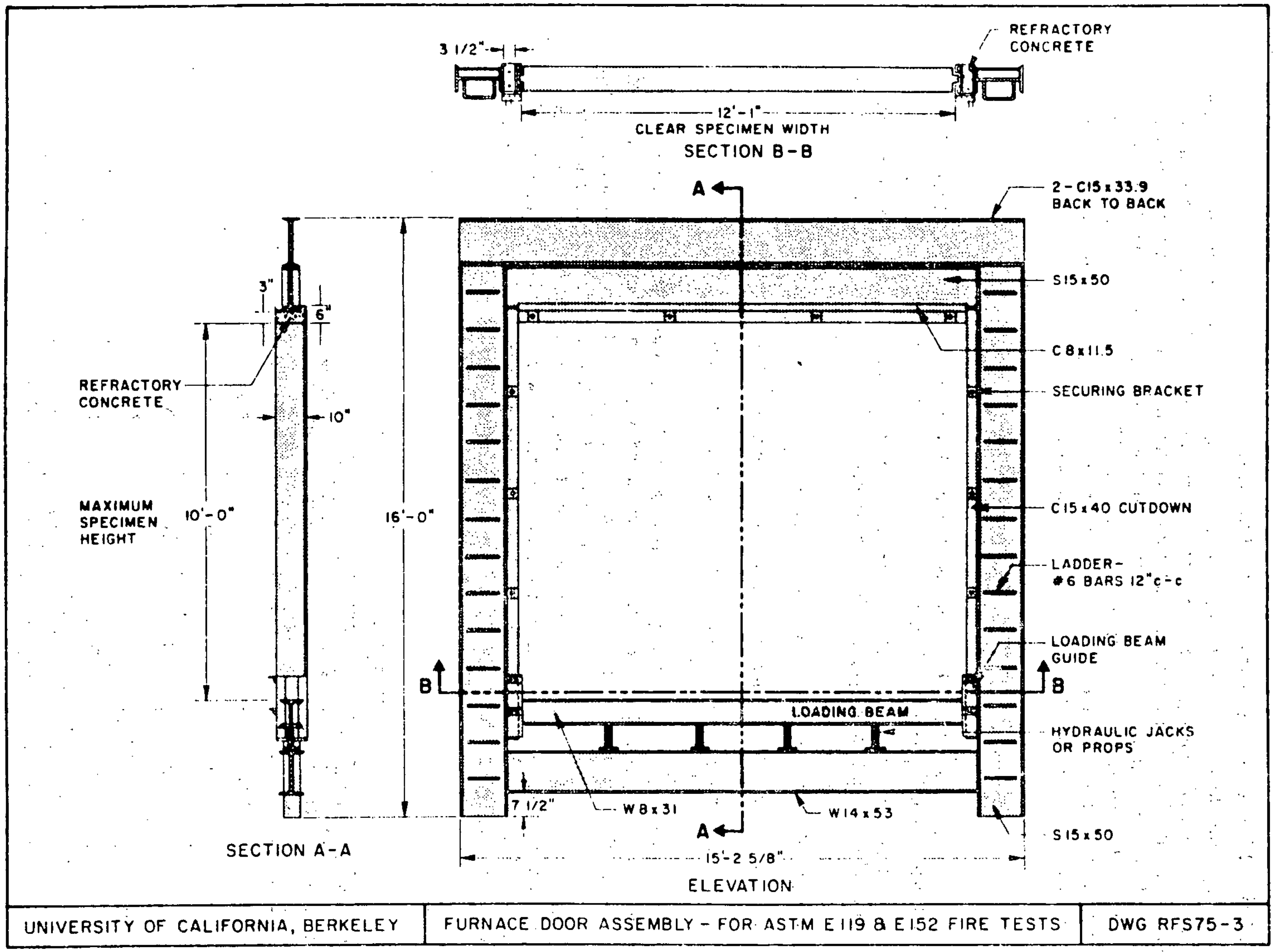


FIGURE 2: FURNACE DOOR ASSEMBLY

3. DESCRIPTION OF EXPERIMENTAL ASSEMBLIES

Each of the three experiments employed identical walls. The walls consisted of a 76 mm (3 in) thick, phenolic impregnated, paper honeycomb core covered on each side with three layers of 13 mm (1/2 in) thick gypsum wallboard. The finished walls were .152 m (6 in) thick, 2.44 m (8 ft-0 in) high and 3.66 m (12 ft-0 in) in length. A total of six penetrations were introduced into each wall. The penetrations measured .152 m x .152 m (6 in x 6 in) and were symmetrically arranged as shown in Fig. 3. The conditions present at each of the penetrations during the experiments are explained in the following sections.

3.1. Experiment #1 - Effects of Differential Furnace Pressure and Short Term Excess Pyrolyzate Production on Unprotected Penetrations

This experiment was conducted to investigate the following three variables under local conditions of both positive and negative furnace pressure:

a) open penetration without excess pyrolyzate or cable;

b) open penetration with excess pyrolyzate but without cable; and,

c) open penetration with cable but without excess pyrolyzate.

Excess pyrolyzates were introduced locally to selected penetrations by the installation of a fuel pan beneath the penetration. The fuel pans consisted of steel containers measuring .152 m x .152 m x .30 m (6 in x 6 in x 12 in). The pans were mounted beneath the penetration as shown in Fig. 4. Each fuel pan contained a total of 1 kg (2.2. lbs) of polyethylene. The conditions at each of the penetrations are given in Table I. Details of the installation of cable and fuel pans are presented in Fig. 4. Each of the six penetrations were instrumented with three 20 AWG Type K thermocouples, also shown in Fig. 4. The experimental assembly was subjected to the heating history prescribed by ASTM E-119.

TABLE I

Conditions at Each of the Six Penetrations During Experiment # 1

Penetration Designation	Pressure Differential	Excess Pyrolyzates	Cable Present	Penetration Seal
1A	Positive	Yes	No	No
1B	Negative	Yes	No	No
2A	Positive	No	No	No
2B	Negative	No	No	No
3A	Positive	No	Yes	No
3B	Negative	No	Yes	No

3.2. Experiment #2 - Effects of Differential Furnace Pressure and Long Term Excess Pyrolyzate Production on Protected and Unprotected Penetrations.

This experiment was conducted in order to evaluate the effects of excess pyrolyzate production and furnace pressure over a longer time period than was possible during Experiment #1. Additionally, this experiment investigated the effects of excess pyrolyzates and furnace pressure on two different cable types and on a ceramic fiber sealant material.

The fuel containers for the production of excess pyrolyzates were increased in size from the .152m x .152 m x .30 m (6 in x 6 in x 12 in) pans utilized in the first experiment to .152 m x .30 m x .30 m (6 in x 12 in x 12 in). Fuel pans containing 6.8 kg (15 lbs) polyethylene, were fitted beneath each of the six penetrations. The conditions at each of the penetrations are presented in Table II. The pressure conditions shown in Table II are for the general condition at the penetration. However, as explained earlier, the furnace pressure was cycled during the test to produce short periods in which all of the penetrations were subjected to either positive or negative pressure differentials. Details of the installation of cable and fuel pans are presented in Fig. 5. The thermocouple placement utilized during the first experiment was used at each of the penetrations during this experiment as was the ASTM E-119 temperature-time history.

TABLE II

Conditions at Each of the Six Penetrations During Experiment # 2

Penetration Designation	Pressure Differential	Excess Pyrolyzates	Cable Present	Penetration Seal
1A	Positive	Yes	Yes	No
1B	Negative	Yes	Yes	No
2A	Positive	Yes	Yes	No
2B	Negative	Yes	Yes	No
3A	Positive	Yes	Yes	Yes
3B	Negative	Yes	Yes	Yes

3.3. Experiment #3 - Investigation of Methods for Rate Controlled Introduction of Excess Pyrolyzates and Evaluation of a Combustible Penetration Seal Under Negative Pressure Test Conditions

This experiment was conducted to evaluate alternate methods of introducing excess pyrolyzates into the furnace and to investigate the fire resistance performance of a highly combustible sealant material when tested under negative pressure conditions.

The size of the fuel containers utilized during Experiment #2,.152 m x .30 m x .30 m (6 in x 12 in x 12 in) was not changed; however, different fuel materials were employed. The polyethylene utilized during the first two experiment was replaced with 6.8 kg (15 lbs) of paraffin in five of the containers and with No. 2 heating oil in the sixth. These changes were made for two reasons. First, the paraffin wax proved to be more readily available and less expensive than the polyethylene. Second, the fuel oil was investigated as an excess pyrolyzate source because of the ability to regulate its supply to the fuel pan during an experiment. This would then enable conducting long duration experiments having a constant supply of excess pyrolyzates.

The conditions present at each of the six penetrations are presented in Table III and Fig. 6. The design of the heating oil excess pyrolyzate container is shown in Fig. 26.

TABLE III				
Conditions at Each of the Six Penetration During Experiment # 3				
Penetration Designation	Pressure Differential	Excess Pyrolyzates	Cable Present	Penetration Seal
1A	Negative	Heating Oil	No	No
1B	Negative	Paraffin	Yes	Silicon Foam
2A	Negative	Paraffin	Yes	Ceramic Fiber
2B	Negative	Paraffin	Yes	Ceramic Fiber
3A	Negative	Paraffin	Yes	Silicon Foam
3B	Negative	Paraffin	Yes	Urethane Foam

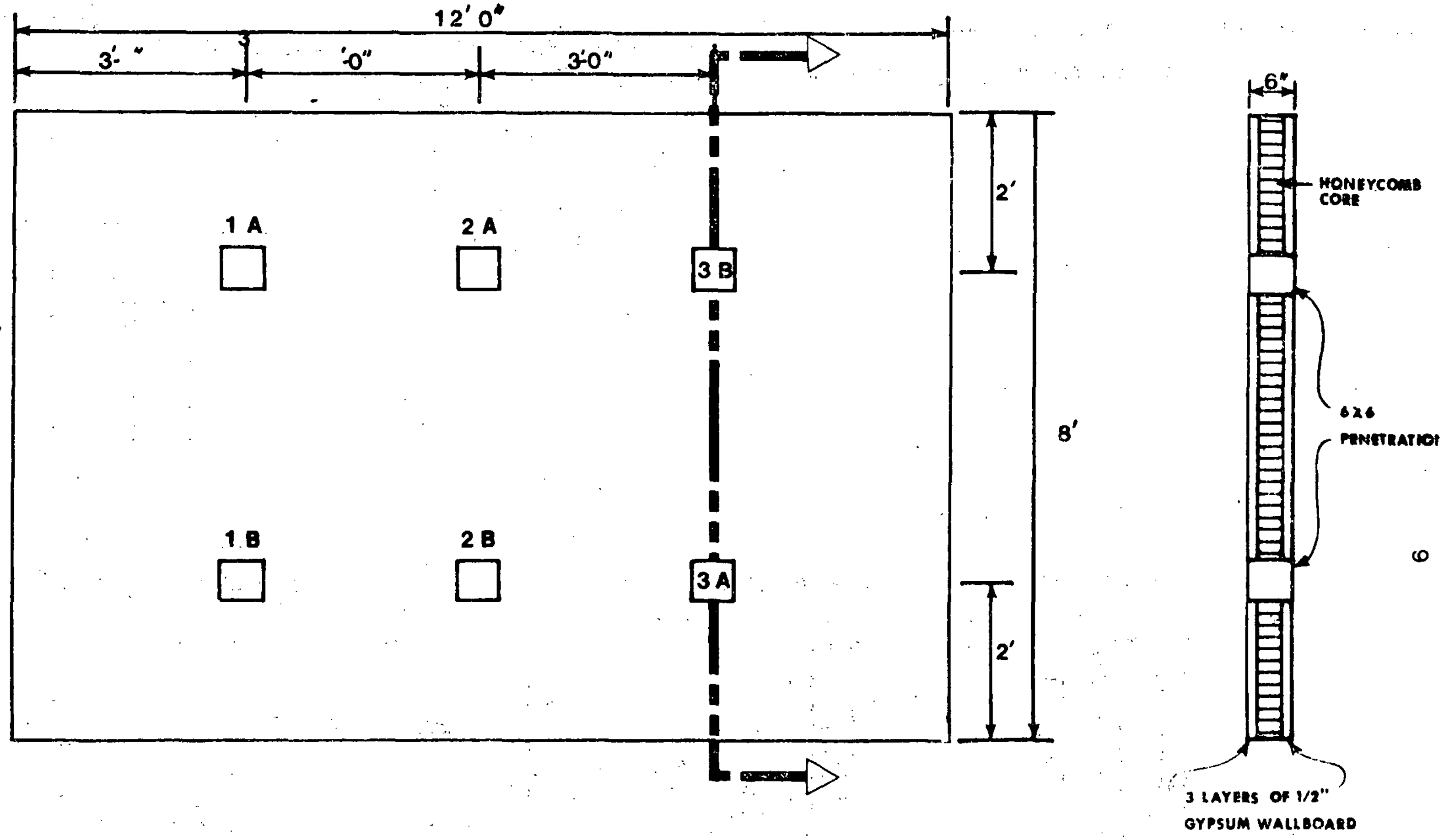
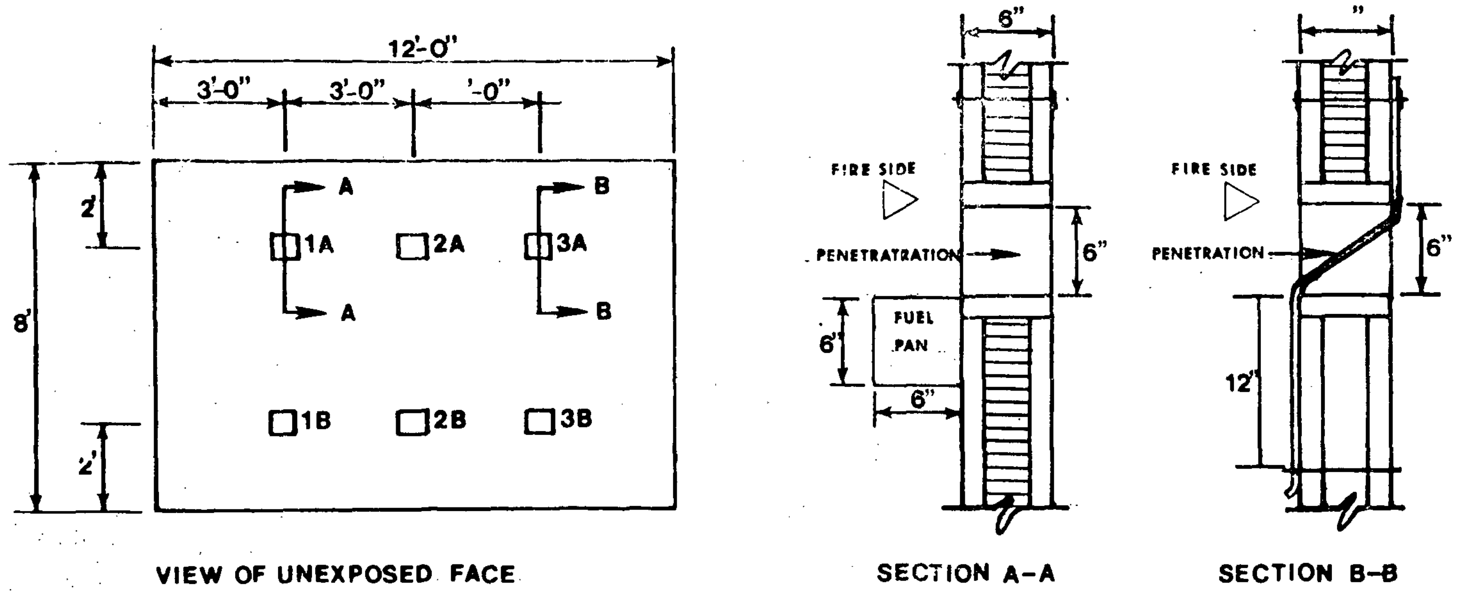


FIGURE 3: CONSTRUCTION OF EXPERIMENTAL WALLS AND LOCATION OF PENETRATIONS



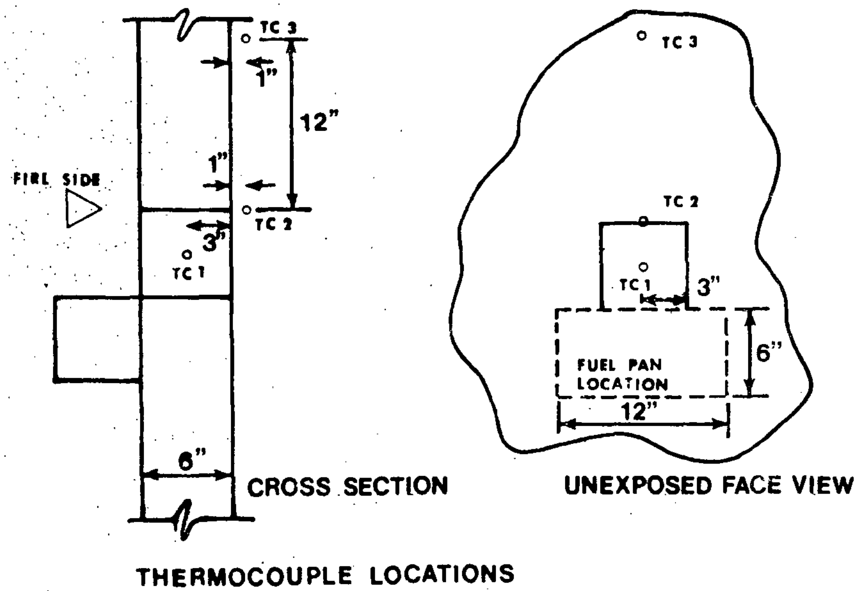
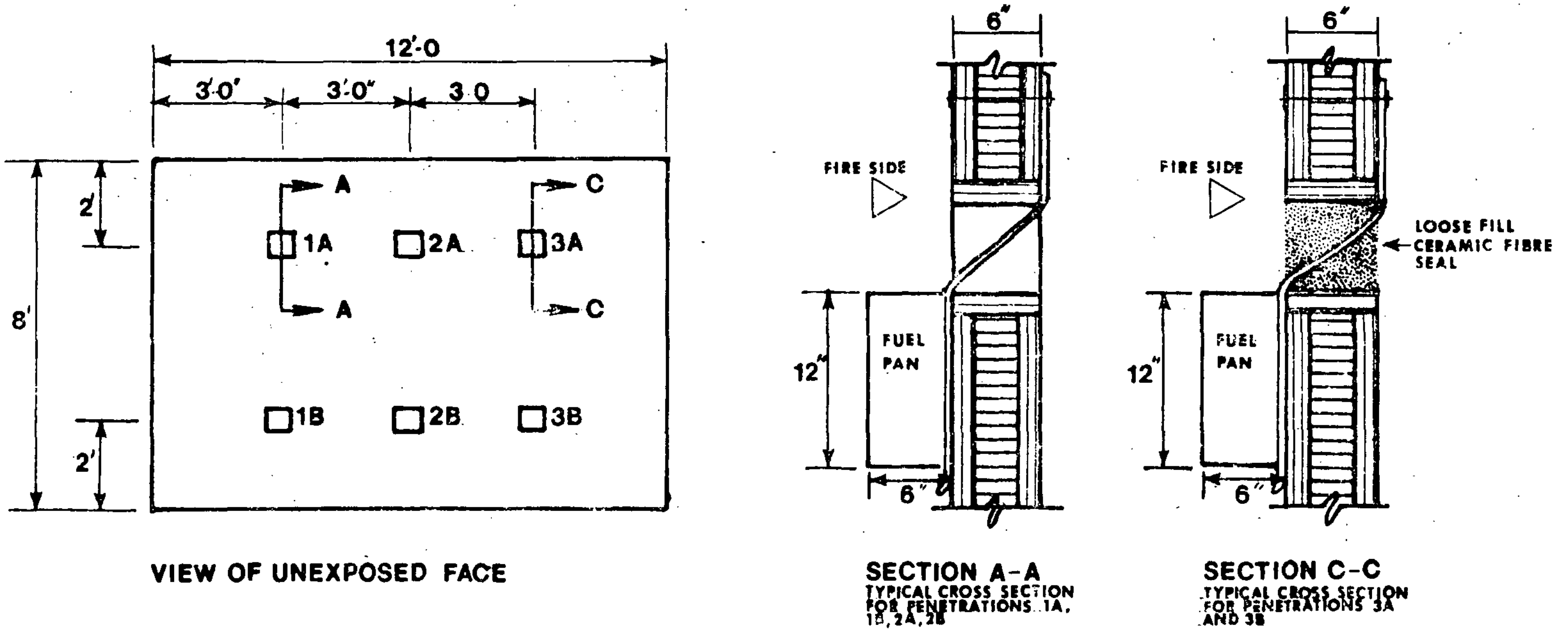


FIGURE 4 : EXPERIMENTATION NO.1
PENETRATION LOCATIONS AND INSTALLATION
OF FUEL PANS, CABLE & THERMOCOUPLES



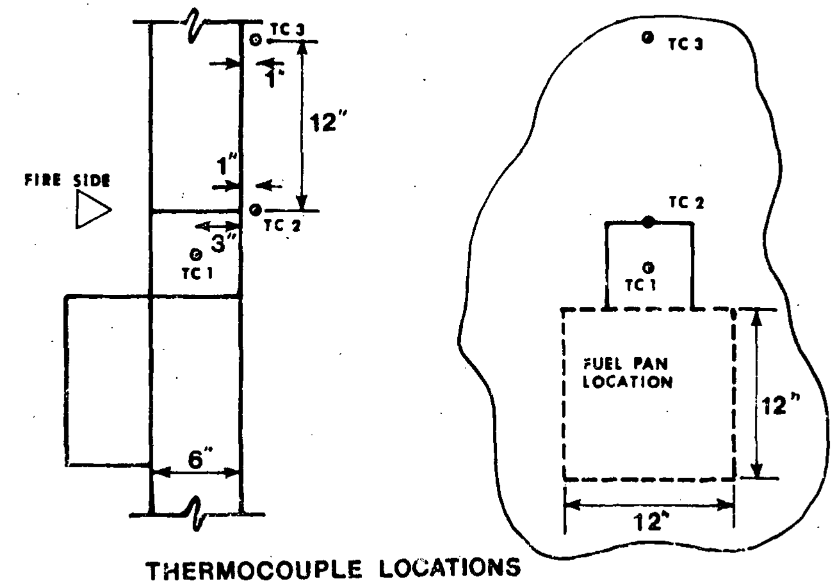


FIGURE 5 : EXPERIMENTATION NO. 2
PENETRATION LOCATIONS AND INSTALLATION
OF FUEL PANS, CABLE & THERMOCOUPLES

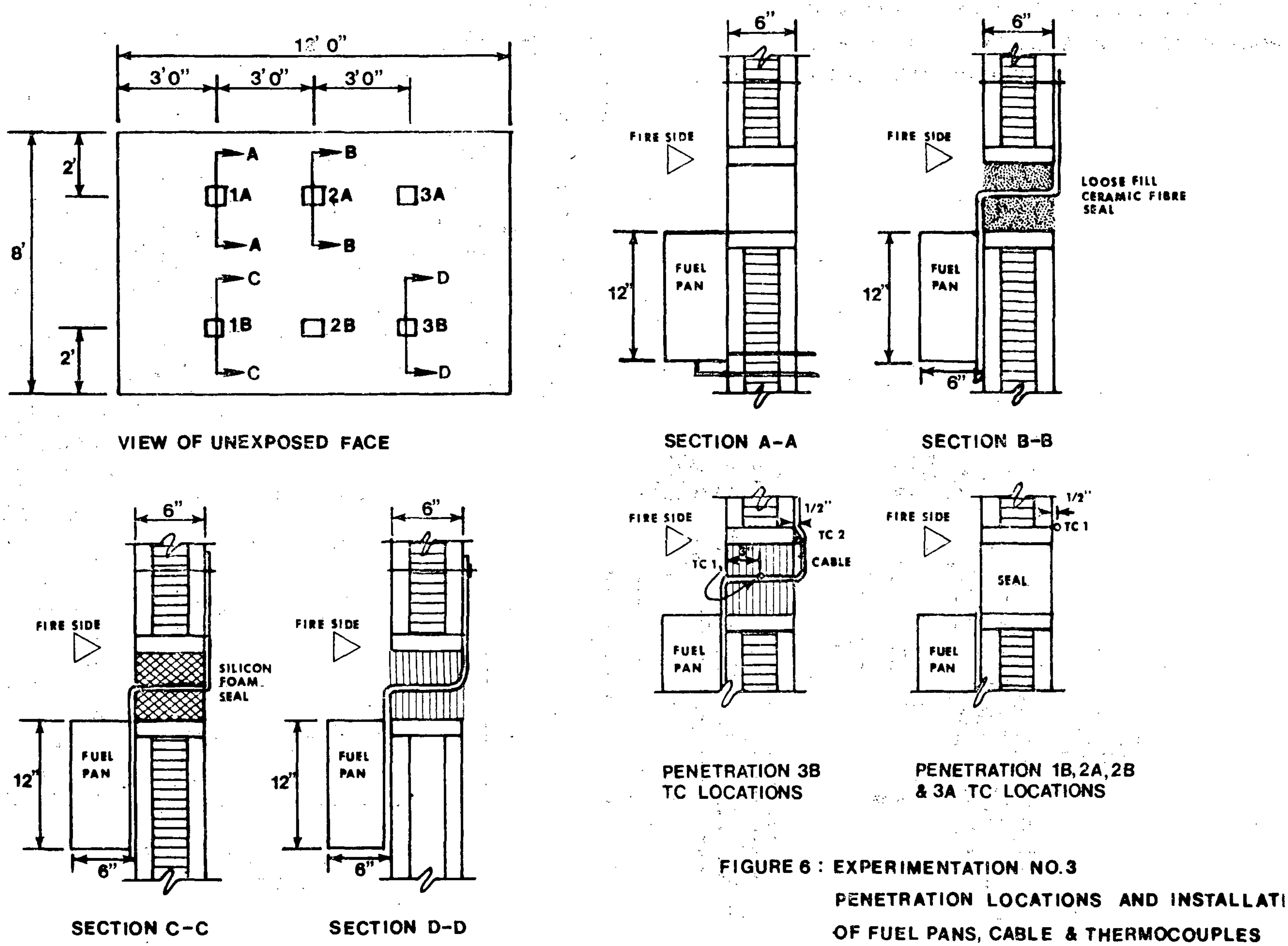


FIGURE 6 : EXPERIMENTATION NO.3
PENETRATION LOCATIONS AND INSTALLATI
OF FUEL PANS, CABLE & THERMOCOUPLES

4. EXPERIMENTAL PROCEDURE & RESULTS

4.1. Experiment #1 - Effects of Differential Furnace Pressure and Short Term Excess Pyrolyzate Production on Unprotected Penetrations

The experimental assembly was subjected to the ASTM E-119 temperature-time history for a period of approximately 33 minutes. The end point of this experiment was determined by the time required to combust all excess pyrolyzates contained within the two fuel pans. The furnace temperature-time history is presented in Fig. 7 and Tables IV and V. The internal furnace pressure at both the upper and lower penetrations, is presented in Fig. 8 and Table VI. The log of visual observations recorded during this experiment is presented in Table VII.

