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Investigation of Fire Stop Test Parameters Final Report

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INVESTIGATION OF FIRE STOP TEST PARAMETERS FINAL REPORT

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ABSTRACT

An experimental investigation was performed to determine the effects of pressure differential, fire exposure conditions and sample construction on the performance of fire stops used to seal electric cable and conduit penetrations through concrete fire barriers. Experiments were conducted using a differential pressure of -12 to +125 Pa, various sample constructions and two fire exposure conditions. Results indicate that the effect of pressure differential is not significant for those fire-stop materials which do not have cracks or other through openings that allow passage of gases during fire exposure. However, if the material allows passage for gases through cracks or other holes, such as those left open after a cable pull, the pressure differential affects fire stop performance. Effects of the size of the opening; size, location and type of the penetrating items installed through the opening; and severity of fire exposure on the performance of fire stops are demonstrated.

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FORWARD

This investigation is part of the Fire Research Program of the U.S. Nuclear Regulatory Commission (NRC). This program was established as a result of the Browns Ferry fire and the recommendations made in NUREG-0050.[1] The objective of this program is to obtain data to confirm or modify the current regulatory guides and standards for fire protection and to determine the adequacy of generic designs and materials with respect to fire safety.[2] This program consists of eight elements which encompass a broad range of fire protection concerns in light water reactor (LWR) power plants. A part of one element of this program is to obtain information on test parameters used to evaluate fire stops. This investigation sponsored by Sandia Laboratories, provides a limited assessment of several of these test parameters.

All the fire experiments were conducted at UL's Fire Protection Department in Northbrook, Illinois. The author acknowledges the assistance of Thomas Plens in constructing, instrumenting and conducting these experiments; Sandi Hansen in obtaining computer generated graphics of the data; and R. Parks and W. Christian in preparing the text.

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INVESTIGATION OF FIRE STOP TEST PARAMETERS

1. Introduction

Fire stops installed in nuclear power plants are generally qualified by testing in accordance with IEEE 634-1978.[3] This Standard prescribes the test procedure and method to evaluate results. The test procedure consists of subjecting the fire stop sample to a fire exposure in accordance with Standard ASTM E119.[4] Immediately after fire exposure, the sample is subjected to a water spray (hose stream test). Fire stops are acceptable if they withstand the fire test without passage of flame or gases hot enough to ignite cable on the non-fire side, and if they limit the temperature on the non-fire side to less than 700 F. Additionally, the sample must withstand the hose stream test without developing an opening which allows the passage of a water stream.

Although pressure differentials (the pressure at one side of the fire stop with respect to the other side) exist at various areas in the plant under normal operation, the IEEE 634 test method does not require a specific pressure differential to be applied during the test. The Standard recognizes this aspect, but does not address it.

Also, according to IEEE 634, sample selection for testing is to be representative of the fire stop installed in the field. In order to facilitate the selection, suggested guidelines are given for size of opening and types and sizes of cables but, data substantiating the selection is not given. The effects of varying the sample construction by changing its size, number of cables and location of cables is not known.

This investigation was conducted to develop information on the effect changes in pressure differential and sample construction have on the performance of the fire stop. Additionally, the effect of subjecting the fire stops to a fire exposure less severe in temperature than the ASTM E119 exposure was also investigated.

2. Experimental Procedure

2.1 General

This investigation consisted of conducting 50 small-scale fire experiments using several types of fire stop samples. A summary of the experiments conducted is shown in Table 1. These experiments were organized into twenty-one groups to facilitate comparison of results. Within each group, the parameter under consideration was varied with the sample and test procedure held constant.

Each sample was subjected to the prescribed fire exposure until either flaming occurred on the unexposed side or until the appropriate information was obtained. During each experiment, temperatures of the unexposed surface and visual observations of physical performance were recorded. For some experiments, temperatures within the fire stop material were recorded for supplemental information.

2.2 Samples

All fire stops were installed in 6 in. (150 mm)+ thick concrete floor slabs. Openings in all but three slabs were either circular 6 in. (150 mm) in diameter or 12 in. (310 mm) square. The remaining slabs had circular openings of 2 in. (51 mm), 9 in. (230 mm) and 13 in. (330 mm) in diameter.

The fire stop materials used were silicone foam, silicone elastomer, and a fire stop device. These are representative of materials currently used in nuclear power plants. The silicone foam and silicone elastomer were two-component materials which vulcanized at room temperature (RTV). These materials which were mixed, poured into the openings, and cured in accordance with the manufacturer's installation instructions. The nominal free rise densities were 30 pcf (0.48 Mg/m^3) and 90 pcf (1.42 Mg/m^3) for the silicone foam and silicone elastomer, respectively. However, the device was constructed from several separate components of steel plates, intumescent material, and a neoprene gasket. The device was installed by friction fit from the compression of the neoprene material in accordance with the manufacturer's installation instructions.

\+ - Equivalent SI units included in parenthesis may only be approximate.

Various types of penetrating items were used in the construction of the fire stop samples. The penetrating items included cables, cable trays, conduits, and pipes. Details of these items are presented in Appendix A.

Samples were constructed with the penetrating items protruding about 12 in. (300 mm) below the exposed surface and 36 in. (910 mm) above the unexposed surface. When cable trays were used the penetrating items were fastened to them on the unexposed side for support.

These samples were designed to facilitate performance measurement so as to provide an increased data base upon which the evaluation of changes in parameters could be made. It should not be misconstrued that the samples were designed to obtain a 3 hr fire rating which is required for field installed fire stops as specified in Appendix R of 10CFR Part 50. A summary description of the various experimental samples is shown in Tables 2-8. Examples of the appearance of the fire stop samples prior to test are shown in Figures 1 and 2.

2.3 Apparatus

2.3.1 Furnace

The small scale floor furnace (Fig. 3) of Underwriters Laboratories Inc. was used in these experiments.

2.3.2 Enclosure

In some experiments, to obtain the desired pressure differential, an enclosure was placed on the unexposed side of the sample, and the air pressure within the enclosure either increased or decreased as needed. The general construction of the enclosure was as shown in Fig. 4. Air flowed continuously through the enclosure through the ports. The inlet and exhaust ports were adjusted to provide the desired pressure control. Flow through the ports was diverted toward the walls of the enclosure away from the sample and penetrating items.

2.3.3 Instrumentation

Type K Chromel-Alumel thermocouples were used for all temperature measurements of the unexposed surface of the fire stop materials and of the material interior for some samples. All thermocouples on the unexposed surface were covered by a 0.75 in. (19 mm) by 0.75 in. (19 mm) by 0.16 in. (4 mm) thick asbestos pad. Pressure was measured with probes connected to either a manometer or an electronic barometer.

2.4 Method

Summaries of the experiments are shown in Tables 9-16. Except in three experiments, the samples were subjected to a fire exposure with the furnace temperatures controlled in accordance with the standard temperature-time curve specified in ASTM E119 (shown in Figure 5). In the remaining experiments, the furnace temperatures were controlled in accordance with the other less severe temperature-time curve also shown in Figure 5. The pressure differential between the exposed surface and unexposed surface was measured and controlled to the desired pressure for each experiment. Positive pressure differential was obtained by having a greater pressure at the exposed surface of the fire stop with respect to the unexposed surface. A negative pressure differential was obtained by having a greater pressure at the unexposed surface of the fire stop with respect to the exposed surface. Experiments were conducted until flaming occurred on the unexposed side or until the appropriate information was obtained.

3. Experimental Results

3.1 General

The results of all the experiments are included in Appendix C. The temperatures on the unexposed surface of the fire stop material were plotted versus time for each experiment and are shown in Figures C1-C65. The experiment duration and the time at which flaming occurred on the unexposed side are shown in Tables C1-C3.

The effect of each parameter was considered separately. In order to determine the effect of changes in each parameter, results of applicable experiments were compared (see Table 1 for groups of applicable experiments). The primary means of assessing results was to compare the appropriate unexposed surface temperatures. If a comparison could not be obtained due to minor changes in temperature during the experiment, or if supplemental data was desired, a comparison of time to flaming was conducted. Also in evaluating pressure differential, sample construction - cable type, and sample construction - opening size, a comparison of visual observations was conducted.

3.2 Effect Of Pressure Differential

Results indicated that for those materials which remained integral during the test and did not allow a path for gas flow, the effect of changes in pressure differential was not significant.

In tests with a positive pressure differential between 0.01 and 0.50 in H_2O (2 and 125 Pa), no significant change was observed in the transmission of heat through the material, in the time at which flaming occurred, or in the formation of cracks in the decomposing material. The rate of heat transmission through the silicone foam and silicone elastomer materials can be seen by the rate at which a specific temperature propagates through the material. The propagation rate of the 725 F (285 C) temperature was selected for comparison since it also represents the approximate front of the char layer. As shown in Fig. 6, the rate at which this temperature propagated through the material was not significantly affected by changes in the positive pressure differential. For the device the propagation rate of 300 F (149 C) temperature was arbitrarily selected for comparison since a specific temperature associated with the degradation of the material was not readily obtainable. Fig. 7 shows that the propagation rate of the 300 F (149 C) temperature also was not significantly affected by the pressure differential.

The time at which flaming occurred on the unexposed side was not affected by changes in positive pressure differential. The times at which flaming occurred for the experiments with silicone foam are shown in Table 16. It ranged from 110 min to 116 min. This is considered within the normal range of repeatability for failure times (for structural integrity) of fire resistant assemblies. During the conduct of all the experiments for the silicone elastomer and device in Groups 3 through 6, flaming did not occur on the unexposed side.

The formation of cracks in the decomposing material was not affected by changes in the positive pressure differential. In all experiments which produced flaming failure, propagation of a crack through the material was rapid, usually occurring within 5 min. after crack formation. Collapse of the material occurred immediately after the crack propagated through the material and ignition of the unexposed surface was almost instantaneous. Because of this, flame passage through the crack was not a significant factor in the ignition process.

Testing with a negative pressure differential did not significantly affect the performance of the silicone foam material installed without through openings. One experiment was conducted at a negative pressure differential of 0.05 in H_2O (12 Pa) while a similar sample was tested at a positive pressure differential of 0.01 in H_2O (2 Pa). The time of failure was essentially the same (154 min for -0.05 in H_2O (-12 Pa) and 153 min for 0.01 in H_2O (2 Pa)). However, the failure mode was different for these experiments. For the positive pressure differential experiment, the material cracked, collapsed, and the unexposed surface of the material ignited. In the negative pressure differential experiment the material cracked, collapsed, and the cable ignited.

Testing with a positive pressure differential affected the performance of the silicone elastomer material installed with through openings. Two experiments were conducted with two nominal 0.50 in. (12 mm) diameter holes in the silicone elastomer material created by pulling cables from the bundle after the material had been installed. One experiment was conducted at 0.015 in H_2O (3 Pa) pressure differential, while the other experiment was conducted at -0.05 in H_2O (-12 Pa). During the positive pressure experiment smoke and hot gases issued through the holes. However, the gases were sufficiently cooled that flames from the fire side did not issue through the holes. After 15 min, the hot gases were melting the cable material surrounding the holes. The smoke and gases issuing from the holes was rich in unburned fuel and could be ignited by a small flame source such as a match. During the negative pressure experiment, smoke and hot gases were not observed issuing through the holes. However, after 27 mins, the radiant heat from the furnace began to melt the cable material surrounding the holes which produced smoking on the unexposed side.

3.3 Effect Of Fire Exposure

Three experiments were conducted with a fire less severe in temperature than the standard temperature-time curve specified in ASTM E119. As expected, temperatures on the unexposed side of the samples for these experiments were lower than for comparable samples subjected to a ASTM E119 fire exposure (Figs. 8 and 9). Consequentially, the time to failure increased for the samples exposed to the less severe fire. For example, failure occurred at 153 mins for Experiment P7 while it occurred at 177 mins for Experiment FC1.

3.4 Effect Of Changes In Sample

Changes in sample construction investigated were conductor type and size, cable type, conduit or pipe type and size, cable loading, and opening size. Results indicate that changes in fire stop construction can effect the performance.

Changes in conductor type (copper vs. aluminum) affected unexposed surface temperatures of the fire stop material near the conductor (Fig. 10). The temperature rise near the copper 300 MCM cable was greater than at the aluminum 300 MCM cable. Increasing the conductor size also resulted in increased temperature on the unexposed surface of the fire stop material near the conductor as shown in Fig. 11.

The physical performance of different cable jacket/insulation types was compared. It was observed that during each experiment, the temperature of the cable gradually increased for about the first 4 in. (100 mm) above the base of the cable on the unexposed side of the fire stop. As the temperature increased, each cable jacket/insulation material reacted differently. For example, one cable jacket/insulation material melted quickly, dripped, and the molten material then coagulated into a mass on the surface. Another cable jacket/insulation material did not melt, but swelled and cracked near the base.

The size of pipe or conduit affected the temperature of the surrounding fire stop material as shown in Fig. 12. Based upon the temperature at the material-pipe interface, the temperature tended to be greater near the 3 in. pipe than at the smaller 1 in. pipe. The type of conduit, either steel or aluminum, also had an effect on the surrounding fire stop material temperature as shown in Fig. 13. The temperature at the material-pipe interface tended to be generally greater near the aluminum conduit than near the steel conduit.

It was observed that increasing the number of cables penetrating the fire stop increased the temperature of the fire stop material near the cables as shown in Fig. 14. The temperature near a three layer bundle of cable was greater than the temperature near a one layer bundle of cable.

The size of the opening appeared to affect the structural integrity of the material. It was observed that for the larger openings 6 in. (152 mm), 9 in. (230 mm) and 12 in. (305 mm), the material tended to deflect downward at the center of the opening during fire exposure. The rate of deflection appeared to increase with increasing opening size. This downward deflection tended to affect the performance of the material by causing cracks along the periphery of the opening, which in turn decreased the structural integrity of the material.

4. Recommendations

This report has provided only a limited, qualitative assessment of the effects due to changes in pressure differential, fire exposure, and sample construction. It is recommended that further study of these data be conducted to determine if other effects can be ascertained, if quantitative relationships can be derived, and to define further experimental data which may be needed.

5. References

1. U.S. Nuclear Regulatory Commission, Recommendations Related to Browns Ferry Fire, USNRC Report NUREG-0050, February 1976. Available for purchase from National Technical Information Service, Springfield, Virginia 22161.

2. U.S. Nuclear Regulatory Commission, Water Reactor Safety Research Program, USNRC Report NUREG-0006, February 1979. Available for purchase from National Technical Information Service, Springfield, Virginia 22161.

3. "IEEE Standard Cable Penetration Fire Stop Qualification Test," IEEE 634-1978. Available for purchase from the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, New York 10017.

4. "Standard Methods Of Fire Tests Of Building Construction And Materials," ASTM E119-80. Available for purchase from the American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA 19103.

Table 1

Experimental Summary

Parameter	Group	Experiments	Description
Pressure Differential	1	P22, P19, P1, P3, P5	Pressure +2 to +125 Pa; silicone foam; cables
	2	P23, P20, P2, P4, P6	Pressure +2 to +125 Pa; silicone foam; no cables
	3	P9, P11	Pressure +2 and +125 Pa; silicone elastomer; cables
	4	P10, P12	Pressure +2 and +125 Pa; silicone elastomer; no cables
	5	P13, P15	Pressure +2 and +125 Pa; device; cables
	6	P14, P16	Pressure +2 and +125 Pa; device; no cables
	7	P7, P8	Pressure +2 and -12 Pa; silicone foam; cables
	8	P21	Pressure +125 Pa; silicone foam with formed crack
	9	P17, P18	Pressure +3 and -12 Pa; silicone elastomer with two holes created by cable pull
Fire Exposure	10	FC1, FC2,	Silicone Foam - less severe temperature curve
		P7*	Silicone Foam - ASTM E119 temperature curve
	11	FC3	Silicone Elastomer - less severe temperature curve
		CL1*	Silicone Elastomer - ASTM E119 temperature curve
Sample (Conductor Size & Type)	12	CT1, CT3	300 MCM CU Cable
		CT2, CT4	300 MCM AL Cable
	13	CS1	3C/12 AWG Cable - Silicone Elastomer
		CS2	7C/12 AWG Cable - Silicone Elastomer
		CT1*	300 MCM Cable - Silicone Elastomer

* - Experiment used for comparison with others in group

Table 1 (Cont'd)

Parameter	Group	Experiments	Description
	14	CS3	3C/12 AWG Cable - Device
		CS4	7C/12 AWG Cable - Device
		CT4*	300 MCM Cable - Device
Sample (Cable Type)	15	T1	Cable Type A - Silicone Elastomer
		T2	Cable Type G - Silicone Elastomer
		T3	Cable Type H - Silicone Elastomer
		CS2*	Cable Type F - Silicone Elastomer
	16	T4	Cable Type A - Device
		CS4*	Cable Type F - Device
Sample (Pipe)	17	PS1	1 in. Steel Pipe
		PS2	3 in. Steel Pipe
Sample (Conduit)	18	CD1	1 in. Steel Conduit
		CD2	1 in. AL Conduit
	19	CD3	3 in. Steel Conduit
		CD4	3 in. AL Conduit
Sample (Cable Loading)	20	CL1	One Layer of Cables
		CL2	Three Layers of Cables
Sample (Opening)	21	S1	2 in. (51 mm) Opening
		S2	6 in. (152 mm) Opening
		S3	9 in. (230 mm) Opening
		S4	12 in. (300 mm) Opening

* - Experiment used for comparison with others in group

TABLE 2

Pressure Differential Samples

Sample Reference	Floor Type	Slab No.	Fire Stop Material Type	Fire Stop Material Thickness, In. (mm)	Hole 1 Cable Type*	Hole 1 Cable No.	Hole 2 Cable Type	Hole 2 Cable No.
100	I	5	SF	6.0 (150)	A	3	None	
101	I	2	SR	6.0 (150)	A	3	None	
102	I	2	D	3.75 (95)	A	3	None	

SF = Silicone Foam

SR = Silicone Elastomer

D = Fire Stop Device

* = See Appendix A

TABLE 3

Pressure Differential Samples

Sample Reference	Floor Slab Type	Floor Slab No.	Fire Stop Material Type	Fire Stop Material Thickness, In. (mm)	Cable Type*	Cable No.
103	II	2	SF	6.0 (150)	B	1
103**	II	1	SF	6.0 (150)	B	1
103***	II	2	SR	2.5 (64)	B	31

SF = Silicone Foam

SR = Silicone Elastomer

* = See Appendix A

** = Fire stop formed with a 0.38 in. (10 mm) wide by 9.5 in. (240 mm) long by 4 in. (100 mm) deep crack, as seen from the unexposed side, along one edge of the opening.

*** = Fire stop formed with two holes caused by pulling cables out after material had cured. Cable tray used as raceway for the cable bundle.

TABLE 4

Fire Exposure Samples

Sample Reference	Floor Slab Type	Floor Slab No.	Fire Stop Material Type	Fire Stop Material Thickness, In. (mm)	Cable Type*	Cable No.
104	II	2	SF	6.0 (150)	B	1
105	II	1	SR	4.0 (100)	A	11

SF = Silicone Foam

SR = Silicone Elastomer

* = See Appendix A

TABLE 5

Sample Constructions - Conductors

Sample Reference	Floor Slab Type*	Floor Slab No.	Hole 1 Fire Stop Material Type	Hole 1 Fire Stop Material Thickness, In. (mm)	Hole 1 Cable Type*	Hole 1 Cable No.	Hole 2 Fire Stop Material Type	Hole 2 Fire Stop Material Thickness, In. (mm)	Hole 2 Cable Type*	Hole 2 Cable No.
106	I	1	SR	6.0 (150)	C	1	D	3.75 (95)	C	1
107	I	1	SR	6.0 (150)	E	1	D	3.75 (95)	E	1
108	I	1	SR	6.0 (150)	F	1	D	3.75 (95)	F	1
109	I	1	SR	6.0 (150)	B	1	D	3.75 (95)	B	1
110	I	1	SR	6.0 (150)	A	1	D	3.75 (95)	A	1
111	I	1	SR	6.0 (150)	G	1	SR	6.0 (150)	H	1

SR = Silicone Elastomer

D = Fire Stop Device

* = See Appendix A

TABLE 6

Sample Constructions - Penetrating Items

Sample Reference	Floor Slab Type*	Floor Slab No.	Penetrating Items Type	Penetrating Items No.	Penetrating Items Size**	Cable Per Item Type	Cable Per Item No.
112	II	1	Steel Pipe	3	1	None	
			Steel Pipe	2	3	None	
113	II	1	Steel Conduit	3	1	A	1
			Steel Conduit	2	3	A	3
114	II	1	AL Conduit	3	1	A	1
			AL Conduit	2	3	A	3

Silicone elastomer, 4.0 in. (100 mm) thick, used as fire stop material.

* = See Appendix A

** = Trade Size (In.)

TABLE 7

Sample Constructions - Cable Loading

Sample Reference	Floor Slab Type*	Floor Slab No.	Cable Type*	Cable No.	Fire Stop Material Type	Fire Stop Material Thickness, In. (mm)
115	I	1	A	11	SR	4.0 (101)
116	I	1	A	33	SR	4.0 (101)

Cables installed in 6 in. wide cable tray.

SR = Silicone Elastomer

* = See Appendix A

TABLE 8

Sample Constructions - Opening Sizes

Sample Reference	Floor Slab Type*	Floor Slab No.	Hole Diameter Size In. (mm)	Fire Stop Material Type	Fire Stop Material Thickness, In. (mm)
117	III	1	2 (51) and 6 (150)	SF	6.0 (150)
118	IV	1	9 (230)	SF	6.0 (150)
119	V	1	12 (300)	SF	6.0 (150)

All samples installed without cables.

SF = Silicone Foam

* = See Appendix A

TABLE 9

Pressure Differential Experiments

Group No.	Experiment Identification	Sample Reference	Pressure In H2O (Pa)	General Description
	P22	100	+0.01 (+2)	
	P19	100	+0.05 (+12)	Silicone foam
1	P1	100	+0.05 (+12)	with cables
	P3	100	+0.50 (+125)	
	P5	100	+0.50 (+125)	
	P23	100	+0.01 (+2)	
	P20	100	+0.05 (+12)	
2	P2	100	+0.05 (+12)	Silicone foam
	P4	100	+0.25 (+62)	without cables
	P6	100	+0.50 (+125)	
3	P9	101	+0.50 (+125)	Silicone elastomer
	P11	101	+0.01 (+2)	with cables
4	P10	101	+0.50 (+125)	Silicone elastomer
	P12	101	+0.01 (+2)	without cables
5	P13	102	+0.05 (+12)	Device with
	P15	102	+0.50 (+125)	cables
6	P14	102	+0.05 (+12)	Device without
	P16	102	+0.50 (+125)	cables

TABLE 10

Pressure Differential Experiments

Group No.	Experiment Identification	Sample Reference	Pressure In H2O (Pa)	General Description
7	P7 P8	103 103	+0.01 (+2) -0.05 (-12)	Silicone foam with cable
8	P21	103**	+0.50 (+125)	Silicone foam with formed crack
9	P17 P18	103*** 103***	+0.015 (+3) +0.05 (-12)	Silicone elastomer with two holes created by cable pull

TABLE 11

Fire Exposure Experiments

Group No.	Experiment Identification	Sample Reference	General Description
10	FC1 FC2	104 104	Silicone foam with cable
11	FC3	105	Silicone elastomer with cables

Experiments conducted with furnace temperature controlled as shown in Fig. 5.

TABLE 12

Sample Experiments - Conductor Type & Size

Group No.	Experiment Identification	Sample Reference	General Description
12	CT1	106	Silicone elastomer - 300MCM Cu
	CT2	106	Device - 300MCM Cu
	CT3	107	Silicone elastomer - 300MCM AL
	CT4	107	Device - 300 MCM AL
13	CS1	109	Silicone elastomer - 3C/12 AWG
	CS2	108	Silicone elastomer - 7C/12 AWG
14	CS3	109	Device - 3C/12 AWG
	CS4	108	Device - 7C/12 AWG

TABLE 13

Sample Experiments - Cable Type

Group No.	Experiment Identification	Sample Reference	General Description
	T1	110	Silicone elastomer Cable Type A
15	T2	111	Silicone elastomer Cable Type G
	T3	111	Silicone elastomer Cable Type H
16	T4	110	Device - Cable Type A

TABLE 14

Sample Experiments - Conduit or Pipe Type & Size

Group No.	Experiment Identification	Sample Reference	General Description
17	PS1	112	1 in. steel pipe
	PS2	112	3 in. steel pipe
18	CD1	113	1 in. steel conduit
	CD2	114	1 in. AL conduit
19	CD3	113	3 in. steel conduit
	CD4	114	3 in. AL conduit

TABLE 15

Sample Experiments - Cable Loading

Group No.	Experiment Identification	Sample Reference	General Description
20	CL1	115	One layer of cables
	CL2	116	Three layers of cables

TABLE 16

Sample Experiments - Size

Group No.	Experiment Identification	Sample Reference	General Description
21	S1	117	2 in. (51 mm) opening
	S2	117	6 in. (152 mm) opening
	S3	118	9 in. (230 mm) opening
	S4	119	12 in. (305 mm) opening

TABLE 17

Flame Occurrence Time - Pressure Experiments

Pressure in H_2O (Pa)	Experiment Identification	Time (Min)
0.05 +12	P1	116
0.25 +62	P3	110
0.50 +125	P5	112