The temperatures recorded at penetrations 1A and 1B are presented in Figs. 9 and 10, and Tables VIII and IX, respectively. A comparison of these penetration temperatures clearly indicate the effects of furnace pressure and excess pyrolyzates on penetration fire performance. The combined effects of furnace pressure and excess pyrolyzates are shown schematically in Fig. 11. If, as was done through-out most of this experiment, the neutral pressure plane within the furnace is maintained at approximately the 1/3 height of the wall, then, the upper penetration will be subjected to negative pressure.

Fig. 11 shows that under these conditions, there will be an outflow of heated combustion gases and unburned excess pyrolyzates through the upper penetration. This results in both radiative and convective heating at the penetration boundary as well as exposure of the non-fire wall face, above the penetration, to the heating effects of an exterior fire plume. However, as shown in the same figure, the lower penetration acts as a conduit for the flow of cool ambient air into the test furnace (i.e., fire compartment). Thus, the lower penetration receives a radiant heat flux from its view angle of the furnace interior, but, at the same time, is convectively cooled by the inflow of ambient air. This air inflow also precludes the occurrence of a flame plume on the non-fire face of the wall assembly above the lower penetration. A comparison of the temperature recorded at penetrations 1A (Fig. 9) and 1B (Fig. 10), with the furnace pressure shown in Fig. 8 serve to support the preceding discussion.

For example, thermocouple 1A-1 (located at the midpoint of penetration 1A) remained within the temperature range of about 675-875°C when subjected to a positive internal furnace pressure of 1.75-8 pascals (.007-.032 in H_2O). However, when the internal furnace pressure was decreased to -1 pascal, (.044 in H_2O) at an elapsed time of approximately 14 minutes, the temperature dropped to about 250°C. Thermocouple 1B-1 remained within the temperature range of 50-200 C when subjected to furnace pressures of -0.25 (-.001 in H_2O) to -9.75 pascals (.039 in H_2O) increased to about 635°C when, at an elapsed time of about 4 minutes, it was subjected to a positive furnace pressure of 1.75 pascals (.007 in H_2O).

The temperatures recorded at penetrations 2A and 2B, see Figs. 12 and 13, and Tables X and XI, respectively, show much the same temperature-pressure relationships noted for penetrations 1A and 1B. However, since 2A and 2B were open penetrations not fitted with fuel pans, the temperature changes at thermocouple locations 2A-2, 2A-3, and 2B-2 are not as pronounced as those noted at locations 1A-3, 1B-2, and 1B-3. The absence of excess pyrolyzates at penetrations 2A and 2B resulted in convective heating by products of combustion rather than by a flame plume. The effect of heating by products of combustion versus a flame plume is shown by a comparison of the temperature histories at thermocouples locations 2A-3 and 1A-3.

A comparison of the temperature recorded at thermocouple locations 2A-2 and 3A-2 (Fig. 14 and Table XII) provide an indication of the effect of a combustible material (i.e., cable insulation at penetration 3A being present in a wall penetration).

4.2. Experiment #2 - Effects of Differential Furnace Pressure and Long Term Excess Pyrolyzate Production on Protected and Unprotected Penetrations

The experimental assembly was subjected to the ASTM E-119 temperature-time history for a period of approximately one hour. As in the first experiment, the duration was a function of the excess pyrolyzate supply. The furnace temperature-time history is presented in Fig. 16 and Tables XIV and XV. Malfunction of a transducer precluded quantitative measurement of the internal furnace pressure during this experiment. However, through a combination of visual observations and thermocouple data, it was possible to determine whether a penetration was at a negative or positive pressure during all phases of this experiment. Based on this information a qualitative record of the furnace pressure at both the upper and lower penetrations is presented in Fig. 17. The log of visual observations recorded during this experiment is presented in Table XVI.

An examination of Fig. 18 and Table XVII shows the temperatures recorded at penetration 1A, and clearly indicates the effects of the furnace pressure cycles, indicated in Fig. 17, on penetration temperatures. During each of the positive pressure cycles a flame plume extended from the unexposed face of the penetration causing the sharp increases in temperature noted at locations 1A-2 and 1A-3. As shown, under conditions of positive furnace pressure the unexposed face of the wall, .30 m (12 in) above the penetration (thermocouple location 1A-3), was subjected to temperatures in the range of approximately 800-1050°C. In contrast to this, during periods of negative furnace pressure the same location was exposed to temperatures of only 50-100°C. As noted earlier, the combination of positive furnace pressure and excess pyrolyzates has the potential for causing flame impingement on the unexposed face of fire resistive building elements whenever penetrations are inadequately fire-stopped.

Fig. 19 presents the temperatures that were recorded at penetration 1B. This penetration was subjected to positive furnace pressure only during the first 5-6 minutes of this experiment. During this period thermocouple 1B-3 recorded a peak temperature of approximately 250°C. Immediately after the furnace pressure at penetration 1B was reduced to a negative value, the temperature at thermocouple 1B-3 dropped below approximately 50°C, where it remained throughout the test. Figs. 20 and 21 and Tables XIX and XX illustrate the temperature histories at penetrations 2A and 2B, respectively. They show much the same behavior as penetrations 1A and 1B.

The temperature histories recorded at penetrations 3A and 3B are presented in Figs. 22 and 23 and Tables XVI and XXII, respectively. Both penetrations were fire-stopped with a loose-fill ceramic fiber, The temperatures at both the upper (3A) and lower (3B) penetrations were nearly identical. The approximately linear temperature rise noted at thermocouples 3A-1 and 3B-1 was due to heat conduction along the cables and, to a limited degree, to combustion of the cable insulation. The temperatures on the unexposed face of the wall remained below approximately 75°C throughout the experiment.

4.3. Experiment #3 - Investigation of Methods for Rate Controlled Introduction of Excess Pyrolyzates and Evaluation of a Combustible Penetration Seal Under Negative Pressure Test Conditions

This experimental assembly was subjected to a post-flashover fire environment for a period of approximately 46 minutes. As discussed below, difficulty with furnace control due to the large amounts of excess pyrolyzates during this experiment prevented maintaining the ASTM E-119 temperature-time history after an elapsed time of approximately 18 minutes. The temperature history of the furnace is presented in Fig. 24 and Tables XXIII and XXIV. The internal furnace pressure, at both the upper and lower penetrations, is presented in Fig. 25 and Table XXV. The log of visual observations recorded during this experiment is presented in Table XXVI.

During this experiment problems were encountered in controlling the temperature of the furnace because of the amount and type of excess pyrolyzates present. Seam failures on two of the containers resulted in the spillage of fuel within the test furnace and a subsequent increase in the total pyrolysis rate of excess fuel within the furnace. In addition, the change from polyethylene to paraffin resulted in a higher rate of pyrolysis than had been experienced in Experiment #2. The net result was that the furnace temperature increased to the point that all of the methane fired furnace burners had to be shut down in order to regain control. Since the furnace burners are not equipped with automatic pilots, manual reignition was necessary. The time required for manual ignition resulted in the furnace temperature drop shown in Fig. 24. After reignition of the burners was complete, the furnace temperature was once again brought up to the E-119 curve where upon furnace control was again lost and the experiment was terminated. As noted in Section 3.3, one objective of this experiment was the investigation of a method for introducing known amounts of excess pyrolyzates into the furnace by controlling the flow of fuel to the pyrolyzate container. The use of a liquid fuel, introduced into the pyrolyzate container at a controlled rate, appears to be a viable means for the localized production of excess pyrolyzates. However, the design shown in Fig. 26 will require refinement and further testing to improve its performance before it can be of general utility in such experiments.

Two types of cable penetration seal materials were utilized during this experiment. Penetrations 1B and 3A were sealed with silicon foam and penetrations 2A and 2B were packed with ceramic fiber. Under the conditions present during this experiment, both materials appeared to perform well under both positive and negative furnace pressures. The temperatures recorded at the unexposed face of penetrations 1B and 3A , and 2A and 2B, are shown in Fig. 27 and Table XXVII.

Penetration 3B was sealed with a highly combustible material, polyurethane foam boardstock. The purpose of penetration 3B was to investigate the performance of a highly combustible packing material when exposed to a negative pressure, post-flashover fire environment. The temperatures recorded at two locations in and around this penetration are presented in Fig. 28 and Table XXVIII. The condition of the unexposed face of penetration 3B both at the beginning and end of this experiment is shown in Figs. 29 and 30, respectively. The performance of this penetration casts doubts on the validity of cable penetration tests conducted using negative test furnace pressures. In Fig. 30 it is evident that the urethane foam packing material is virtually consumed and yet, under negative furnace pressure, the entrainment of cool ambient air through the penetration has prevented the passage of heated gases and flame to the unexposed face of the barrier. The performance of the urethane foam during this experiment is not surprising based on the performance noted during the previous two experiments for open penetrations subjected to negative pressure.

5. CONCLUSIONS

The experimental work presented in this report has investigated the effects of two variables, test furnace pressure differential and excess pyrolyzates, on the performance of penetrations introduced into fire resistive wall assemblies. The results indicate that these variables can have a pronounced effect on the measured fire resistance of penetrations.

As discussed in Section 4, the pressure within the fire test furnace, with respect to the non-fire side of the barrier element, will determine the direction of leakage through the barrier. This is shown schematically in Fig. 11 where it can be seen that leakage will occur from a region of high pressure to a region of low pressure. Thus, if the test furnace is maintained as an area of relative low pressure, as in the general practice during qualification tests, any leakage through the test assembly will be from its non-fire side into the furnace. Conversely, if the furnace is operated at a positive pressure differential, any leakage will occur from the furnace to the non-fire side of the test assembly.

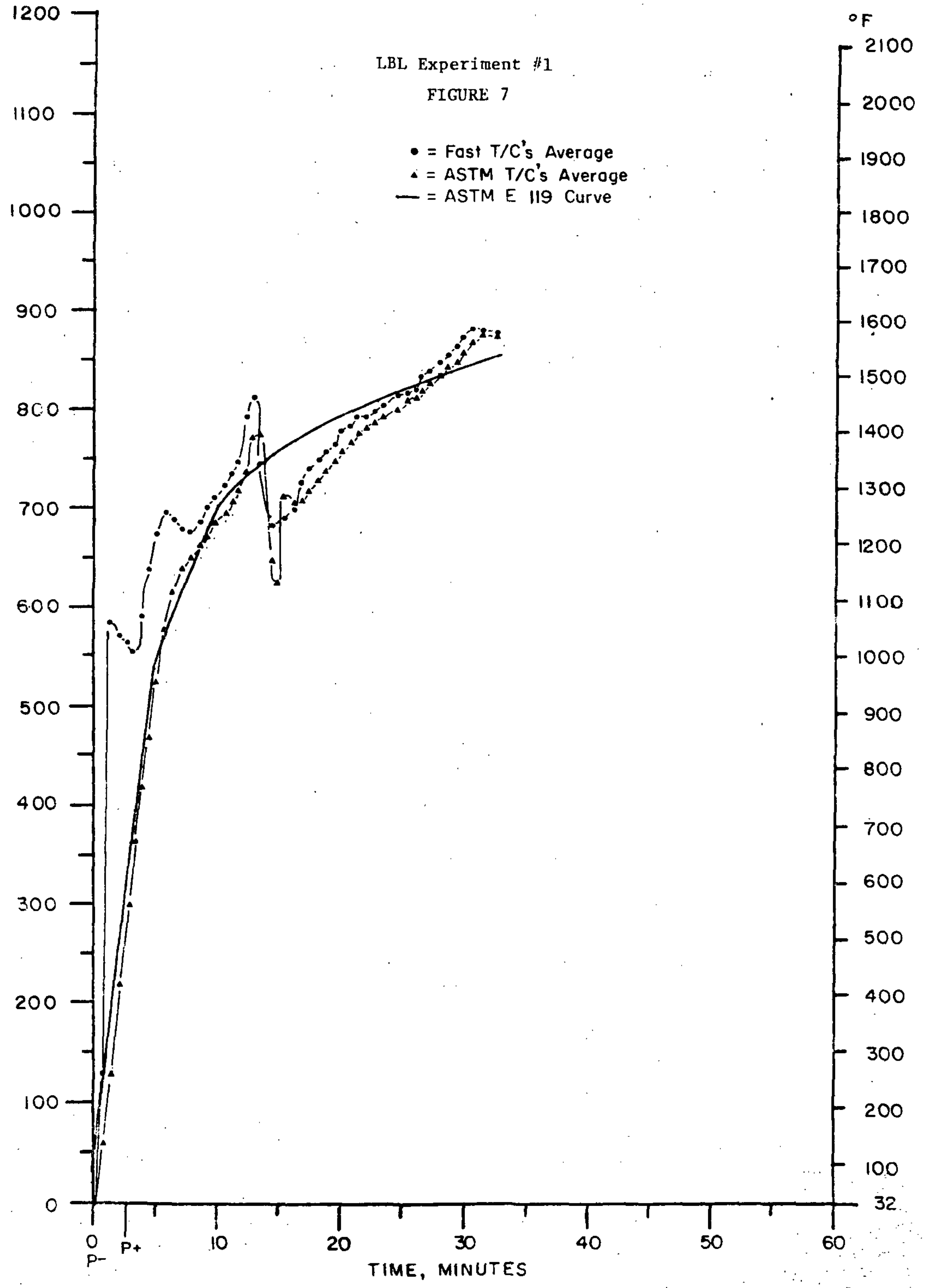
This simple relationship can have a substantial impact on the measured fire resistance of penetration seals which develop cracks or other through openings upon exposure to post-flashover fire temperatures. This is particularly true when excess pyrolyzates are produced by the post-flashover fire. Excess pyrolyzates represent fuel in a gaseous state which, due to limited oxygen concentration within the fire compartment, are unable to undergo combustion. Thus, if positive pressure and excess pyrolyzates occur simultaneously during a post-flashover fire, the development of through openings in the penetration seal can result in the occurrence of a flame plume on the non-fire side of the barrier element. Such a condition would mark the end of the fire resistance function of the barrier element.

The effects of furnace pressure, without excess pyrolyzates on open penetrations were investigated at penetrations 2A and 2B during the first experiment. Fig. 8 indicates the furnace pressure during this experiment while the temperatures recorded at penetration 2A and 2B are shown in Figs. 12 and 13, respectively. During periods of positive pressure, the temperature at the center of penetration 2A closely approximated the furnace temperature. However, when the pressure was reduced to a negative value, at an elapsed time of approximately 14 minutes, the temperature at 2A-1 was reduced by about 450°C to a value of approximately 400°C. Similar behavior was noted at penetration 2B. However, penetration 2B was not exposed to positive pressure in excess of 2 pascals during this experiment, and consequently, did not attain the peak temperatures recorded at location 2A-1. The effects of excess pyrolyzates at penetrations 1A and 1B during Experiment #1 were not pronounced because of the small amounts used.

The effects of excess pyrolyzates were, however, very pronounced during Experiment #2. An examination of the temperatures recorded at penetrations 1A and 1B, Figs. 18 and 19, respectively, during Experiment #2, clearly indicate the effects of excess pyrolyzates in combination with both positive and negative furnace pressures. Fig. 17 provides a qualitative indication of the furnace pressure during this experiment. As shown, the upper penetrations were subjected to four distinct periods of positive pressure. A comparison of Figs. 17 and 18 indicate a correlation between positive furnace pressure and high temperatures both within the penetration (location 1A-1) and on the non-fire side of the wall (locations 1A-2 and 1A-3). The high temperatures, often in excess of the furnace temperature were caused by a flame plume which extended from the penetration and exposed the non-fire side of the wall. The temperature history at penetration 1B, Fig. 19, indicates high temperatures during the initial five minutes of the test when it was subjected to positive pressure. After an elapsed time of approximately 5 minutes, the pressure at penetration 1B was reduced to a negative value where it remained throughout the experiment. During the low pressure portion of the experiment, the temperature at penetration 1B did not exceed 100°C.

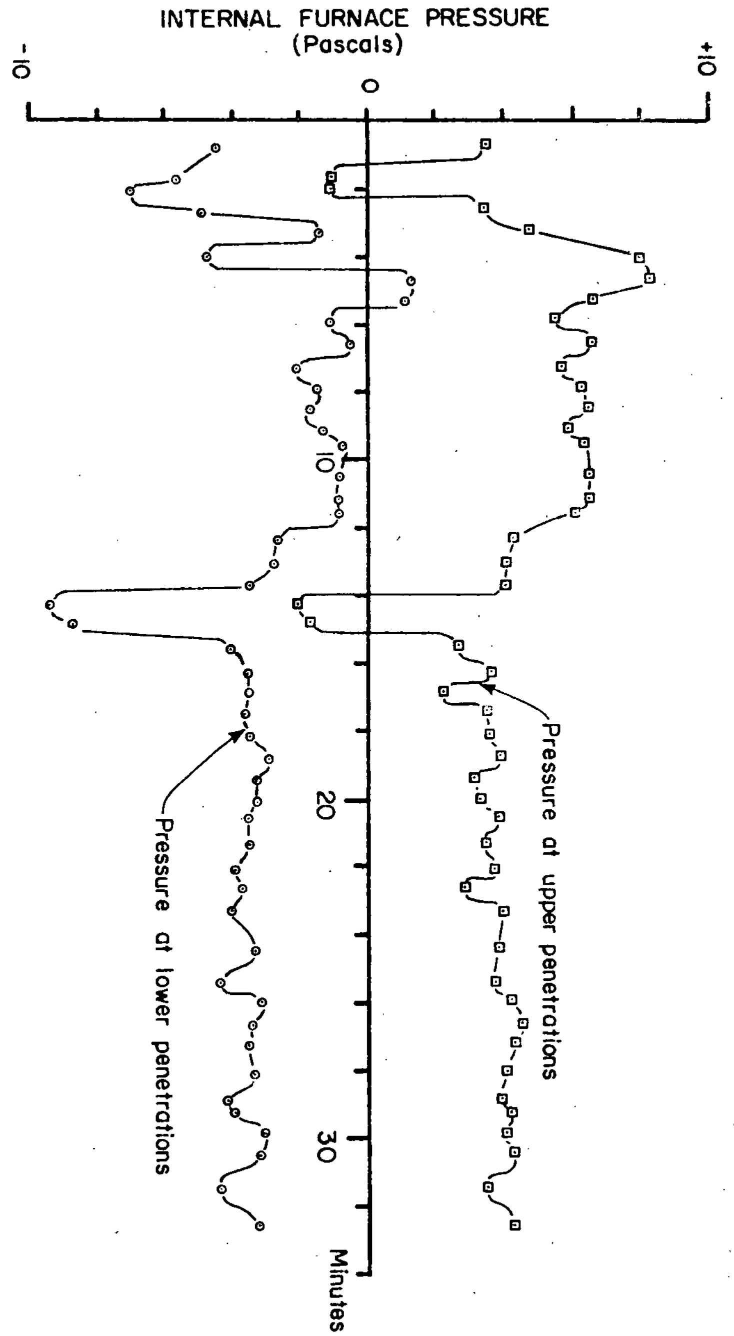
The effects of negative furnace pressure and excess pyrolyzates were investigated at penetration 3B during Experiment #3, for the case of a highly combustible penetration seal material. During this experiment, penetration 3B was sealed with a highly combustible urethane foam boardstock. As shown in Fig. 25, the furnace pressure at penetration 3B was maintained at a negative pressure throughout this experiment, thus, preventing leakage of combustion gases, and excess pyrolyzates through the penetration. The temperatures recorded at this penetration are presented in graphical form in Fig. 28. The temperatures at location 3B-1 shows a steady increase in temperature caused by progressive combustion of the urethane foam seal. However, due to the negative pressure, the temperature at location 3B-2 remained very near its initial ambient value. The condition of the seal at the beginning and end of the experiment is shown in Figs. 29 and 30, respectively. In Fig. 30 it is evident that the urethane foam seal is nearly destroyed and yet there is no passage of gas or flame to the non-fire side of the wall assembly. The performance of the urethane foam during this experiment serves to illustrate the inadviseability of evaluating the fire resistive capabilities of proposed penetration seal designs using a test furnace that is operated at negative internal pressure differentials.

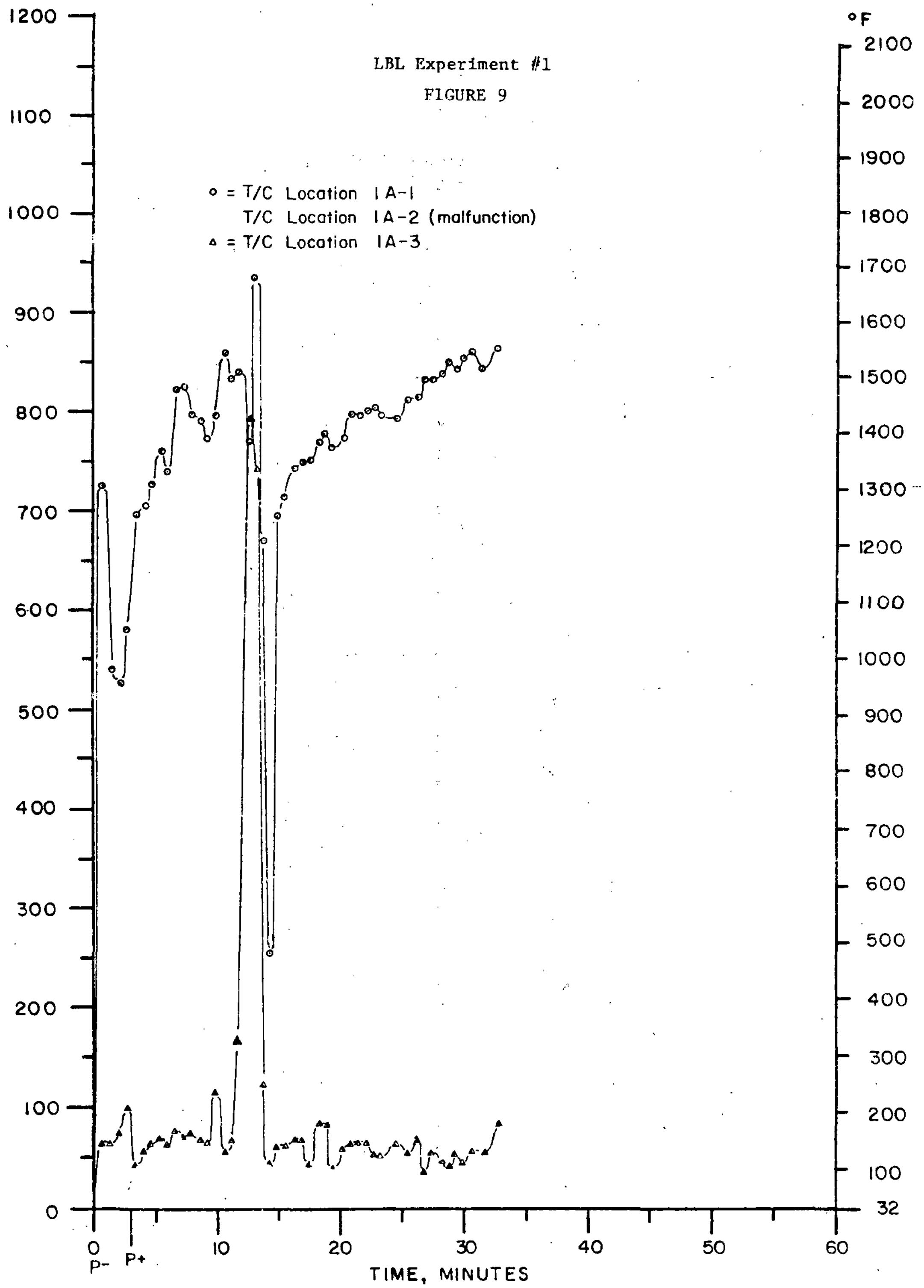
The three experiments discussed in this report represent a first step in determining the effects of furnace pressure and excess pyrolyzates on the measured fire resistance of penetration seals. Since both conditions are known to exist during the ventilation controlled phase of post-flashover burning, we believe they should be represented by the test standard that is utilized to rate the fire resistance of penetration seals. If these variables are not incorporated into such a test standard, then, the premature failure of seals in field use will occur if the seal design utilizes materials which are subject to the formation of cracks or other through openings when exposed to post-flashover fire temperatures.


LBL Experiment #1
FIGURE 7
• = Fast T/C's Average
▲ = ASTM T/C's Average
— = ASTM E 119 Curve
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
0
P-
P+
10
20
30
40
50
60
TIME, MINUTES

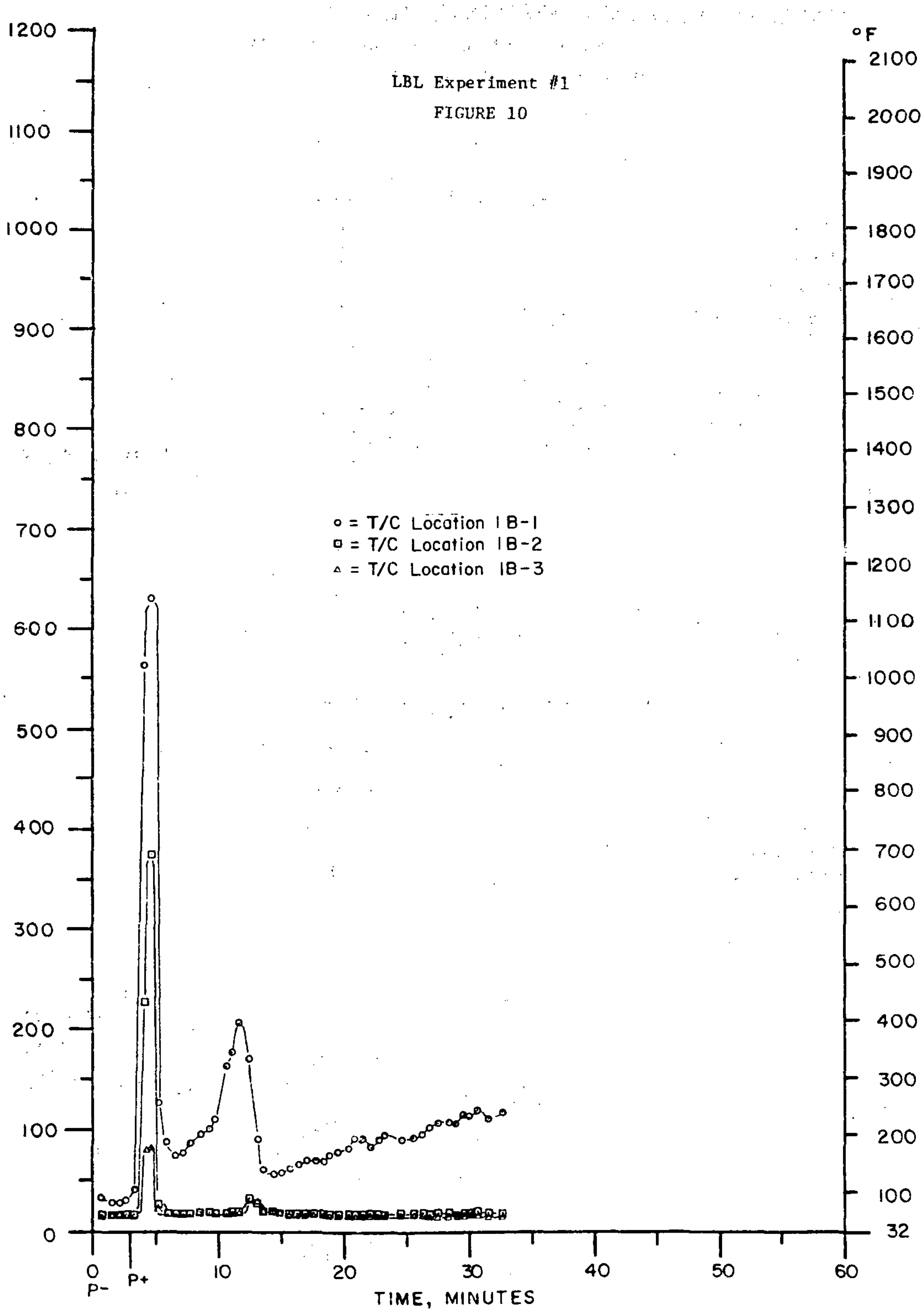
LBL Experiment #1

FIGURE 8





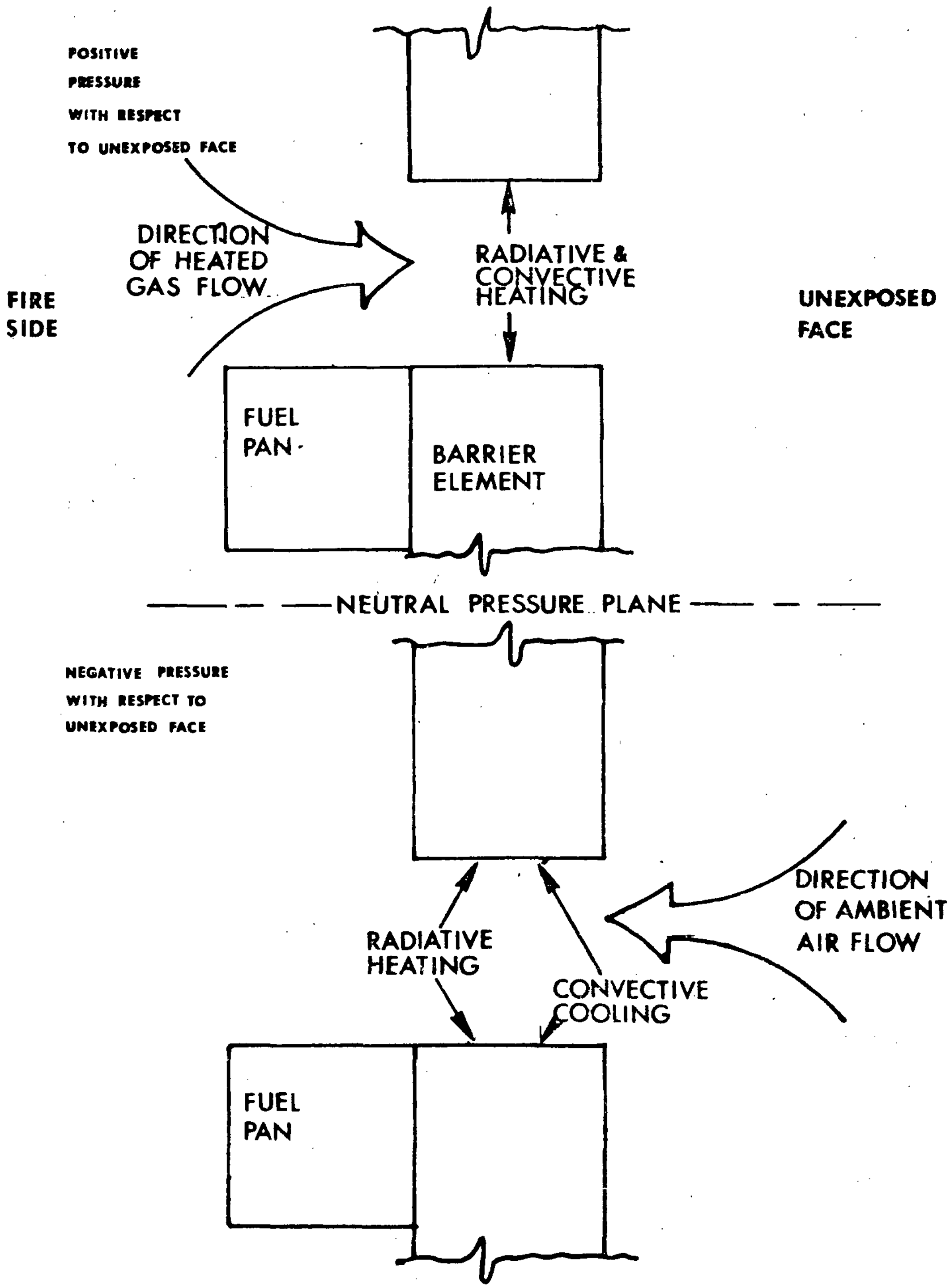
LBL Experiment #1
FIGURE 9
o = T/C Location 1A-1
T/C Location 1A-2 (malfunction)
△ = T/C Location 1A-3
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
0
10
20
30
40
50
60
P-
P+
TIME, MINUTES

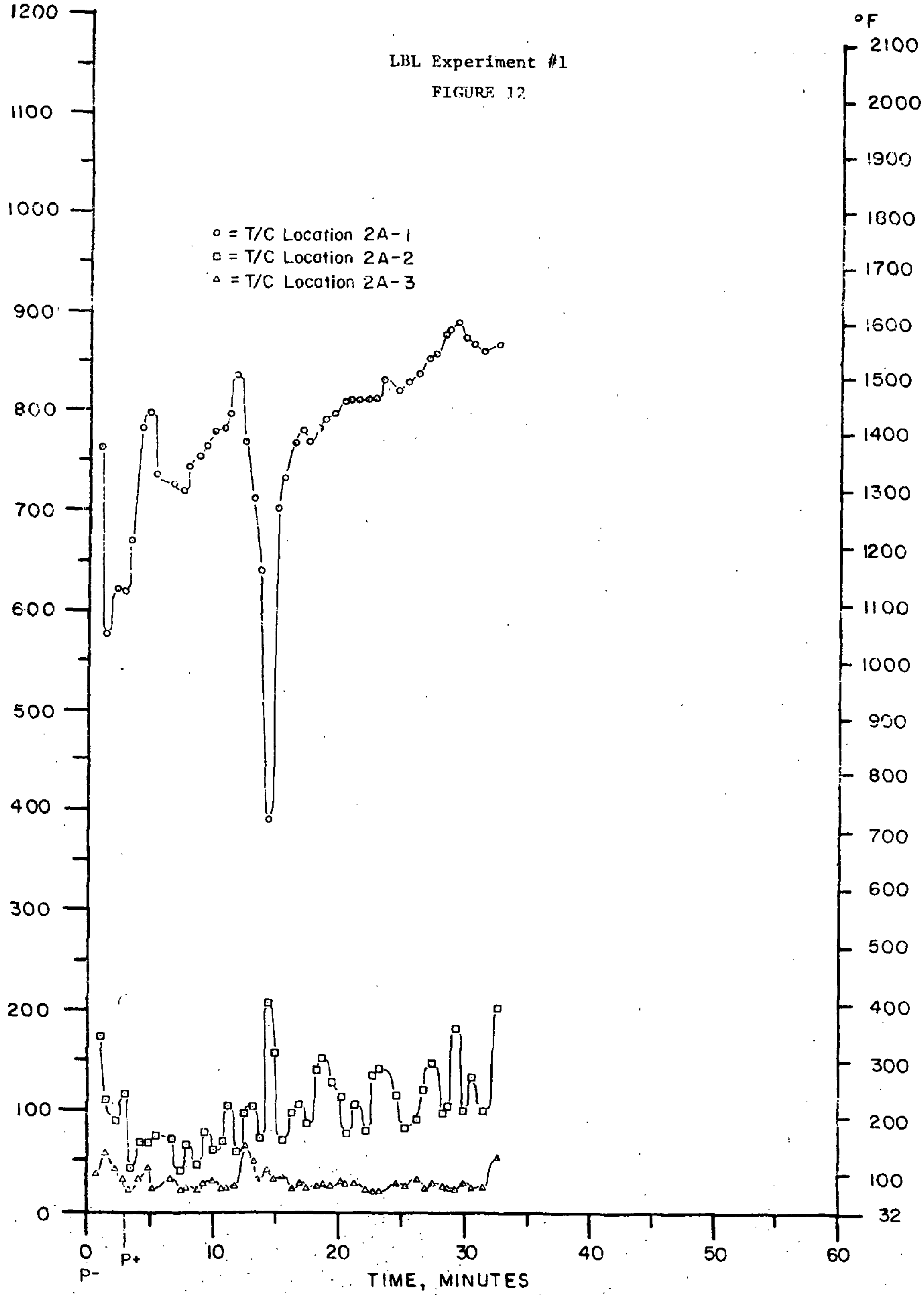


LBL Experiment #1
FIGURE 10
o = T/C Location IB-1
□ = T/C Location IB-2
Δ = T/C Location IB-3
°F
TIME, MINUTES
P-
P+

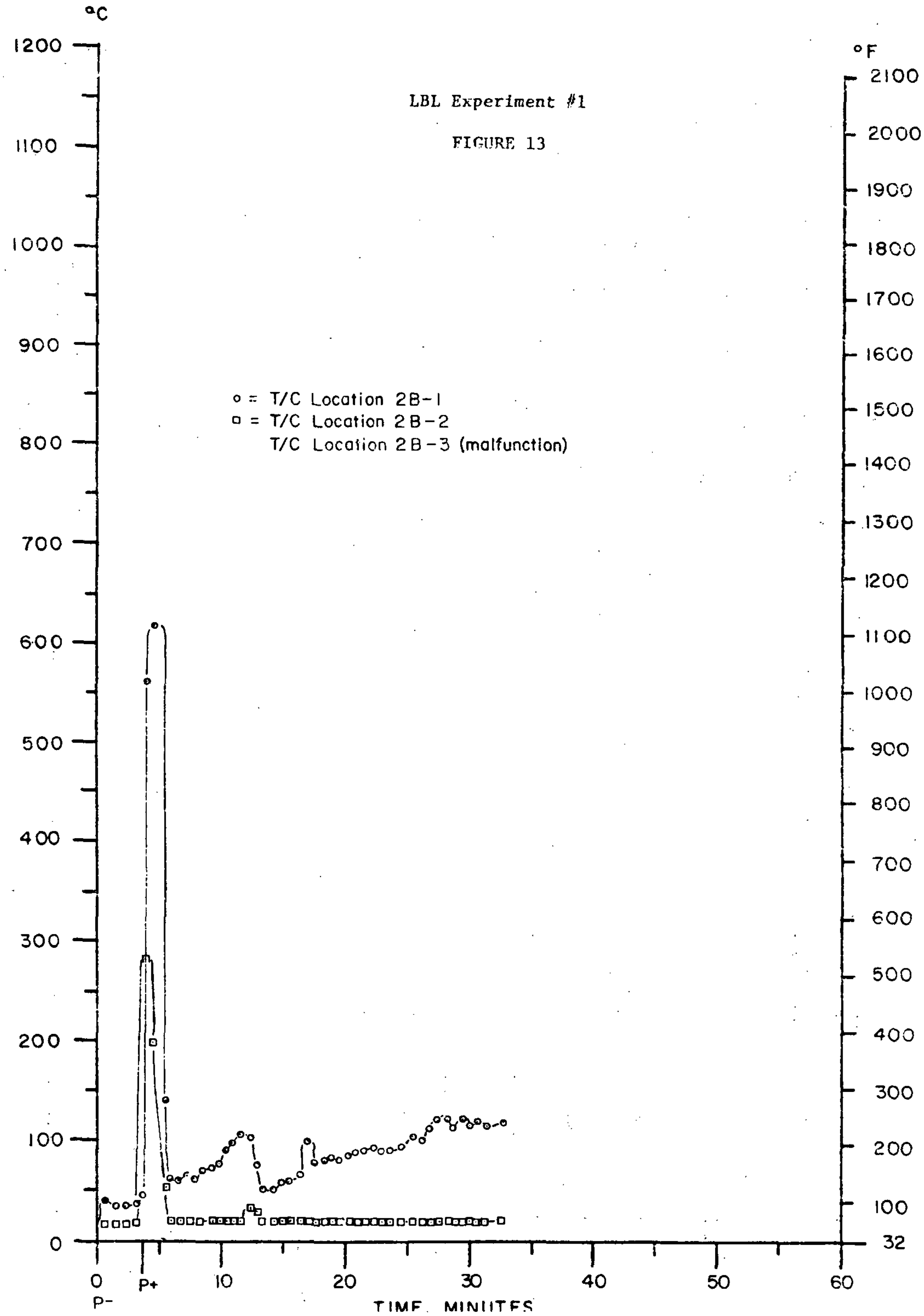
FIGURE 11: SCHEMATIC REPRESENTATION

EFFECTS OF FURNACE PRESSURE AND EXCESS PYROLYZATES ON PENETRATION FIRE PERFORMANCE.

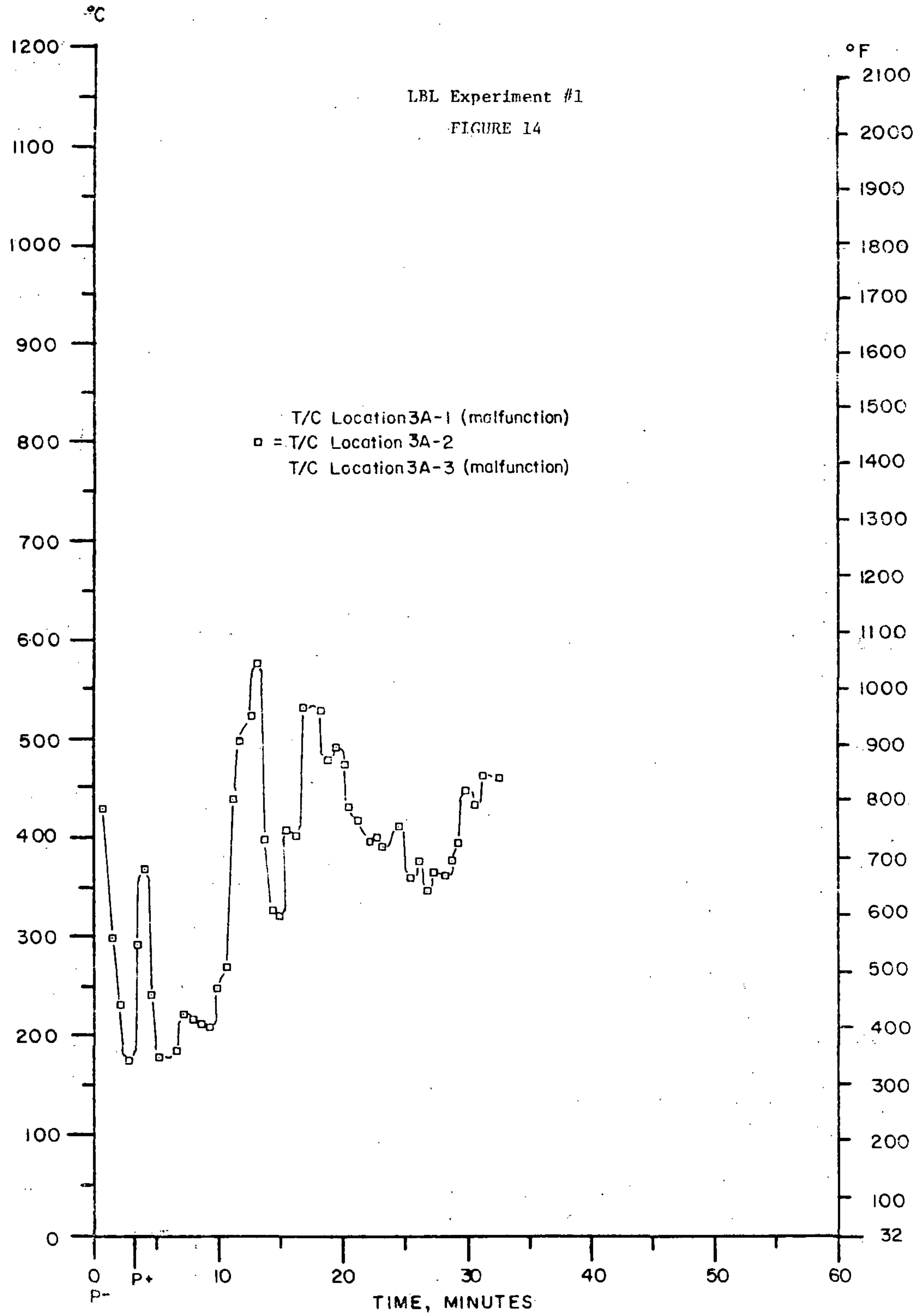




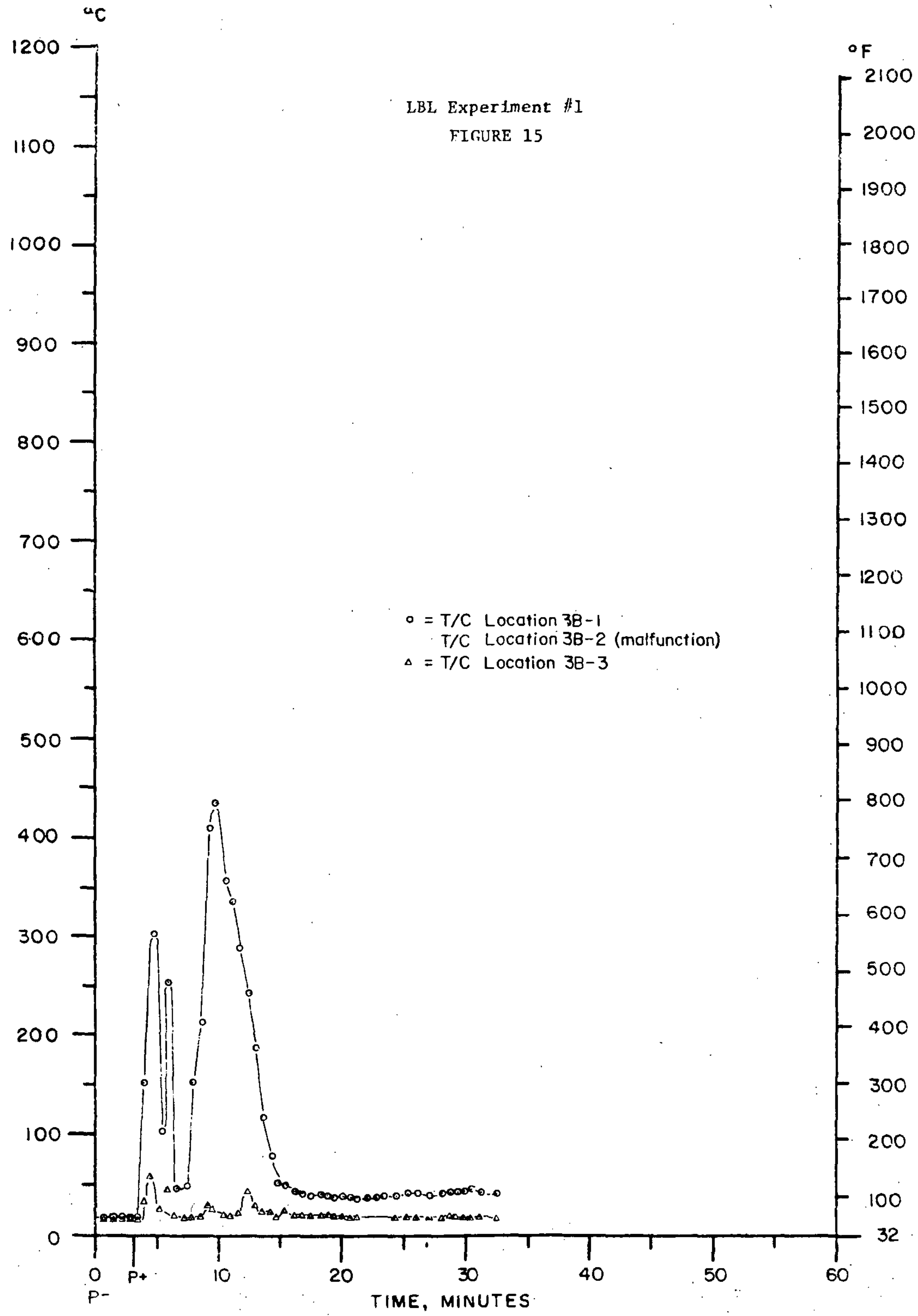
LBL Experiment #1
FIGURE 12
o = T/C Location 2A-1
□ = T/C Location 2A-2
△ = T/C Location 2A-3
°F
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
0
P-
P+
10
20
30
40
50
60
TIME, MINUTES