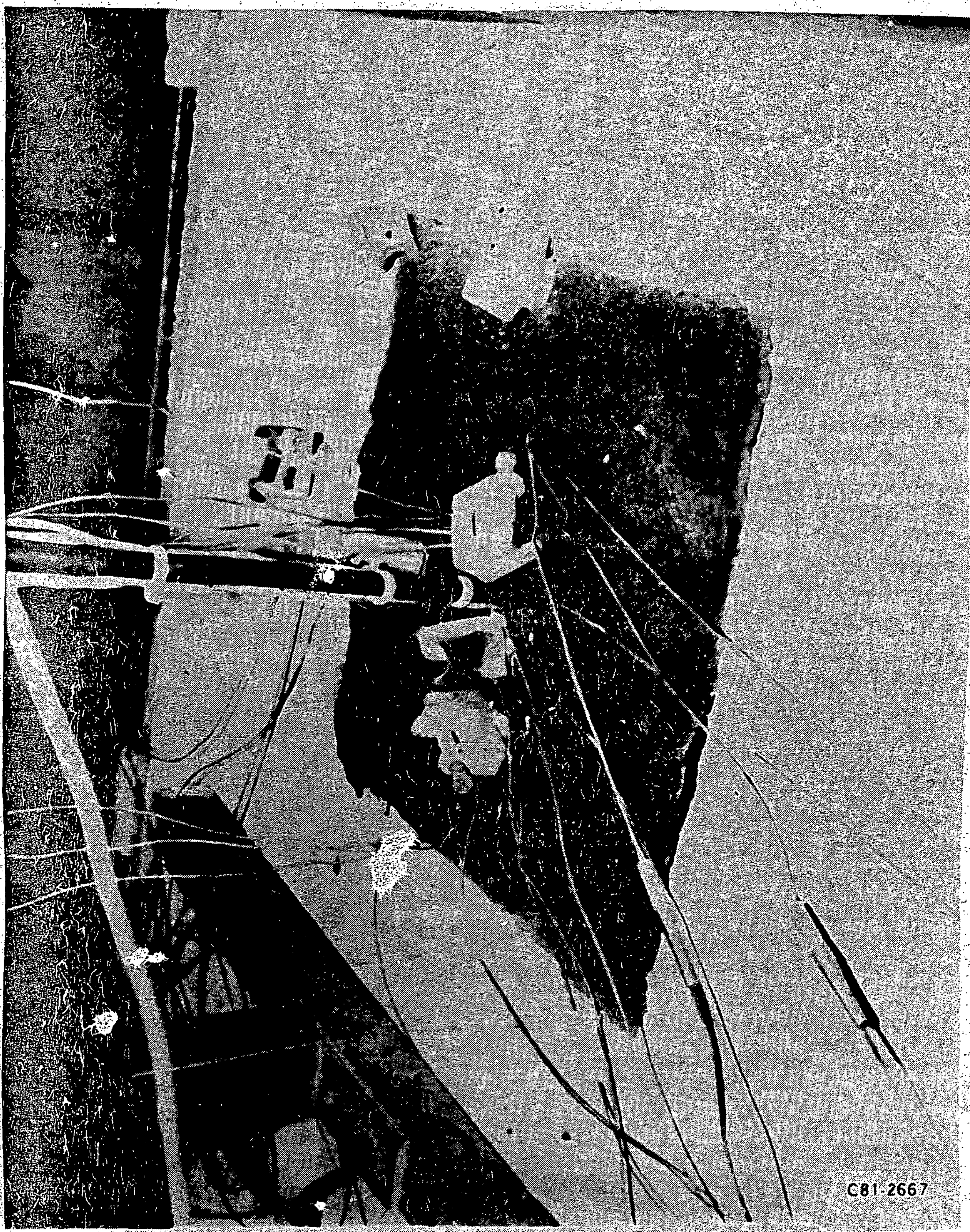


Figure 1. Appearance Of Unexposed Side Of Fire Stop Sample Prior To Experiment

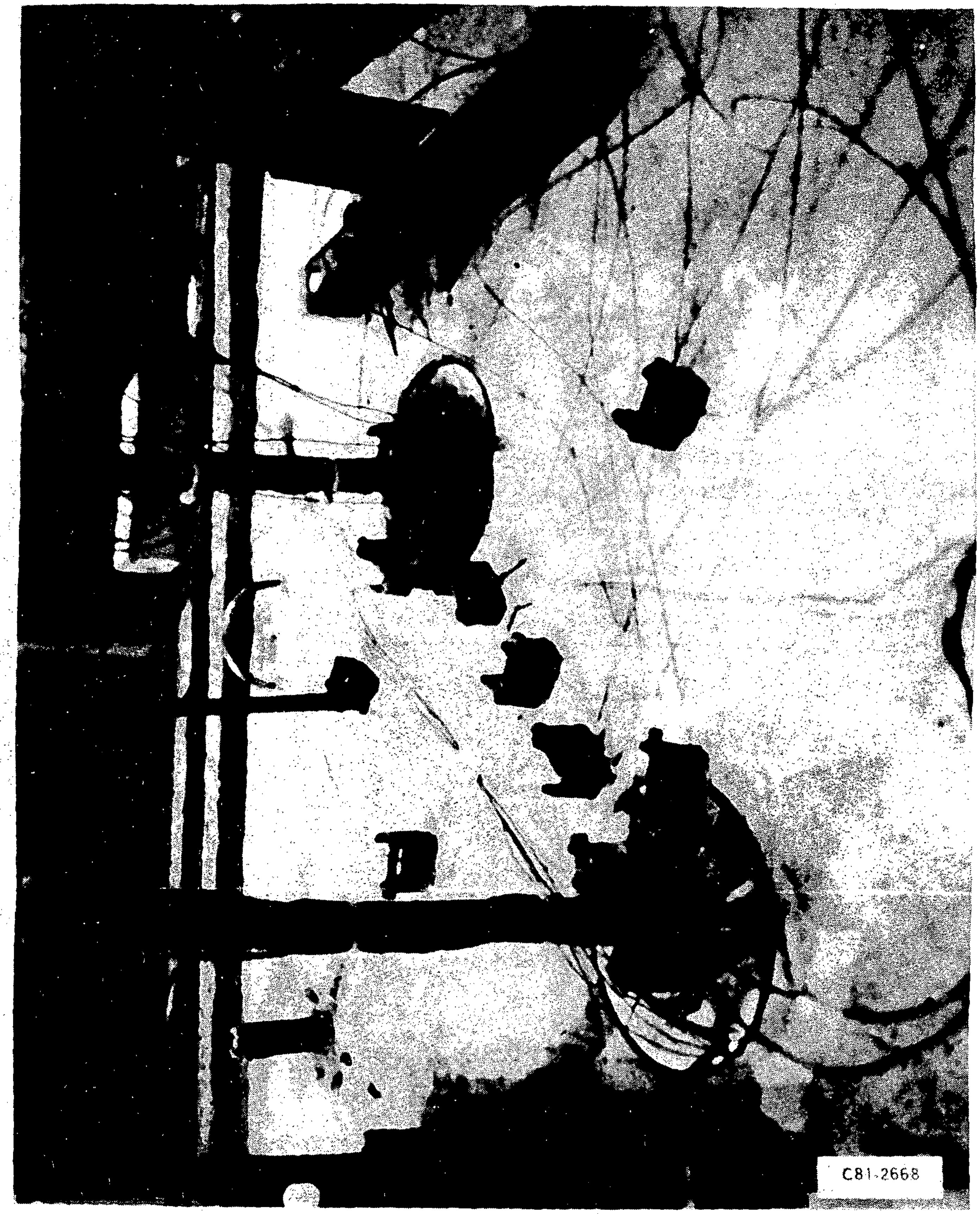


Figure 2 - Appearance Of Unexposed Side Of Fire Stop Sample Prior To Experiment

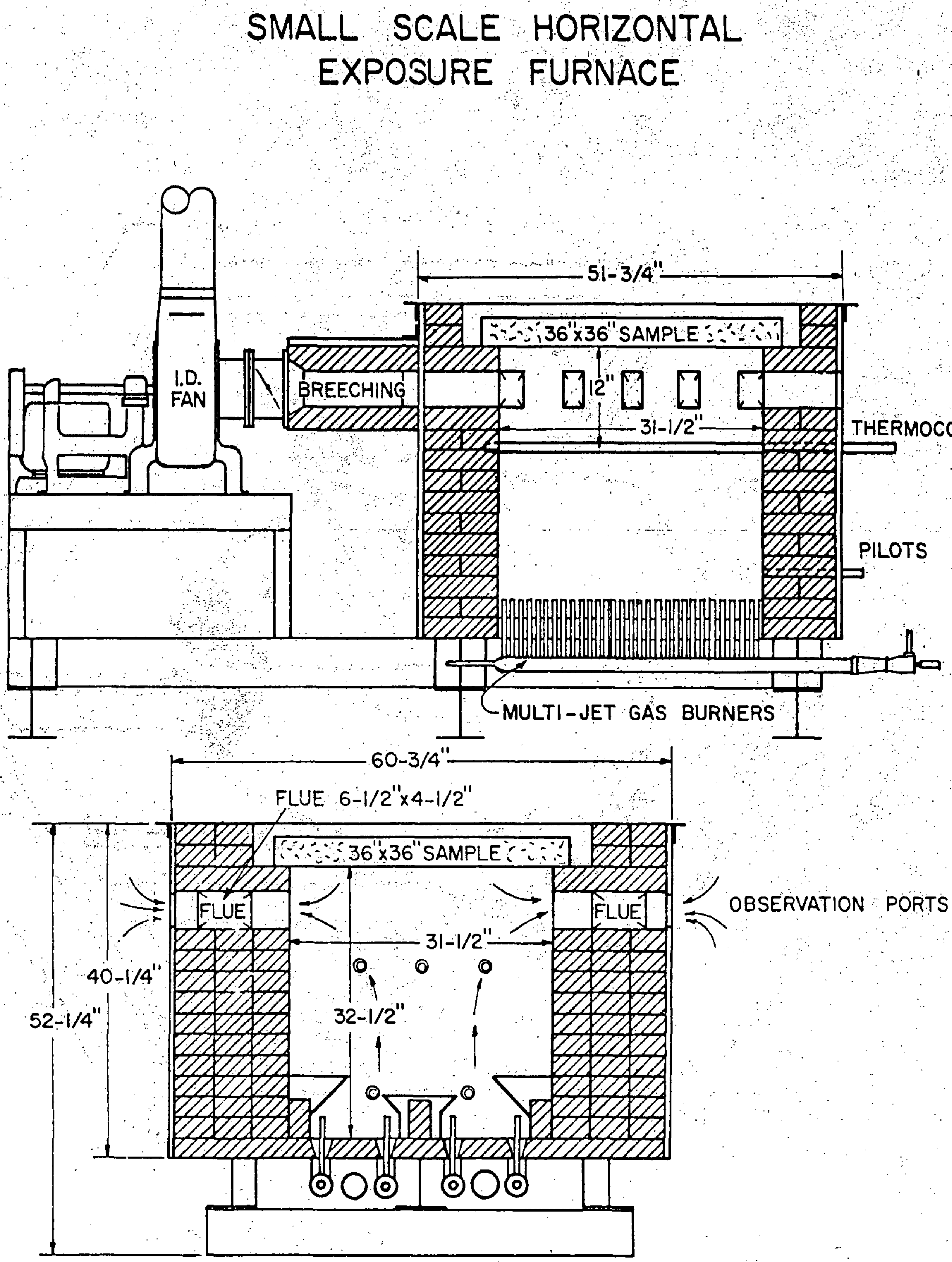


Figure 3 - Furnace

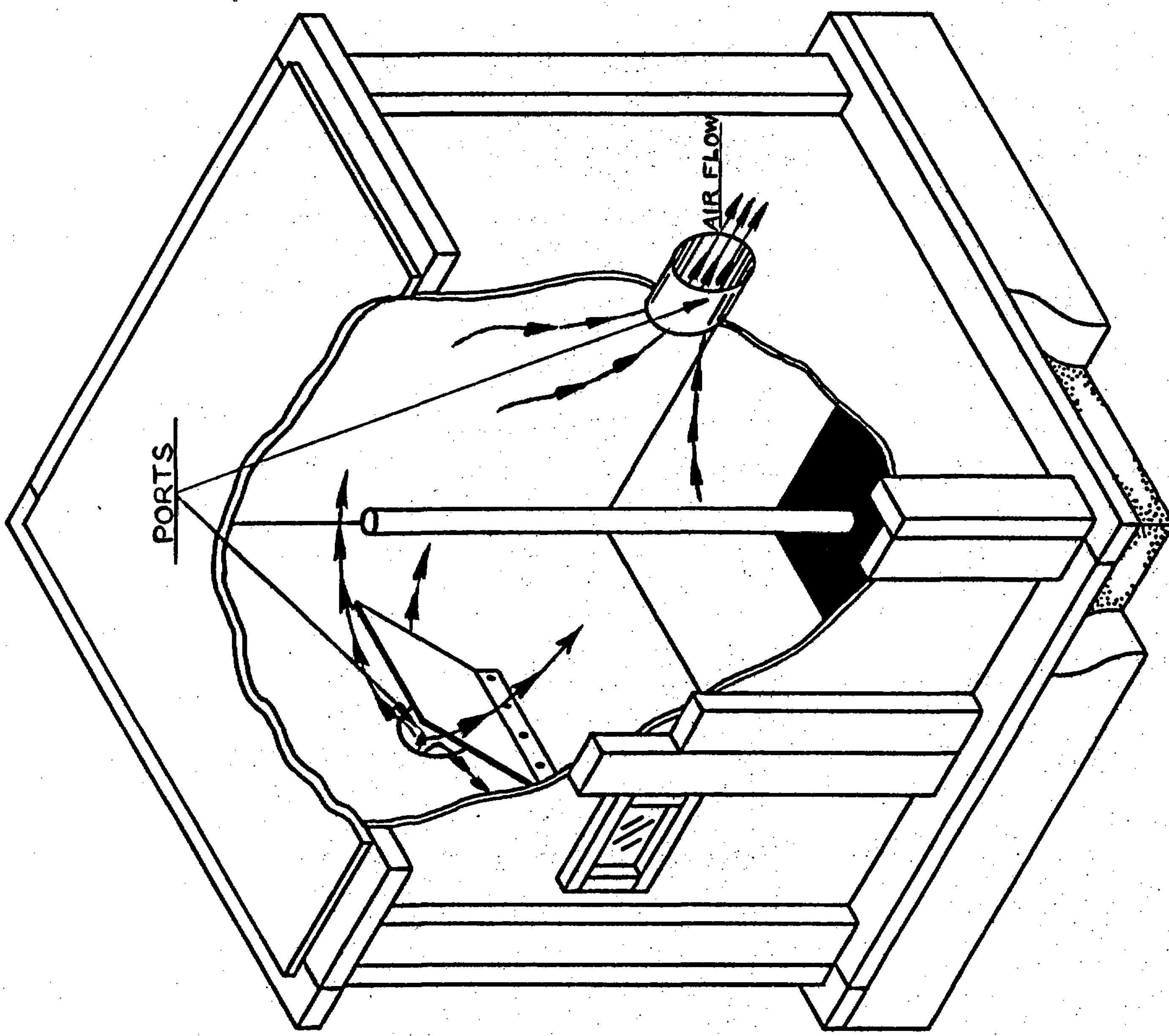


Figure 4 - Enclosure

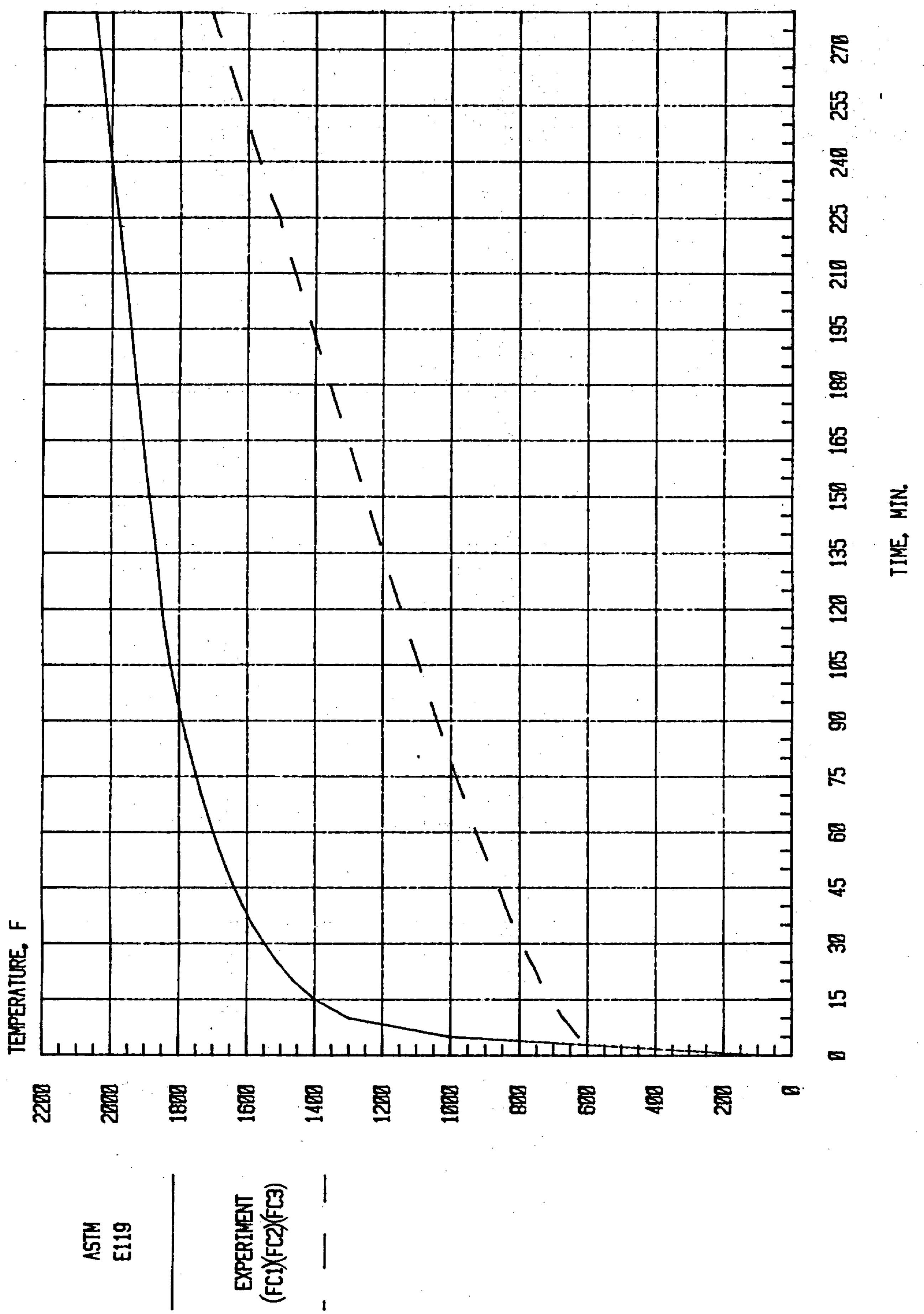
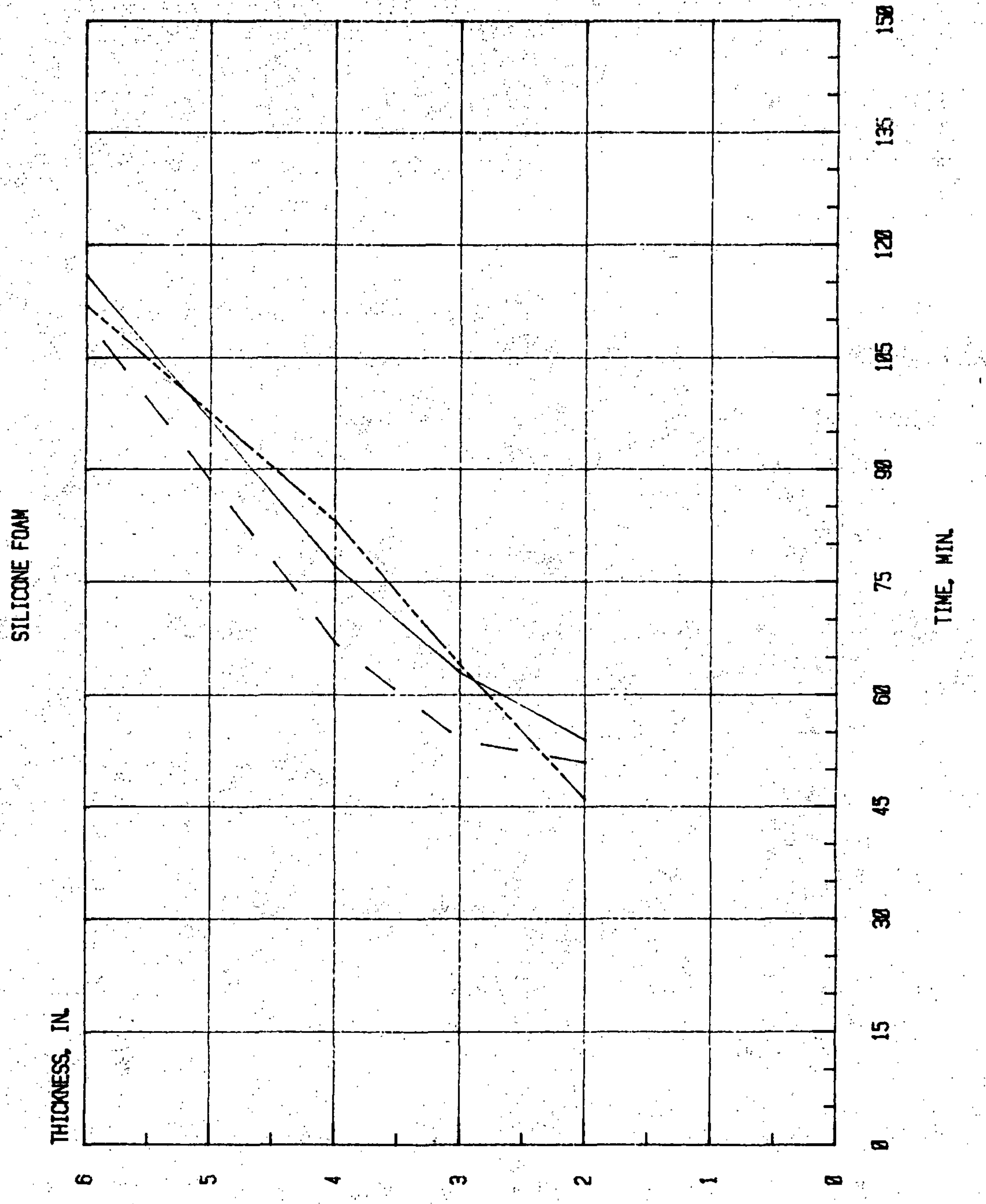


Figure 5 - Temperature-Time Curve



Temperature Rise Through The Material At The Center Of Fire Stop

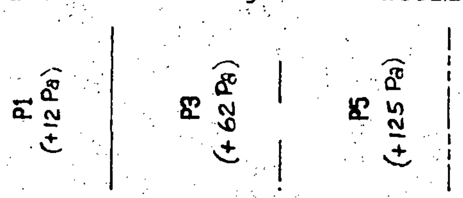
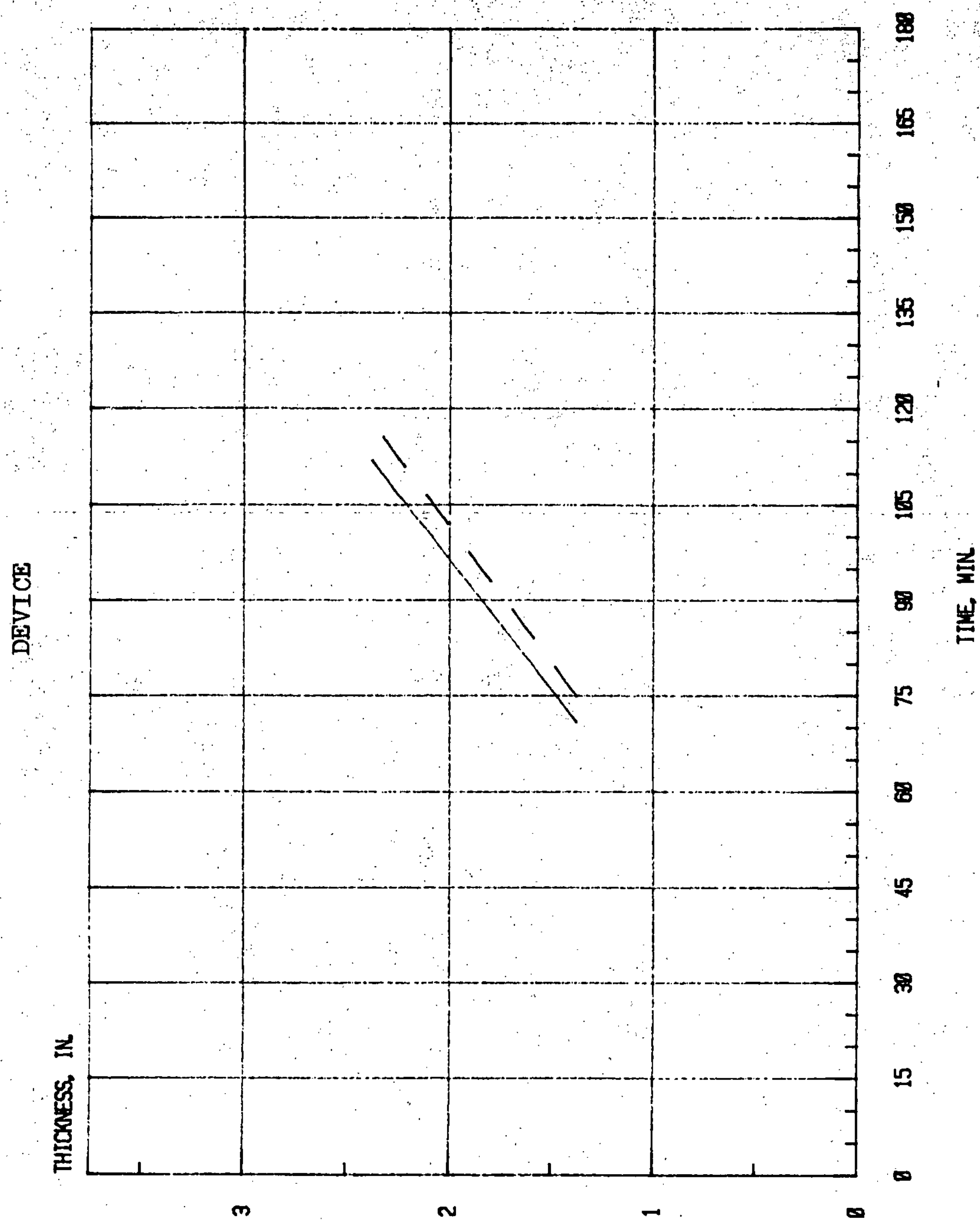


Figure 6 - The Rate Of Propagation Of 725 F (285 C) Temperature (Experiments P1, P3, P5)



Temperature Rise Through The Device At 1.5 In. (38 mm) From The Center

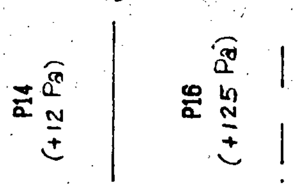
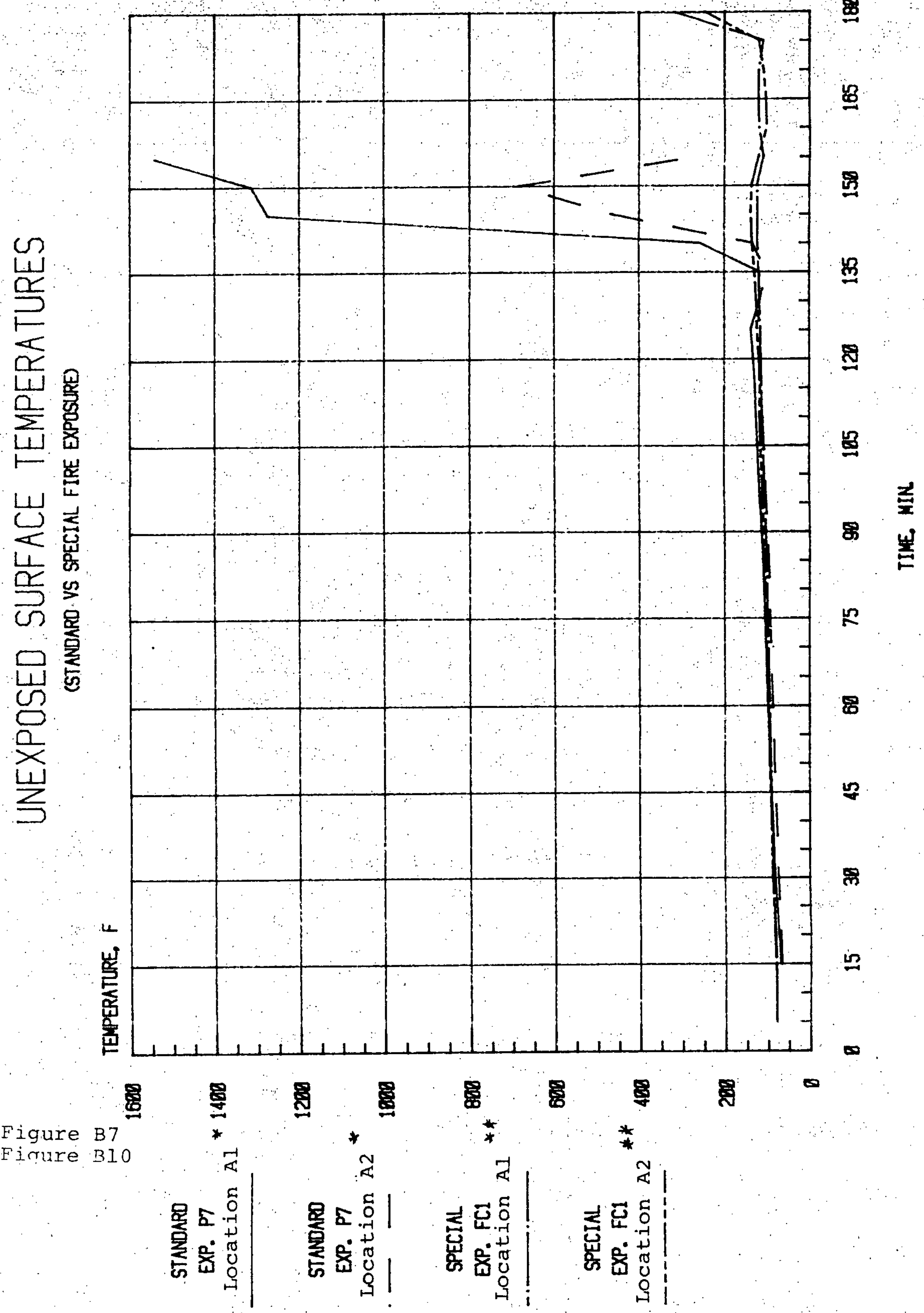
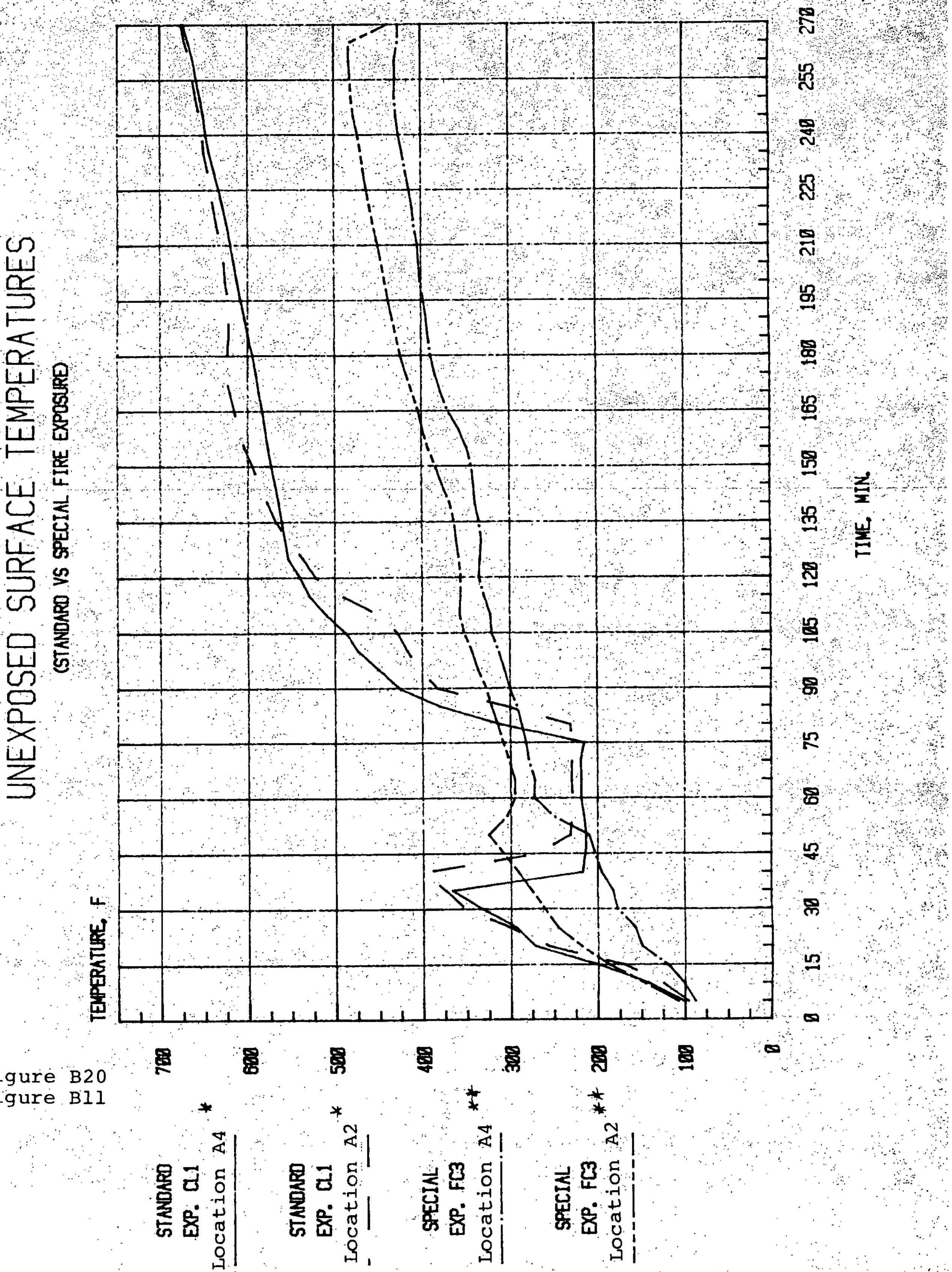


Figure 7 - The Rate Of Propagation Of 300 F (149 C) Temperature
(Experiments P14, P16)



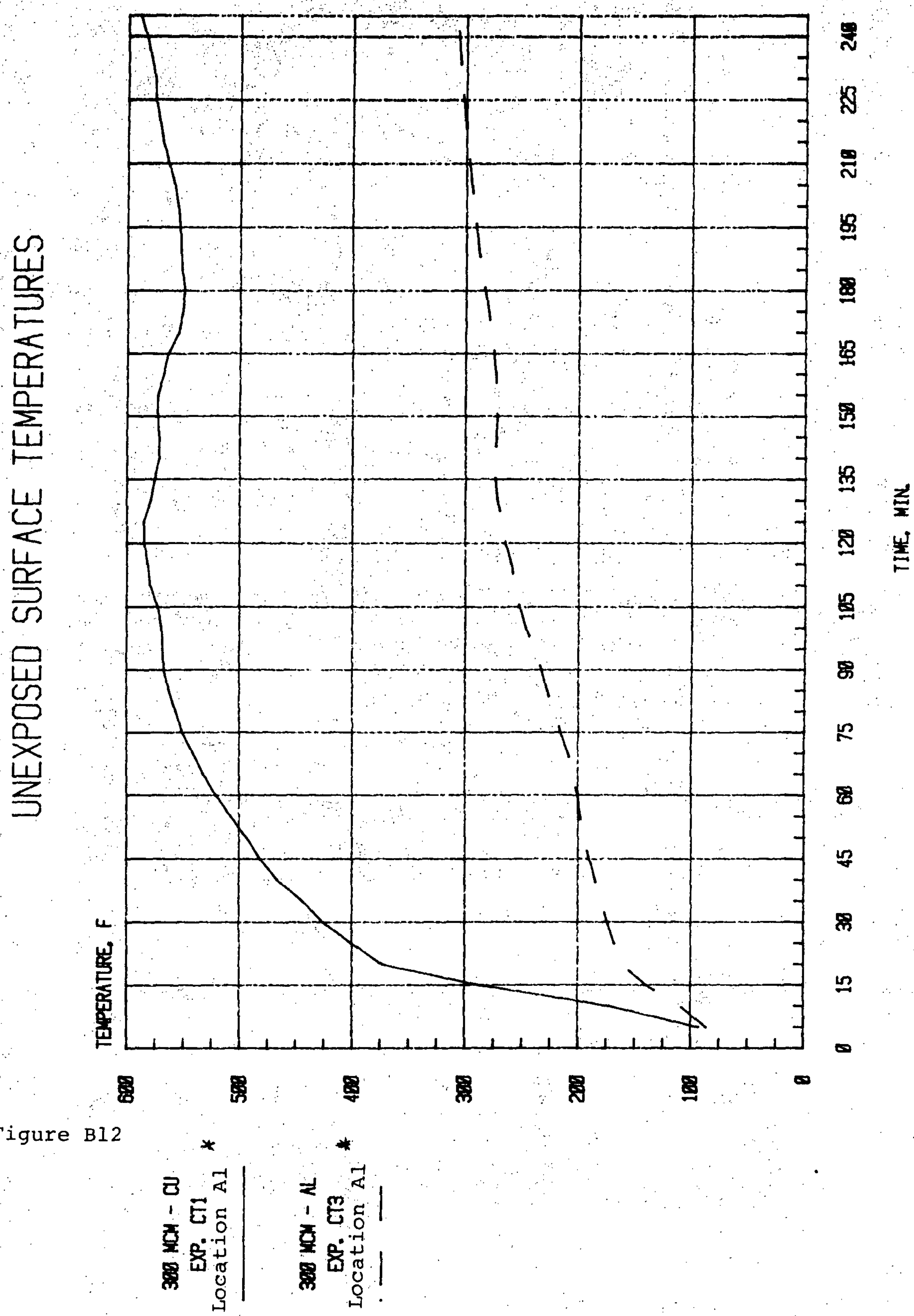
* See Figure B7
** See Figure B10

Figure 8 - Unexposed Surface Temperatures Of Fire Stop Material (Standard Versus Special Fire Exposure)



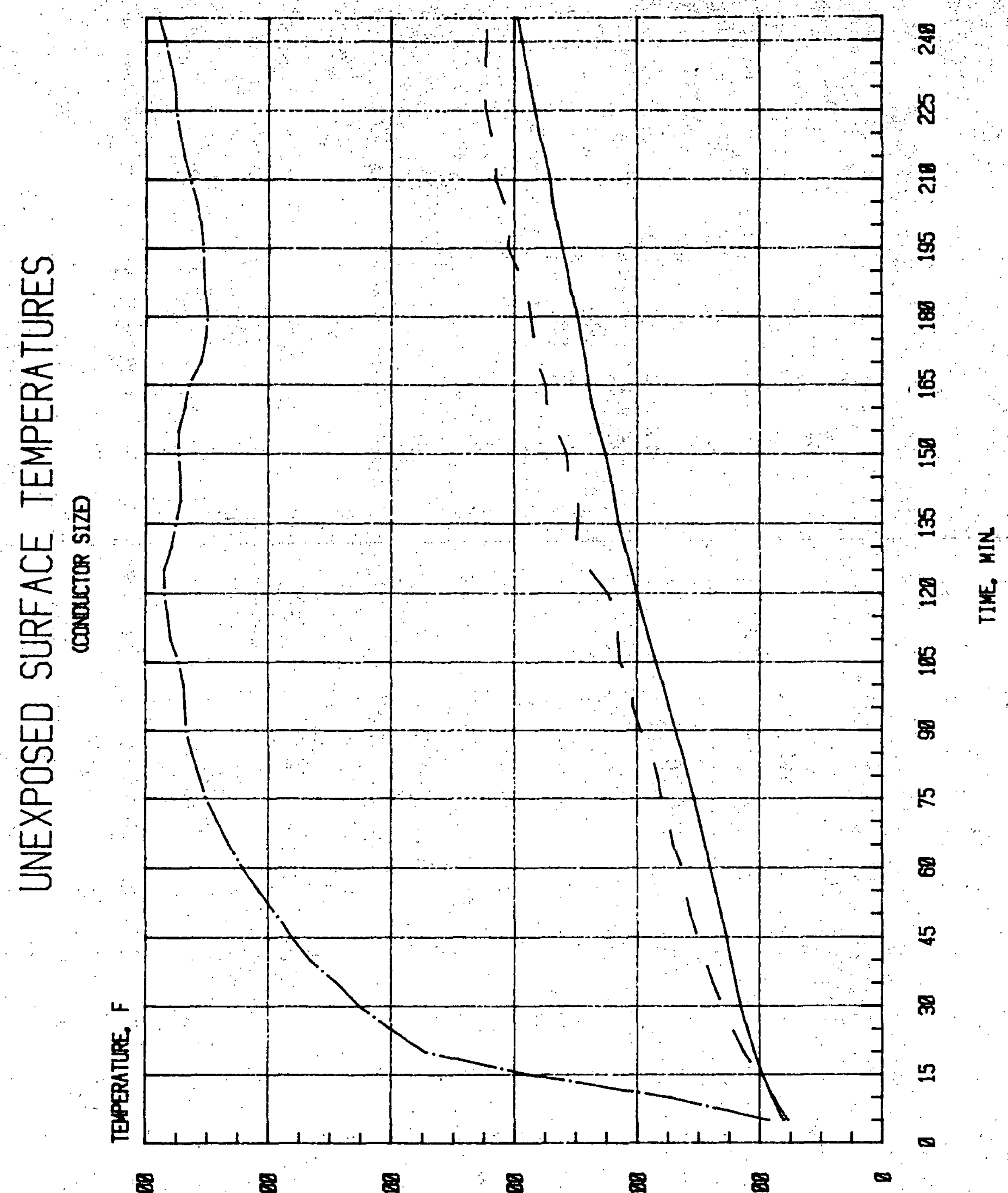
* See Figure B20
** See Figure B11

Figure 9 - Unexposed Surface Temperatures Of Fire Stop Material (Standard Versus Special Fire Exposure)



* See Figure B12

Figure 10 - Unexposed Surface Temperatures Of Fire Stop Material (Copper Versus Aluminum Conductor)



* See Figure B13
** See Figure B12

3C/12 AWG
EXP. CS1
Location A1 *

7C/12 AWG
EXP. CS2
Location A1 *

300 MCM
EXP. CT1
Location **

Figure 11 - Unexposed Surface Temperatures Of Fire Stop Material (conductor Size)

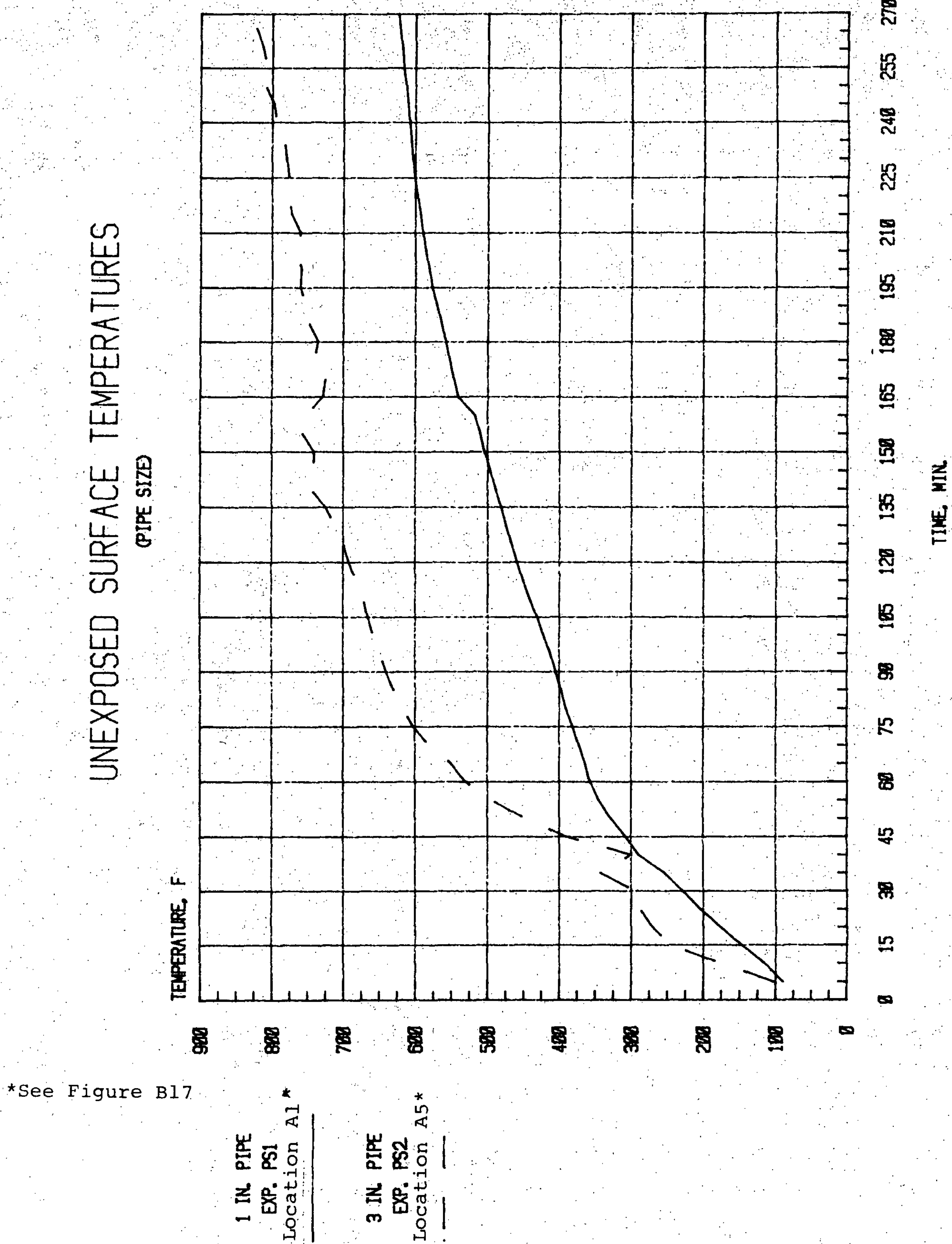
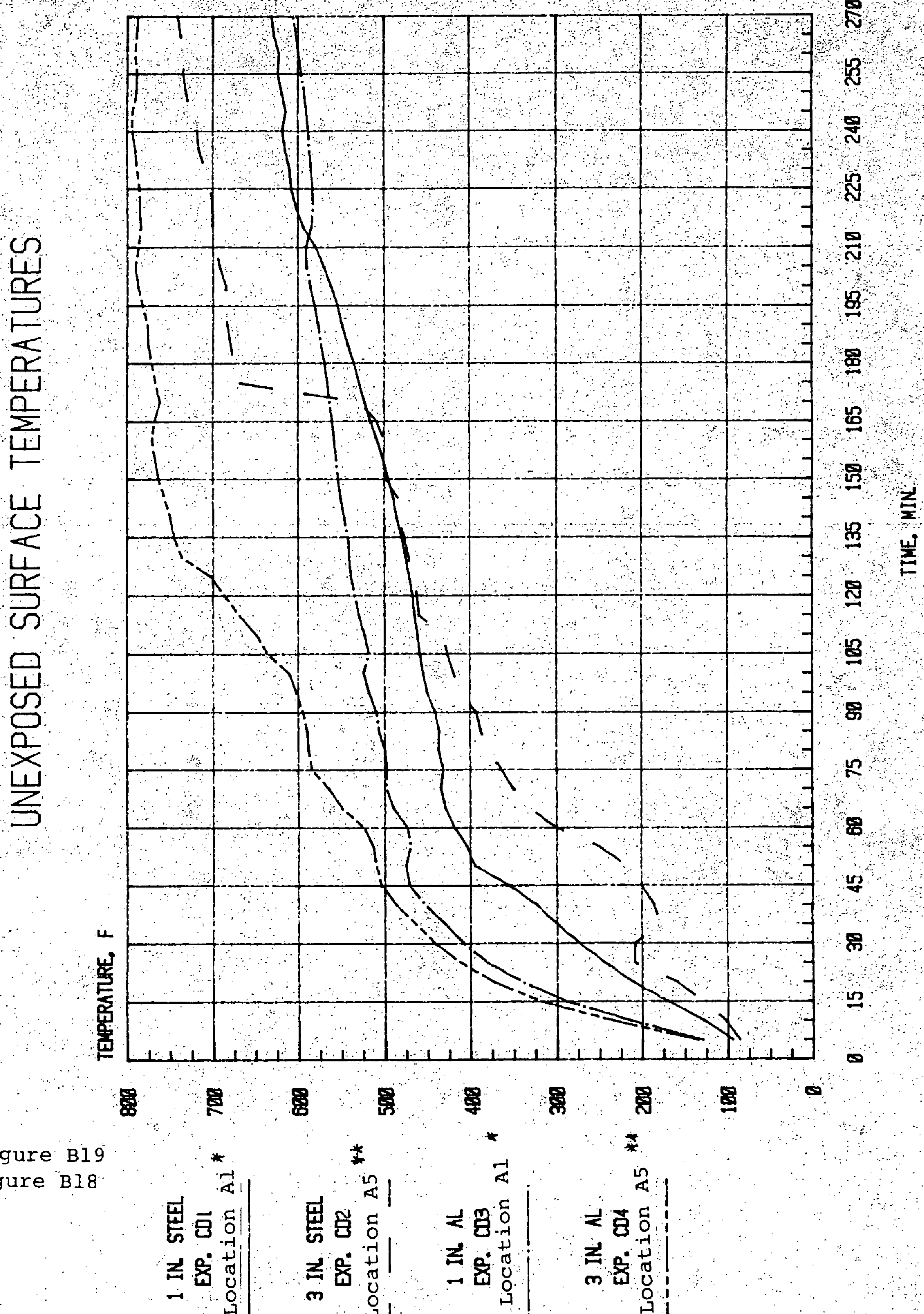
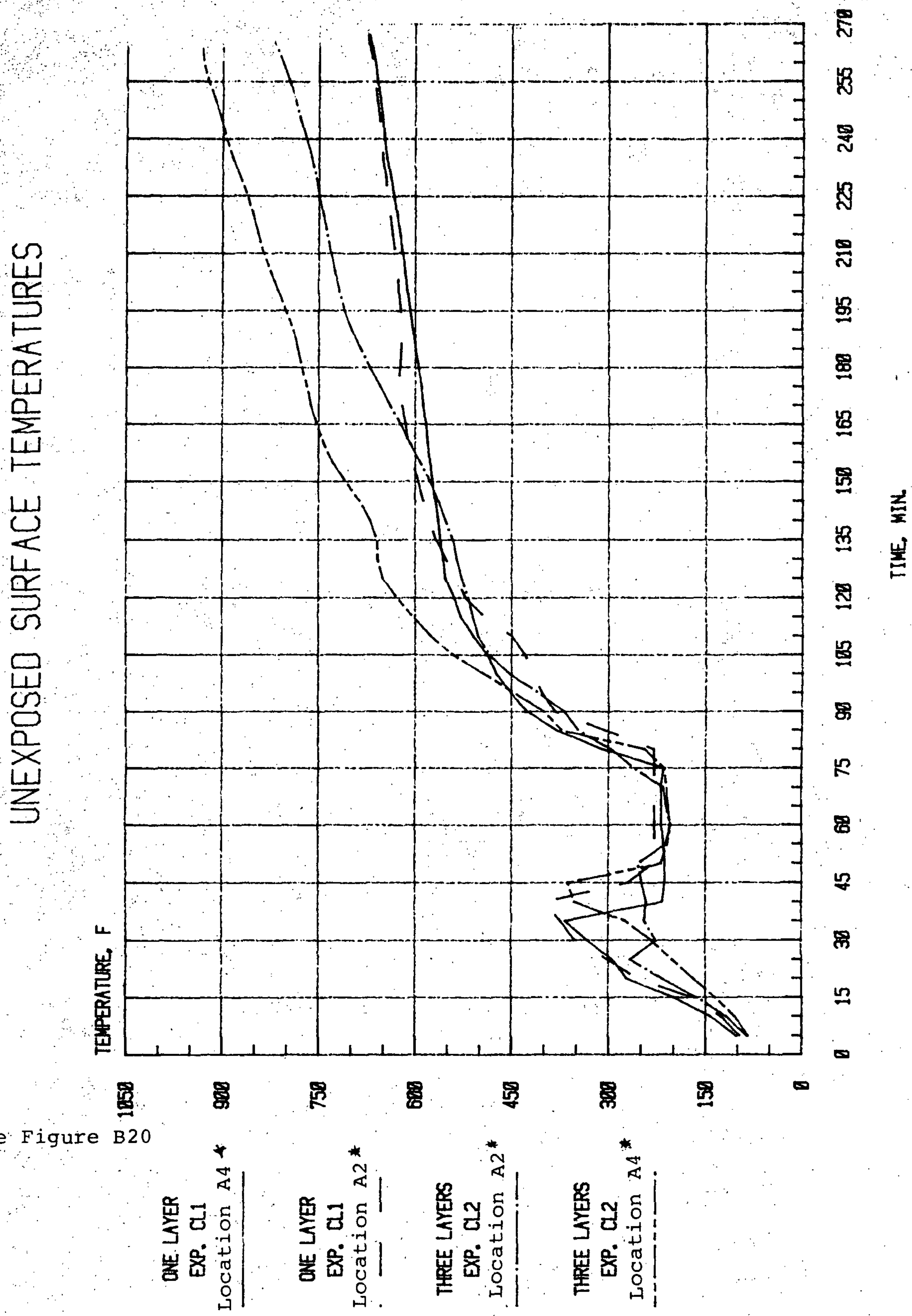


Figure 12 - Unexposed Surface Temperatures Of Fire Stop Material (Pipe Size)



** See Figure B19
* See Figure B18

Figure 13 - Unexposed Surface Temperatures Of Fire Stop Material (Steel Versus Aluminum Conduit)



*See Figure B20

Figure 14 - Unexposed Surface Temperatures Of Fire Stop Material (Cable Loading)

APPENDIX A

Sample Details

Floor Slabs - The reinforced concrete floor slabs were 36 in. (915 mm) by 36 in. (915 mm) by 6 in. (150 mm) thick. The slabs were cast with openings as shown in Fig. A1. The concrete consisted of one part Type I portland cement, 2.13 parts sand, and 3.45 parts gravel by bulk volume and mixed with about 7 gal of water per bag of cement. The strength of the concrete, as determined from standard 6 in. (150 mm) by 12 in. (305 mm) cylinders aged 28 days at room temperature, ranged between 3290-3430 psi (22.68-23.65 MPa) and averaged 3350 psi (23.10 MPa). The 28 day unit weight was 146.7 pcf (2.35 Mg/m^3).

Silicone Foam And Silicone Elastomer - The materials were two-component silicone systems. The mixing ratio of Parts A and B was 1:1 on a volume basis and in accordance with the manufacturer's installation instructions. The free rise densities were between 27.5-32.0 pcf (0.44-0.51 Mg/m^3) for the silicone foam and 86.0-89.0 pcf (1.38-1.43 Mg/m^3) for the silicone elastomer.

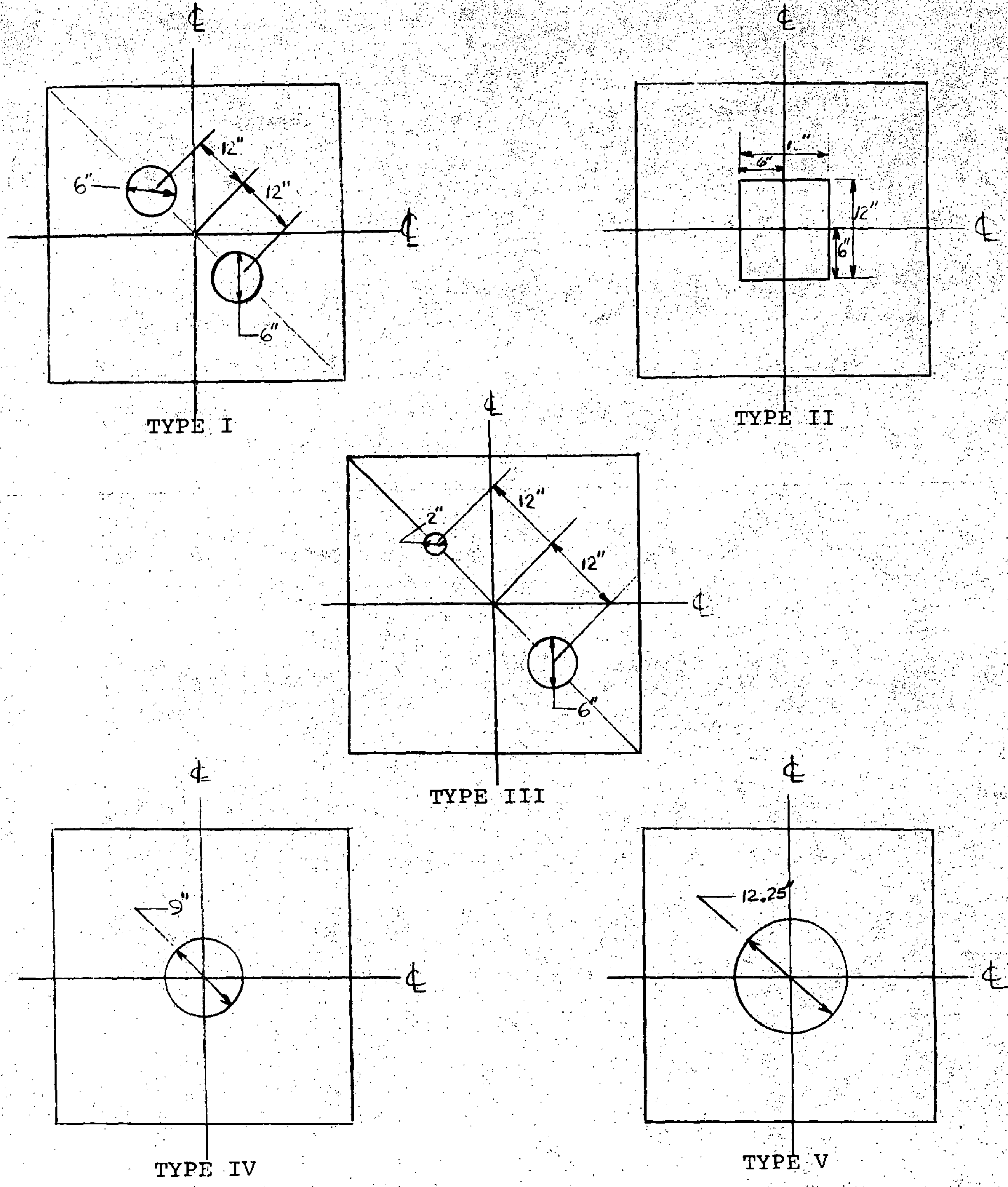
Fire Stop Device - The devices used consisted of three components. Steel pressure discs, 0.365 in. (9 mm) thick, were located one at the top and one at the bottom. Between the steel discs were two layers of 1 in. (25 mm) thick intumescent material with a 1 in. (25 mm) thick neoprene grommet at the center. The devices were installed by tightening screws until the grommet material squeezed around the cables and the inside of the opening.

Cables - Seven types of cables were used in these experiments. Details of their construction are shown in Table A1.

Cable Trays - The cable tray used was a steel, open-ladder type, nominally 6 in. (150 mm) wide, with 3.375 in. (86 mm) side rails, and a 9 in. (230 mm) spacing between rungs.

Pipe And Conduit - The 1 in. and 3 in. trade size, schedule 40 steel pipe was used. Also 1 in. and 3 in. rigid steel and aluminum conduits were used.

Cable Type	Conductor No./Size	Conductor Type	Generic Description	Cable Cross Section Diameter, In. (mm)	Insulation/Jacket Material	Approximate Conductor Insulation/ Jacket Thickness, In. (mm)	Cable Jacket Material	Approximate Cable Jacket Thickness, In. (mm)
G	7/12AWG	Cu	EPR-Hypalon/Hypalon	0.785 (19.9)	Ethylene propylene rubber/chloro-sulphonated poly-ethylene	0.028/0.017 (0.71/0.43)	Chlorosulphonated polyethylene	0.134 (3.4)
H	7/12AWG	Cu	XLPO/XLPO	0.493 (12.5)	Crosslinked polyolefin	0.030/- (0.76/-)	Crosslinked polyolefin	0.054 (1.4)
F	7/12AWG	Cu	PE-PVC/PVC	0.602 (15.3)	Polyethylene/ Polyvinyl chloride	0.029/0.012 (0.74/0.31)	Polyvinyl chloride	0.062 (1.6)
A	7/12AWG	Cu	PVC-NYLON/PVC	0.515 (13.1)	Polyvinyl chloride/ nylon	0.022/0.006 (0.56/0.15)	Polyvinyl chloride	0.050 (1.3)
B	3/12AWG	Cu	PE-PVC/PVC	0.445 (11.3)	Polyethylene/ Polyvinyl chloride	0.039/0.012 (0.99/0.30)	Polyvinyl Chloride	0.056 (1.42)
C	300MCM	Cu	PVC	0.821 (20.8)	Polyvinyl chloride	0.149 (3.78)	______	______
E	300MCM	AL	PVC	0.832 (21.1)	Polyvinyl chloride	0.140 (3.56)	______	______



ALL SLABS - NOMINAL 36 x 36 x 6 IN. THICK

Figure A1 - Floor Slabs

APPENDIX B

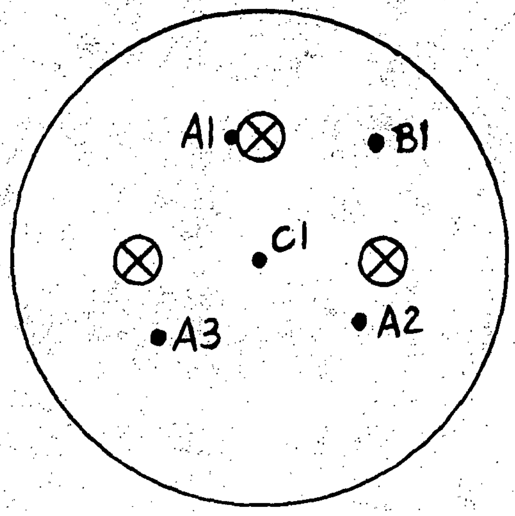
Instrumentation

Unexposed Surface Temperatures - Temperatures on the unexposed surface of the fire stop were measured with No. 28 gague Chromel Alumel thermocouples. The thermocouple bead was held against the surface and covered with a 0.75 by 0.75 by 0.156 in. (19 by 19 by 4 mm) asbestos pad. Locations of these thermocouples are shown in Figs. B1 - B21.

Fire Stop Material Temperatures - Temperatures within the silicone elastomer in experiments P1, P3 and P5 were measured with No. 28 gauge Chromel Alumel thermocouples with a 0.062 in. (1.6 mm) diameter inconel shield. Temperatures between layers of the device in experiments P14 and P16 were measured with unshielded No. 28 gauge Chromel Alumel thermocouples. The locations of these thermocouples are shown in Fig. B22.

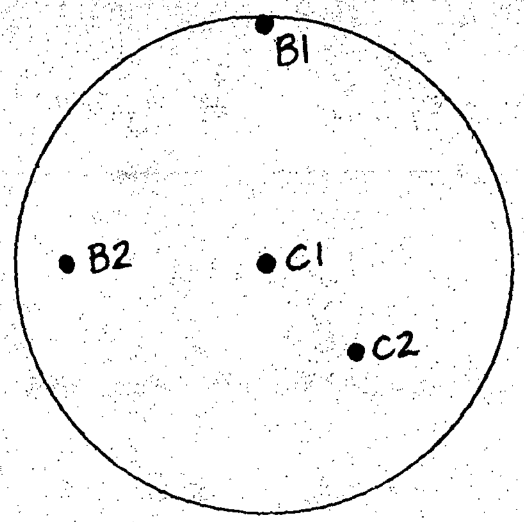
Furance Temperatures - Furnace temperatures were measured with three shielded thermocouples of the type specified in ASTM E119. The thermocouples were located 12 in. (305 mm) from the exposed surface and symmetrically distributed within the furnace chamber.

Pressure Differential - The pressure differential at the exposed surface with respect to the unexposed surface was measured with probes connected to a manometer or electronic barometer. The probes were located as shown in Fig. B23.