°C
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
LBL Experiment #1
FIGURE 13
○ = T/C Location 2B-1
□ = T/C Location 2B-2
T/C Location 2B-3 (malfunction)
0
P-
P+
10
20
30
40
50
60
TIME, MINUTES



°C
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
LBL Experiment #1
FIGURE 14
T/C Location 3A-1 (malfunction)
□ = T/C Location 3A-2
T/C Location 3A-3 (malfunction)
0
P-
P+
10
20
30
40
50
60
TIME, MINUTES


°C
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
LBL Experiment #1
FIGURE 15
o = T/C Location 3B-1
T/C Location 3B-2 (malfunction)
Δ = T/C Location 3B-3
0
P-
P+
10
20
30
40
50
60
TIME, MINUTES

LBL Experiment #1

TABLE IV

TIME MIN	SEC	TEMPERATURE °C AT THERMOCOUPLE NO. 1	2	3	4	5	6	7	8	9	AVE 1-9
	43	121	139	141	131	129	127	152	118	118	122
1	21	552	636	650	533	586	639	544	490	600	582
2	04	528	604	638	529	576	623	517	511	594	569
2	42	514	598	629	527	573	601	528	526	597	563
3	21	502	585	620	516	561	602	503	520	579	552
4	00	562	612	655	566	591	643	551	547	597	588
4	38	600	678	689	616	665	683	606	588	657	636
5	17	641	737	699	669	730	685	655	628	674	672
5	56	666	751	730	689	744	722	665	650	688	694
6	34	656	726	737	668	712	740	633	647	683	687
7	13	645	707	735	658	685	737	615	655	688	678
7	52	638	700	735	653	678	738	611	633	691	675
8	30	647	708	743	665	687	758	617	639	703	684
9	09	664	720	755	684	699	777	627	651	723	698
9	47	676	731	762	697	715	779	742	660	718	708
10	26	689	745	775	719	733	790	665	679	721	722
11	05	705	758	779	734	750	795	679	693	726	733
11	43	718	769	781	769	761	799	695	707	730	745
12	22	805	819	797	895	812	816	769	746	744	793
13	01	876	818	774	976	799	781	782	746	725	811
13	39	818	743	730	835	724	730	683	694	693	745
14	18	699	685	701	701	670	695	637	655	668	683
14	56	653	681	728	685	680	722	669	662	691	684
15	35	664	697	730	685	684	729	650	665	697	689
16	14	676	714	738	698	696	735	658	672	708	699
16	53	694	742	769	723	724	771	683	694	730	725
17	31	710	758	787	739	741	789	700	709	744	741
18	10	717	763	793	744	747	791	711	719	755	749
18	48	726	771	803	755	757	802	716	723	762	757
19	27	734	734	810	763	771	812	730	737	775	768
20	06	743	790	824	769	775	823	739	745	785	777
20	44	749	796	833	775	783	829	743	752	795	783

TABLE IV

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	1	2	3	4	5	6	7	8	9	1-9
21	23	758	805	840	782	793	842	751	762	800	792
22	02	762	806	840	783	794	835	748	762	805	792
22	40	766	808	846	791	795	836	753	765	810	796
23	19	770	813	848	795	800	838	765	776	816	801
24	31	779	822	858	799	811	848	771	786	827	811
25	26	783	824	863	806	814	849	778	789	835	815
26	04	788	829	865	815	818	853	785	792	841	819
26	43	799	842	878	824	832	866	802	805	853	833
27	21	805	851	888	833	842	876	807	814	862	839
28	09	812	856	888	837	847	880	815	821	863	847
28	38	818	861	895	845	850	882	823	830	876	852
29	17	824	867	900	847	858	887	839	844	879	861
29	55	834	879	912	860	870	904	846	852	887	872
30	34	846	885	920	872	873	910	851	857	899	880
31	38	845	880	918	865	871	905	848	858	900	878
32	38	844	879	916	864	870	903	850	856	901	877

LBL Experiment #1

TABLE V

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	11	12	13	14	15	16	17	18	19	11-19
	43	72	47	51	72	45	44	86	47	46	56
1	21	137	130	136	128	121	141	155	120	117	127
2	04	209	226	237	196	212	253	226	214	221	217
2	42	268	308	328	257	292	357	208	291	318	296
3	21	318	377	403	310	361	429	340	355	397	362
4	00	363	433	461	358	417	487	385	410	457	416
4	38	413	486	516	410	471	541	434	463	510	468
5	17	467	540	569	470	539	581	490	518	558	525
5	56	521	606	614	529	603	613	544	566	596	574
6	34	563	647	652	573	644	648	579	600	629	613
7	13	589	667	676	597	661	674	596	618	654	636
7	52	602	675	689	612	667	691	604	629	671	648
8	30	612	681	699	624	670	706	610	637	684	658
9	09	623	639	709	637	677	723	618	647	699	668
9	47	635	697	720	651	686	738	627	656	710	679
10	26	647	707	730	666	678	749	640	668	718	691
11	05	660	719	741	683	712	760	654	681	724	703
11	43	674	731	749	703	726	768	670	694	731	716
12	22	702	749	758	753	743	777	697	714	739	736
13	01	766	775	764	843	776	779	748	736	743	769
13	39	808	773	753	867	769	763	749	732	732	773
14	18	780	748	734	808	741	741	722	710	713	745
14	56	738	720	721	762	717	729	700	697	703	721
15	35	710	707	718	733	707	728	687	693	702	710
16	14	694	704	717	716	702	729	679	693	704	704
16	53	688	710	724	711	705	739	679	700	713	707
17	31	690	721	737	713	715	755	686	711	736	716
18	10	696	732	750	718	726	769	695	723	739	727
18	48	702	742	761	725	735	779	704	733	751	736
19	27	709	751	771	732	746	790	714	743	762	746
20	06	717	762	781	740	756	800	724	753	773	756
20	44	725	770	792	747	765	811	732	761	784	765

TABLE V

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	11	12	13	14	15	16	17	18	19	11-19
21	23	734	779	802	754	774	822	740	770	794	774
22	02	741	786	809	760	781	827	745	777	801	780
22	40	747	791	815	766	786	831	750	781	807	785
23	19	752	795	820	772	790	834	754	786	813	790
24	31	761	804	830	780	798	840	766	797	825	799
25	26	769	811	837	786	806	846	773	805	832	807
26	04	773	814	841	791	809	849	778	808	830	810
26	43	778	821	848	798	816	856	787	816	845	818
27	21	785	829	856	806	822	863	794	823	852	826
28	09	791	834	862	813	831	872	802	831	859	832
28	38	799	843	870	822	839	878	812	841	869	841
29	17	804	848	873	826	843	882	819	849	875	846
29	55	811	856	882	834	853	893	830	860	884	855
30	34	825	869	894	849	865	904	842	871	897	868
31	38	833	874	901	856	870	909	849	877	904	875
32	38	835	873	901	855	869	906	848	875	904	874

LBL Experiment #1

TABLE VI

TIME min:sec	INTERNAL FURNACE PRESSURE (PASCALS)	
	Lower Penetration	Upper Penetration
0 43	-4.45	3.55
1 41	-5.84	-1.03
2 04	-7.03	-1.08
2 42	-4.91	3.43
3 21	-1.46	4.76
4 00	-4.79	8.02
4 38	+1.31	8.30
5 17	+1.07	6.63
5 56	-1.08	5.56
6 34	-0.48	6.62
7 13	-2.07	5.74
7 52	-1.50	6.35
8 30	-1.65	6.50
9 09	-1.33	5.87
9 47	-0.80	6.39
10 26	-0.82	6.59
11 05	-0.89	6.51
11 43	-0.84	6.11
12 22	-2.77	4.38
13 01	-2.81	4.13
13 39	-3.51	4.16
14 18	-9.40	-2.07
14 56	-8.58	-1.71
15 35	-4.05	2.71
16 14	-3.58	3.70
16 53	-3.55	2.24
17 31	-3.62	3.48
18 10	-3.50	3.63
18 48	-2.93	3.90
19 27	-3.32	3.17

TABLE VI

continued

TIME min:sec	INTERNAL FURNACE PRESSURE (PASCALS)	
	Lower Penetration	Upper Penetration
20 06	-3.29	3.33
20 44	-3.55	3.84
21 23	-3.51	3.48
22 02	-3.97	3.79
22 40	-3.76	2.81
23 19	-4.00	3.97
24 31	-3.38	3.86
25 26	-4.37	3.73
26 04	-3.16	4.22
26 43	-3.41	4.55
27 21	-3.45	4.37
28 09	-3.38	4.14
28 38	-4.17	3.93
29 17	-3.96	4.26
29 55	-3.13	4.10
30 34	-3.20	4.34
31 38	-4.32	3.59
32 38	-3.22	4.38

LBL Experiment #1

TABLE VII

TIME		OBSERVATIONS
MIN	SEC	
1	00	Substantial smoke from upper cable "chases".
2	00	Wallboard paper has burned out.
2	30	Positive pressure applied.
4	40	Lower cable and open center hole burn profusely.
5	45	Lower cable on back wall burning. Upper cable melting only.
6	42	Upper cable penetration flicking.
7	12	Upper tray of excess pyrolyzates burning steadily.
		Both lower penetrations which were fueled with excess pyrolyzates
		burning into furnace.
9	30	Cables continue to burn.
10	20	Intermittent burning of back face of lower cable assembly.
		Lower open chases (with excess trays) continue to burn inward.
		Upper open chases (with excess trays) continue to burn outward.
12	30	Trays of excess pyrolyzates near upper cable exhibiting blowtorch
		effect in rear of interior.
13	50	Cables glow in interior.
14	08	Neutral plane raised significantly.
14	10	Trays of excess pyrolyzates appear to have burned out.
24	00	Switched from 1 minute to 5 minute timing intervals on pressure scanners
25	18	Switched from 5 minute to 1 minute timing intervals on pressure scanners

LBL Experiment #1

TABLE VIII

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1A-1	1A-2	1A-3
0	43	724	THERMOCOUPLE MALFUNCTION	62
1	21	538		63
2	04	525		72
2	42	578		98
3	21	695		40
4	00	704		55
4	38	725		62
5	17	759		67
5	56	738		61
6	34	821		75
7	13	824		69
7	52	797		72
8	30	790		65
9	09	873		63
9	47	793		114
10	26	857		53
11	05	833		65
11	43	839		163
12	22	768		170
13	01	933		740
13	39	659		121
14	18	253		42
14	56	693		58
15	33	712		59
16	14	741		66
16	53	747		66
17	31	750		41
18	10	768		82
18	48	776		80
19	27	763		39
20	06	773		57

TABLE VIII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1A-1	1A-2	1A-3
20	44	795	THERMOCOUPLE MALFUNCTION	61
21	23	795		63
22	02	780		63
22	40	803		50
23	19	795		50
24	31	793		62
25	26	810		52
26	04	815		65
26	43	831		34
27	21	831		53
28	09	837		45
28	38	849		40
29	17	846		52
29	55	852		44
30	34	859		54
31	38	841		54
32	38	862		82

LBL Experiment #1

TABLE IX

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1B-1	1B-2	1B-3
	43	34	16	15
1	41	29	16	16
2	04	29	16	16
2	42	31	16	15
3	21	41	16	15
4	00	564	227	80
4	38	630	375	82
5	17	126	27	21
5	56	89	18	139
6	34	75	17	32
7	13	78	17	37
7	52	88	17	125
8	30	96	19	132
9	09	101	19	94
9	47	111	18	29
10	26	163	18	24
11	03	177	19	17
11	43	207	20	18
12	22	170	33	31
13	01	92	28	29
13	39	61	19	19
14	18	57	19	19
14	56	59	18	18
15	35	64	18	17
16	14	68	18	17
16	53	70	18	17
17	31	70	19	18
18	10	70	18	17
18	48	77	18	17
19	27	29	18	17
20	06	83	18	17

TABLE IX

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1B-1	1B-2	1B-3
20	44	91	18	17
21	23	91	18	17
22	02	84	19	17
22	40	91	18	17
23	19	97	18	17
24	31	91	19	18
25	26	93	19	18
26	04	97	19	18
26	43	104	18	17
27	21	107	19	17
28	09	108	19	17
28	38	106	18	17
29	17	115	19	17
29	55	114	19	18
30	34	120	20	18
31	38	112	19	17
32	38	117	19	17

LBL Experiment #1

TABLE X

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2A-1	2A-2	2A-3
	43	762	174	36
1	21	576	110	57
2	04	620	88	40
2	42	618	116	31
3	21	670	42	21
4	00	782	67	31
4	38	798	67	42
5	17	736	74	23
6	34	726	71	26
7	13	719	40	20
7	52	744	65	22
8	30	754	45	21
9	09	765	78	38
9	47	778	60	30
10	26	782	67	22
11	05	797	104	23
11	43	836	58	25
12	22	769	96	64
13	01	712	104	49
13	39	640	73	30
14	18	391	208	40
14	56	703	157	31
15	35	732	70	29
16	14	769	99	23
16	53	781	107	27
17	31	769	88	23
18	10	782	142	25
18	48	794	153	26
19	27	797	129	25
20	06	810	115	30

TABLE X

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2A-1	2A-2	2A-3
20	44	813	77	28
21	23	811	108	28
22	02	812	80	26
22	40	813	136	25
23	19	832	143	25
24	31	821	117	28
25	26	831	84	26
26	04	839	91	32
26	43	854	123	23
27	21	859	149	29
28	09	854	98	25
28	38	838	105	24
29	17	880	184	22
29	55	875	101	28
30	34	869	135	23
31	38	862	101	24
32	38	869	205	53

LBL Experiment #1

TABLE XI

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2B-1	2B-2	2B-3
	43	39	16	THERMOCOUPLE MALFUNCTION
1	21	33	17	
2	04	33	17	
2	42	36	17	
3	21	42	17	
4	00	560	282	
4	38	618	199	
5	17	139	54	
5	56	63	20	
6	34	59	20	
7	13	56	18	
7	52	63	18	
8	30	67	20	
9	09	76	19	
9	47	77	19	
10	26	86	19	
11	05	97	19	
11	43	108	20	
12	22	101	34	
13	01	73	29	
13	39	52	20	
14	18	51	20	
14	56	57	19	
15	35	61	20	
16	14	67	20	
16	53	100	19	
17	31	76	20	
18	10	80	20	
18	48	83	20	
19	27	81	30	
20	06	85	20	

TABLE XI

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2B-1	2B-2	2B-3
20	44	88	21	THERMOCOUPLE MALFUNCTION
21	23	90	29	
22	02	94	21	
22	40	91	29	
23	19	91	20	
24	31	94	21	
25	26	106	22	
26	04	101	22	
26	43	113	22	
27	21	121	21	
28	09	119	22	
28	38	112	22	
29	17	122	22	
29	55	115	22	
30	34	119	23	
31	38	115	22	
32	38	119	21	

LBL Experiment #1

TABLE XII

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3A-1	3A-2	3A-3
	43	THERMOCOUPLE MALFUNCTION	429	THERMOCOUPLE MALFUNCTION
1	21		299	
2	04		231	
2	42		175	
3	21		292	
4	00		368	
4	38		242	
5	17		177	
5	56		252	
6	34		184	
7	13		221	
7	52		216	
8	30		212	
9	09		208	
9	47		249	
10	26		270	
11	05		438	
11	43		496	
12	22		524	
13	01		575	
13	39		397	
14	18		325	
14	56		321	
15	35		406	
16	14		401	
16	53		532	
17	31		584	
18	10		527	
18	48		477	
19	27		493	
20	06		474	

TABLE XII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3A-1	3A-2	3A-3
20	44	THERMOCOUPLE MALFUNCTION	431	THERMOCOUPLE MALFUNCTION
21	23		418	
22	02		397	
22	40		400	
23	19		393	
24	31		412	
25	26		360	
26	04		376	
36	43		347	
27	21		366	
28	09		368	
28	38		378	
29	17		395	
29	55		449	
30	34		432	
31	38		464	
32	38		462	

LBL Experiment #1

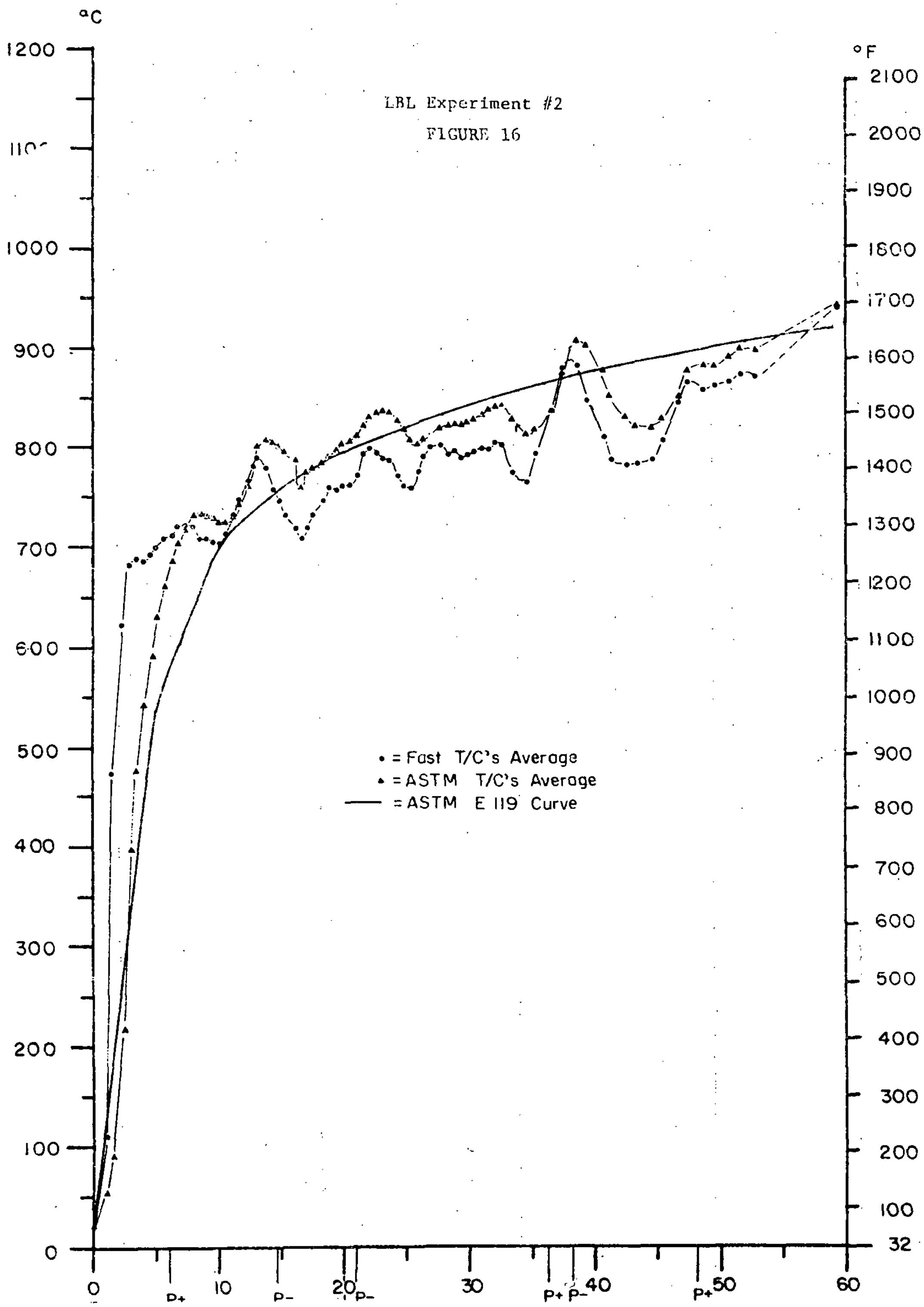
TABLE XIII

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3B-1	3B-2	3B-3
	43	17	THERMOCOUPLE MALFUNCTION	15
1	21	16		15
2	04	17		15
2	42	17		16
3	21	17		15
4	00	151		32
4	38	302		58
5	17	702		25
5	56	252		44
6	34	45		19
7	13	49		16
7	52	153		16
8	30	212		17
9	09	417		29
9	47	435		26
10	26	357		20
11	05	335		19
12	22	242		22
13	01	186		29
13	39	118		24
14	18	79		23
14	56	53		18
15	35	50		24
16	14	44		19
16	53	42		19
17	31	40		19
18	10	41		19
18	48	40		19
19	27	38		18
20	06	39		18
20	44	38		18

TABLE XIII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3B-1	3B-2	3B-3
21	23	37	THERMOCOUPLE MALFUNCTION	17
22	02	38		–
22	40	37		–
23	19	38		–
24	31	39		17
25	26	41		18
26	04	41		17
26	43	41		17
27	21	40		16
28	09	42		17
28	38	43		18
29	17	43		17
29	55	44		17
30	34	46		18
31	38	43		17
32	38	41		16