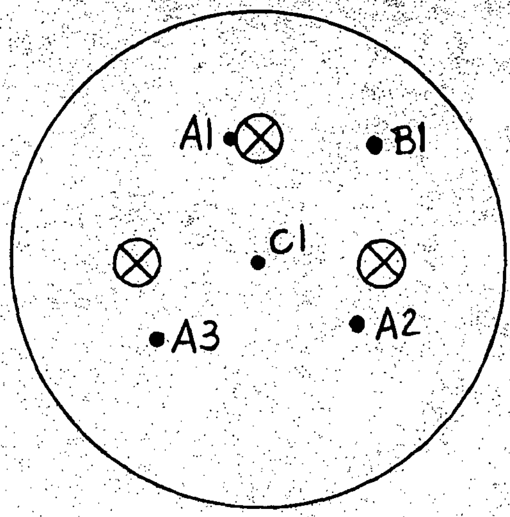
T.C.	Location
A1	In contact with cable jacket and silicone foam
A2	1/2 in. from cable
A3	3/4 in. from cable
B1	1 in. from periphery of silicone foam
C1	Center of silicone foam

Group 1 Thermocouple Locations
Fig. B1



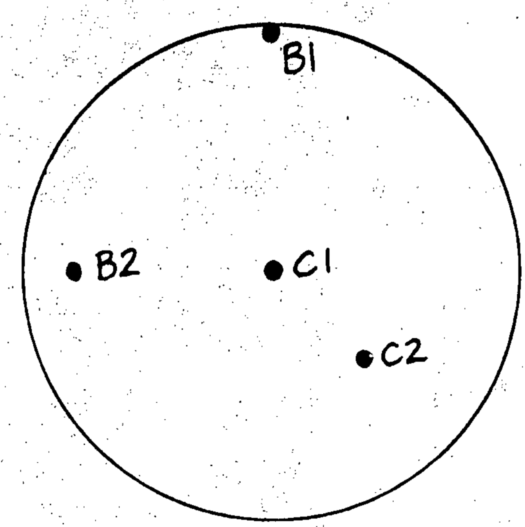
T.C.	Location
B1	At periphery of silicone foam
B2	1/2 in. from periphery of silicone foam
C1	Center of silicone foam
C2	1-1/2 in. from periphery of silicone foam

Group 2 Thermocouple Locations
Fig. B2



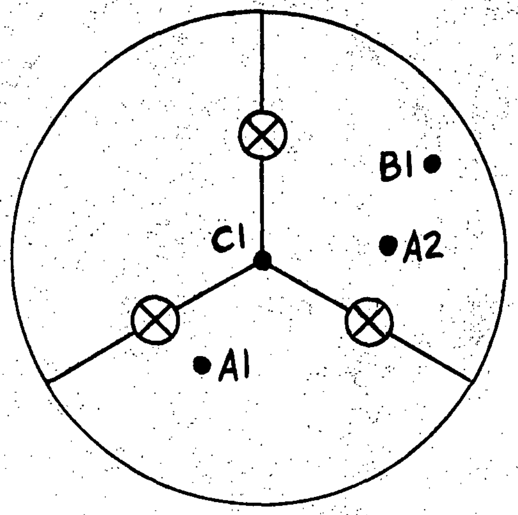
T.C.	Location
A1	In contact with cable jacket and silicone foam
A2	1/2 in. from cable
A3	3/4 in. from cable
B1	1 in. from periphery of silicone foam
C1	Center of silicone foam

Group 3 Thermocouple Location
Fig. B3



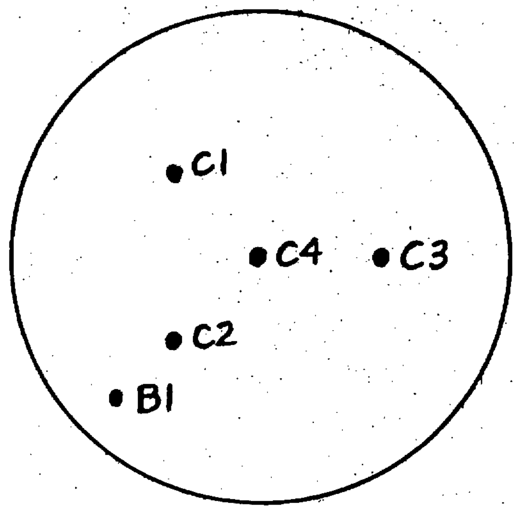
T.C.	Location
B1	At periphery of silicone foam
B2	1/2 in. from periphery of silicone foam
C1	Center of silicone foam
C2	1-1/2 in. from periphery of silicone foam

Group 4 Thermocouple Locations
Fig. B4



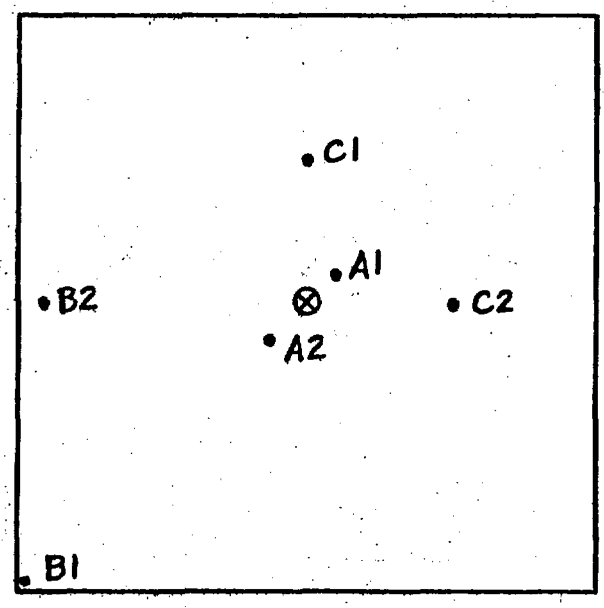
T.C.	Location
A1	1/2 in. from cable
A2	3/4 in. from cable
B1	1/2 in. from periphery of device
C1	Center of device

Group 5 Thermocouple Locations
Fig. B5



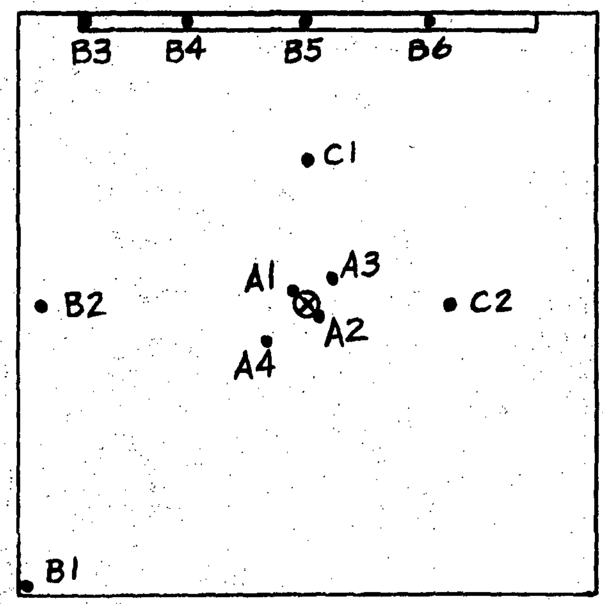
T.C.	Location
B1	1/2 in. from periphery of device
C1	1-1/2 in. from periphery of device
C2	1-1/2 in. from periphery of device
C3	1-1/2 in. from periphery of device
C4	Center of device

Group 6 Thermocouple Locations
Fig. B6



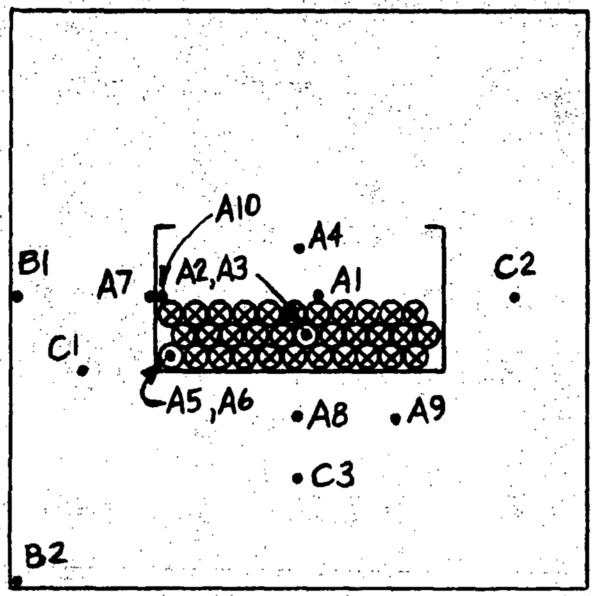
T.C.	Location
A1	1/2 in. from cable
A2	3/4 in. from cable
B1	At periphery of silicone foam
B2	1/2 in. from periphery of silicone foam
C1	3 in. from periphery of silicone foam
C2	3 in. from periphery of silicone foam

Group 7 Thermocouple Locations
Fig. B7



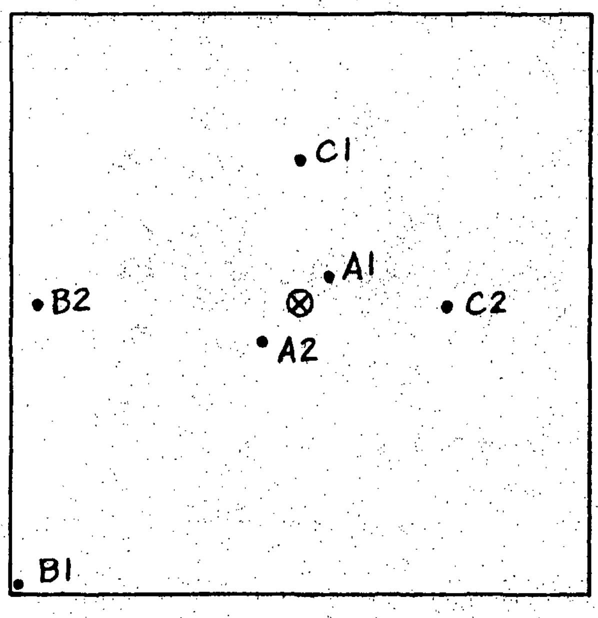
T.C.	Location
A1	In contact with cable jacket and silicone foam
A2	In contact with cable jacket and silicone foam
A3	1/2 in. from cable
A4	3/4 in. from cable
B1	At periphery of silicone foam
B2	1/2 in. from periphery of silicone foam
B3	At periphery of crack in foam
B4	2-5/8 in. from centerline, 3/16 in. from periphery
B5	On centerline, 3/16 in. from periphery
B6	2-5/8 in. from centerline, 3/16 in. from periphery
C1	3 in. from periphery of silicone foam
C2	3 in. from periphery of silicone foam

Group 8 Thermocouple Locations
Fig. B8



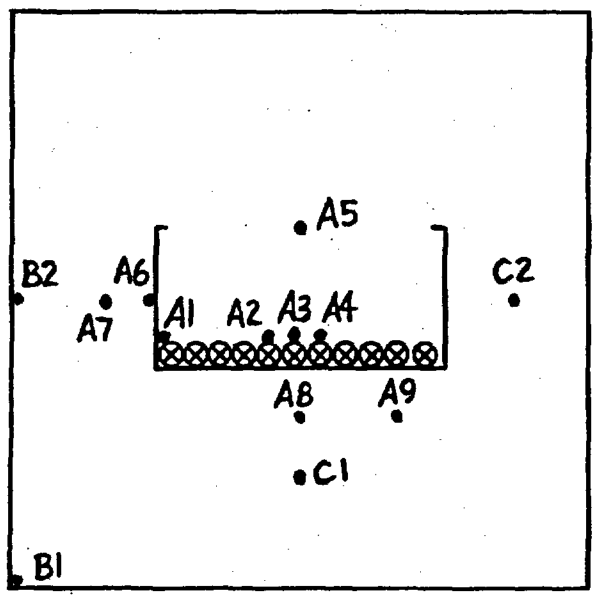
T.C.	Locations
A1	In contact with cable jacket and silicone elastomer
A2	Over center hole in silicone elastomer
A3	Over center hole in silicone elastomer
A4	1 in. from cable
A5	Center of hole in silicone elastomer
A6	Center of hole in silicone elastomer
A7	Unexposed surface in contact with tray and silicone elastomer
A8	1 in. from tray
A9	1 in. from tray
A10	In contact with cable jacket, cable tray and silicone elastomer
B1	At periphery of silicone elastomer
B2	At periphery of silicone elastomer
C1	1-1/2 in. from tray
C2	1-1/2 in. from periphery of hole
C3	2-1/4 in. from periphery of hole

Group 9 Thermocouple Locations
Fig. B9



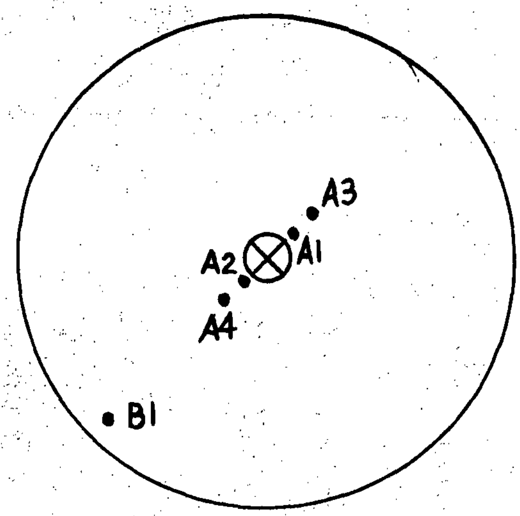
T.C.	Location
A1	1/2 in. from cable
A2	3/4 in. from cable
B1	At periphery of silicone foam
B2	1/2 in. from periphery of silicone foam
C1	3 in. from periphery of silicone foam
C2	3 in. from periphery of silicone foam

Group 10 Thermocouple Locations
Fig. B10



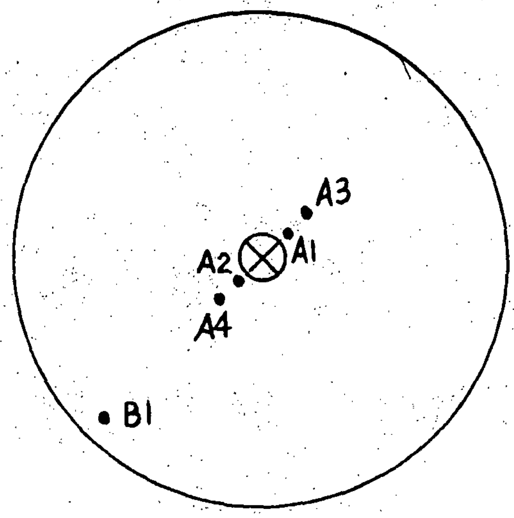
T.C.	Location
A1	In contact with cable tray, cable jacket and silicone elastomer
A2	In contact with cable jacket and silicone elastomer
A3	Center cable in contact with cable jacket
A4	In contact with cable jacket and silicone elastomer
A5	3 in. from edge of tray, 3-3/8 in. from back of tray
A6	1-1/2 in. from tray
A7	1 in. from edge of tray, 1-1/2 in. from front of tray
A8	1 in. from tray
A9	1 in. from tray
B1	In contact with silicone elastomer and concrete
B2	At periphery in contact with concrete and silicone elastomer
C1	2-1/4 in. from periphery of hole
C2	1-1/2 in. from periphery of hole

Group 11 Thermocouple Locations
Fig. B11



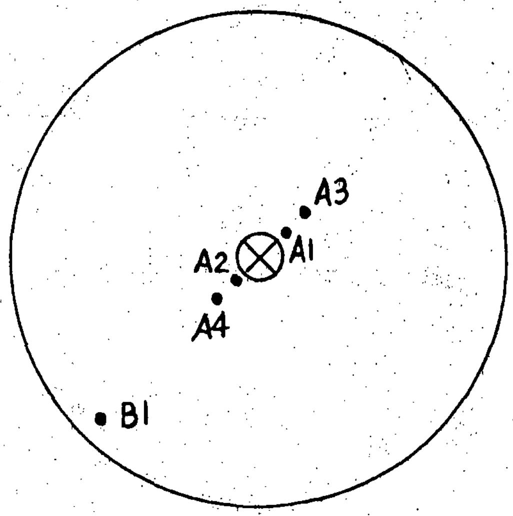
T.C.	Location
A1	1/16 in. from cable jacket
A2	1/16 in. from cable jacket
A3	1/2 in. from cable jacket
A4	1/2 in. from cable jacket
B1	1/4 in. from periphery of hole

Group 12 Thermocouple Locations
Fig. B12



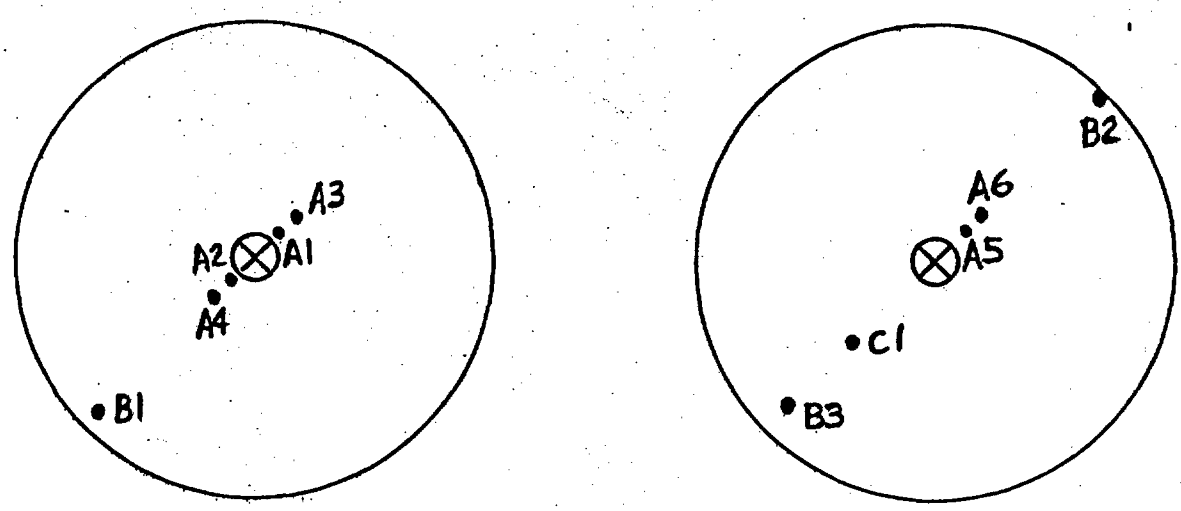
T.C.	Location
A1	1/16 in. from cable jacket
A2	1/16 in. from cable jacket
A3	1/2 in. from cable jacket
A4	1/2 in. from cable jacket
B1	1/4 in. from periphery of hole

Group 13 Thermocouple Locations
Fig. B13



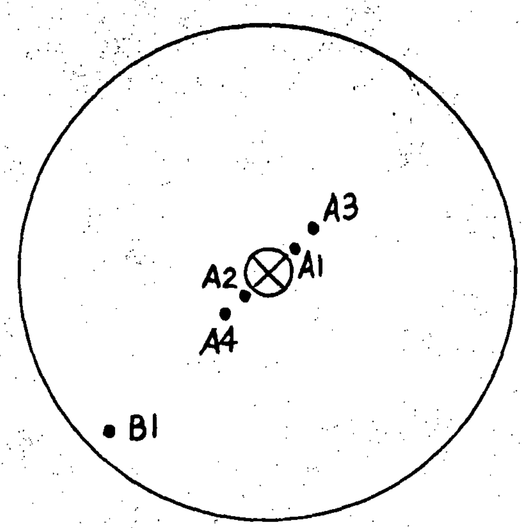
T.C.	Location
A1	1/16 in. from cable jacket
A2	1/16 in. from cable jacket
A3	1/2 in. from cable jacket
A4	1/2 in. from cable jacket
B1	1/4 in. from periphery of hole

Group 14 Thermocouple Locations
Fig. B14



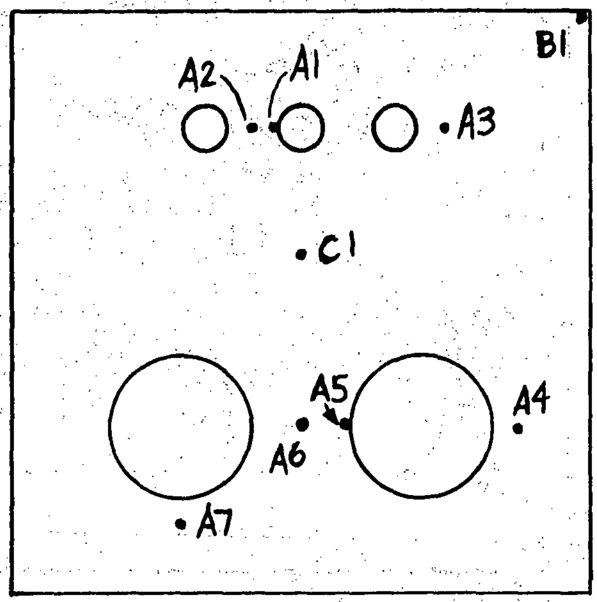
T.C.	Location
A1	1/16 in. from cable jacket
A2	1/16 in. from cable jacket
A3	1/2 in. from cable jacket
A4	1/2 in. from cable jacket
A5	1/4 in. from cable jacket
A6	1/2 in. from cable jacket
B1	1/4 in. from periphery of hole
B2	At periphery in contact with concrete and silicone elastomer
B3	1/2 in. from periphery of hole
C1	1-1/2 in. from cable jacket

Group 15 Thermocouple Locations
Fig. B15



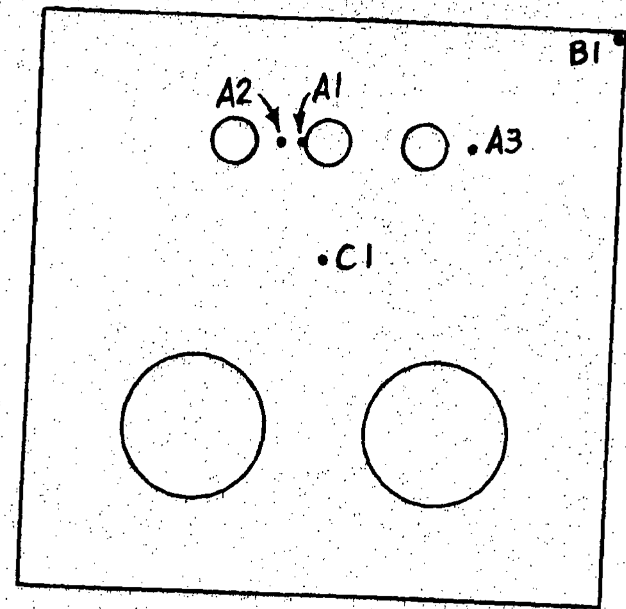
T.C.	Location
A1	1/16 in. from cable jacket
A2	1/16 in. from cable jacket
A3	1/2 in. from cable jacket
A4	1/2 in. from cable jacket
B1	1/4 in. from periphery of hole

Group 16 Thermocouple Locations
Fig. B16



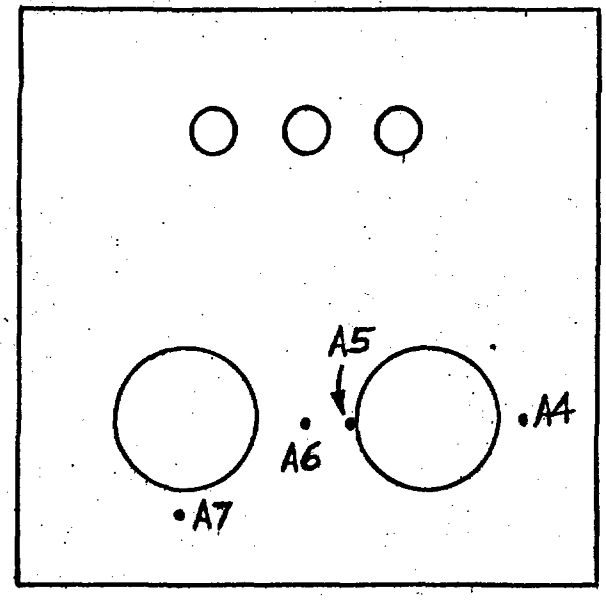
T.C.	Location
A1	In contact with pipe and silicone elastomer
A2	2-1/2 in. from periphery, 1/2 in. from center pipe
A3	2-1/2 in. from periphery, 1/2 in. from pipe
A4	1/2 in. from pipe, 3-1/2 in. from periphery
A5	In contact with 3 in. pipe and silicone
A6	3-1/2 in. from periphery
A7	1/2 in. from center of 3 in. pipe
B1	At periphery in contact with concrete and silicone elastomer
C1	5 in. from periphery

Group 17 Thermocouple Locations
Fig. B17



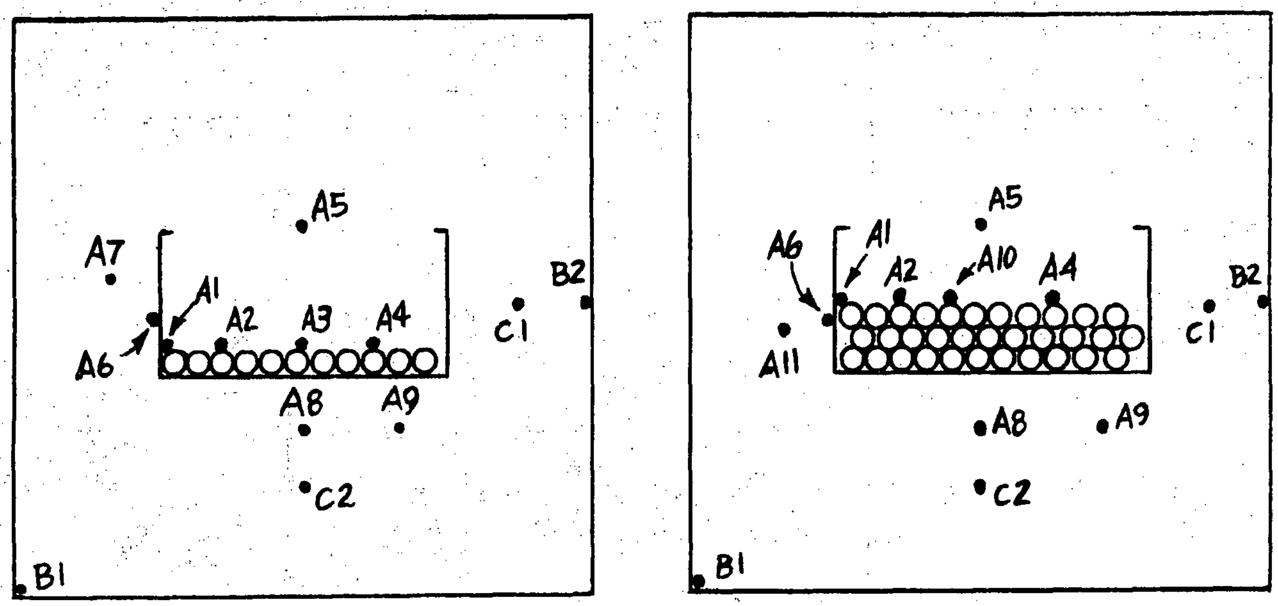
T.C.	Location
A1	In contact with pipe and silicone elastomer
A2	2-1/1 in. from periphery of hole, 1/2 in. from pipe
A3	2-1/2 in. from periphery of hole, 1/2 in. from pipe
B1	At periphery in contact with concrete and silicone elastomer
C1	5 in. from periphery of hole

Group 18 Thermocouple Locations
Fig. B18



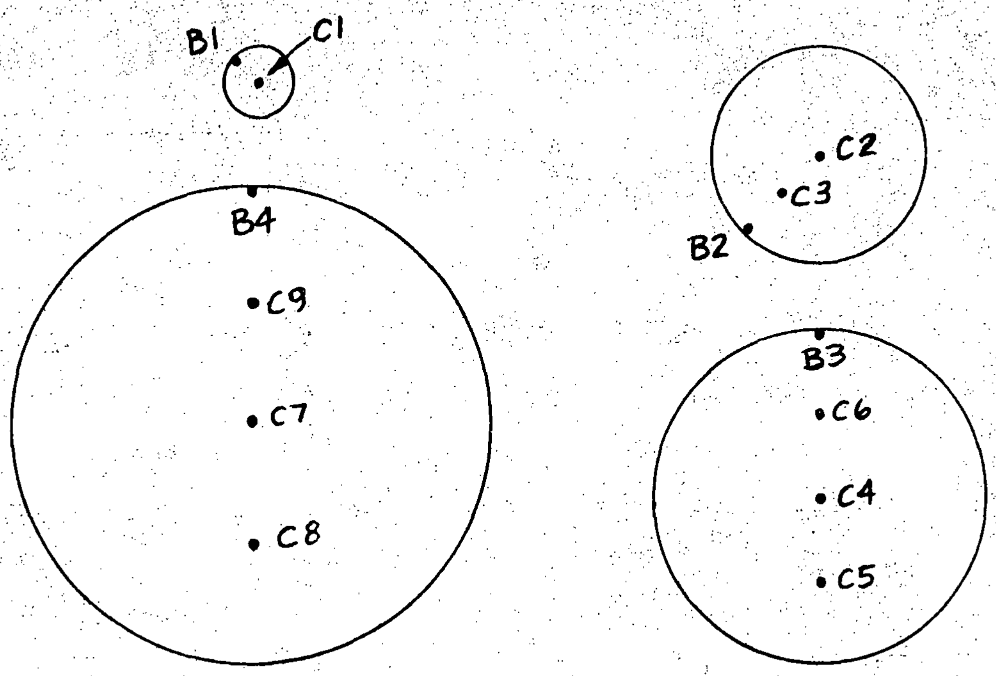
T.C.	Location
A4	1/2 in. from pipe, 3-1/2 in. from periphery
A5	In. contact with silicone elastomer and 3 in. pipe
A6	3-1/2 in. from periphery
A7	1/2 in. from center of 3 in. pipe

Group 19 Thermocouple Locations
Fig. B19



T.C.	Location
A1	Corner of cable tray in contact with cable tray, cable jacket and silicone elastomer
A2	Center of cable in contact with cable jacket and silicone elastomer
A3	In contact with center cable and silicone elastomer
A4	Center cable in contact with cable jacket and silicone elastomer
A5	4-5/16 in. from periphery of hole
A6	1-1/4 in. from back of tray, in contact with tray and silicone elastomer
A7	1 in. from tray
A8	1 in. from tray
A9	1 in. from tray
A10	Center cable in contact with cable jacket and silicone elastomer
A11	1 in. from tray
B1	At periphery in contact with concrete and silicone elastomer
B2	At periphery in contact with concrete and silicone elastomer
C1	1-1/2 in. from periphery of hole
C2	2-1/4 in. from periphery of hole

Group 20 Thermocouple Locations
Fig. B20



T.C.	Location
B1	At periphery in contact with concrete and silicone foam
B2	At periphery in contact with concrete and silicone foam
B3	At periphery in contact with concrete and silicone foam
B4	At periphery in contact with concrete and silicone foam
C1	Center of 2 in. diameter hole
C2	Center of 6 in. diameter hole
C3	1-1/2 in. from periphery of hole
C4	Center of 9 in. diameter hole
C5	2-1/4 in. from periphery of hole
C6	2-1/4 in. from periphery of hole
C7	Center of 12 in. diameter hole
C8	3-1/4 in. from periphery of hole
C9	3-1/4 in. from periphery of hole

Group 21 Thermocouple Locations
Fig. B21

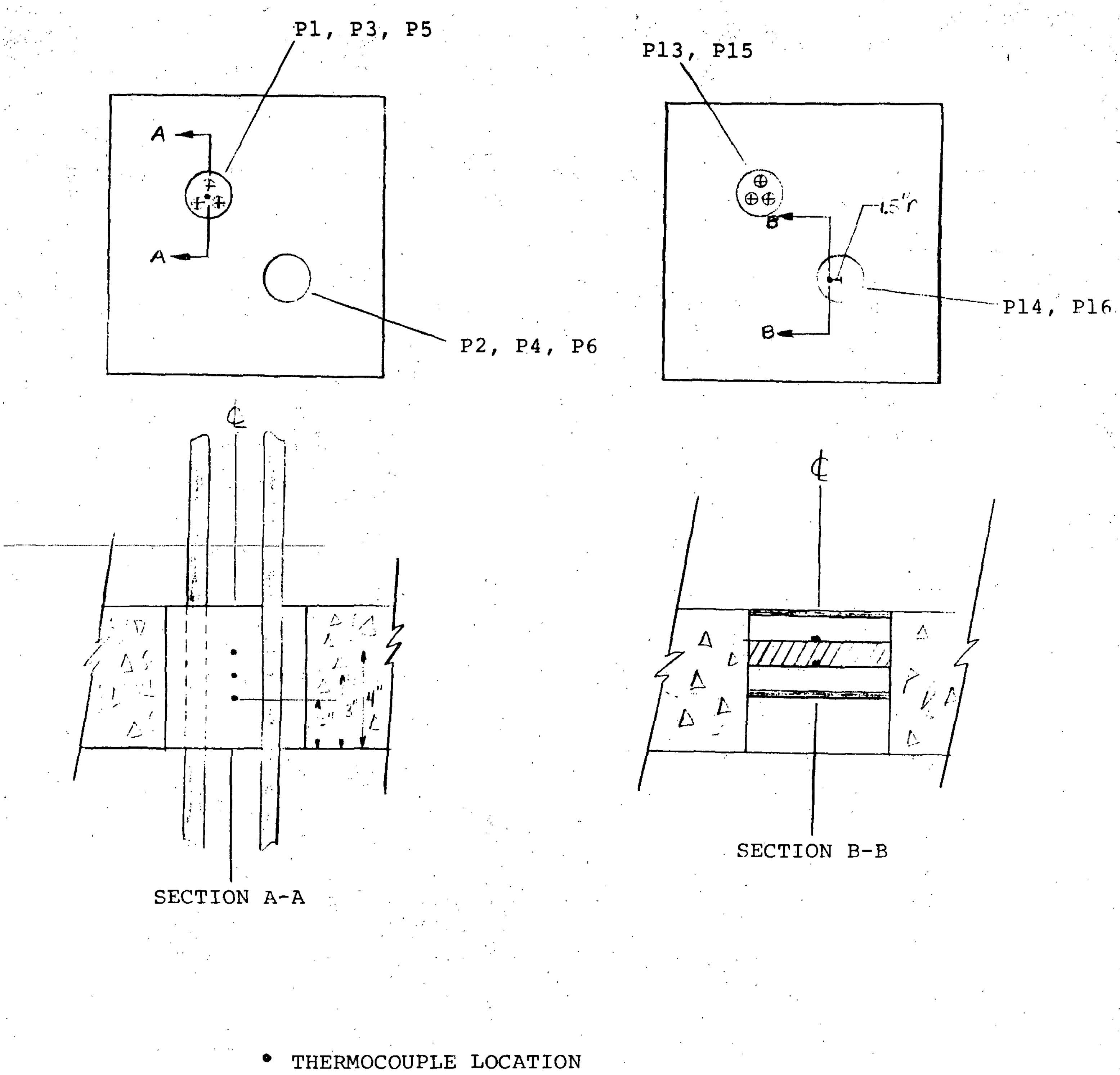
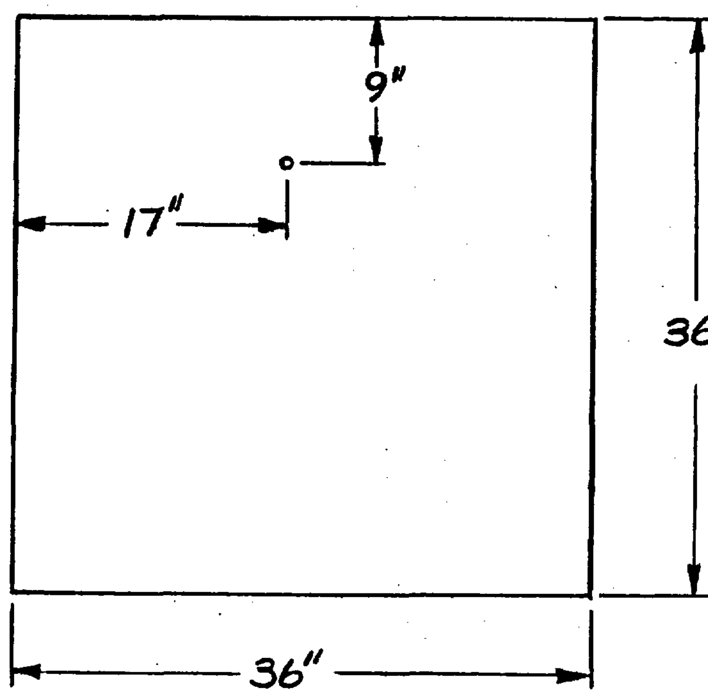


Figure B22 - Location Of Thermocouples Within Fire Stop



Pressure Probe Location
Fig. B23

APPENDIX C

Experimental Results

Unexposed Surface Temperatures - The recorded temperature of each thermocouple was plotted versus time for each experiment. These graphs are shown in Figs. C1-C65.

Experiment Duration And Flaming Times - The experiment duration and time at which flaming occurred on the unexposed side are shown in Tables C1-C3.

Table C1

Duration And Time To Flaming
For Pressure Differential Experiments

Experiment	Duration (Min.)	Time To Flaming (Min.)
P22	215	NR
P19	88	86
P1	117	116
P3	112	110
P5	113	112
P23	215	208
P20	88	NR
P2	117	NR
P4	112	NR
P6	113	NR
P9, P10	270	NR
P11, P12	245	NR
P13, P14, P15, P16	185	NR
P7	155	153
P8	156	154
P21	106	104
P17	125	*
P18	125	NR

* - Smoke, rich in unburned fuel, which issued through hole was ignited by match several times during the experiment

NR - Flaming did not occur during experiment

Table C2

Duration And Time To Flaming
For Fire Exposure Experiments

Experiment	Duration (Min.)	Time To Flaming (Min.)
FC1	180	177
FC2	212	211
FC3	270	NR

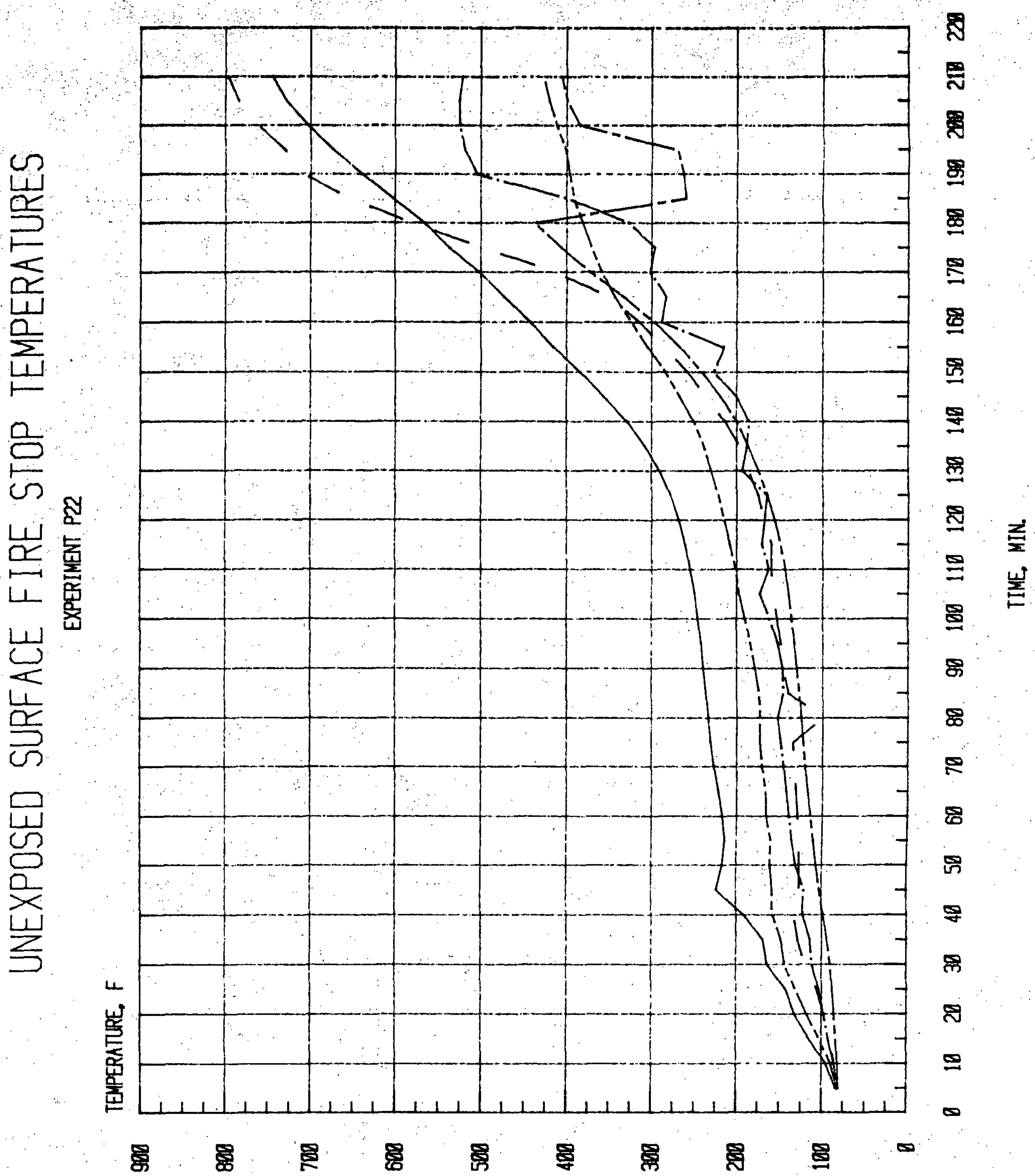
NR - Flaming did not occur during experiment

Table C3

Duration And Time To Flaming
For Sample Experiments

Experiment	Duration (Min.)	Time To Flaming (Min.)
CT1, CT2	245	NR
CT3, CT4	245	NR
CS1, CS2	245	NR
CS3, CS4	245	NR
T1, T1, T3, T4	245	NR
PS1, PS2	270	NR
CD1, CD1	270	NR
CD3, CD4	170	NR
CL1, CL2	270	NR
S1	120	NR
S2	120	119
S3	132	131
S4	125	124

NR - Flaming did not occur during experiment



* See Figure B1

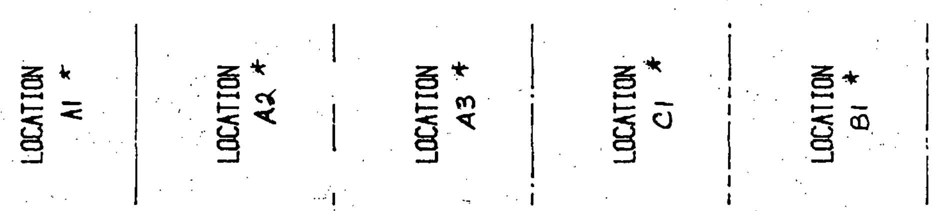
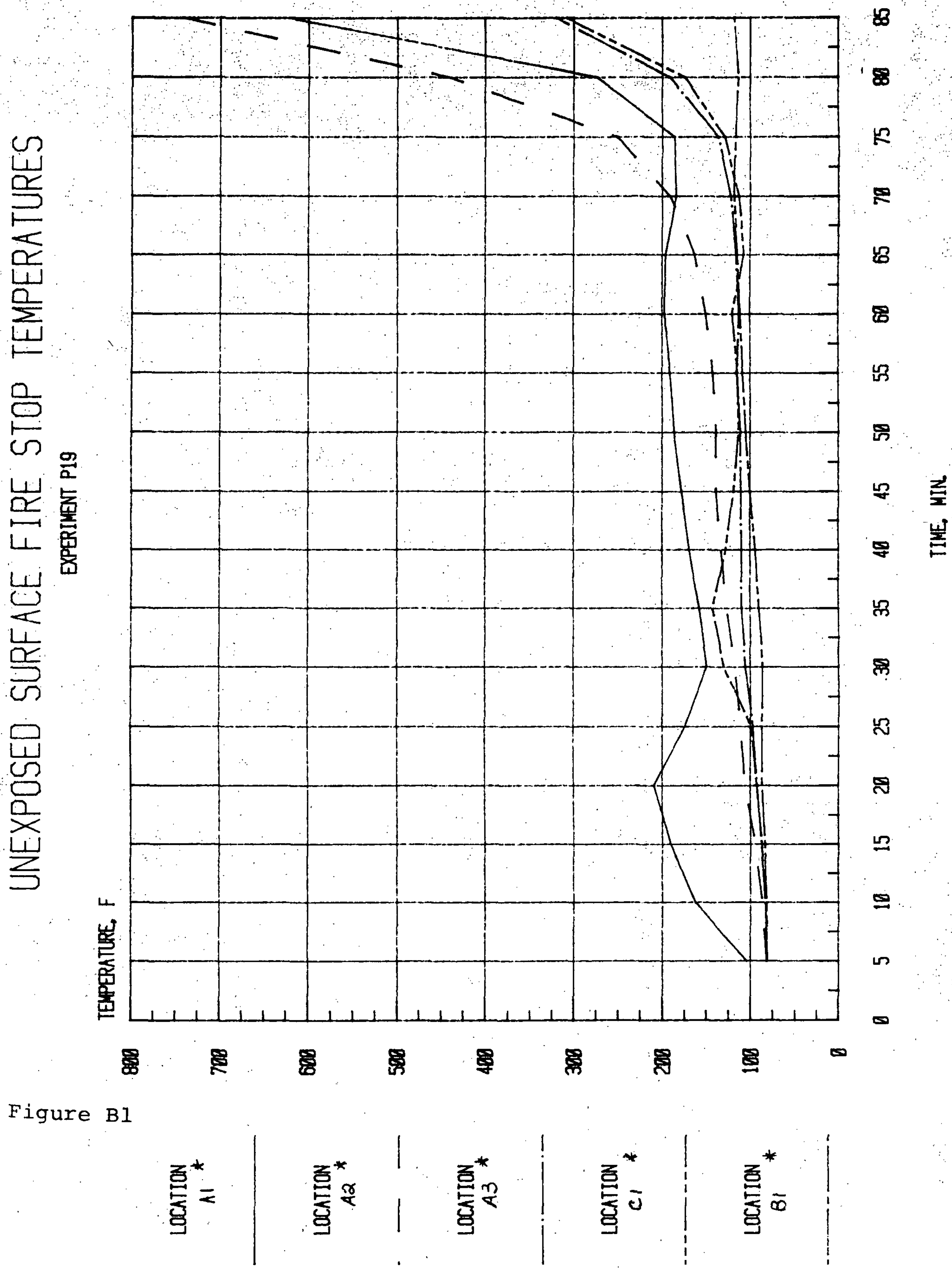
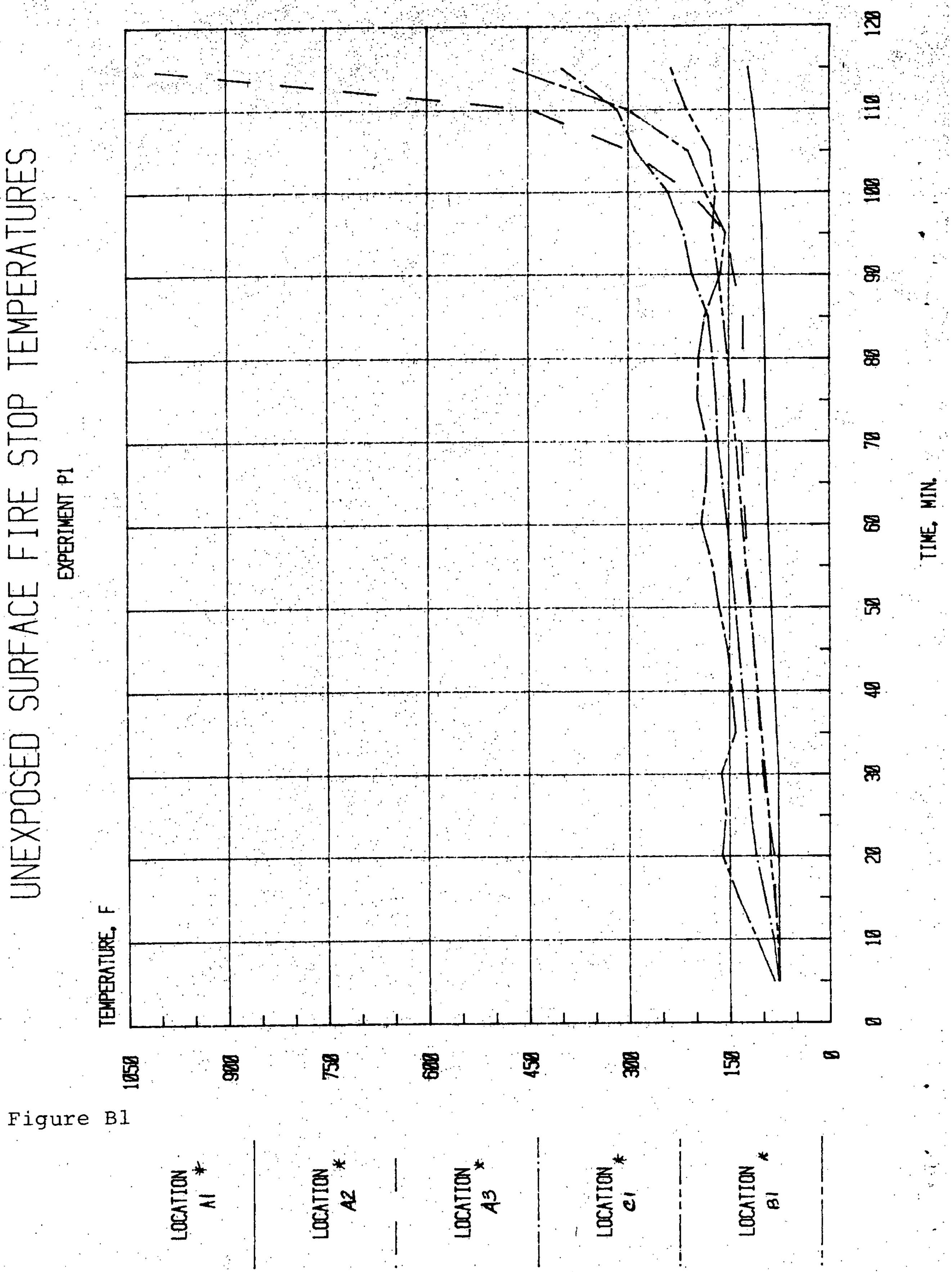


Figure C1 - Unexposed Surface Temperatures Of Fire Stop Material



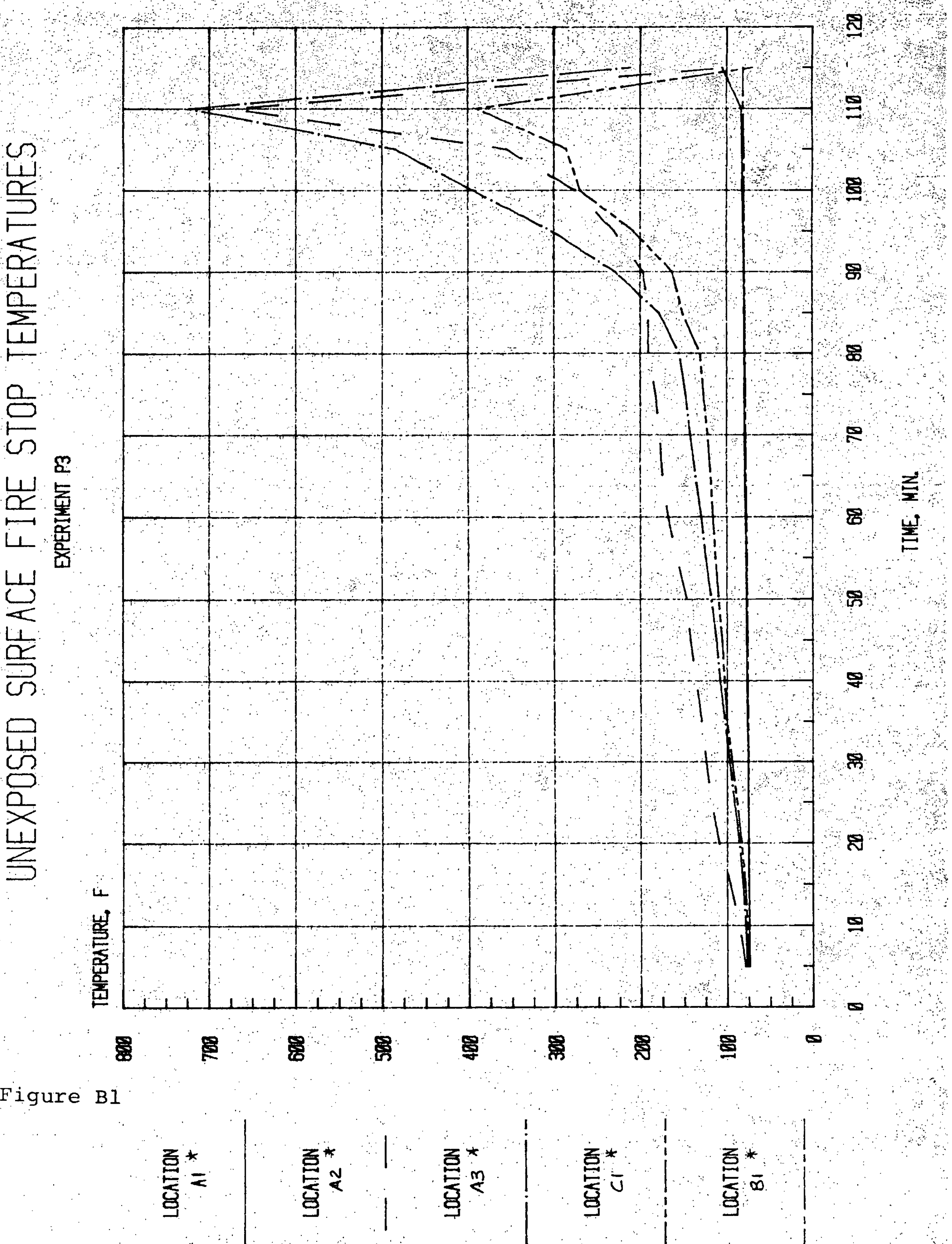
* See Figure B1

Figure C2 - Unexposed Surface Temperatures Of Fire Stop Material



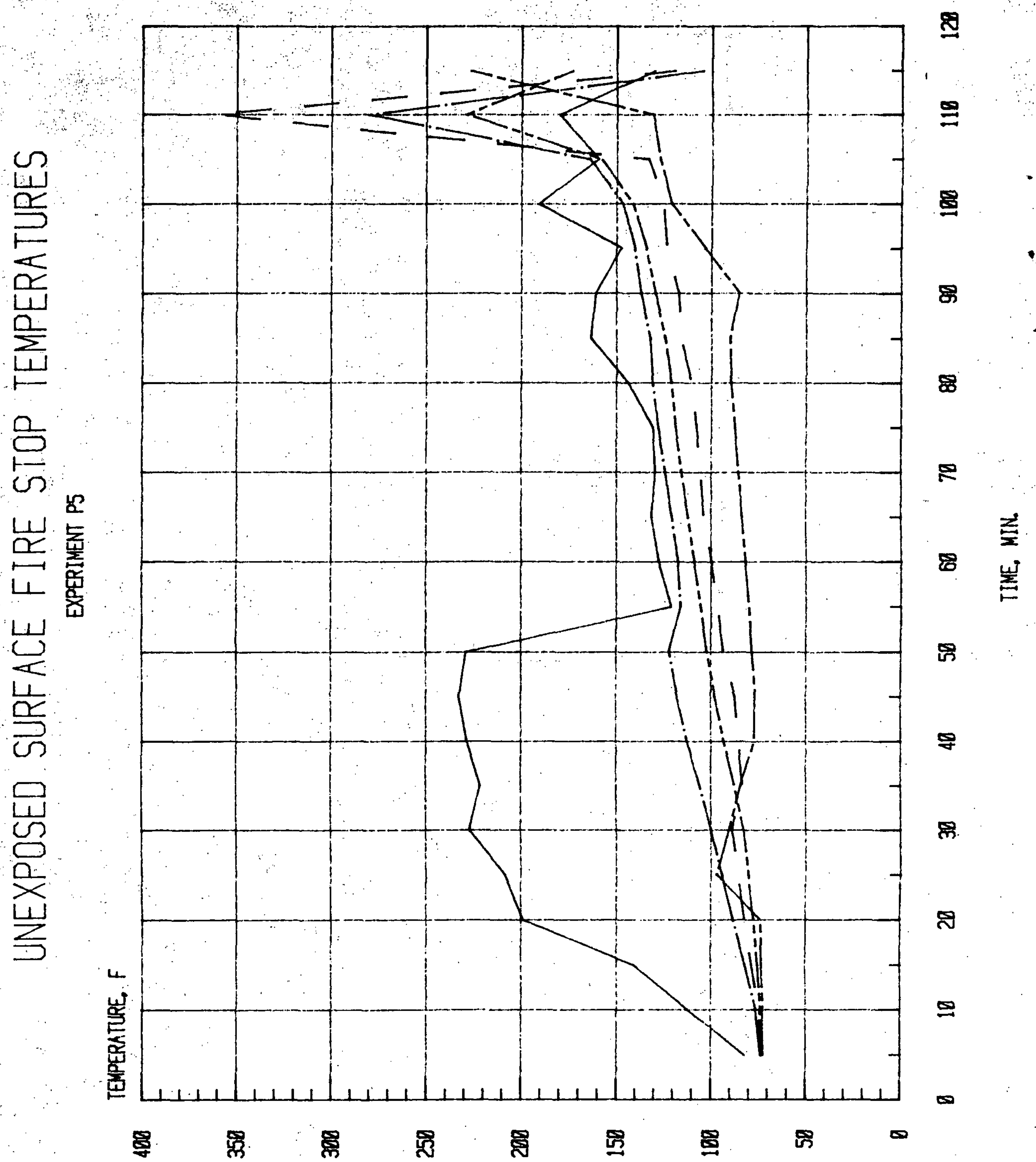
* See Figure B1

Figure C3 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B1

Figure C4 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B1

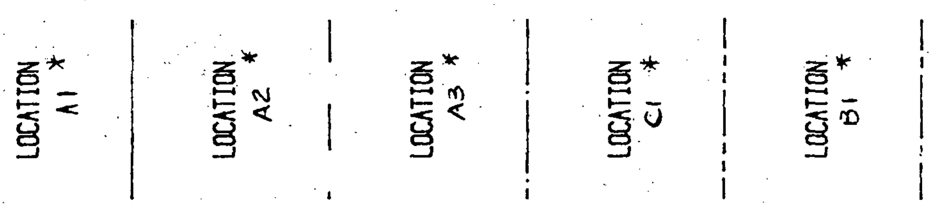
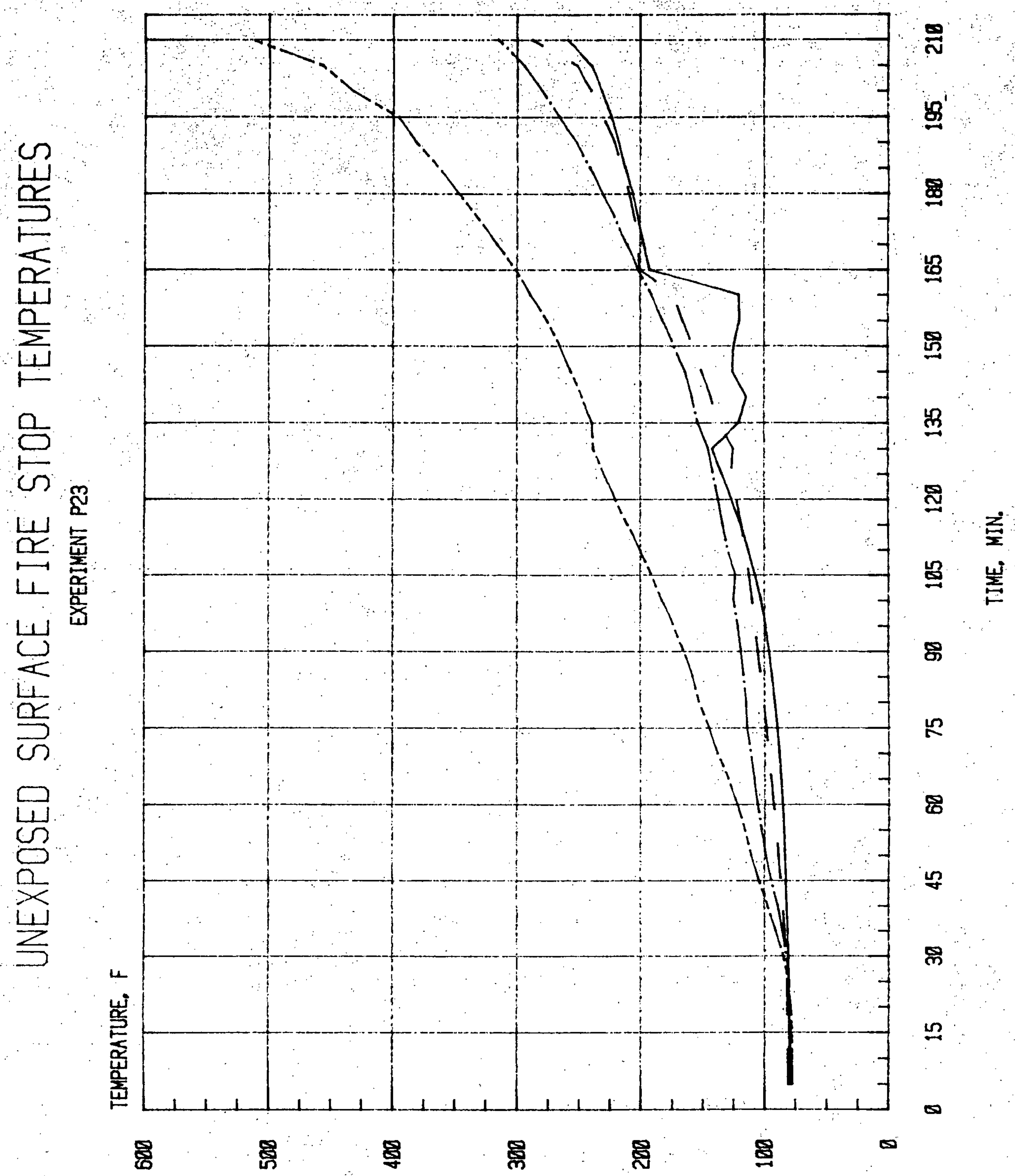