°C
1200
110
1000
900
800
700
600
500
400
300
200
100
0
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
LBL Experiment #2
FIGURE 16
• = Fast T/C's Average
▲ = ASTM T/C's Average
— = ASTM E 119 Curve
0
10
20
30
40
50
60
P+
P−
P−
P+ P−
P+

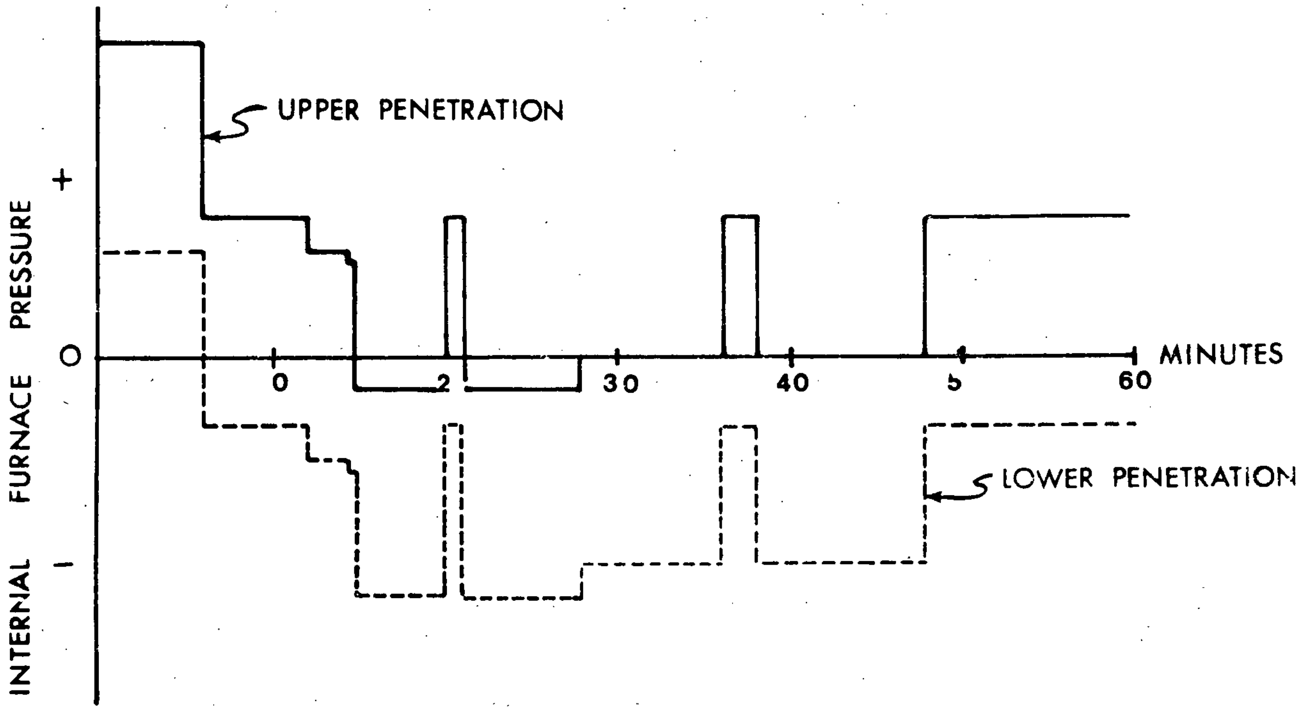
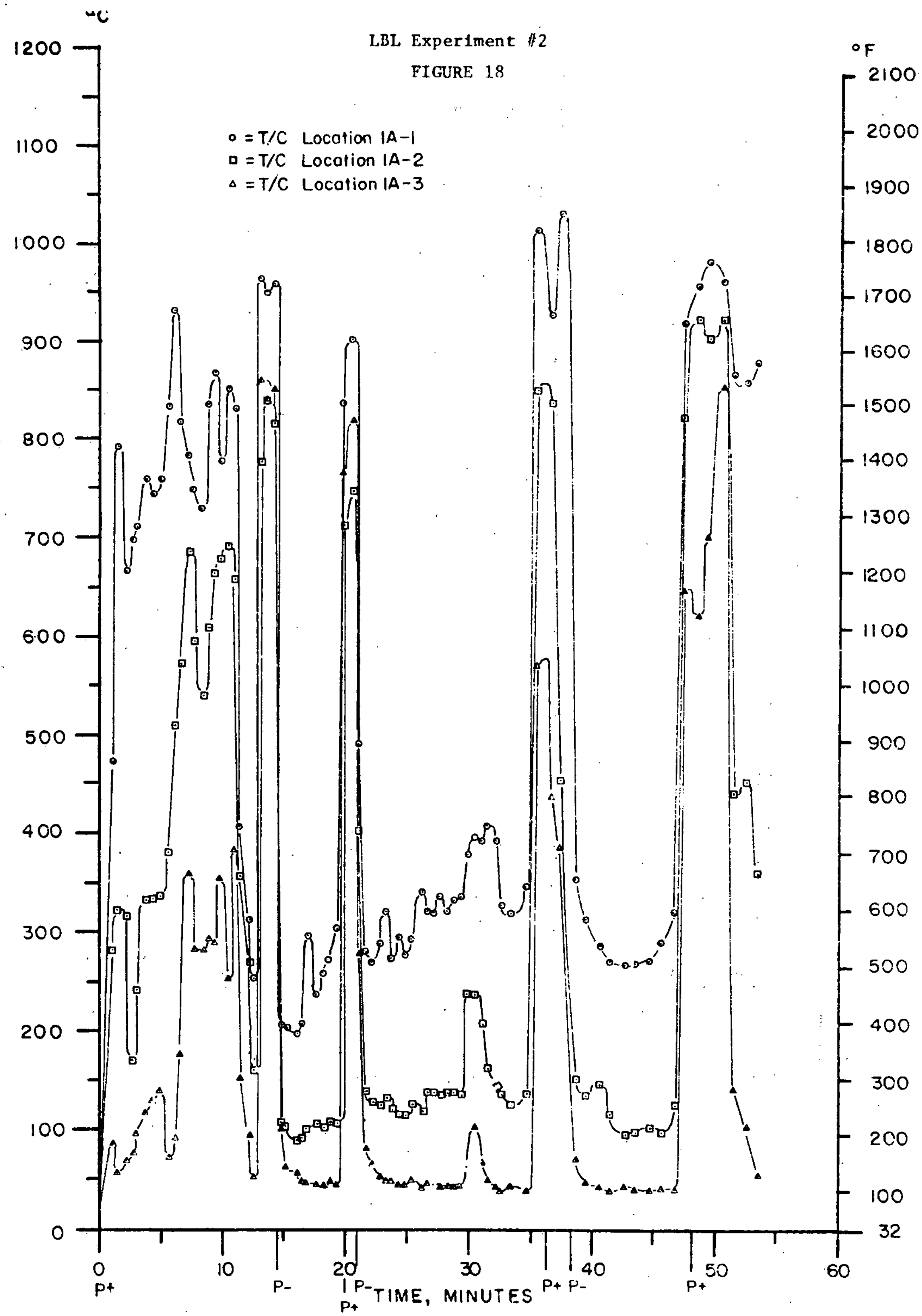
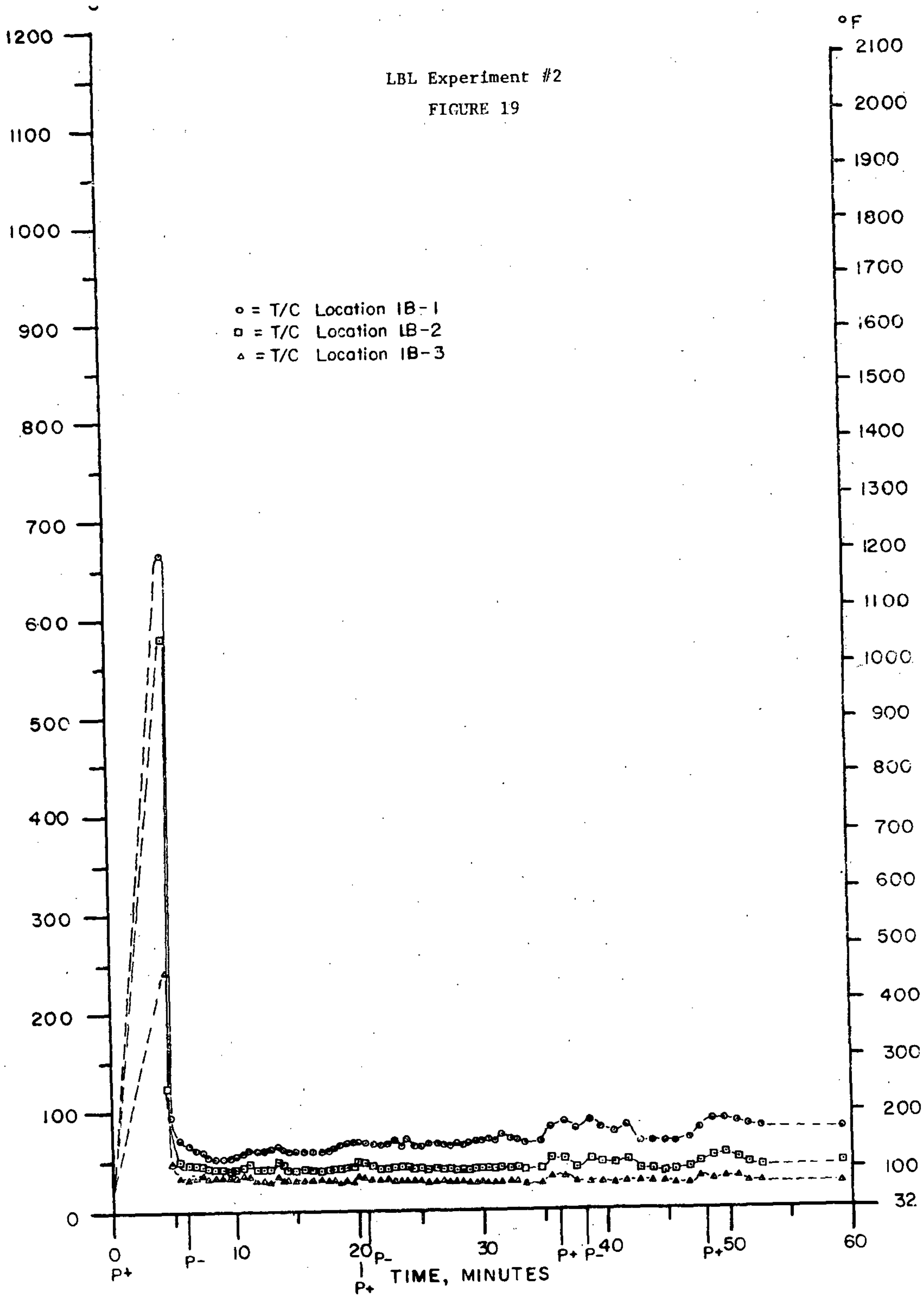


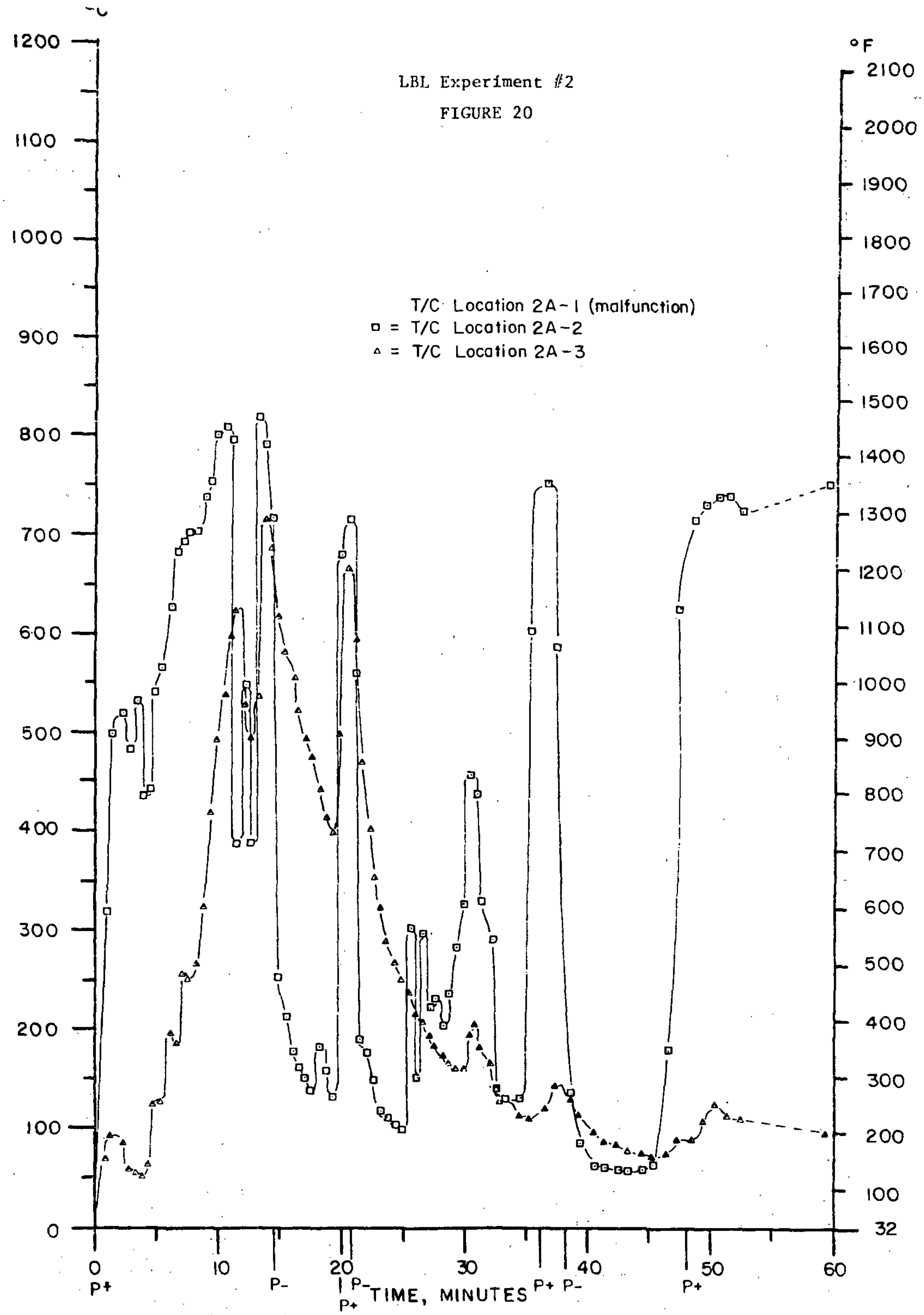
FIGURE 17: INTERNAL FURNACE PRESSURE DURING EXPERIMENT NUMBER 2

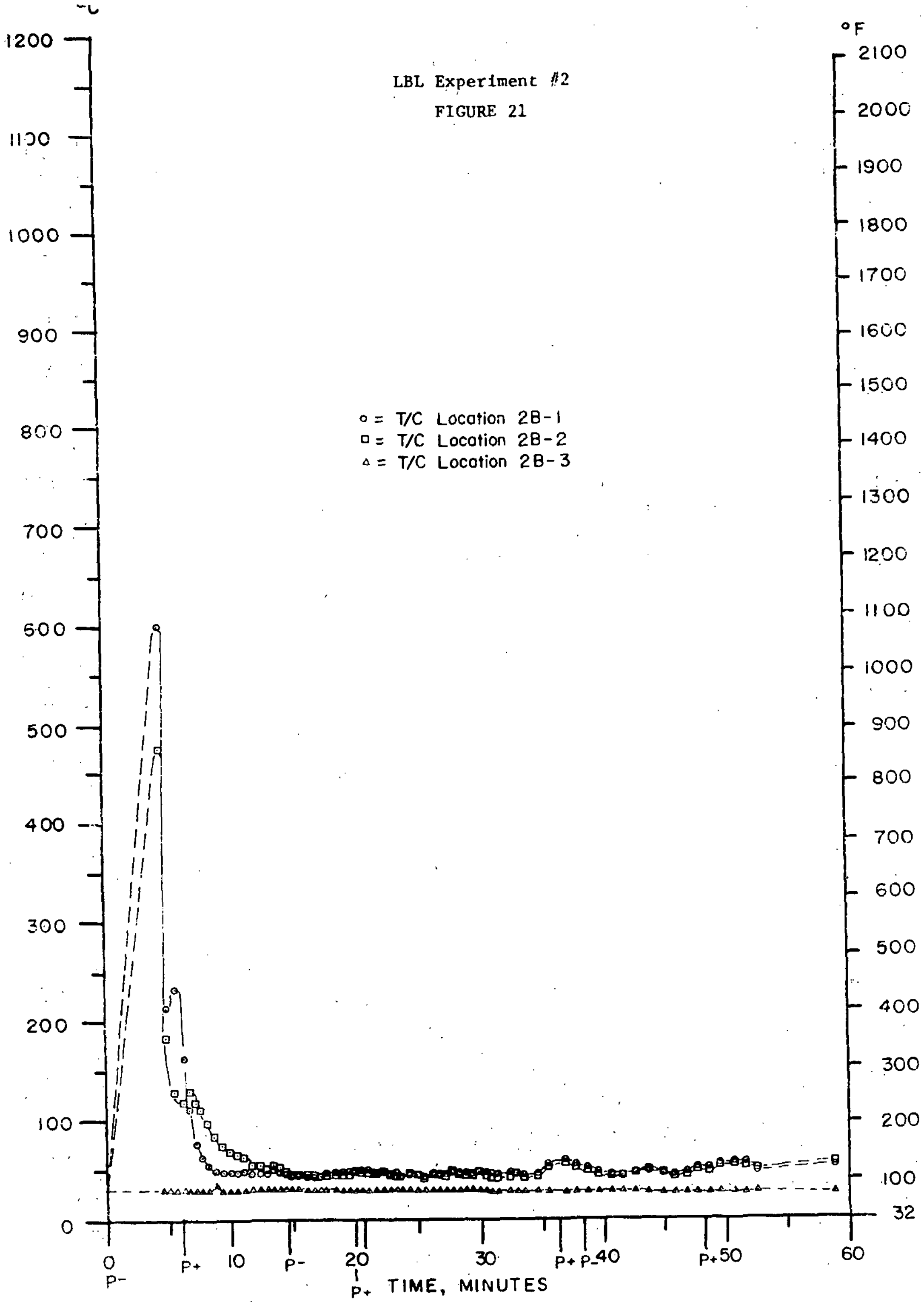


°C
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
LBL Experiment #2
FIGURE 18
°F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
o = T/C Location IA-1
□ = T/C Location IA-2
Δ = T/C Location IA-3
0
10
20
30
40
50
60
P+
P-
P-
P+
TIME, MINUTES
P+ P-
P+

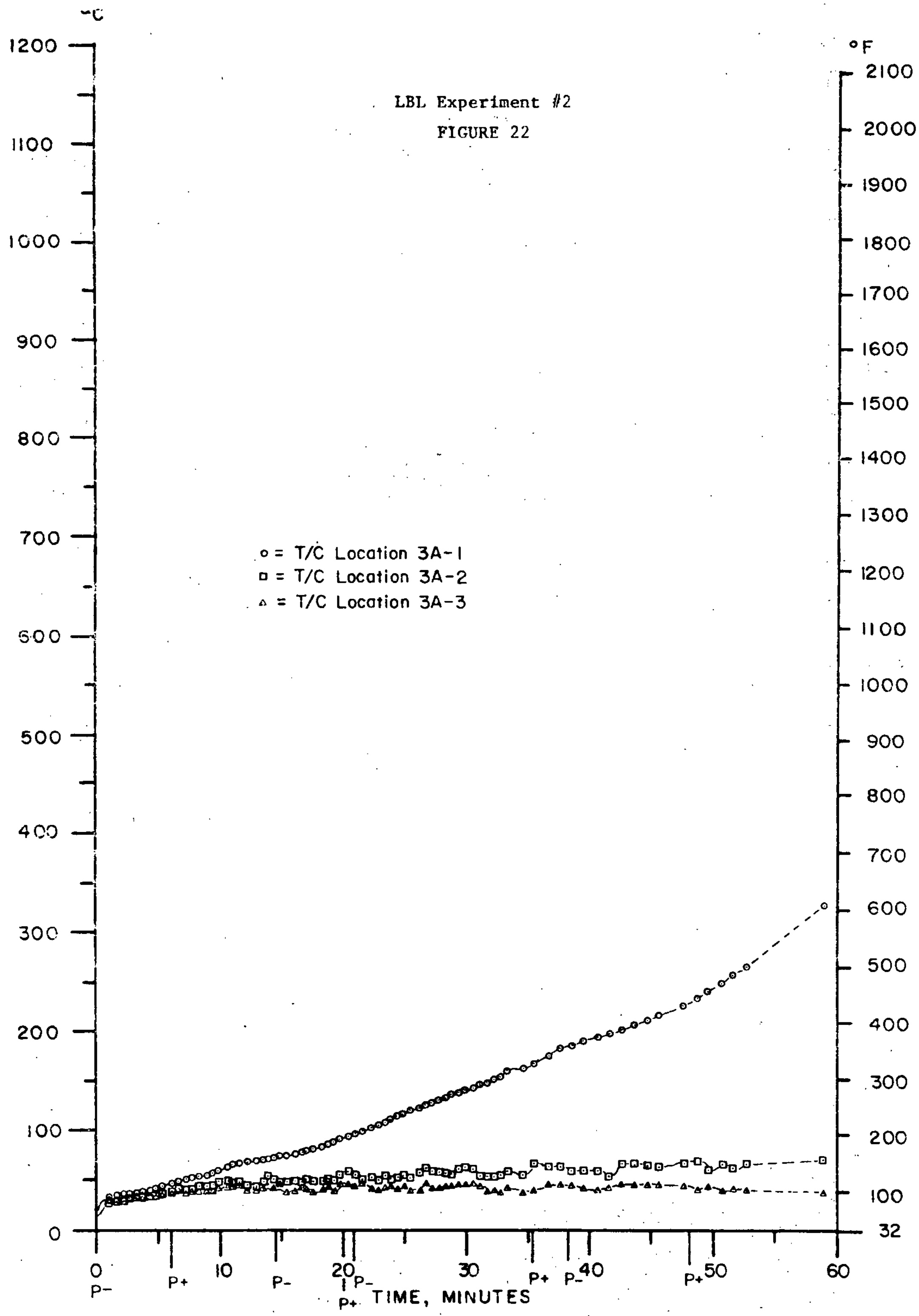


LBL Experiment #2
FIGURE 19
o = T/C Location IB-1
□ = T/C Location IB-2
△ = T/C Location IB-3
°F
TIME, MINUTES
P+
P-
0
10
20
30
40
50
60
1200
1100
1000
900
800
700
600
500
400
300
200
100
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
32