Figure C5 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B2

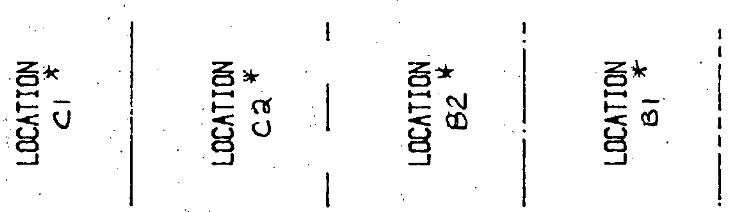
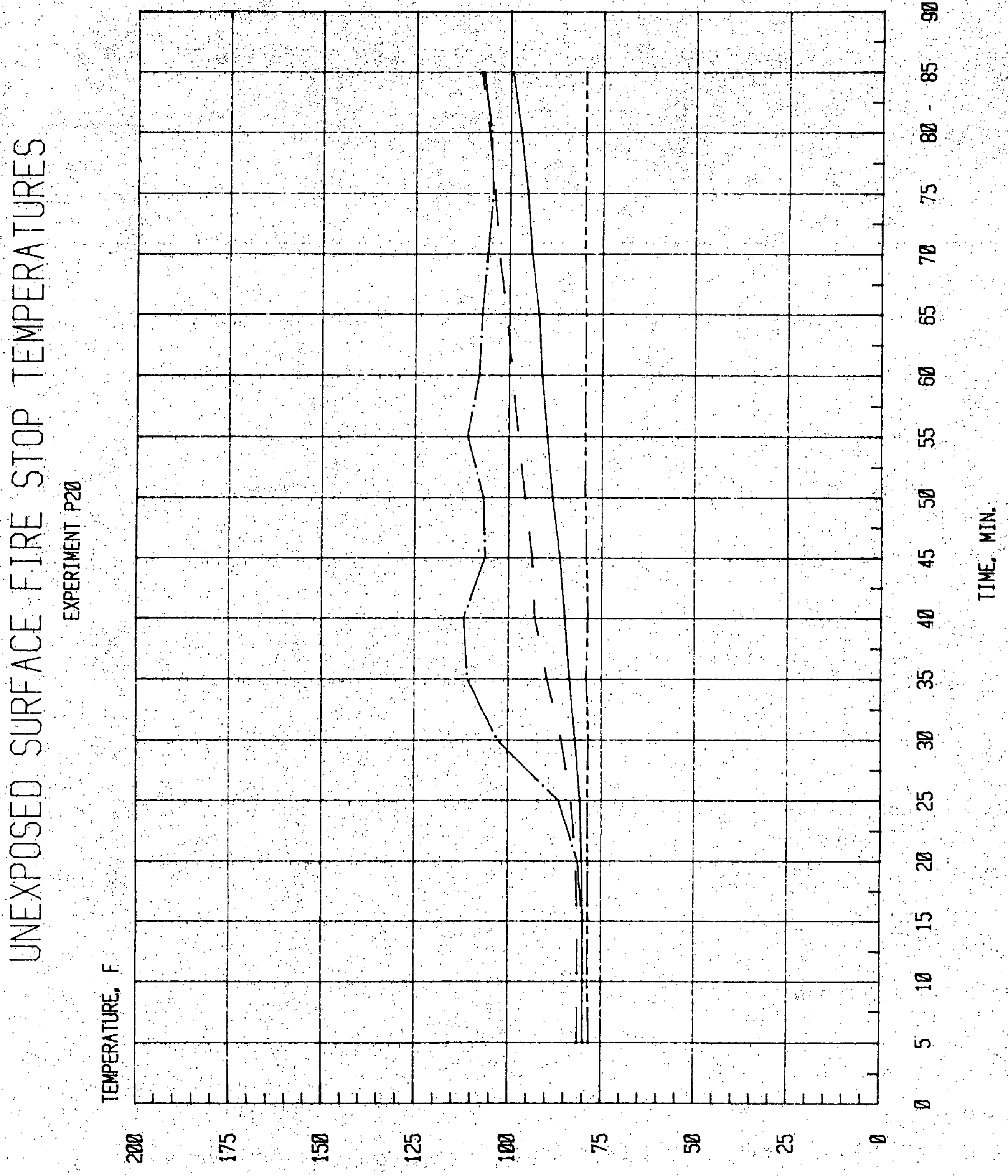


Figure C6 - Unexposed Surface Temperatures Of Unexposed Surface



* See Figure B2

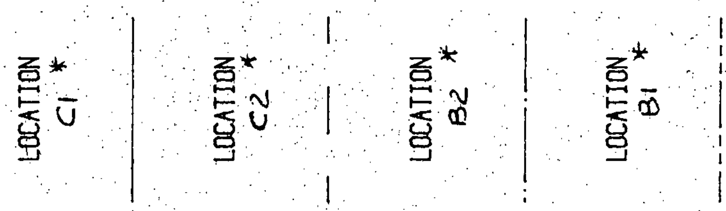
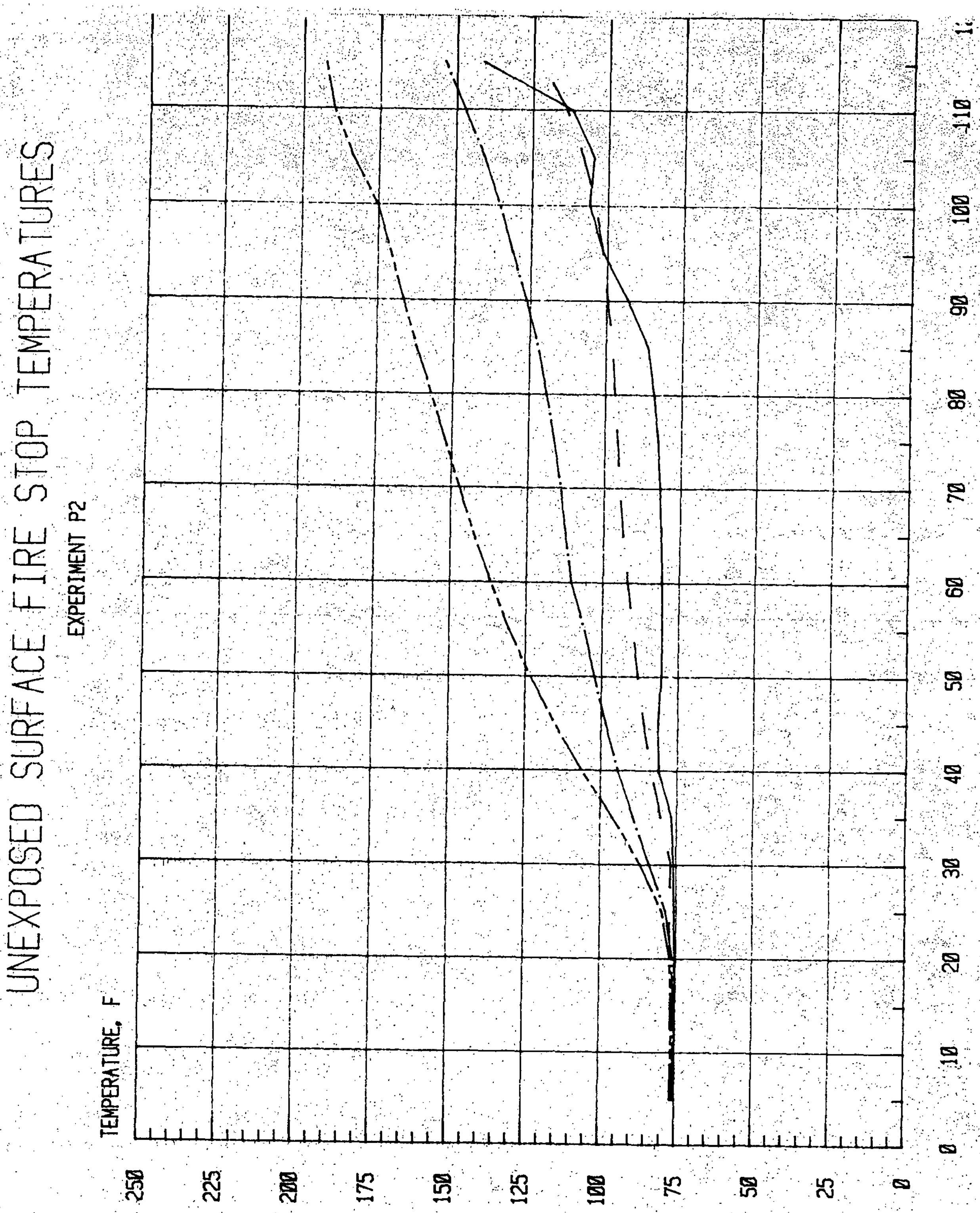


Figure C7 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B2

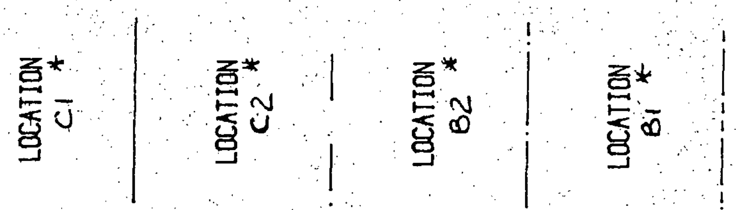
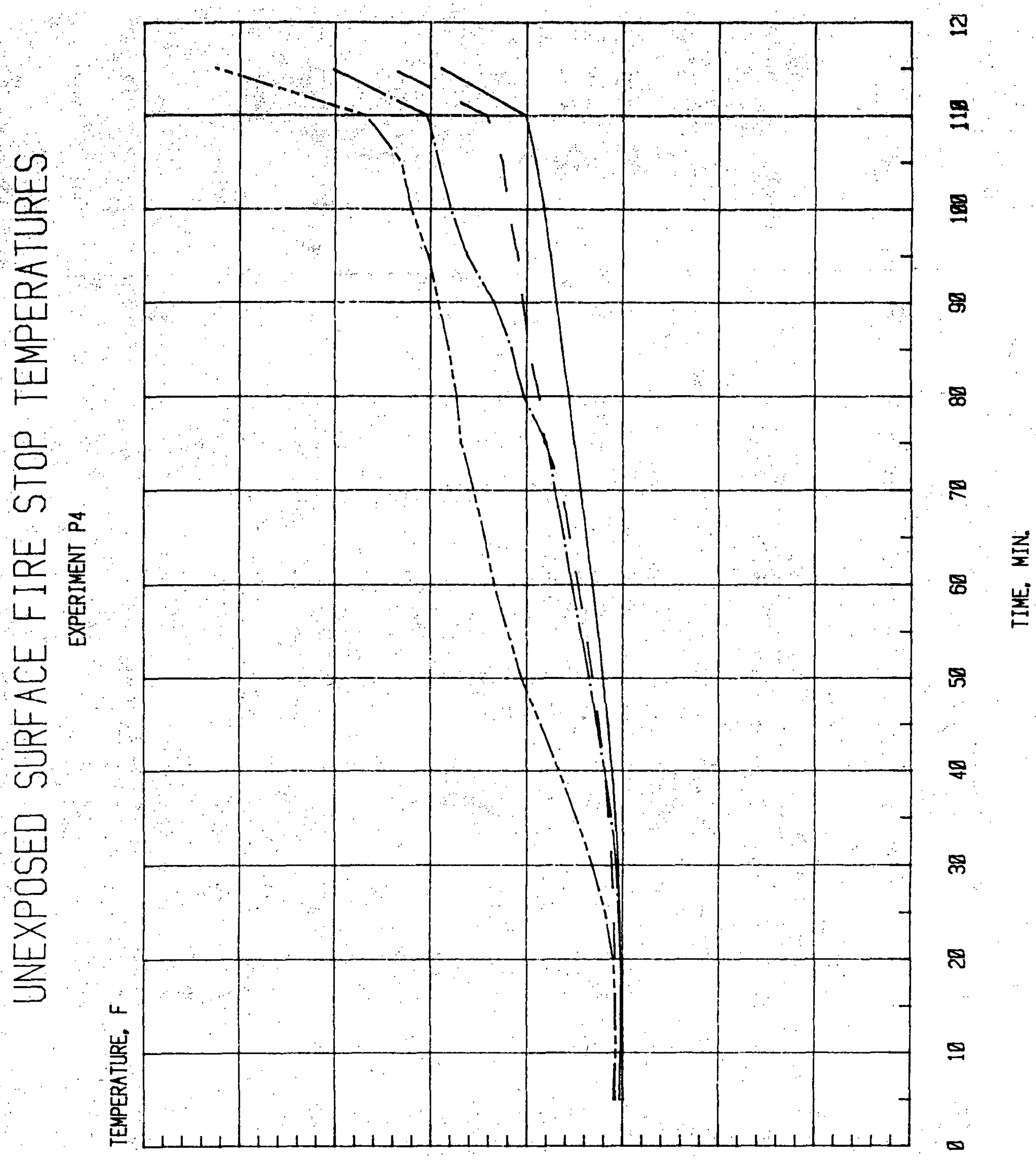


Figure C8 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B2

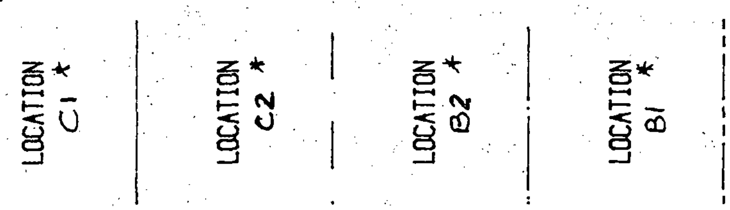
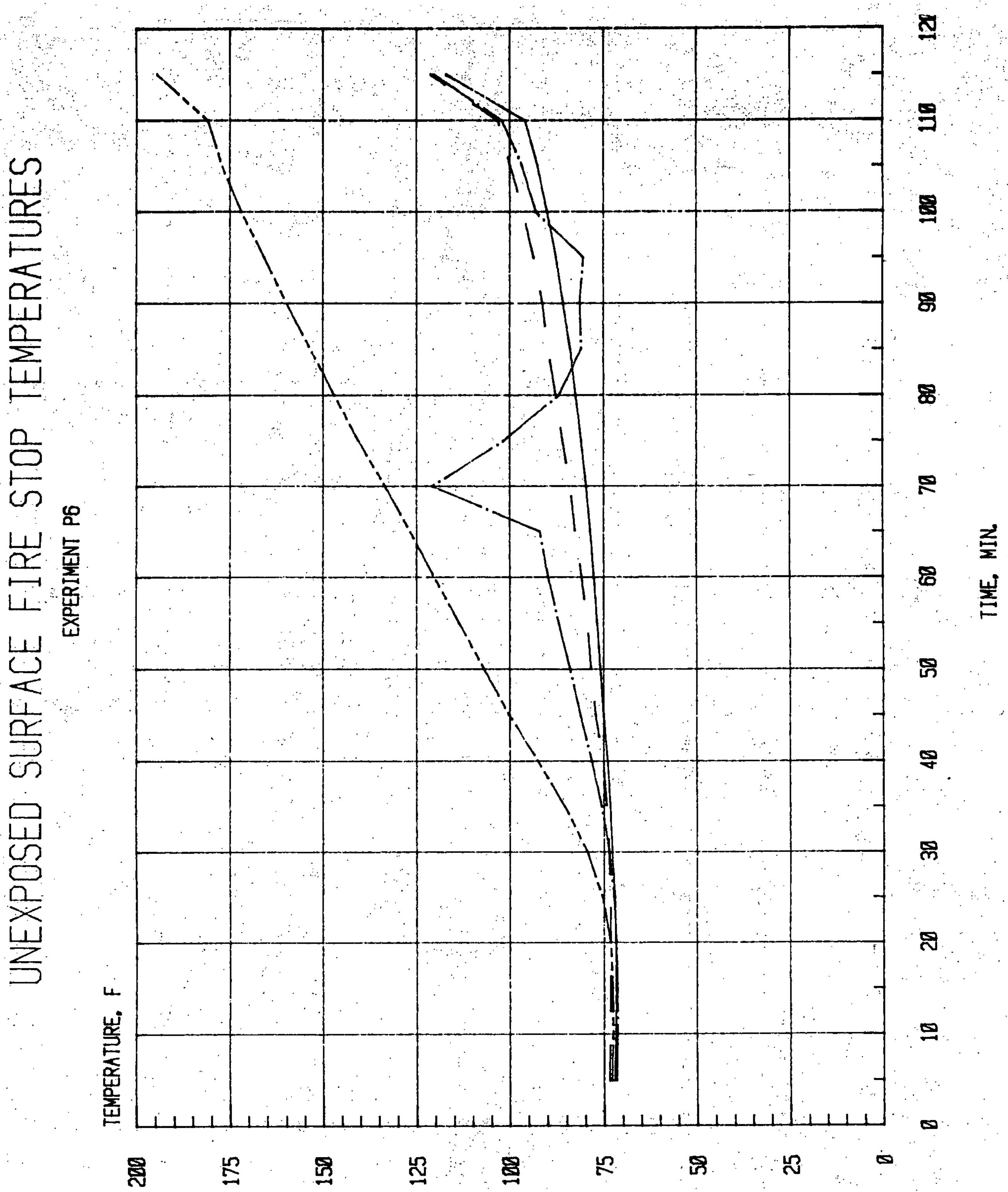


Figure C9 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B2

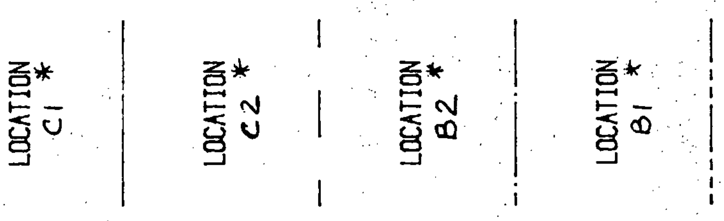
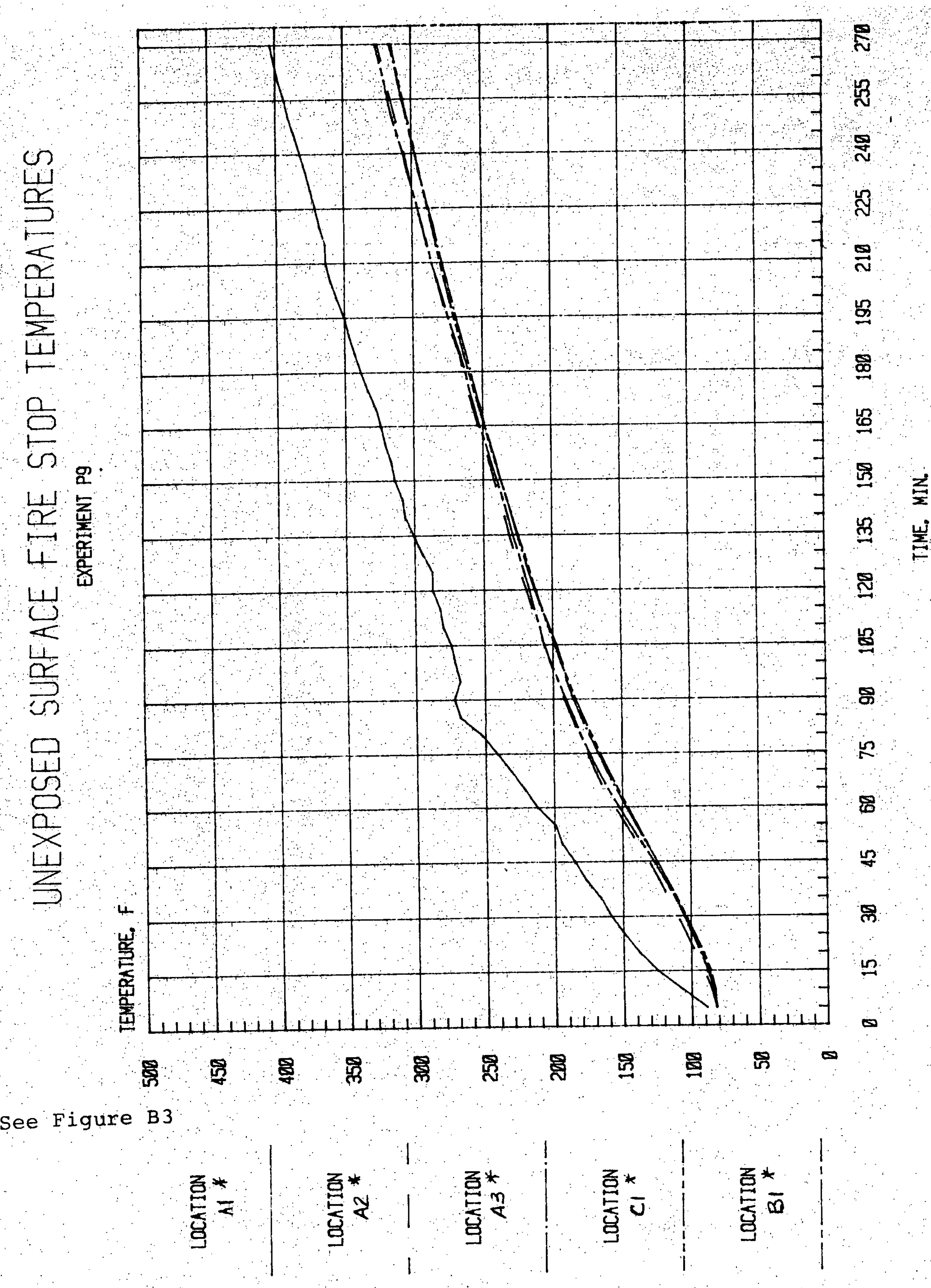
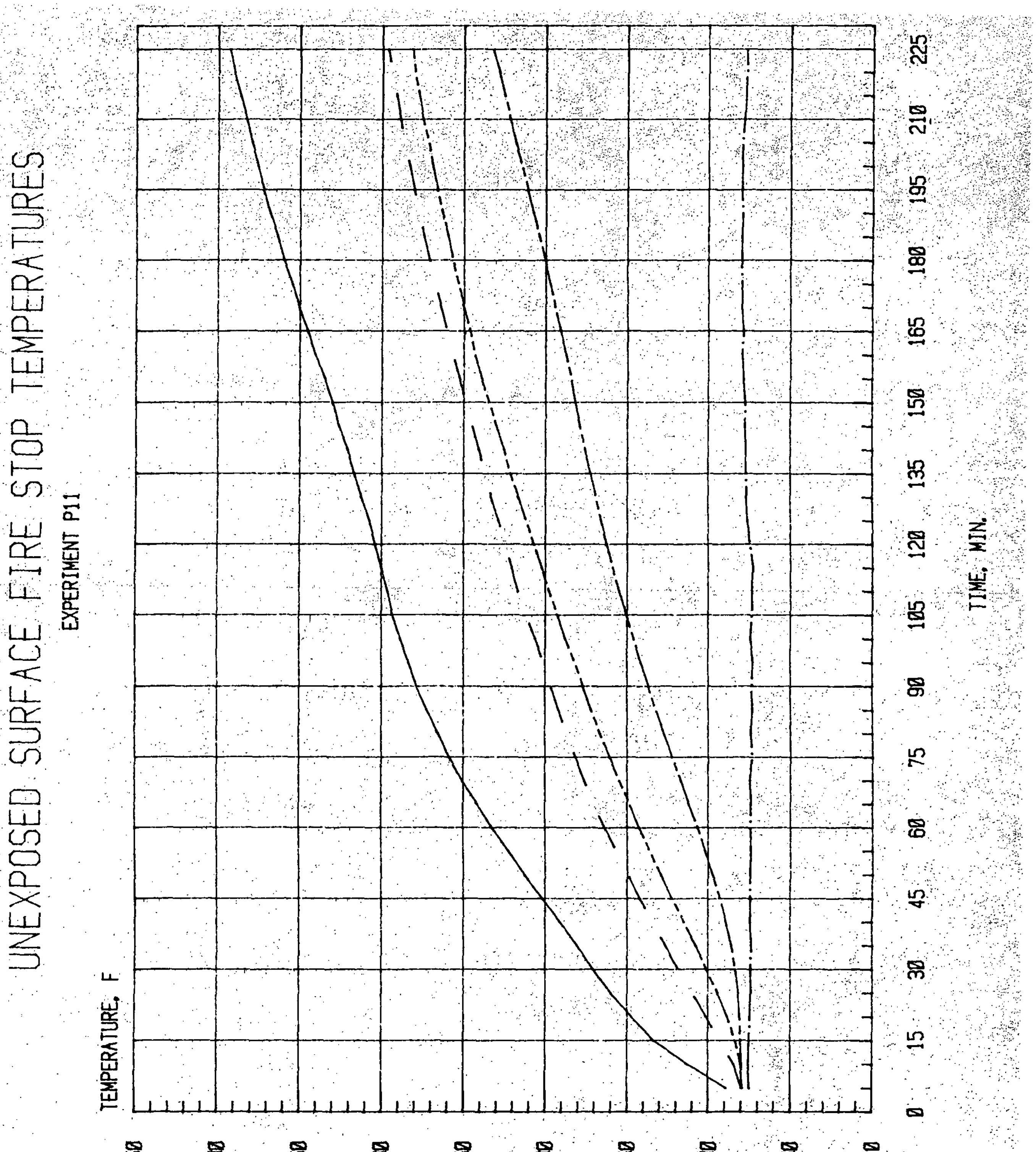


Figure C10 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B3

Figure C11 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B3

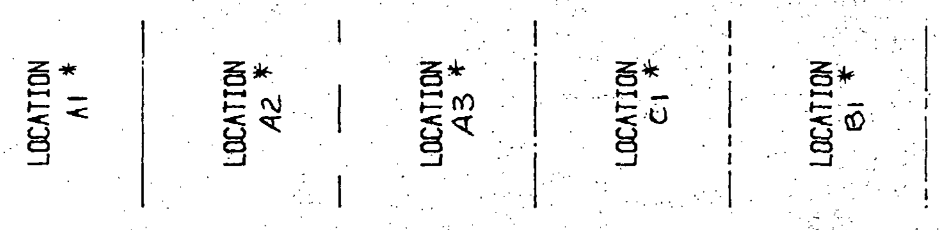
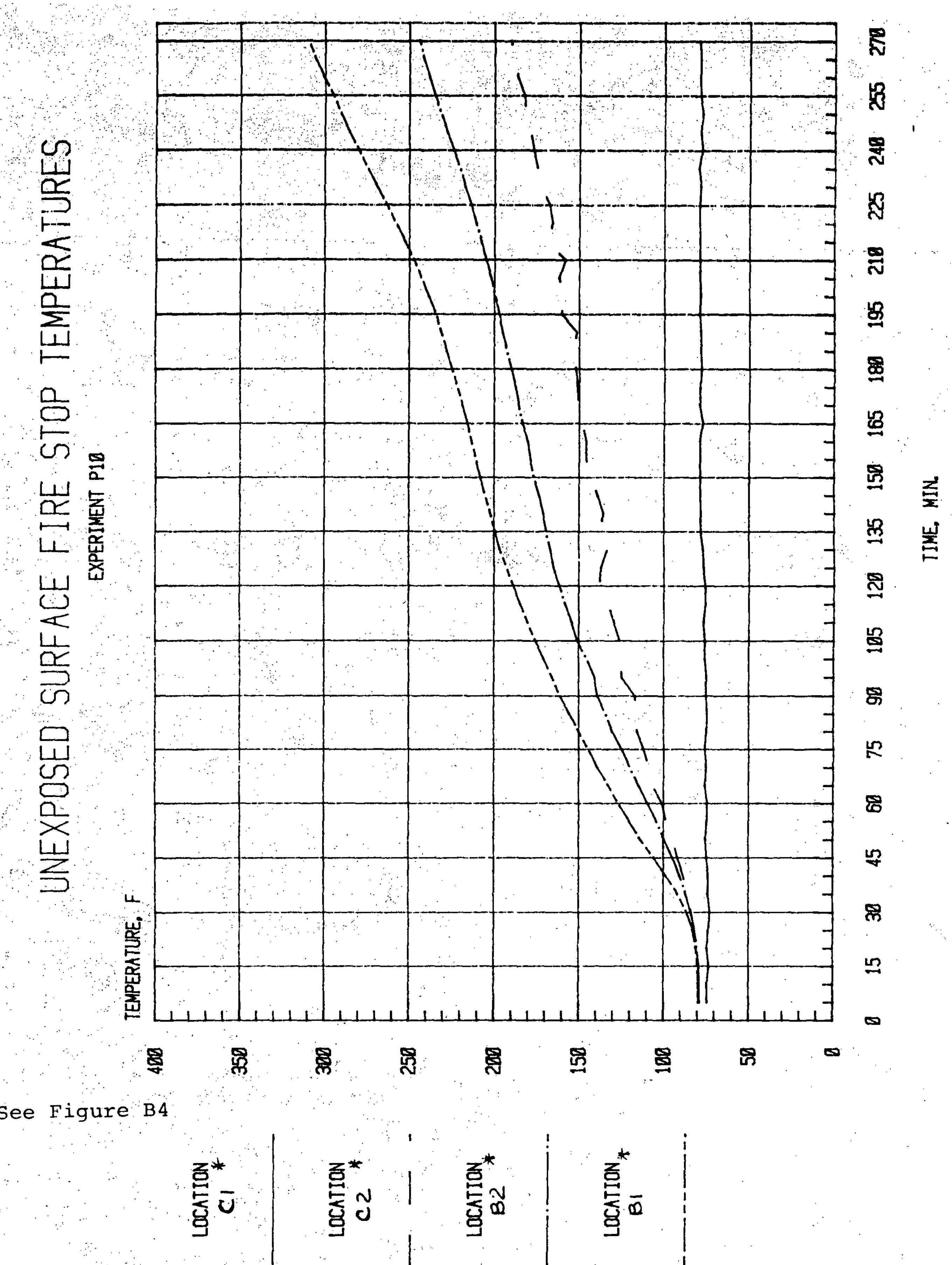
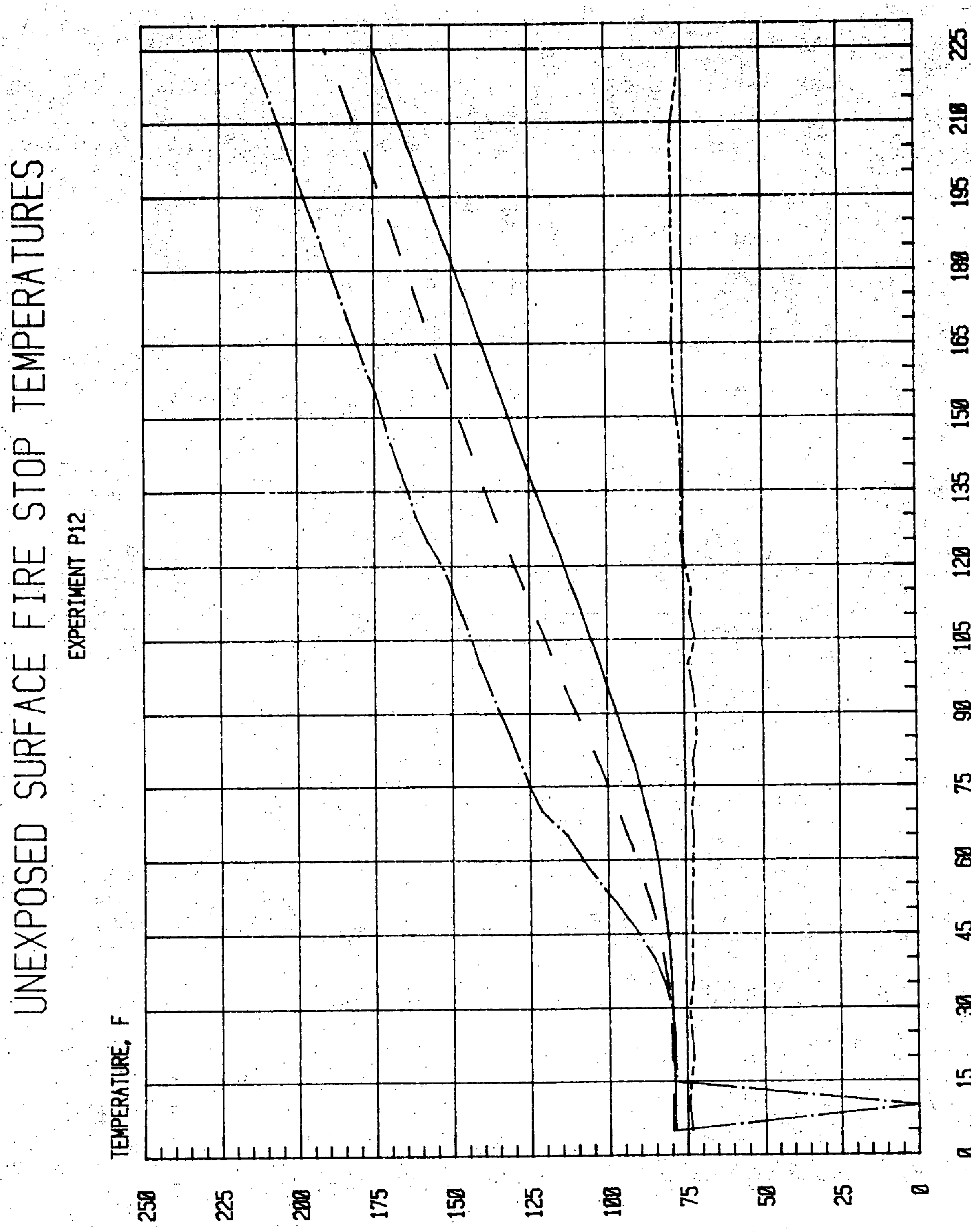