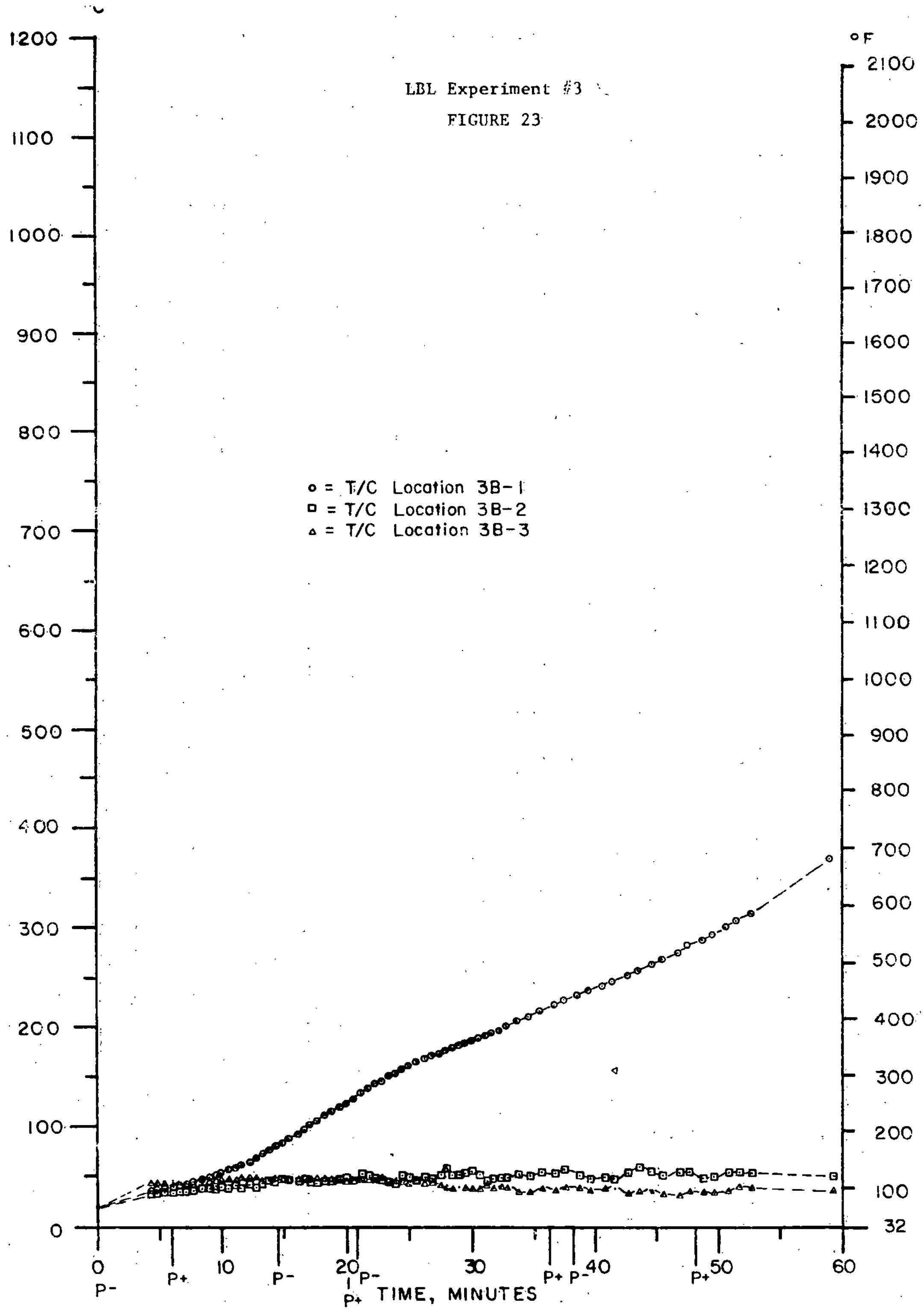

°C
°F
LBL Experiment #2
FIGURE 20
T/C Location 2A-1 (malfunction)
□ = T/C Location 2A-2
△ = T/C Location 2A-3
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
0
10
20
30
40
50
60
P+
P-
P-
P+
P+
P-
P+
TIME, MINUTES



LBL Experiment #2
FIGURE 21
°C
°F
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
○ = T/C Location 2B-1
□ = T/C Location 2B-2
△ = T/C Location 2B-3
0
P-
P+
10
P-
20
P+
30
P+ P-
40
P+
50
60
TIME, MINUTES



LBL Experiment #2
FIGURE 22
°C
°F
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
○ = T/C Location 3A-1
□ = T/C Location 3A-2
△ = T/C Location 3A-3
0
10
20
30
40
50
60
P-
P+
P-
P-
P+
P+
P-
P+
TIME, MINUTES


LBL Experiment #3
FIGURE 23
°C
°F
o = T/C Location 3B-1
□ = T/C Location 3B-2
△ = T/C Location 3B-3
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
32
0
10
20
30
40
50
60
P-
P+
P-
P-
P+
P+
P-
P+
TIME, MINUTES

LBL Experiment #2

TABLE XIV

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	1	2	3	4	5	6	7	8	9	1-9
1	06	111	93	128	108	105	123	130	107	110	103
1	40	477	398	495	477	545	566	627	388	466	475
2	14	609	594	651	622	647	696	709	530	580	624
2	47	638	672	688	671	761	726	704	646	658	684
3	20	655	679	655	665	804	681	708	700	654	688
3	53	673	687	648	679	822	671	720	733	652	686
4	25	695	695	658	689	824	680	718	749	655	693
4	50	703	706	676	696	827	699	704	733	668	700
5	33	704	717	700	727	869	735	678	714	674	709
6	06	692	742	734	734	890	784	642	662	700	712
6	39	683	748	752	719	893	836	623	638	761	720
7	12	687	744	775	718	918	862	600	620	796	720
7	45	668	747	791	690	862	870	574	601	806	720
8	19	647	746	779	673	817	860	565	593	785	709
8	52	750	763	786	658	779	867	553	583	807	709
9	25	742	767	791	647	759	870	547	576	804	705
9	58	740	769	788	644	751	868	544	576	804	702
10	31	743	771	813	647	763	893	540	575	840	714
11	04	659	777	847	671	790	925	553	584	861	732
11	38	689	774	864	702	820	940	566	596	869	748
12	10	754	768	893	715	829	948	576	601	894	766
12	44	809	779	903	726	847	964	575	605	921	782
13	17	853	806	899	721	848	952	565	598	942	789
13	50	795	757	889	719	878	940	564	601	917	777
14	24	774	740	886	711	864	916	553	588	889	757
14	57	798	775	846	703	823	877	538	569	836	745
15	30	815	802	822	690	798	845	528	549	775	731
16	03	817	799	826	693	787	831	531	546	723	723
16	36	814	791	814	689	779	802	529	542	677	708
17	00	845	795	870	704	797	809	541	552	657	719
17	43	865	794	903	722	813	822	559	567	660	733
18	16	875	792	917	740	842	832	579	579	666	746

TABLE XIV

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	1	2	3	4	5	6	7	8	9	1-9
18	49	891	793	927	752	861	843	589	587	674	759
19	22	890	807	933	755	870	843	591	586	675	759
19	55	893	811	926	755	878	834	598	586	683	760
20	29	845	771	924	752	898	873	588	594	750	762
21	02	846	760	934	751	906	900	584	596	798	771
21	35	897	796	928	757	900	932	587	598	859	793
22	08	899	816	938	753	877	934	575	592	861	798
22	42	897	816	941	748	867	923	571	586	867	794
23	15	875	808	927	743	350	922	574	584	872	789
23	48	873	805	930	744	844	902	565	577	831	783
24	21	857	911	911	737	819	870	557	569	773	773
24	54	851	978	876	730	803	840	550	561	708	763
25	38	850	976	867	738	807	837	552	564	695	759
26	02	856	961	892	757	820	876	574	583	732	775
26	35	869	963	906	769	841	905	586	594	759	791
27	08	877	967	909	782	865	907	590	600	768	800
27	41	879	973	904	786	887	909	584	608	766	802
28	14	887	948	887	793	886	883	590	607	737	794
28	57	888	969	901	794	889	884	590	698	723	795
29	20	884	964	890	793	887	882	599	610	711	790
29	53	887	949	896	795	895	891	615	613	706	793
30	26	909	912	913	813	917	915	611	619	695	795
30	59	926	911	915	825	922	893	624	624	693	798
31	32	928	912	912	830	927	899	619	629	686	798
32	05	920	934	923	825	934	912	632	632	684	805
32	33	915	952	881	823	916	914	641	633	678	802
33	32	898	844	845	825	897	883	627	629	669	775
34	32	576	751	844	815	911	913	633	636	674	766
35	32	895	785	868	843	963	951	676	662	702	794
36	32	890	920	885	905	1029	941	710	731	756	838
37	32	931	996	914	947	1081	965	746	766	787	880
38	32	971	900	963	741	1075	1023	739	935	759	884

TABLE XIV

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	1	2	3	4	5	6	7	8	9	1-9
39	32	938	809	944	895	1017	1015	729	713	748	848
40	32	889	729	924	836	954	983	709	689	728	810
41	32	860	690	896	806	913	970	700	676	723	788
42	32	851	693	888	795	895	967	674	678	724	783
43	32	846	678	894	790	885	970	702	676	729	784
44	32	847	693	892	806	881	966	698	680	741	788
45	32	865	722	926	815	920	1008	708	697	759	809
46	32	883	789	990	837	948	1050	735	718	803	847
47	32	901	827	996	851	974	1059	762	738	811	867
48	32	852	894	925	878	1004	949	790	762	826	860
49	32	851	905	916	907	1033	917	809	775	835	863
50	32	861	929	921	882	1100	925	786	788	847	866
51	32	859	942	934	874	1096	940	804	791	864	875
52	32	856	916	933	864	1002	938	803	791	870	873
59	25	910	944	995	909	929	1007	896	904	970	942

LBL Experiment #2

TABLE XV

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	11	12	13	14	15	16	17	18	19	11-19
1	06	58	52	60	60	46	52	64	50	53	55
1	40	94	84	98	90	87	104	112	83	85	90
2	14	221	205	220	196	229	274	272	180	208	217
2	47	373	385	417	362	430	487	452	335	387	397
3	20	442	477	489	434	536	548	515	435	453	476
3	53	505	560	539	491	724	582	561	527	519	541
4	25	559	628	575	539	689	604	597	601	558	591
4	50	605	680	606	578	732	625	625	652	591	630
5	33	640	715	632	613	767	647	647	682	617	660
6	06	659	740	660	745	804	680	656	693	642	685
6	39	669	759	685	666	827	719	658	693	674	704
7	12	677	779	710	679	846	760	655	688	713	721
7	45	678	792	732	681	840	790	646	678	690	731
8	19	674	801	745	677	821	808	636	668	763	632
8	52	670	806	753	671	798	817	626	658	776	731
9	25	665	807	760	664	776	826	616	649	787	728
9	58	661	808	764	657	760	830	607	743	792	725
10	31	659	811	770	753	751	841	600	638	803	726
11	04	661	817	787	652	751	874	597	637	823	731
11	38	670	835	810	759	859	990	508	740	843	743
12	11	703	870	835	668	774	910	600	644	864	760
12	44	765	910	860	681	793	926	604	648	883	783
13	17	835	947	874	692	805	930	607	650	900	801
13	50	855	953	879	700	816	926	608	650	902	807
14	24	839	850	880	794	823	915	609	749	888	804
14	57	843	961	870	704	830	895	607	745	865	800
15	30	876	980	852	702	806	869	603	637	830	794
16	03	900	989	840	700	796	848	599	630	848	787
16	36	913	995	831	698	782	827	596	624	827	759
17	00	926	998	833	698	780	811	594	621	731	775
17	43	936	998	855	705	786	805	597	622	714	778
18	16	944	1000	878	714	799	806	702	727	703	783

TABLE XV

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	11	12	13	14	15	16	17	18	19	11-19
18	49	946	999	901	726	817	813	609	632	699	790
19	22	950	1000	916	736	834	820	615	637	697	797
19	55	954	1003	918	743	846	822	621	640	699	802
20	29	944	1002	917	747	858	830	628	653	710	805
21	02	923	998	924	748	867	849	628	646	736	810
21	35	933	1003	930	752	877	872	631	649	773	821
22	08	952	1009	931	755	877	890	633	649	802	831
22	42	966	1012	931	755	872	896	633	648	816	834
23	15	977	1016	928	755	862	898	632	647	826	836
23	48	982	1017	924	754	849	895	631	645	835	834
24	21	985	1016	915	752	835	879	629	641	806	827
24	55	893	1016	899	749	824	860	627	636	779	818
25	28	977	1012	884	746	819	846	624	632	755	808
26	35	971	1013	887	753	814	857	627	635	745	808
27	08	968	1016	892	761	828	864	632	639	744	813
27	41	970	1020	894	769	842	870	637	644	746	818
28	14	973	1021	891	775	853	868	641	648	742	821
28	47	976	1020	890	781	861	866	645	651	737	823
29	20	980	1018	889	785	865	862	649	654	731	823
29	53	984	1015	890	783	870	864	652	657	728	825
30	26	985	1013	894	796	879	869	657	661	724	828
30	59	989	1012	907	805	892	872	662	666	722	834
31	32	995	1011	910	815	903	872	668	670	720	838
32	05	999	1010	915	821	909	876	672	675	718	842
32	38	1000	1003	0-2	927	011	991	679	681	716	842
33	32	985	942	876	826	897	872	683	685	712	829
34	32	971	872	850	822	886	865	685	687	709	814
35	32	970	839	843	838	807	888	695	701	721	819
36	36	926	864	853	862	969	900	720	728	747	838
37	32	929	938	883	911	1034	925	758	766	780	876
38	32	991	942	921	936	1066	962	776	785	792	907
39	32	1015	915	931	918	1025	973	777	785	792	903

TABLE XV

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE NO.									AVE
MIN	SEC	11	12	13	14	15	16	17	18	19	11-19
40	32	986	873	915	879	967	959	765	774	781	878
41	32	947	838	893	842	916	943	749	761	771	851
42	32	917	815	878	815	886	931	734	754	767	832
43	32	909	800	870	801	864	927	727	749	767	823
44	32	908	795	868	795	861	926	726	750	771	821
45	36	929	799	879	798	870	942	729	756	782	829
46	32	936	820	922	808	896	895	738	768	806	851
47	32	957	852	964	826	927	1011	757	786	836	878
48	32	909	880	947	856	958	979	778	806	850	883
47	32	873	891	922	864	979	936	801	822	859	882
50	32	863	803	814	874	1030	924	812	835	870	891
51	32	863	191	920	876	1051	928	819	845	884	900
52	32	862	917	924	873	1011	932	823	851	894	899
59	25	903	845	980	914	926	998	904	935	988	944

LBL Experiment #2

TABLE XVI

TIME		OBSERVATIONS
MIN	SEC	
	00	START OF TEST.
1	10	WHITE SMOKE IS BEING EMITTED OUT OF PORT 2-B.
2	00	WHITE SMOKE IS COMING OUT OF BOTH 2-A AND 2-B.
2	50	SPARKS ARE COMING OUT OF 2-B.
4	15	NO CHANGE.
4	40	A SMALL AMOUNT OF SMOKE IS COMING OUT OF 1-B.
4	55	3' HIGH FLAMES ARE COMING OUT OF 2-B.
5	30	3' HIGH FLAMES HAVE NOW APPEARED OUT OF 2-A.
5	35	A 2' HIGH FLAME HAS APPEARED OUT OF 1-A.
6	00	PRESSURE HAS BEEN CHANGED. FLAMING HAS CEASED FROM BOTTOM PORTS.
6	40	PORT 2-A HAS A 5' FLAME COMING OUT OF IT WITH THE CABLES BURNING.
		PORT 1-A HAS A 3' FLAME OUT OF IT.
7	10	PORTS 1-A AND 2-A CONTINUE TO FLAME WITH NO FLAMES APPEARING AT ANY
		OF THE OTHER PORTS.
8	40	THE WIRE COMING OUT OF 2-B IS CHARRING AWAY.
10	00	NO CHANGE.
10	30	FLAME HEIGHTS OF 3' AND 5' ARE COMING OUT OF 1-A AND 2-A RESPECTIVELY.
12	00	THE PRESSURE HAS BEEN REDUCED. FLAMING IS STILL OCCURRING OUT OF
		1-A AND 2-A.
13	30	POSITIVE PRESSURE HAS BEEN ESTABLISHED WITH FLAMES CONTINUING TO

TABLE XVI

continued

TIME		OBSERVATIONS
MIN	SEC	
		TO APPEAR OUT OF 1-A AND 2-A.
14	30	THE POSITIVE PRESSURE HAS BEEN REDUCED WITH A SUBSEQUENT REDUCTION
		IN THE FLAME HEIGHTS.
14	40	NEGATIVE PRESSURE HAS BEEN ESTABLISHED, ALL FLAMING HAS CEASED.
15	30	A SUBSTANTIAL AMOUNT OF WHITE SMOKE IS COMING OUT OF 2-A FROM THE
		SMOLDERING CABLES.
17	00	NEGATIVE PRESSURE CONTINUES WITH NO CHANGE.
18	30	NO CHANGE.
20	00	POSITIVE PRESSURE HAS BEEN REESTABLISHED WITH 5-6' HIGH FLAMES COMING
		OUT OF PORTS 1-A AND 2-A.
20	55	PRESSURE IS CHANGED TO NEGATIVE WITH THE FLAME RECEDING BACK INTO THE
		PORTS.
22	30	NO CHANGE.
24	00	NO CHANGE.
28	00	THE WHITE SMOKE FROM PORT 2-A HAS ALMOST CEASED TO APPEAR. SMALL
		INTERMITTENT FLAMES APPEAR FROM PORTS 1-A AND 2-A AT APPROXIMATELY
		2 MINUTE INTERVALS.
34	00	NO CHANGE.
36	00	POSITIVE PRESSURE IS REESTABLISHED WITH FLAMES APPEARING OUT OF 1-A
		BUT NOT 2-A.

TABLE XVI

continued

TIME		OBSERVATIONS
MIN	SEC	
38	05	NEGATIVE PRESSURE IS ESTABLISHED WITH ALL FLAMING CEASED.
42	00	NO CHANGE.
48	00	POSITIVE PRESSURE IS ESTABLISHED WITH A 5' HIGH FLAME COMING OUT OF 1-A.
51	35	FLAMING HAS CEASED FROM 1-A. NO FLAMING VISIBLE FROM ANY OF THE PORTS.
52	00	A SMALL AMOUNT OF WHITE SMOKE IS APPEARING FROM PORT 3-A.
55	00	THE CERAMIC FIBER IN PORT 3-A IS BROWNING.
58	00	A SUBSTANTIAL AMOUNT OF SMOKE IS COMING OUT OF PORT 3-A.
60	00	NO CHANGE, END OF TEST.

LBL Experiment #2

TABLE XVII

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1A-1	1A-2	1A-3
1	06	473	282	86
1	40	791	322	57
2	14	666	316	70
2	47	698	171	77
3	20	710	242	96
3	53	758	332	117
4	25	744	333	130
4	50	758	336	140
5	33	833	380	73
6	06	931	508	91
6	39	817	673	176
7	12	783	685	359
7	45	748	595	179
8	19	729	538	178
8	52	835	608	194
9	25	866	664	189
9	58	776	677	354
10	31	850	691	254
11	04	830	657	383
11	38	406	356	152
12	11	312	270	95
12	44	253	161	52
13	17	964	776	859
13	50	949	839	840
14	24	957	815	850
14	57	206	108	100
15	30	204	103	64
16	03	198	90	56
16	36	308	93	49
17	00	296	101	48
17	43	237	106	45

TABLE XVII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1A-1	1A-2	1A-3
18	16	259	103	44
18	49	262	109	47
19	22	304	107	44
19	55	836	711	765
20	29	901	746	818
21	02	491	401	279
21	35	381	140	81
22	08	270	129	65
22	42	284	125	52
23	15	320	132	49
23	48	274	121	48
24	21	294	116	44
25	28	293	126	50
26	02	340	119	41
26	35	322	139	46
27	08	320	139	44
27	41	336	136	43
28	14	321	137	44
28	47	332	138	42
29	20	335	136	43
29	53	378	238	64
30	26	395	237	103
30	59	392	308	67
31	32	407	163	49
32	05	392	149	42
32	38	326	136	38
33	32	319	125	43
34	32	345	132	39
35	32	1012	849	570
36	32	926	836	436
37	32	1029	453	385

TABLE XVII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1A-1	1A-2	1A-3
38	32	353	153	70
39	32	313	136	48
40	32	286	122	42
41	32	271	116	39
42	32	267	95	43
43	32	269	98	40
44	32	271	102	39
45	32	290	98	41
46	32	320	125	40
47	32	919	822	645
48	32	956	921	571
49	32	980	903	700
50	32	961	921	852
51	32	866	440	142
52	32	858	451	104
59	25	878	359	55

LBL Experiment #2

TABLE XVIII

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1B-1	1B-2	1B-3
1	06			
1	40			
2	14	◁ NO DATA AVAILABLE ▷		
2	47			
3	20			
4	25	665	580	241
4	50	95	128	49
5	33	72	50	33
6	06	67	47	32
6	39	62	47	33
7	12	60	45	35
7	45	55	44	33
8	19	53	42	33
8	52	53	42	33
9	25	54	41	33
9	58	55	42	33
10	31	58	44	35
11	04	61	48	35
11	38	60	41	31
12	10	61	41	60
12	44	63	41	29
13	17	65	50	40
13	50	63	49	35
14	24	61	42	31
14	57	60	41	30
15	30	60	42	30
16	03	60	41	30
16	36	60	40	31
17	00	61	41	30
17	43	63	42	30
18	16	66	43	29

TABLE XVIII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1B-1	1B-2	1B-3
18	49	68	44	30
19	22	69	45	29
19	55	69	50	35
20	29	69	49	33
21	02	67	44	31
21	35	66	43	31
22	08	67	43	30
22	42	72	44	29
23	15	66	44	29
23	48	63	44	29
24	21	65	42	29
24	55	65	43	29
25	28	67	42	28
26	02	68	43	29
26	35	67	42	29
27	08	66	42	28
27	41	68	41	29
28	14	67	41	29
28	47	69	41	28
29	20	70	42	28
29	53	70	42	29
30	26	72	42	28
20	59	70	42	27
31	32	76	44	27
32	05	72	42	28
32	38	71	44	27
33	32	68	41	26
34	32	69	42	27
35	32	84	53	34
36	32	89	41	34
37	32	77	44	28

TABLE XVIII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	1B-1	1B-2	1B-3
38	32	90	51	27
39	32	83	48	27
40	32	79	48	26
41	32	80	50	27
42	32	69	41	29
44	32	68	39	28
45	32	68	40	26
46	32	72	43	26
47	32	82	48	32
48	32	90	54	30
49	32	90	57	32
50	32	88	51	32
51	32	85	46	27
52	32	79	44	27
59	25	81	48	26

LBL Experiment #2

TABLE XIX

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2A-1	2A-2	2A-3
1	06	THERMOCOUPLE MALFUNCTION	318	69
1	40		497	92
2	14		517	84
2	47		481	58
3	20		530	54
3	53		434	50
4	25		442	63
4	50		638	124
5	33		564	126
6	06		626	195
6	39		682	185
7	12		692	255
7	45		701	250
8	19		702	265
8	52		737	323
9	25		753	418
9	58		799	490
10	31		807	536
11	04		794	597
11	38		385	620
12	10		547	526
12	44		387	491
13	17		814	534
13	50		789	712
14	24		715	684
14	57		252	616
15	30		213	580
16	03		178	554
16	36		163	520
17	00		151	492
17	43		138	473

TABLE XIX

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2A-1	2A-2	2A-3
18	16	THERMOCOUPLE MALFUNCTION	183	441
18	49		158	413
19	22		133	396
19	55		679	496
20	29		715	664
21	02		559	592
21	35		190	467
22	08		177	401
22	42		147	353
23	15		118	321
23	48		111	288
24	21		103	268
24	55		99	250
25	28		303	238
26	02		151	217
26	35		297	209
27	08		222	194
27.	41		233	184
28	14		204	174
28	47		237	167
29	20		283	162
29	53		326	162
30	26		456	195
30	59		436	205
31	32		329	181
32	05		291	166
32	38		140	140
33	32		130	127
34	32		131	112
35	32		603	110
36	32		751	121

TABLE XIX

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2A-1	2A-2	2A-3
37	32	THERMOCOUPLE MALFUNCTION	589	144
38	32		136	129
39	32		85	113
40	32		63	97
41	32		62	88
42	32		59	84
43	32		58	77
44	32		59	75
45	32		65	73
46	32		180	75
47	32		626	90
48	32		715	87
49	32		731	108
50	32		738	125
51	32		739	115
52	32		724	111
59	25		751	97