Figure C11 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B4

Figure C13 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B4

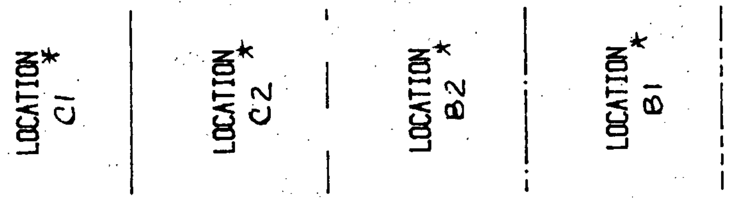
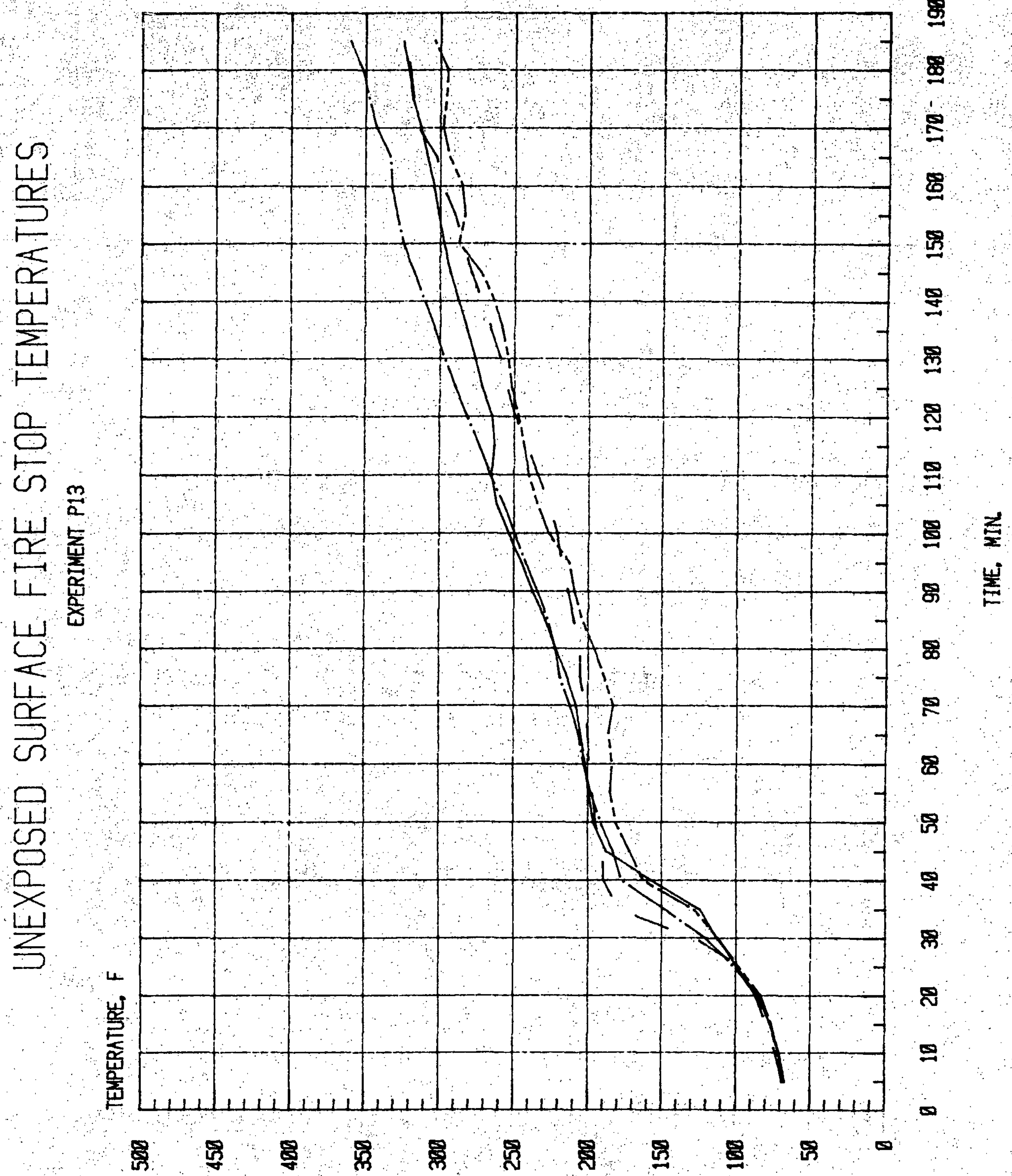


Figure C14 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B5

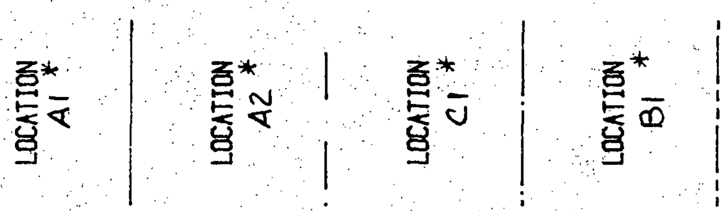
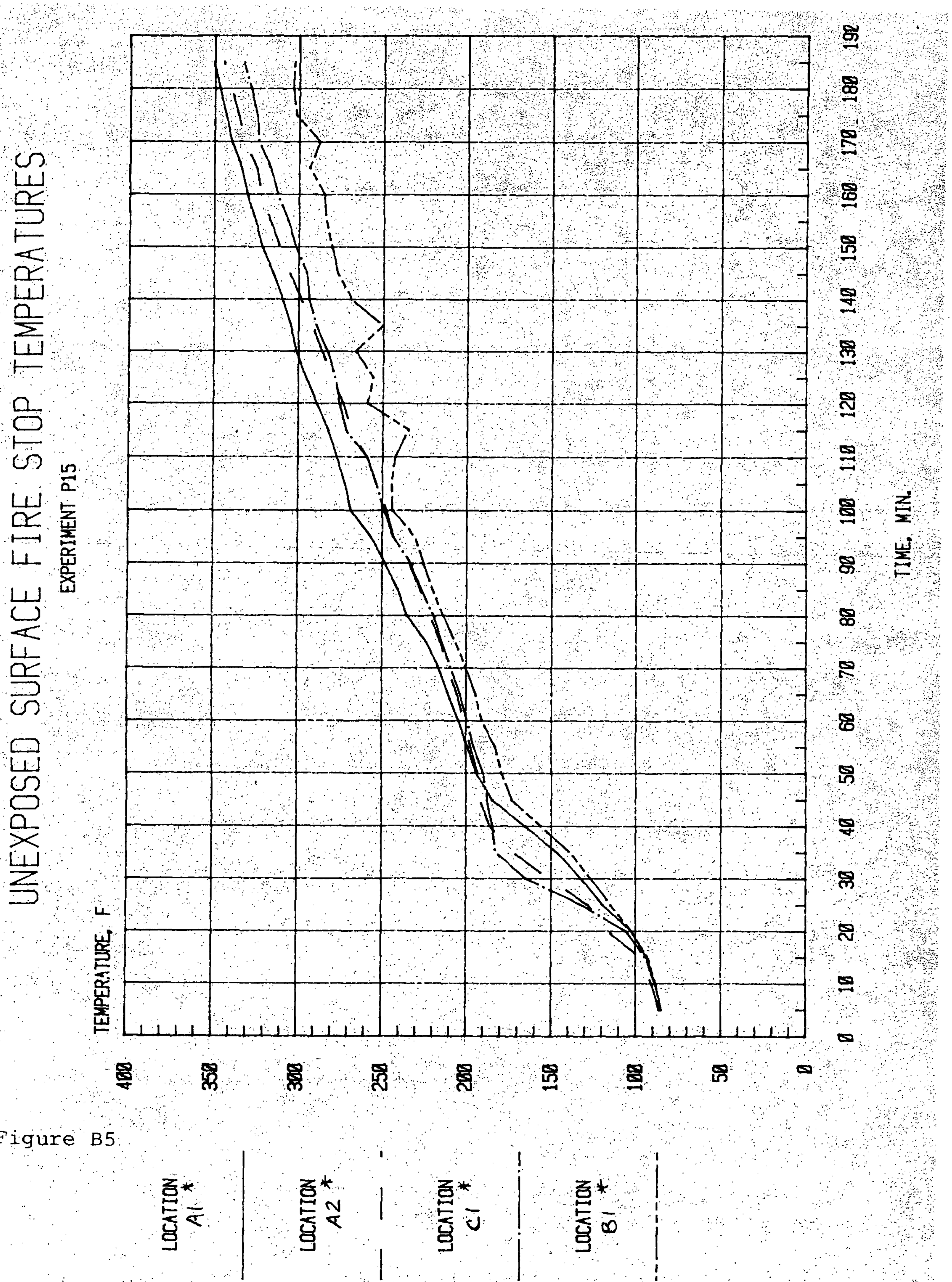


Figure C15 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B5

Figure C16 - Unexposed Surface Temperatures of Fire Stop Material

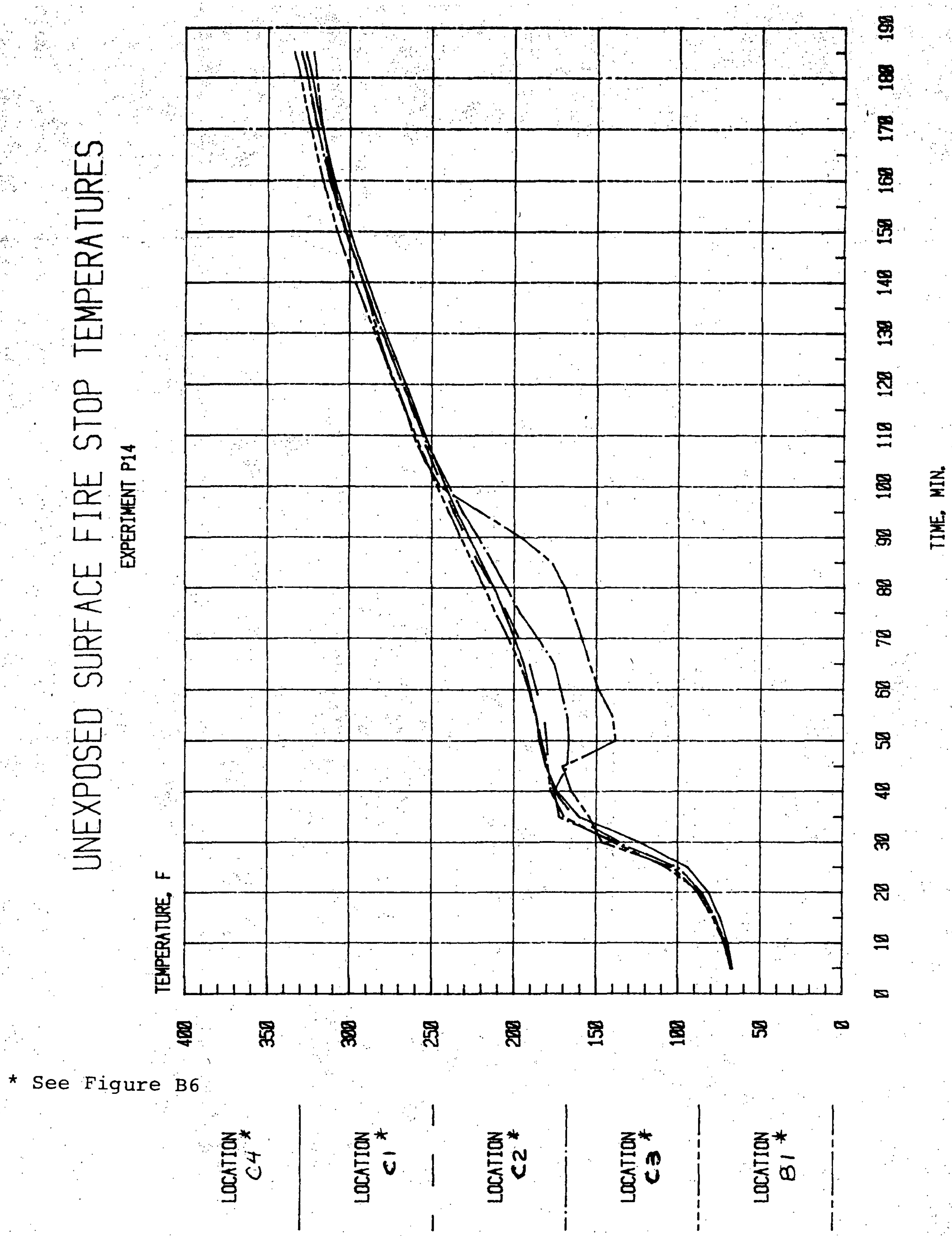


Figure C17 - Unexposed Surface Temperatures of Fire Stop Material

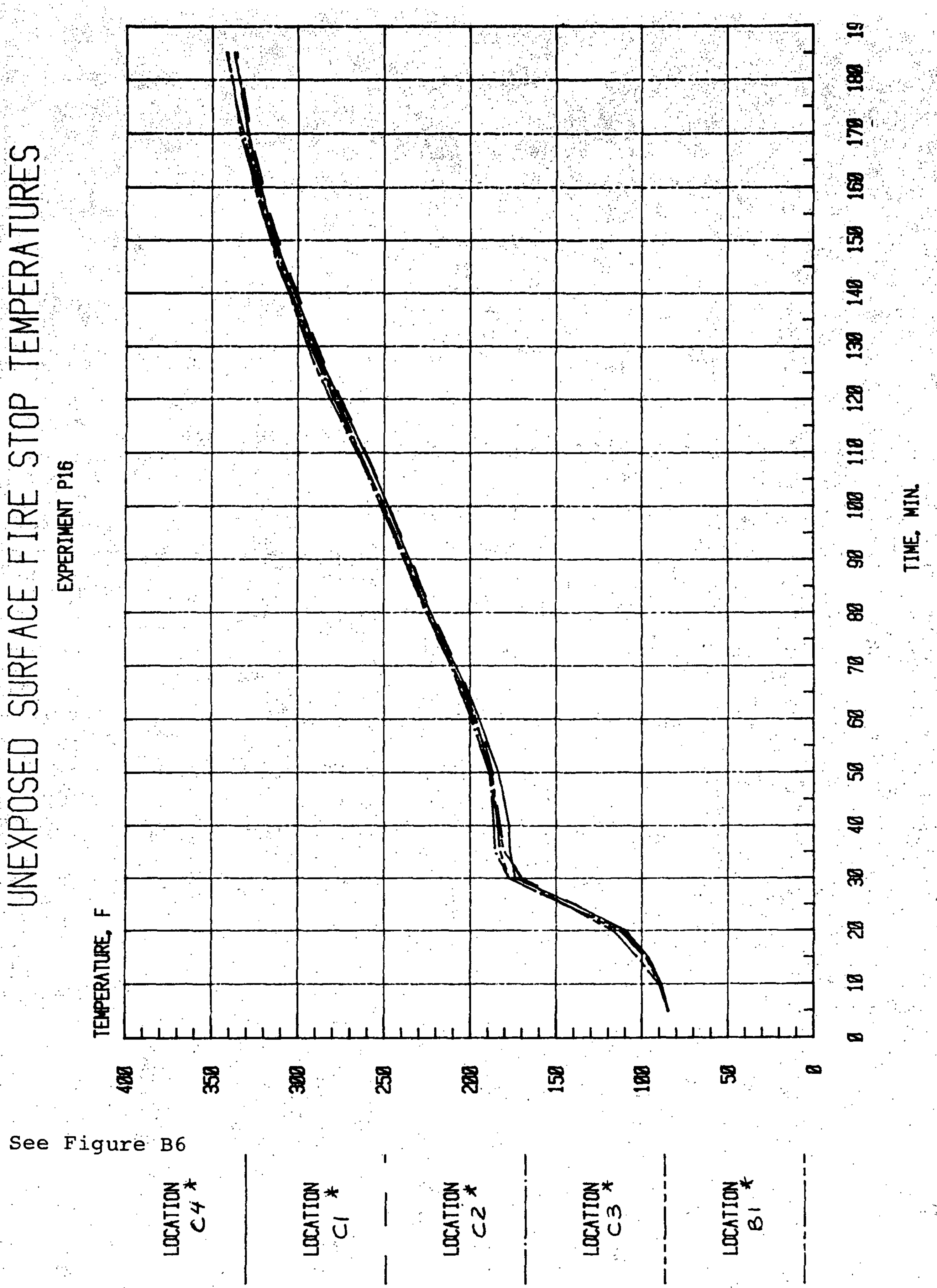
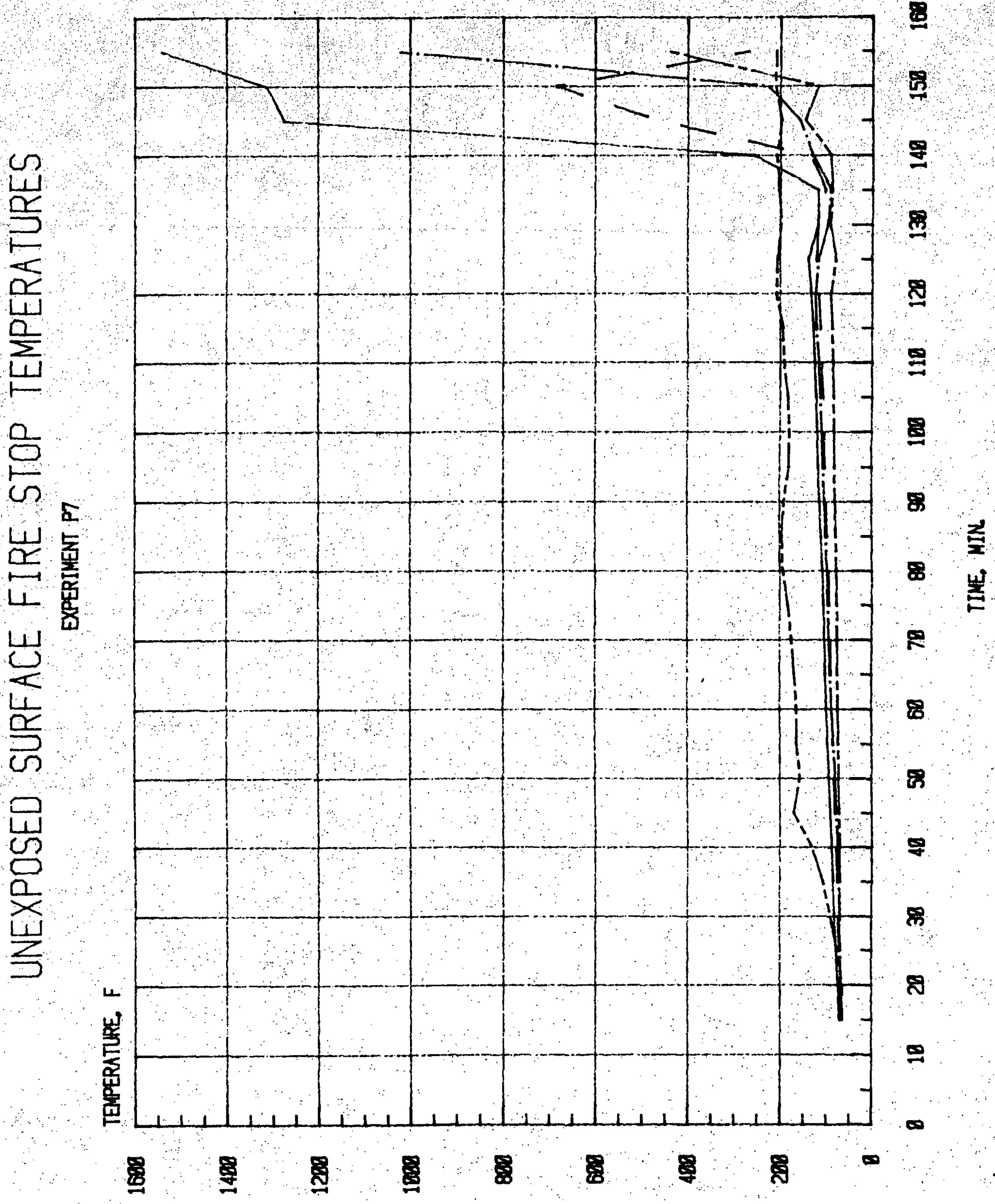


Figure C18 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B7

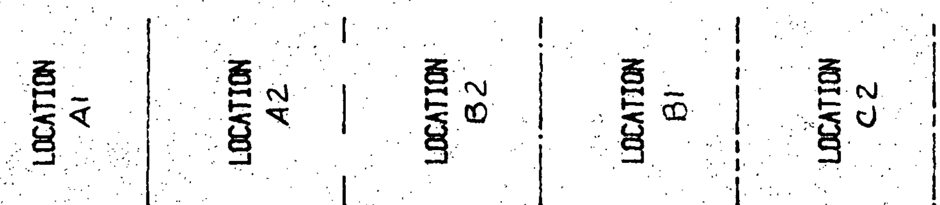


Figure C19 - Unexposed Surface Temperatures of Fire Stop Material

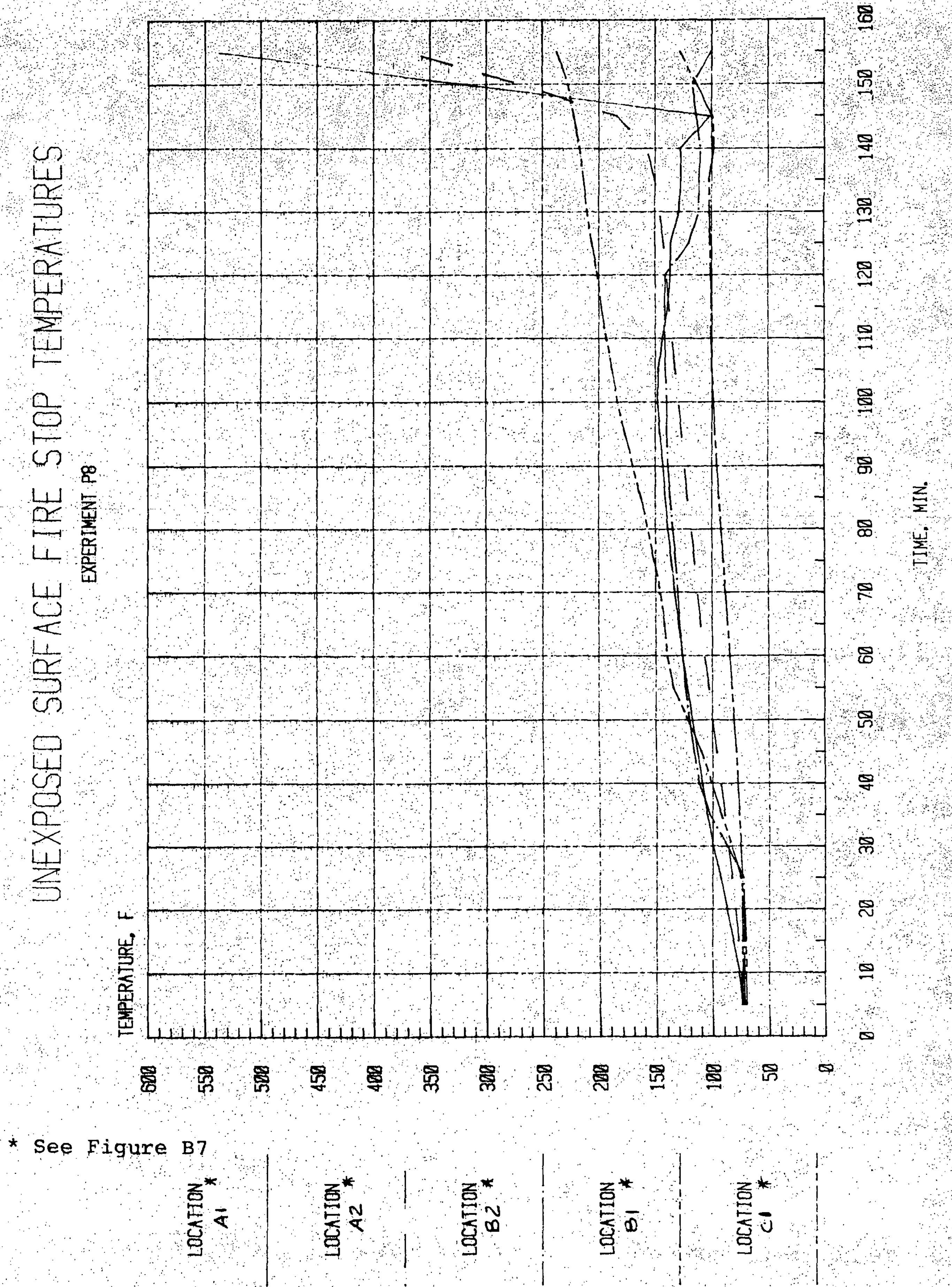
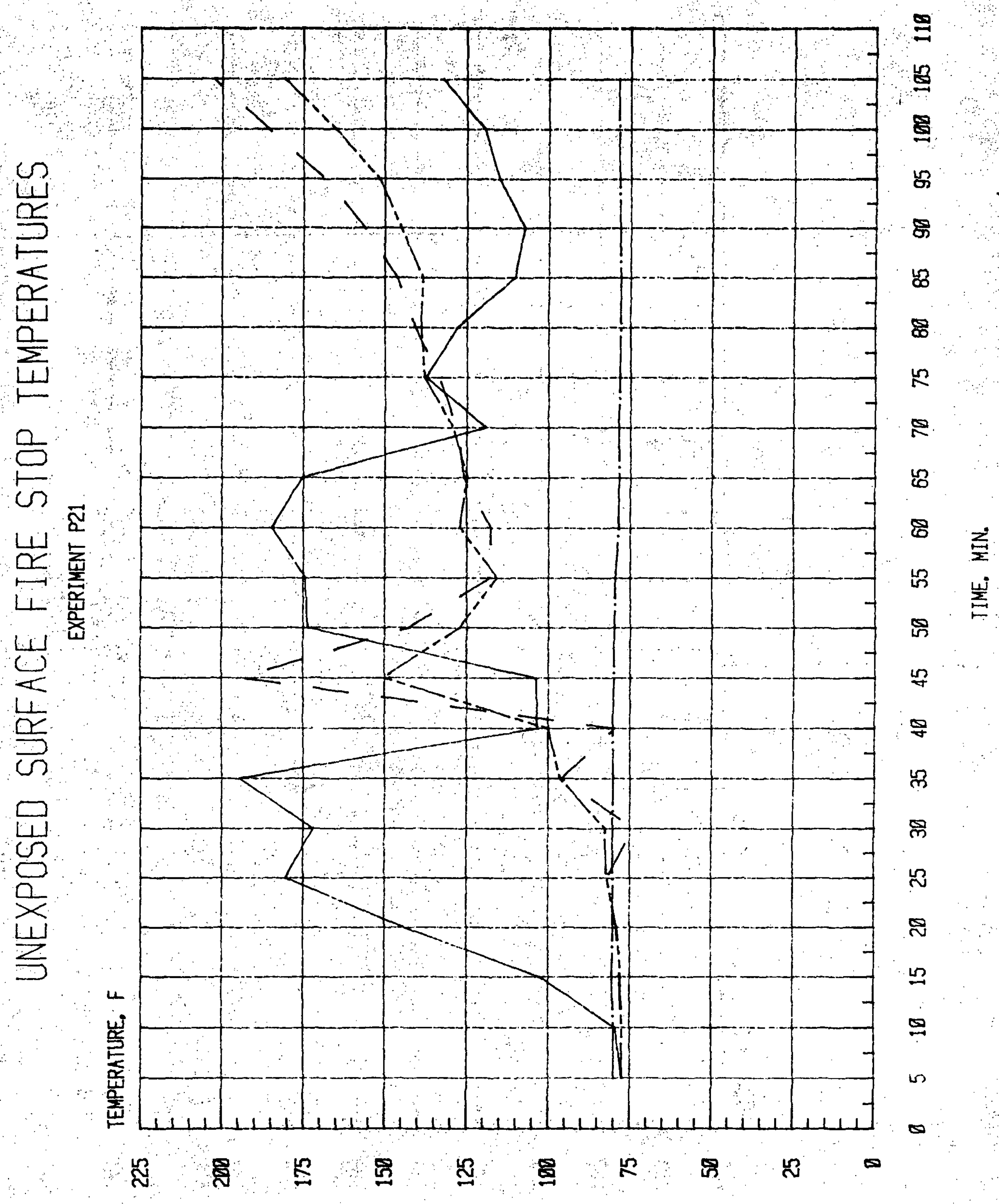