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TABLE XX

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2B-1	2B-2	2B-3
1	06			
1	40	◁— NO	DATA AVAILABLE	—▷
2	14			
2	47			
3	20			
3	53			
4	25	598	474	29
4	50	214	181	29
5	33	233	128	29
6	06	161	116	29
6	39	110	128	28
7	12	76	116	28
7	45	61	108	28
8	19	54	95	28
8	52	49	81	33
9	25	47	73	28
9	58	47	67	28
10	31	47	63	28
11	04	48	61	28
11	38	46	52	29
12	11	46	52	29
12	44	45	49	29
13	17	49	53	29
13	50	48	50	29
14	24	45	47	29
14	57	43	45	29
15	30	43	45	29
16	03	43	45	28
16	36	43	45	28
17	00	44	44	28
17	43	46	44	28

TABLE XX

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2B-1	2B-2	2B-3
18	16	47	45	28
18	49	47	45	28
19	22	48	45	28
19	55	49	48	28
20	29	49	47	28
21	02	48	47	28
21	35	48	46	28
22	08	47	47	28
22	42	45	44	28
23	15	46	43	28
23	48	43	43	28
24	21	44	45	28
24	55	44	44	28
25	28	43	42	28
26	02	46	44	27
26	35	45	44	27
27	08	45	43	27
27	41	47	48	27
28	14	46	45	27
28	47	46	44	27
29	20	45	44	27
29	53	47	47	27
30	26	47	44	27
30	59	45	42	26
31	32	45	42	26
32	05	46	43	26
32	38	45	45	26
33	32	44	41	26
34	32	46	43	26
35	32	55	51	26
36	32	59	55	26

TABLE XX

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	2B-1	2B-2	2B-3
37	32	54	50	26
38	32	51	48	26
29	32	47	43	26
40	32	45	44	26
41	32	44	44	26
42	32	46	46	26
43	32	47	49	26
44	32	46	47	25
45	32	45	43	25
46	32	47	43	25
47	32	52	49	25
48	32	51	47	25
49	32	55	51	25
50	32	57	54	25
51	32	56	51	25
52	32	47	49	25
59	25	53	55	24

LBL Experiment #2

TABLE XXI

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3A-1	3A-2	3A-3
1	06	33	26	28
1	40	35	28	29
2	14	36	29	30
2	47	36	32	32
3	20	37	32	33
3	53	38	33	32
4	25	39	33	33
4	50	42	34	32
5	33	44	36	34
6	06	47	38	36
6	39	49	41	38
7	12	51	40	36
7	45	52	41	38
8	19	54	44	38
8	52	55	44	37
9	25	57	45	38
9	58	59	48	41
10	31	63	49	41
11	04	65	48	42
11	38	67	48	44
12	10	68	45	39
12	44	69	44	39
13	17	70	49	42
13	50	71	55	45
14	24	73	41	42
14	57	74	48	46
15	30	75	48	38
16	03	76	49	39
16	36	78	48	42
17	00	79	51	40
17	43	81	49	38

TABLE XXI

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3A-1	3A-2	3A-3
18	16	84	49	40
18	49	86	51	42
19	22	89	50	38
19	55	91	55	46
20	29	94	59	45
21	02	97	55	44
21	35	100	51	47
22	08	103	53	41
22	42	106	51	39
23	15	109	55	42
23	48	112	51	44
24	21	115	54	41
24	55	118	55	44
25	28	121	53	39
26	02	124	58	39
26	35	126	63	46
27	08	129	59	42
27	41	132	59	42
28	14	134	57	45
28	47	137	56	44
29	20	139	62	45
29	53	142	63	45
30	26	144	61	46
30	59	147	55	44
31	32	149	54	39
32	15	152	54	40
32	38	155	56	38
33	32	160	59	43
34	32	164	56	38
35	32	168	67	41
36	32	176	64	46

TABLE XXI

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3A-1	3A-2	3A-3
37	32	184	64	46
38	32	187	60	45
39	32	191	60	42
40	32	195	60	41
41	32	199	55	43
42	32	203	67	46
43	32	208	66	45
44	32	212	65	46
45	32	217	64	46
47	32	226	67	44
48	32	235	69	42
49	32	242	61	44
50	32	250	66	41
51	32	258	63	42
52	32	266	66	41
59	25	328	71	39

LBL Experiment #2

TABLE XXII

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3B-1	3B-2	3B-3
1	06	NO DATA AVAILABLE		
1	40			
2	14			
2	47			
3	20			
3	53			
4	25	36	32	44
4	50	37	33	44
5	33	38	34	43
6	06	39	33	44
6	39	41	34	44
7	12	43	34	45
7	45	45	35	44
8	19	47	38	44
8	52	49	38	46
9	25	51	37	45
9	58	53	39	46
10	31	56	38	47
11	04	58	41	45
11	38	61	38	49
12	11	64	41	49
12	44	68	39	49
13	17	72	43	44
13	50	76	46	46
14	24	80	45	49
14	57	84	48	48
15	30	88	47	48
16	03	93	45	49
16	36	97	47	50
17	00	101	45	49
17	43	106	44	50

TABLE XXII

continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3B-1	3B-2	3B-3
18	16	111	45	48
18	49	115	45	47
19	22	120	46	47
19	55	124	47	44
20	29	129	46	45
21	02	134	53	46
21	35	138	51	46
22	08	143	49	46
22	42	147	46	48
23	15	151	45	46
23	48	154	44	47
24	21	158	50	45
24	55	171	49	42
25	28	165	45	45
26	02	168	49	42
26	35	171	48	43
27	08	173	51	41
27	41	176	57	39
28	14	179	51	38
28	47	181	51	40
29	20	184	52	39
29	53	186	53	38
30	26	189	51	38
30	59	192	45	41
31	32	194	47	38
32	05	197	48	39
32	38	201	48	38
33	32	206	41	34
34	32	210	50	34
35	32	216	54	37

TABLE XXII

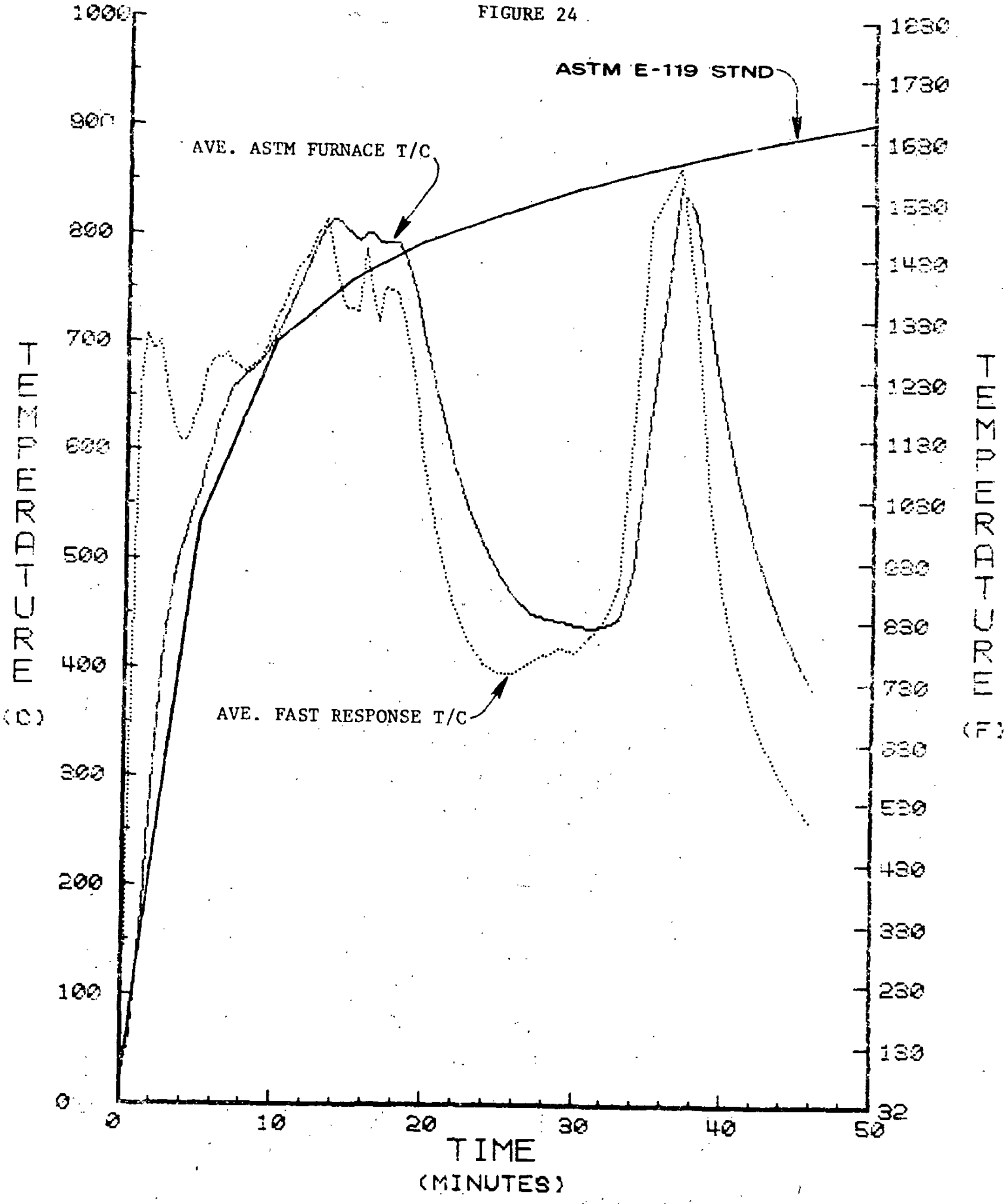
continued

TIME		TEMPERATURE °C AT THERMOCOUPLE LOCATION		
MIN	SEC	3B-1	3B-2	3B-3
36	32	223	53	35
37	32	338	56	39
38	32	232	50	38
39	32	237	48	36
40	32	242	49	37
41	32	247	48	37
42	34	252	54	33
43	32	238	59	35
44	32	264	55	36
45	32	269	50	32
46	32	275	53	31
47	32	282	54	35
48	32	208	48	34
40	32	294	50	34
50	32	300	54	35
51	32	307	54	39
52	32	314	53	38
59	25	369	51	35

EXPERIMENT #3; AVE. FURNACE TEMPS. (ASTM TCS; FAST TCS) & STND. E-119 CURVE

LBL Experiment #3

FIGURE 24



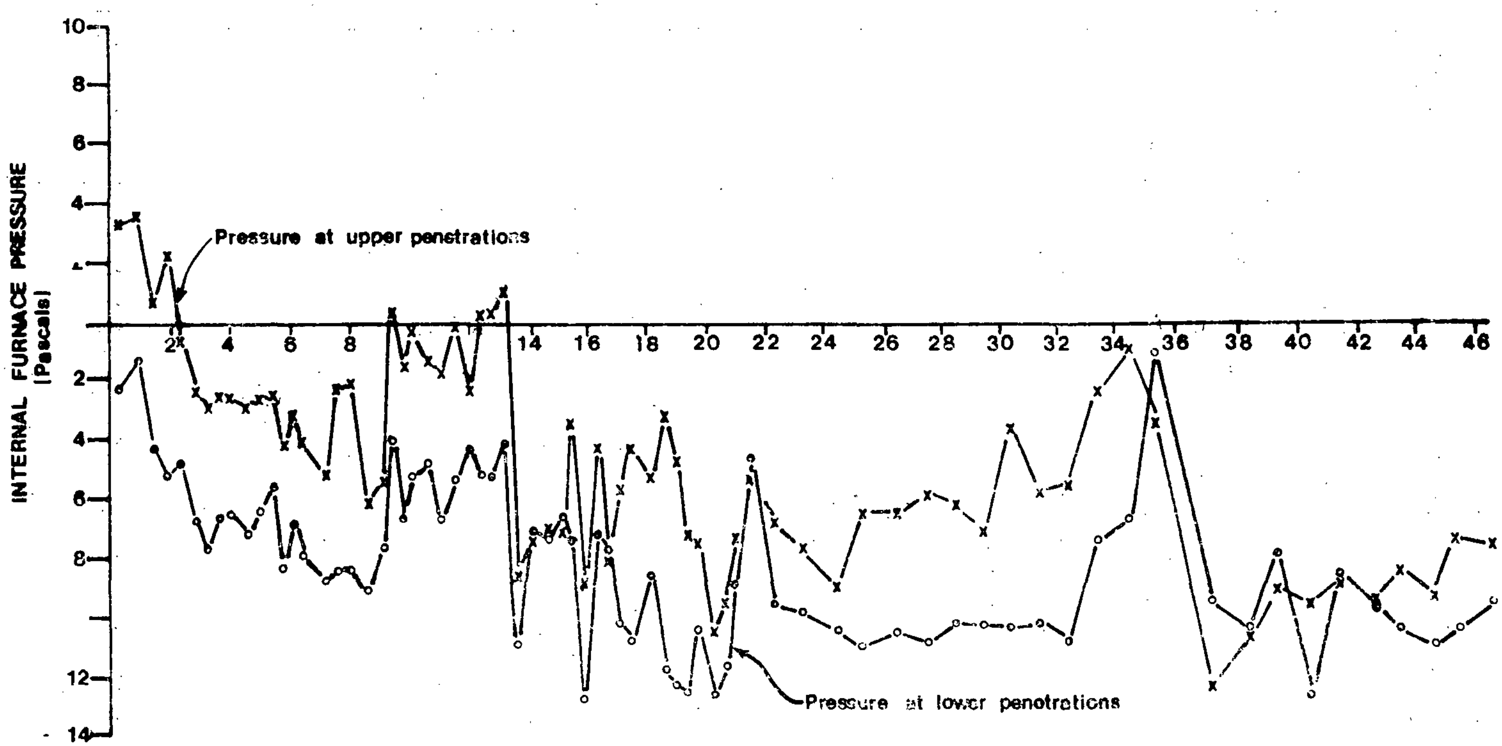
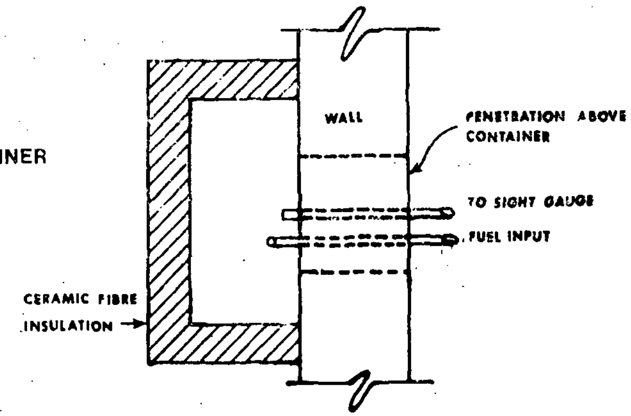


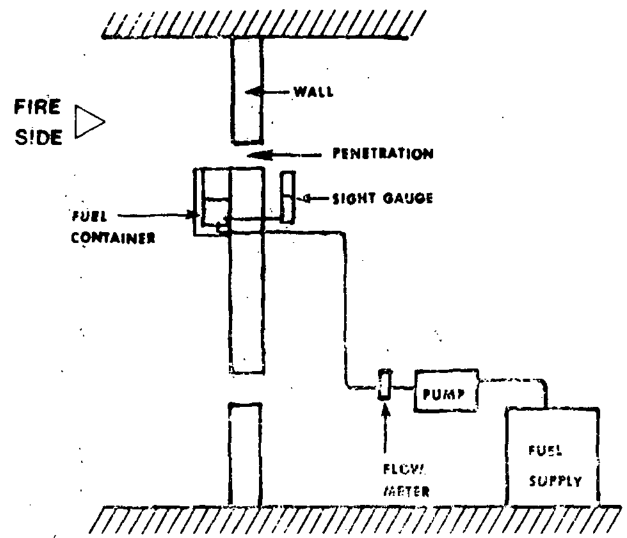
FIGURE 25: EXPERIMENT No.3: FURNACE INTERNAL PRESSURE HISTORY

FIGURE 26: DESIGN OF LIQUID FUEL EXCESS PYROLYZATE CONTAINER

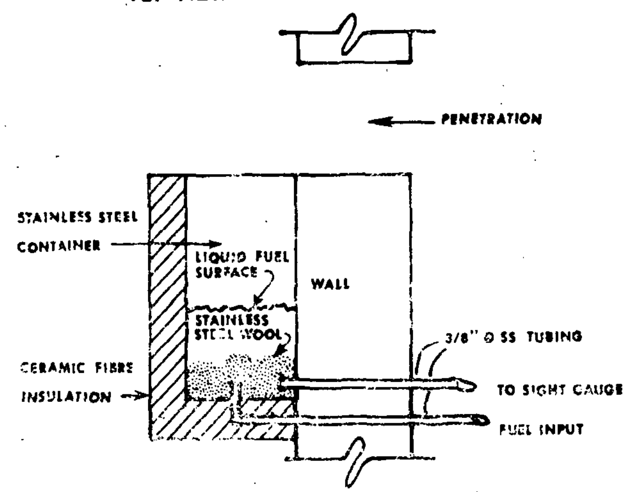
UTILIZED IN EXPERIMENT NO. 3



TOP VIEW

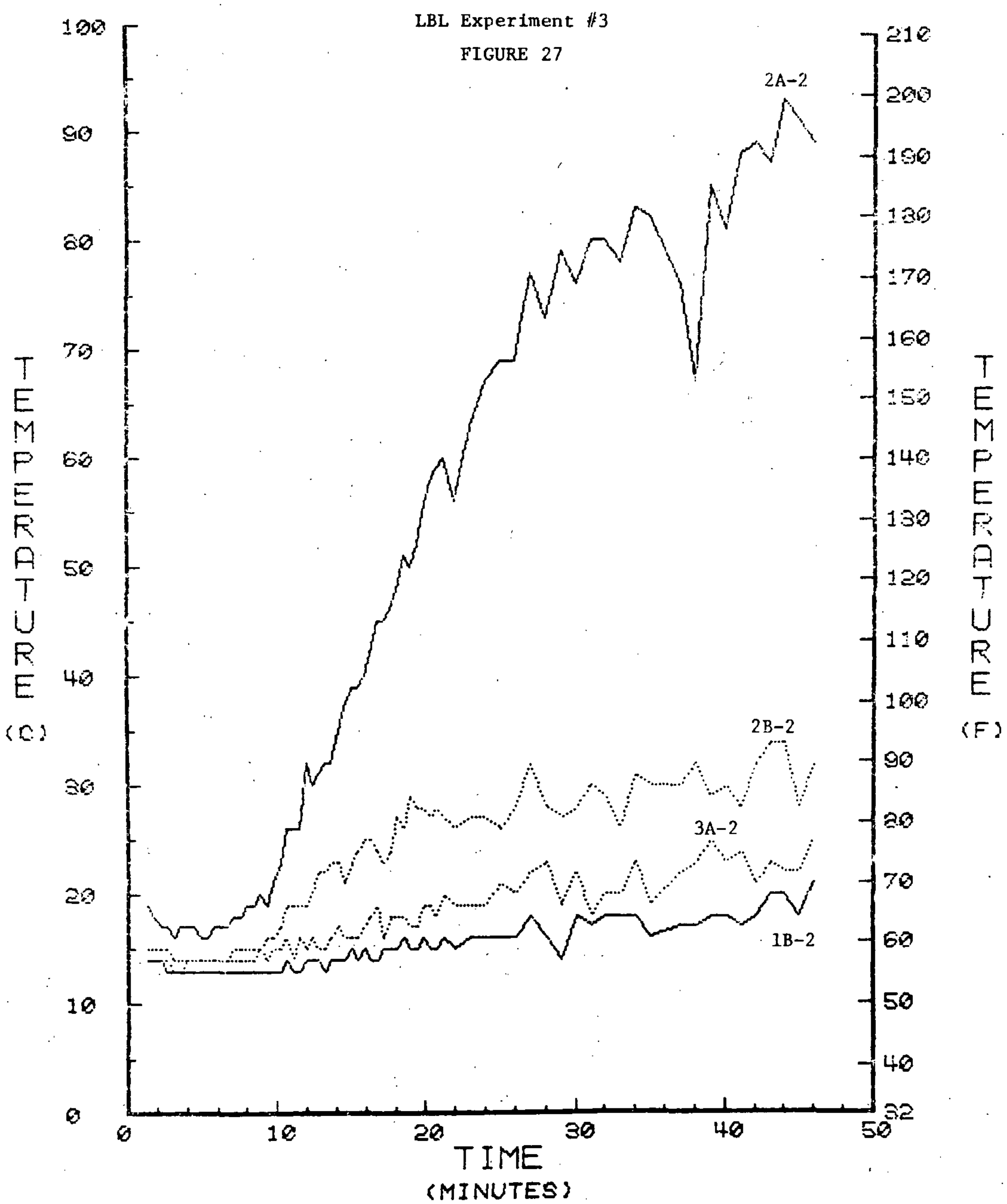


SCHEMATIC DIAGRAM

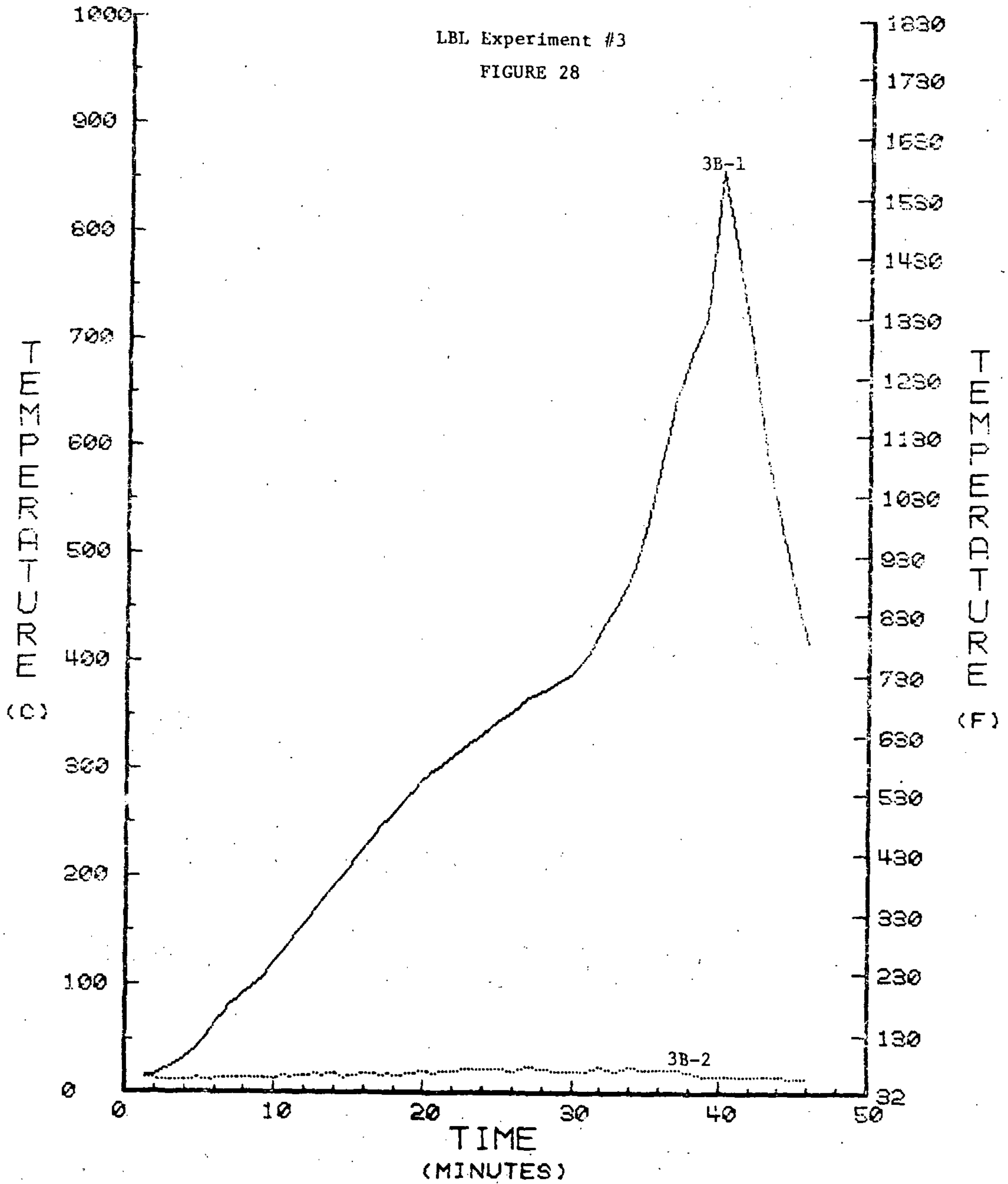


FUEL CONTAINER SIDE VIEW

EXPERIMENT #3: TEMPS. AT PENETRATIONS 1B,2A,2B & 3A



EXPERIMENT #3, TEMPERATURES AT PENETRATION 5E



LBL Experiment #3

TABLE XXIII

TIME (H:M:S)	TEMPERATURE (C) AT THERMOCOUPLE NUMBER: 1	2	3	4	5	6	7	8	9	AVG 1-9
00:00:04	107	103	42	122		133	51	111	168	91
00:00:30	341	350	278	425		430	348	444	537	395
00:00:56	579	530	476	681		742	570	747	776	658
00:01:23	626	603	527	714		769	601	733	774	707
00:01:49	611	631	533	700		761	596	705	758	692
00:02:16	614	669	552	693		764	600	687	751	701
00:02:42	581	681	541	640		722	567	630	696	661
00:03:08	549	689	528	589		683	535	587	640	625
00:03:35	533	697	523	570		671	524	565	613	608
00:04:01	528	731	537	557		691	531	549	611	609
00:04:27	537	761	555	561		729	551	564	620	624
00:04:54	550	780	571	574		779	580	575	629	645
00:05:20	575	794	590	601		827	611	613	649	673
00:05:47	602	795	598	597		839	617	622	652	684
00:06:13	613	804	604	596		840	620	625	646	685
00:06:39	627	819	615	593		843	622	626	629	690
00:07:06	646	820	617	589		818	611	602	602	679
00:07:32	662	823	620	589		800	604	590	588	674
00:07:58	684	833	628	593		791	603	578	576	673
00:08:25	695	838	634	611		787	607	577	572	679
00:08:51	708	844	640	616		794	613	578	569	683
00:09:17	726	848	649	630		821	630	595	575	695
00:09:44	748	853	661	640		875	658	607	588	715
00:10:10	783	860	675	654		880	666	617	594	729
00:10:36	843	860	691	676		887	678	622	595	743
00:11:03	861	870	703	749		875	693	631	598	762
00:11:29	876	872	710	793		869	701	634	597	770
00:11:56	879	875	714	845		865	712	640	600	779
00:12:22	881	891	725	876		879	727	660	604	794
00:12:48	889	902	733	873		884	731	684	607	802
00:13:14	881	917	739	886		895	740	716	612	813
00:13:41	877	914	730	839		807	690	663	582	785
00:14:07	885	952	740	759		742	645	607	551	750
00:14:34	894	935	731	734		727	631	578	533	732
00:15:00	900	985	756	718		717	628	561	520	731
00:15:26	915	933	733	731		711	624	656	522	729

TABLE XXIII

continued

TIME (H:M:S)	TEMPERATURE (C) AT THERMOCOUPLE NUMBER: 1	2	3	4	5	6	7	8	9	AVG 1-9
00:15:53	933	879	728	846		745	662	775	530	786
00:16:19	946	816	693	806		735	641	642	524	745
00:16:46	899	811	675	785		719	624	579	515	718
00:17:12	969	827	706	866		735	656	577	535	750
00:17:38	974	895	734	872		704	652	553	516	747
00:18:05	928	990	764	844		691	646	531	506	745
00:18:31	848	922	710	851		687	632	510	494	717
00:18:57	794	860	665	849		668	612	489	480	691
00:19:24	750	770	605	787		628	566	463	458	645
00:19:50	684	704	549	696		585	515	437	434	592
00:20:16	628	659	509	657		551	481	416	412	555
00:20:42	579	623	475	609		525	450	394	393	523
00:21:09	538	589	443	559		501	421	377	374	492
00:22:00	474	545	401	521		472	388	347	349	453
00:23:00	439	520	373	475		443	359	326	323	422
00:24:00	419	508	358	438		433	342	311	301	403
00:25:00	416	475	341	424		452	343	311	293	395
00:26:00	413	453	330	432		462	346	314	295	396
00:27:00	421	454	334	441		502	368	323	303	407
00:28:00	424	454	336	444		520	377	327	308	412
00:29:00	433	456	341	457		510	376	339	317	419
00:30:00	428	452	337	473		458	356	347	331	414
00:31:00	432	457	345	463		523	385	367	355	431
00:32:00	433	460	349	472		532	392	386	370	441
00:33:00	456	495	378	486		592	429	431	436	476
00:34:00	585	655	515	619		781	576	634	597	636
00:35:00	898	882	724	881		804	697	753	654	811
00:37:00	1060	1066	853	994		745	725	749	577	863
00:38:00	970	855	708	863		647	619	569	505	739
00:39:00	640	650	506	607		544	467	459	432	559
00:40:00	497	549	407	484		462	378	391	373	462
00:41:00	426	484	347	414		409	322	342	326	402
00:42:00	379	435	304	361		369	281	307	296	359
00:43:00	343	397	271	328		336	251	281	269	326
00:44:00	315	365	244	303		308	226	259	246	300
00:45:00	291	335	221	280		285	205	242	229	277
00:46:00	271	311	202	261		267	188	225	216	259

LBL Experiment #3

TABLE XXIV

TIME (H:M:S)	TEMPERATURE (C) AT THERMOCOUPLE NUMBER: 11	12	13	14	15	16	17	18	19	AVG 11-19
00:00:04	34	26	28	41	28	42	60	34	69	31
00:00:30	48	46	43	61	44	66	80	50	94	53
00:00:56	79	86	73	111	94	139	129	108	166	99
00:01:23	133	150	125	189	181	254	201	201	277	179
00:01:49	194	224	192	273	277	374	275	290	390	265
00:02:16	259	304	269	353	371	481	349	374	487	354
00:02:42	315	381	345	413	449	551	406	437	550	422
00:03:08	360	443	408	451	500	587	440	476	583	468
00:03:35	396	490	453	473	531	608	460	501	598	498
00:04:01	424	529	490	488	551	625	471	516	605	520
00:04:27	448	567	523	499	572	645	477	528	612	539
00:04:54	472	607	558	510	596	673	482	541	619	560
00:05:20	496	652	598	523	625	710	487	556	628	583
00:05:47	525	694	642	536	651	743	492	571	637	607
00:06:13	554	733	683	547	672	767	476	582	644	628
00:06:39	581	767	717	556	691	784	499	595	647	646
00:07:06	603	789	741	563	705	790	500	602	644	658
00:07:32	624	809	755	569	715	788	499	606	638	665
00:07:58	645	826	763	575	724	784	499	607	630	671
00:08:25	664	840	772	583	734	781	499	607	623	676
00:08:51	681	852	781	592	745	780	500	608	617	682
00:07:17	697	863	792	601	758	787	503	613	613	690
00:09:44	717	873	807	610	772	807	507	620	612	700
00:10:10	742	884	824	621	785	823	512	627	614	712
00:10:36	774	894	841	634	798	835	519	636	616	724
00:11:03	808	903	856	661	814	842	534	645	618	739
00:11:29	840	910	867	698	825	844	556	654	620	754
00:11:56	862	916	875	743	836	844	580	664	622	768
00:12:22	878	926	883	784	850	849	600	678	625	782
00:12:48	888	934	889	819	864	855	617	694	627	795
00:13:14	894	940	874	845	873	861	638	714	630	806
00:13:41	876	952	898	851	874	848	668	723	631	813
00:14:07	909	985	895	835	858	821	667	711	625	811
00:14:34	923	1000	879	818	845	900	657	695	619	804
00:15:00	936	1017	905	803	831	765	644	678	611	798
00:15:26	949	1014	910	797	822	775	634	672	605	794

TABLE XXIV

continued

TIME (H:M:S)	TEMPERATURE (C) AT THERMOCOUPLE NUMBER: 11	12	13	14	15	16	17	18	19	AVG 11-19
00:15:53	953	978	930	833	828	775	629	707	603	799
00:16:19	976	940	946	842	833	773	621	710	600	800
00:16:46	961	914	947	845	824	768	610	694	596	791
00:17:12	960	907	944	860	828	770	603	681	596	791
00:17:38	964	934	946	874	824	762	596	667	593	791
00:18:05	953	973	959	880	812	754	587	652	588	792
00:18:31	918	955	964	878	796	746	577	636	583	780
00:18:57	878	921	939	874	780	735	567	620	576	763
00:19:24	838	873	888	860	759	718	554	603	566	738
00:19:50	796	824	831	825	736	694	540	586	553	709
00:20:16	756	781	780	790	712	670	524	568	539	680
00:20:42	718	744	737	756	689	646	509	550	525	652
00:21:09	684	710	699	722	667	624	493	534	511	627
00:22:00	625	654	638	664	629	587	465	503	484	583
00:23:00	570	602	583	605	593	549	437	472	456	541
00:24:00	530	566	549	557	569	520	417	448	431	510
00:25:00	500	533	522	521	547	501	399	428	409	484
00:26:00	479	507	498	497	524	488	383	412	393	464
00:27:00	463	488	483	481	515	485	370	402	383	451
00:28:00	453	476	477	472	515	492	361	395	377	446
00:29:00	447	469	476	468	513	501	356	391	375	443
00:30:00	443	464	468	467	506	488	355	389	372	439
00:31:00	440	461	464	467	505	490	357	391	374	438
00:32:00	438	460	468	467	503	500	361	395	380	440
00:33:00	439	463	475	468	504	515	367	402	392	446
00:34:00	467	515	513	500	577	598	398	462	444	493
00:35:00	612	697	621	635	761	723	498	608	548	628
00:37:00	975	1024	807	955	940	775	721	807	620	845
00:38:00	1043	968	770	958	870	737	703	745	604	820
00:39:00	856	804	693	820	759	674	631	664	567	721
00:40:00	722	699	622	701	667	608	563	594	525	634
00:41:00	636	623	565	617	594	552	506	538	486	569
00:42:00	570	565	518	554	537	506	460	492	451	517
00:43:00	518	519	479	503	491	468	422	453	420	475
00:44:00	477	480	447	464	452	434	391	420	392	440
00:45:00	442	447	420	430	420	406	364	392	368	410
00:46:00	412	419	395	402	392	381	340	367	346	384

LBL Experiment #3

TABLE XXV

TIME min:sec		INTERNAL FURNACE PRESSURE (PASCALS)	
		Lower Penetration	Upper Penetration
0	29	-2.23	3.36
0	56	-1.35	3.55
1	22	-4.35	0.60
1	49	-5.34	2.15
2	15	-4.69	-0.68
2	41	-6.73	-2.54
3	08	-7.78	-3.27
3	34	-6.65	-2.73
4	01	-6.40	-2.67
4	27	-7.39	-2.95
4	53	-6.69	-2.77
5	20	-5.72	-2.58
5	46	-8.25	-4.26
6	12	-6.80	-3.32
6	39	-7.91	-4.17
7	05	-8.72	-5.18
7	31	-8.41	-2.36
7	58	-8.45	-2.07
8	24	-9.27	-6.15
8	50	-7.76	-5.46
9	17	-4.04	0.30
9	43	-6.64	-1.52
10	10	-5.21	-0.17
10	36	-4.78	-1.30
11	02	-6.73	-1.72
11	29	-5.42	-0.05
11	55	-4.40	-2.50
12	21	-5.21	0.46

TABLE XXV

continued

TIME min:sec		INTERNAL FURNACE PRESSURE (PASCALS)	
		Lower Penetration	Upper Penetration
12	48	-5.24	0.50
13	14	-4.10	1.11
13	40	-10.79	-8.36
14	07	-7.15	-7.46
14	33	-7.50	-7.37
14	59	-6.55	-7.36
15	26	-7.60	-3.56
15	52	-12.80	-8.48
16	19	-7.28	-4.30
16	45	-7.92	-8.10
17	11	-10.13	-5.81
17	38	-10.87	-4.39
18	04	-8.55	-5.34
18	30	-11.87	-3.39
18	57	-12.24	-4.94
19	23	-12.53	-7.44
19	49	-10.37	-7.56
20	16	-12.66	-10.46
20	42	-11.69	-9.47
21	08	-8.89	-7.38
21	35	-4.56	-5.50
22	25	-9.52	-6.76
23	25	-9.95	-7.54
24	25	-10.30	-8.98
25	25	-10.97	-6.49
26	25	-10.37	-6.44
27	25	-10.59	-5.96
28	25	-10.13	-6.12
29	25	-10.16	-7.00

TABLE XXV

continued

TIME min:sec	INTERNAL FURNACE PRESSURE (PASCALS)	
	Lower Penetration	Upper Penetration
30 25	-10.20	-3.60
31 25	-10.11	-5.91
32 25	-10.66	-5.71
33 25	-7.47	-2.38
34 25	-6.57	-0.81
35 25	-0.99	-3.53
37 25	-9.48	-12.20
38 25	-10.26	-10.43
39 25	-7.93	-9.05
40 25	-12.62	-9.47
41 25	-8.33	-8.38
42 25	-10.27	-9.64
43 25	-10.27	-8.48
44 25	-10.78	-9.38
45 25	-10.34	-7.36
46 25	-9.34	-7.62

LBL Experiment #3

TABLE XXVI

TIME		OBSERVATIONS
MIN.	SEC.	
0	15	The paper on the gypsum wallboard has begun burning, the cable is
		involved in flame and blisters are beginning to form on its
		insulation.
1	15	There is flaming at the excess pyrolyzate container at penetration 3B.
1	55	There is flaming at the excess pyrolyzate container at penetration 2B.
2	10	There is flaming at the excess pyrolyzate container at penetration 1B.
2	20	There is evidence of blistering on the cables but they are not in
		flame.
6	00	There is melted paraffin leaking from the bottom of the fuel
		container.
7	00	There are bubbling sounds in the furnace from paraffin containers.
11	00	Heavy smoke appears out of the stack.
12	00	Heavy flaming appears out of north stacks.
13	40	The gas is tunred off.
17	40	Paraffin continues to drop, accelerating flaming.
18	00	There is heavy flaming over paraffin containers.
21	00	An attempt is made to restart the test, the lower pans are still
		burning.
25	35	12 burners are reignited.
32	49	All burners reignited.

TABLE XXVI

continued

TIME		OBSERVATIONS
MIN.	SEC.	
33	00	The gas rate is increased.
35	00	The lower containers are leaking.
36	00	North stacks evidence heavy flaming.
36	30	Gas is turning off.

LBL Experiment #3

TABLE XXVII

TIME (H M S)	TEMP °C AT PENETRATION LOCATION NO. 1B	3A	2A	2B
00:00:04				
00:00:30				
00:00:56				
00:01:23	14	15	19	14
00:01:49	14	15	18	14
00:02:16	14	15	17	14
00:02:42	13	15	17	14
00:03:08	13	14	16	13
00:03:35	13	14	17	13
00:04:01	13	14	17	14
00:04:27	13	14	17	14
00:04:54	13	14	16	14
00:05:20	13	14	16	14
00:05:47	13	14	17	14
00:06:13	13	14	17	14
00:06:39	13	14	17	14
00:07:06	13	14	18	15
00:07:32	13	14	18	15
00:07:58	13	14	19	15
00:08:25	13	14	19	15
00:08:51	13	15	20	15
00:09:17	13	14	19	16
00:09:44	13	15	21	16
00:10:10	13	15	23	17
00:10:36	14	16	26	19
00:11:03	13	14	26	19
00:11:29	13	16	26	19
00:11:56	14	15	32	19
00:12:22	14	16	30	20
00:12:48	14	15	31	22
00:13:14	13	15	32	22
00:13:41	14	16	32	23
00:14:07	14	17	35	23
00:14:34	14	16	37	21
00:15:00	15	16	39	23
00:15:26	14	16	39	24
00:15:53	15	17	40	25
00:16:19	14	18	42	25
00:16:46	14	19	45	24
00:17:12	15	16	45	23
00:17:38	15	18	46	24
00:18:05	15	18	48	27
00:18:31	16	18	51	26
00:18:57	15	17	50	29
00:19:24	15	17	52	28
00:19:50	16	19	55	28
00:20:16	15	19	58	27
00:20:42	15	18	59	28
00:21:09	16	20	60	27
00:22:00	15	19	56	26
00:23:00	16	19	63	27
00:24:00	16	19	67	27
00:25:00	16	21	69	26
00:26:00	16	20	69	28
00:27:00	18	22	77	32
00:28:00	16	23	73	28
00:29:00	14	19	79	27
00:30:00	18	22	76	28
00:31:00	17	18	80	30
00:32:00	18	20	80	29
00:33:00	18	20	78	26
00:34:00	18	23	83	31
00:35:00	16	19	82	30
00:37:00	17	22	76	30
00:38:00	17	23	67	32
00:39:00	18	25	85	29
00:40:00	18	23	81	30
00:41:00	17	24	88	28
00:42:00	18	21	89	32
00:43:00	20	23	87	34
00:44:00	20	22	93	34
00:45:00	18	22	91	28
00:46:00	21	25	89	32

LBL Experiment #3

TABLE XXVIII

TIME H M S	TEMP °C AT PENETRATION LOCATION 3B TC 25	TEMP °C AT PENETRATION LOCATION 3B TC 26
00:00:04		
00:00:30		
00:00:56		
00:01:23	16	14
00:01:49	17	14
00:02:16	19	13
00:02:42	22	13
00:03:08	25	13
00:03:35	29	13
00:04:01	33	13
00:04:27	38	13
00:04:54	43	14
00:05:20	51	13
00:05:47	60	13
00:06:13	69	14
00:06:39	76	14
00:07:06	83	14
00:07:32	88	14
00:07:58	93	14
00:08:25	98	14
00:08:51	103	14
00:09:17	109	15
00:09:44	117	15
00:10:10	125	15
00:10:36	132	16
00:11:03	140	15
00:11:29	148	16
00:11:56	156	16
00:12:22	163	16
00:12:48	171	18
00:13:14	179	17
00:13:41	186	18
00:14:07	193	18
00:14:34	200	15
00:15:00	208	17
00:15:26	216	17

TIME H M S	TEMP °C AT PENETRATION LOCATION 3B TC 25	TEMP °C AT PENETRATION LOCATION 3B TC 26
00:15:53	224	19
00:16:17	232	18
00:16:46	240	18
00:17:12	247	17
00:17:38	254	18
00:18:05	261	17
00:18:31	268	17
00:18:57	275	19
00:19:24	282	19
00:19:50	289	20
00:20:16	295	20
00:20:42	301	19
00:21:09	305	21
00:22:00	313	20
00:23:00	323	22
00:24:00	333	23
00:25:00	345	22
00:26:00	354	21
00:27:00	366	25
00:28:00	373	23
00:29:00	381	20
00:30:00	390	21
00:31:00	407	20
00:32:00	429	24
00:33:00	452	21
00:34:00	479	24
00:35:00	523	23
00:37:00	646	23
00:38:00	687	20
00:39:00	723	17
00:40:00	858	17
00:41:00	782	16
00:42:00	700	16
00:43:00	598	16
00:44:00	540	16
00:45:00	476	15
00:46:00	419	15

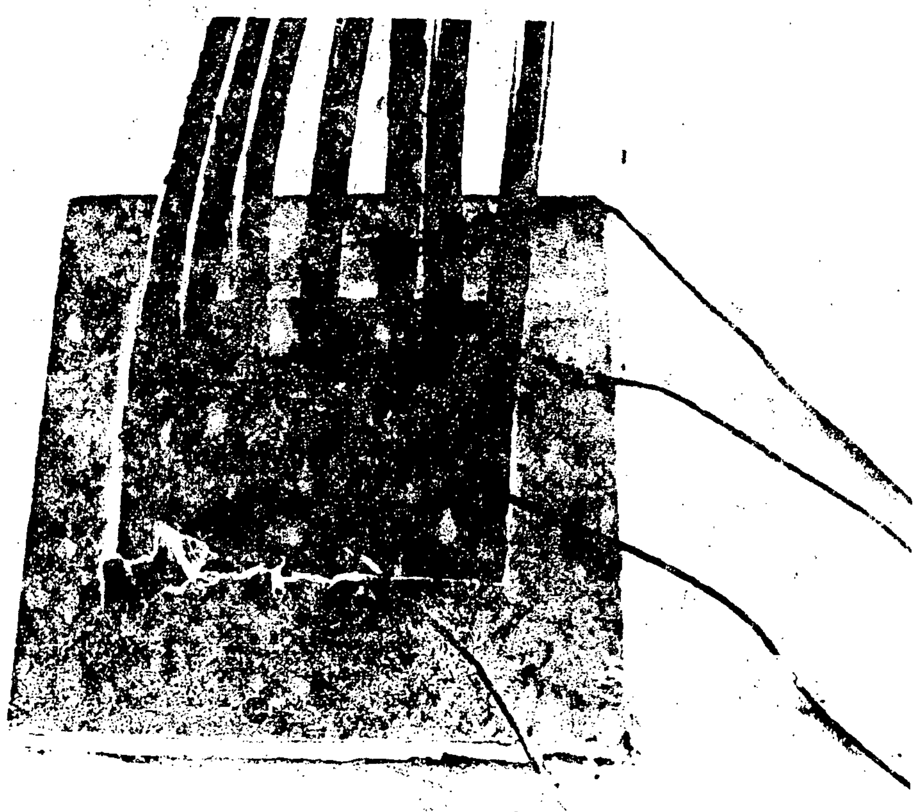


FIG 29: Photograph of Urethane Foam Seal at Beginning of Experiment

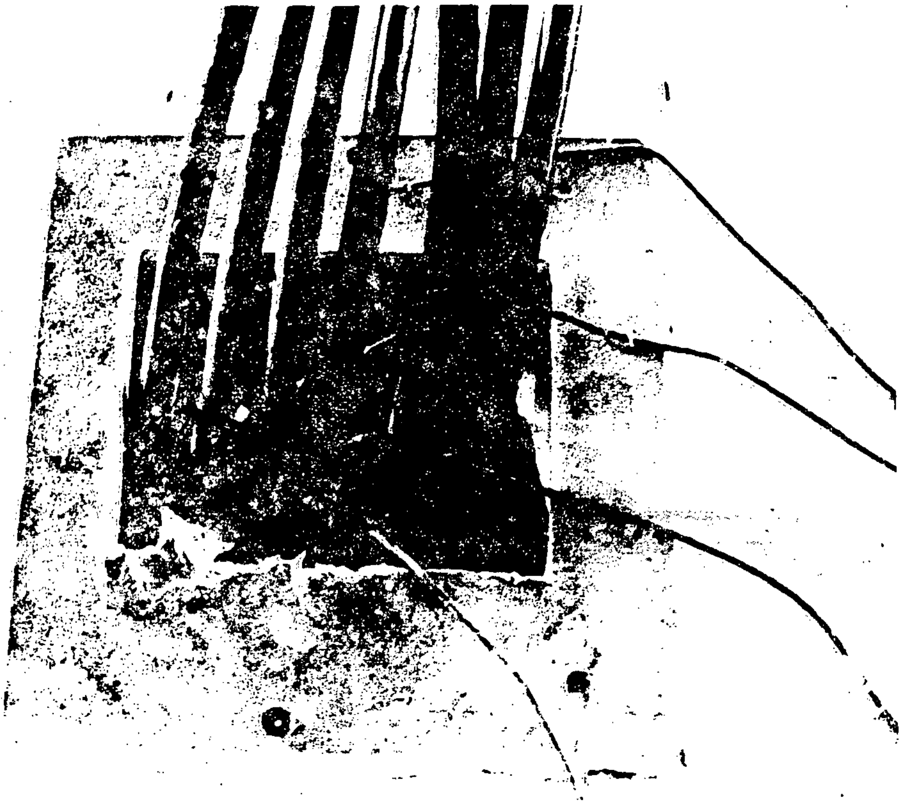


FIG 30: Photograph of Urethane Foam Seal at End of Experiment

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