Figure C20 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B8

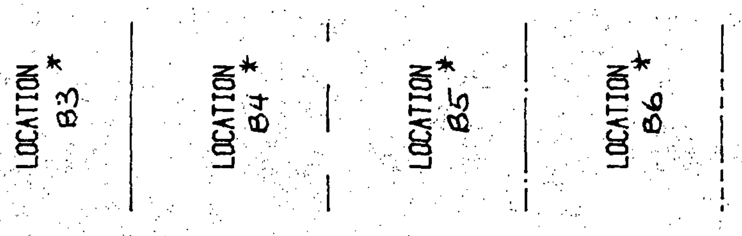
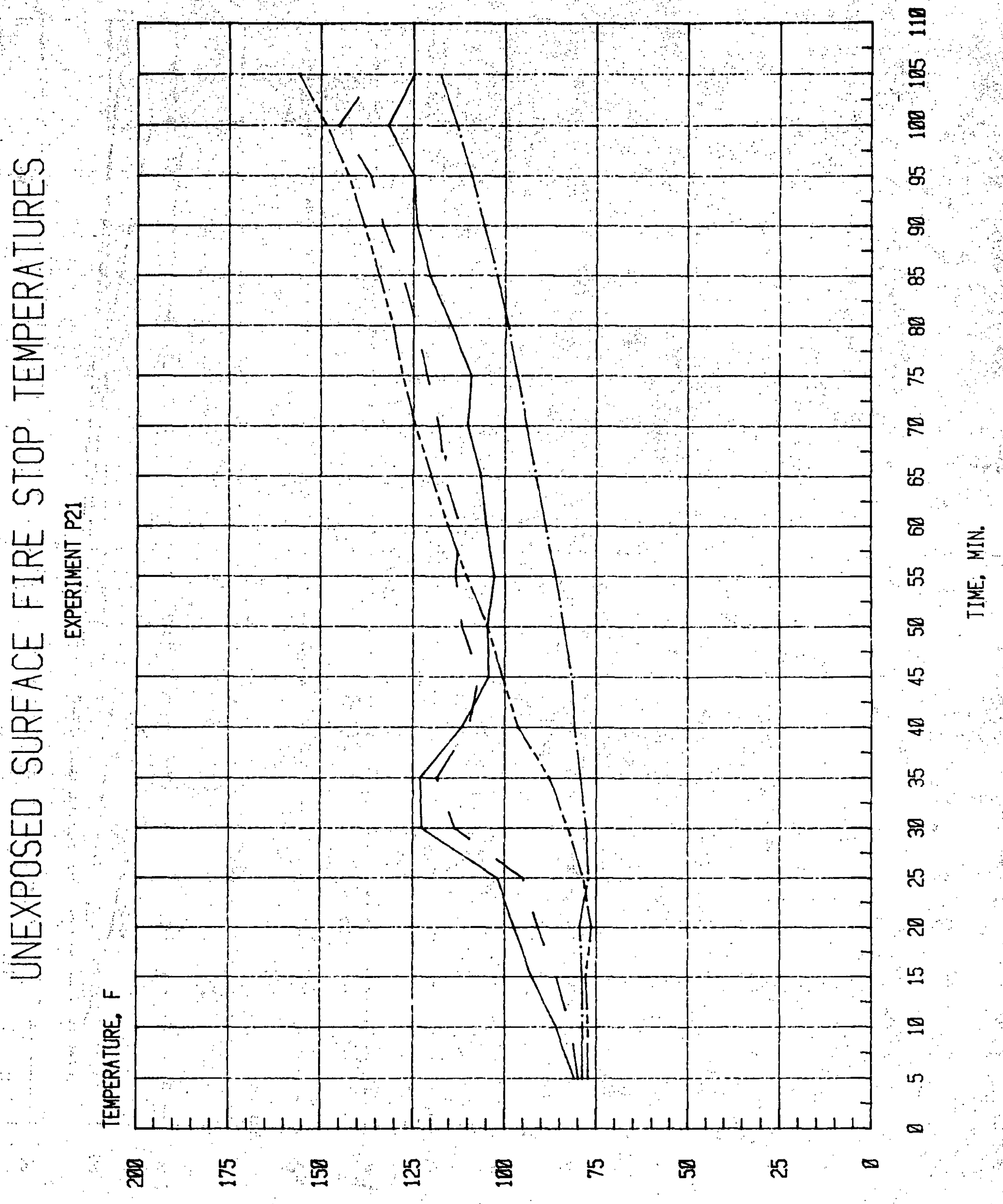


Figure C21 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B8

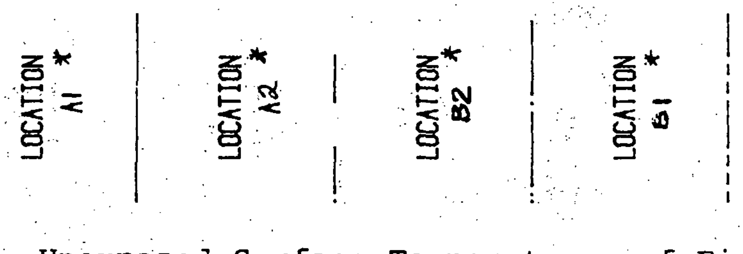
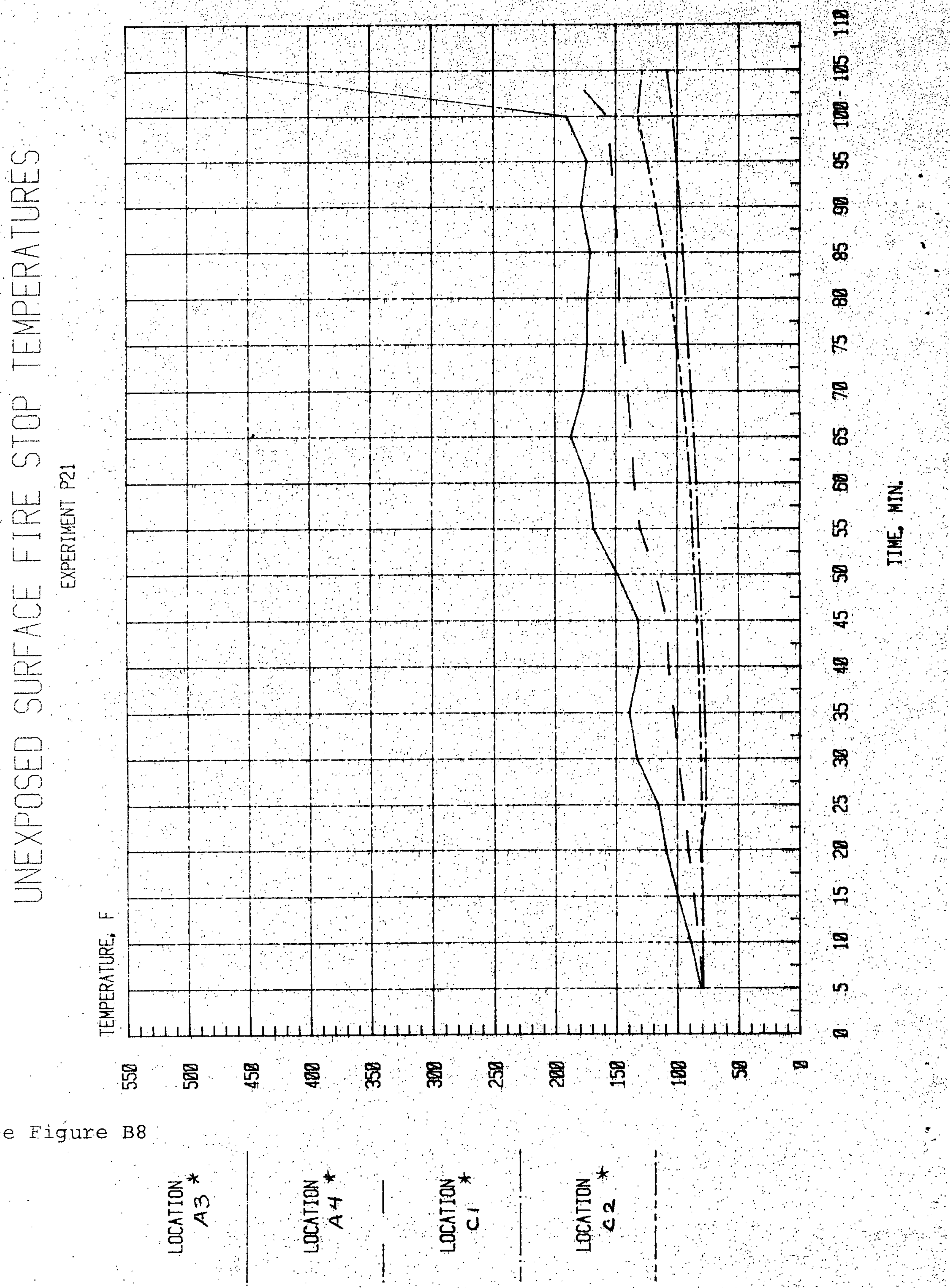
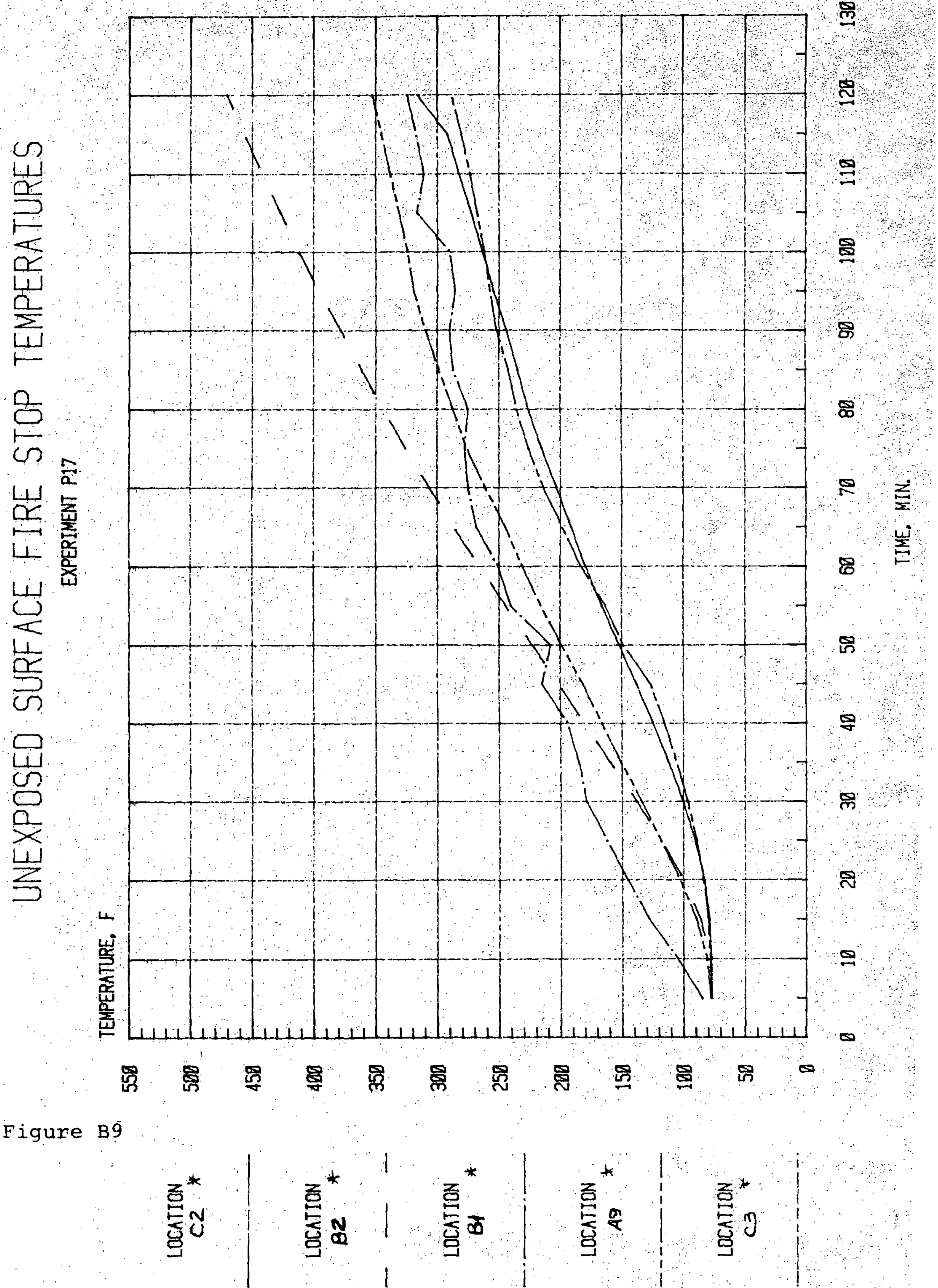


Figure C22 - Unexposed Surface Temperatures of Fire Stop Material



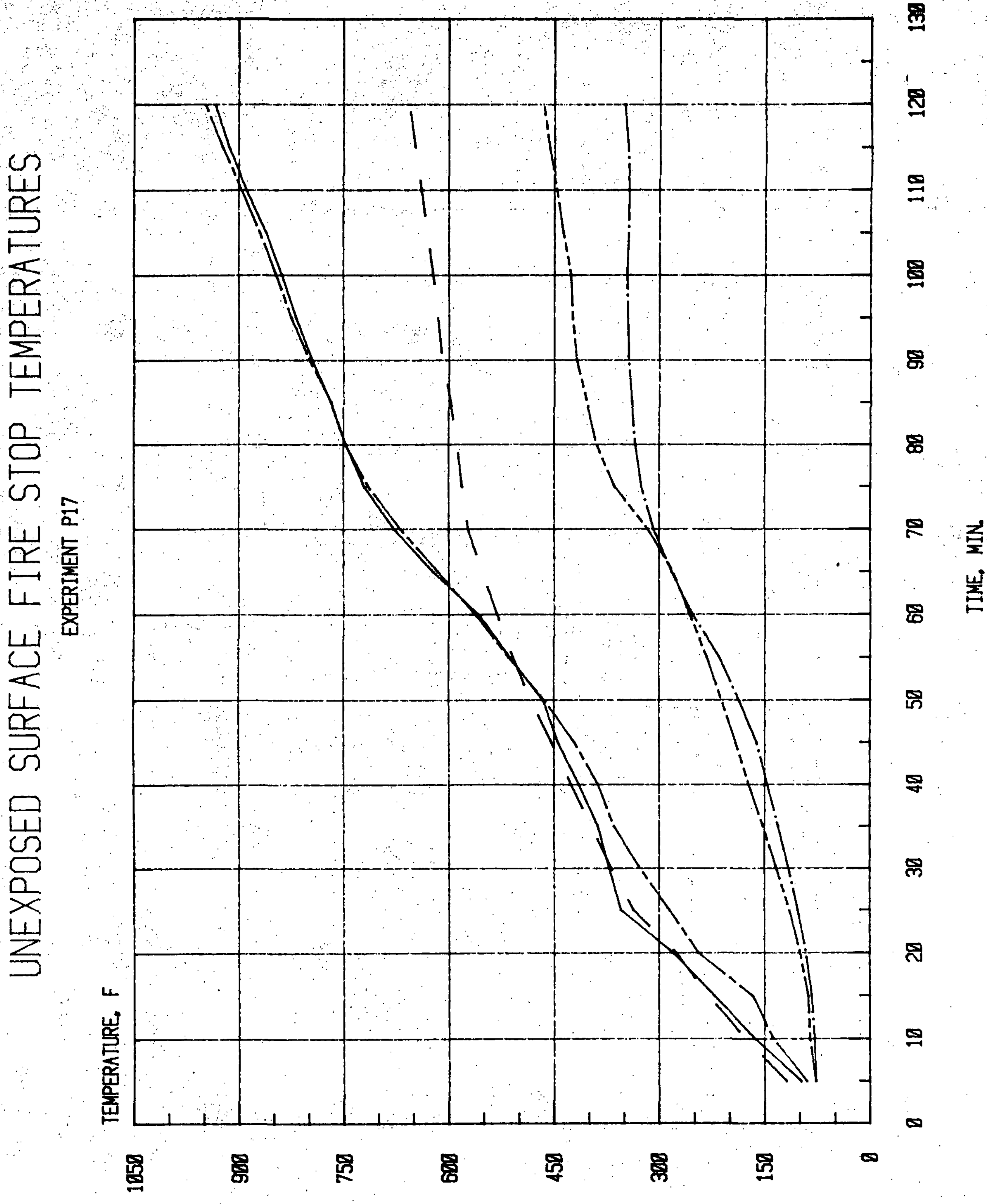
* See Figure B8

Figure C23 - Unexposed Surface Temperatures of Fire Stop Material



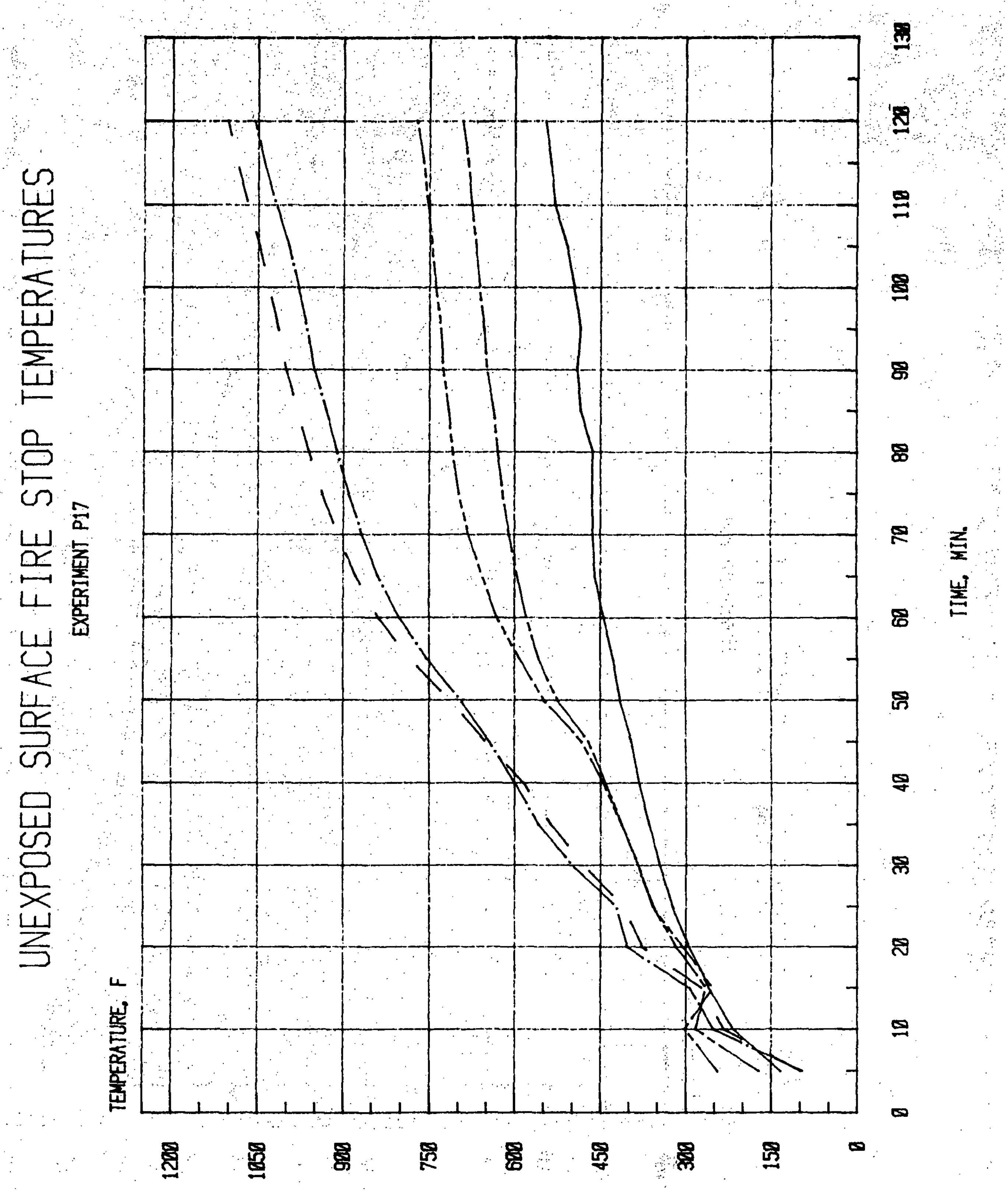
* See Figure B9

Figure C24 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B9

Figure C25 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B9

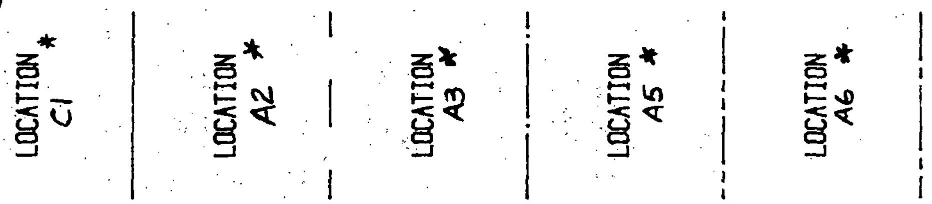


Figure C26 - Unexposed Surface Temperatures of Fire Stop Material

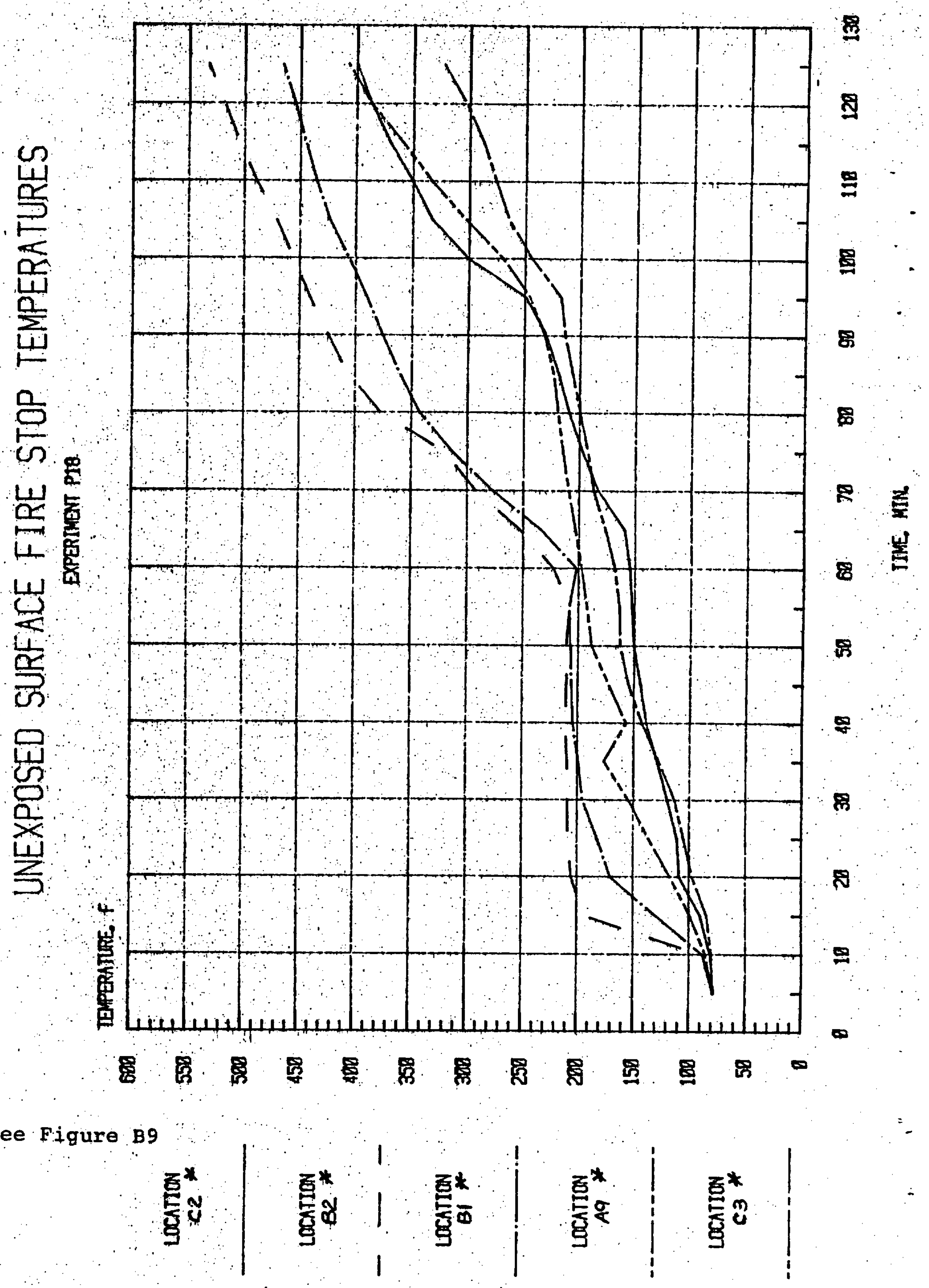
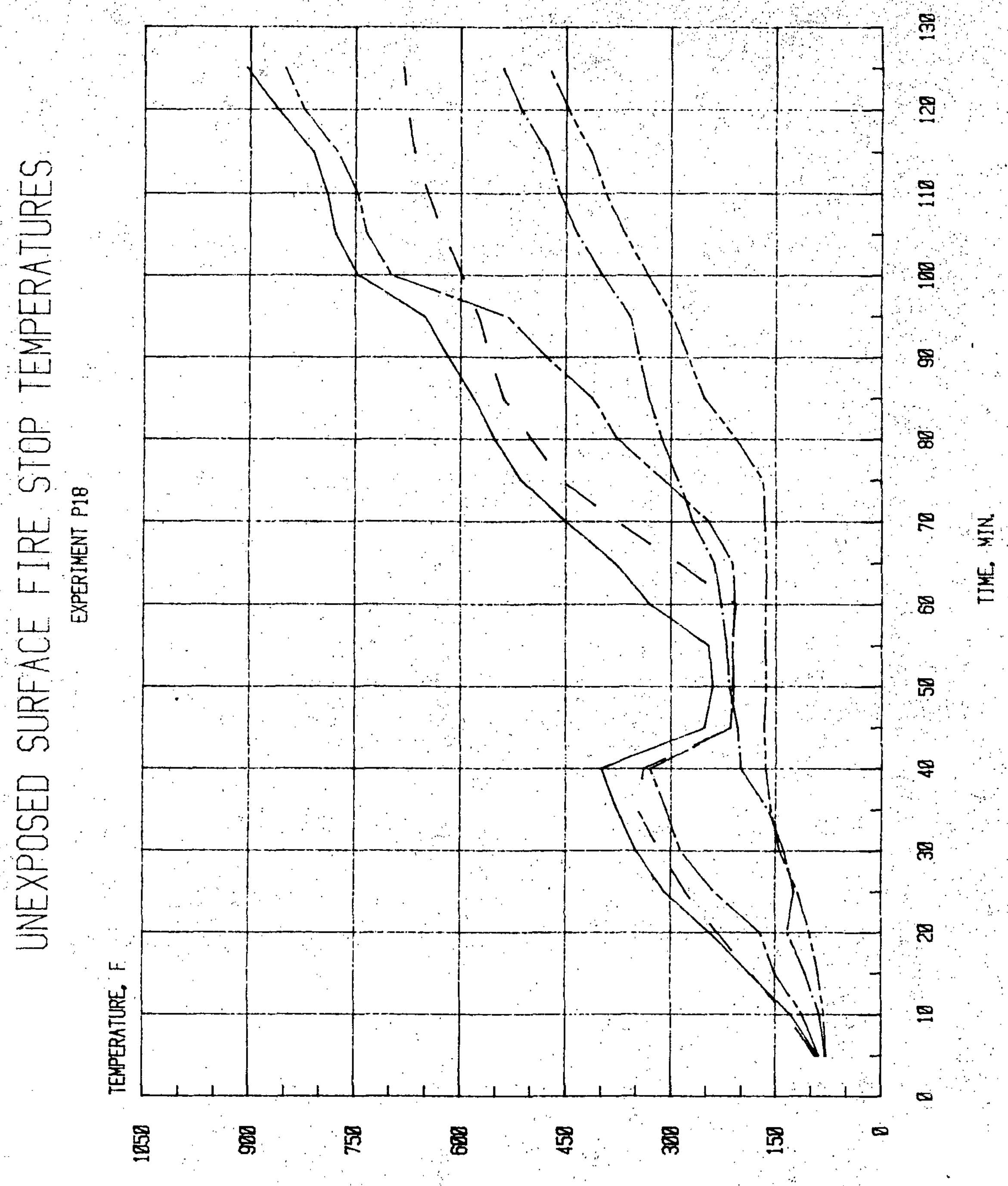


Figure C27 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B9

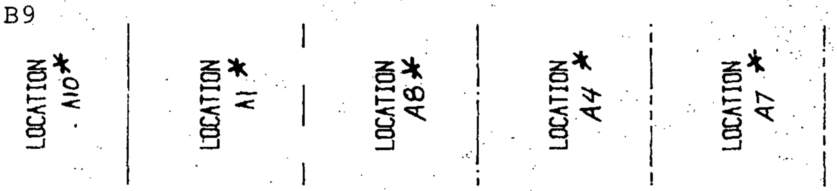
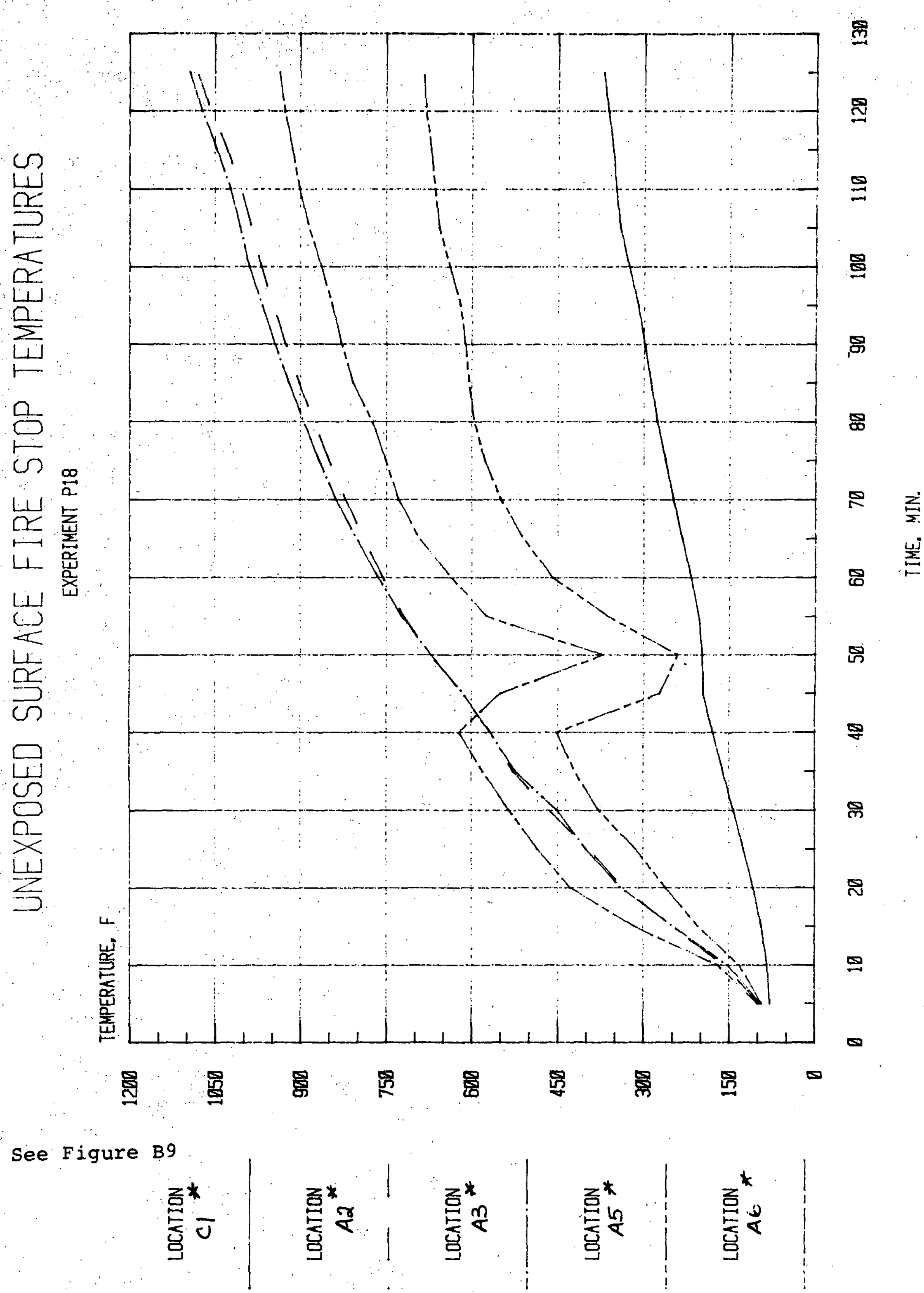
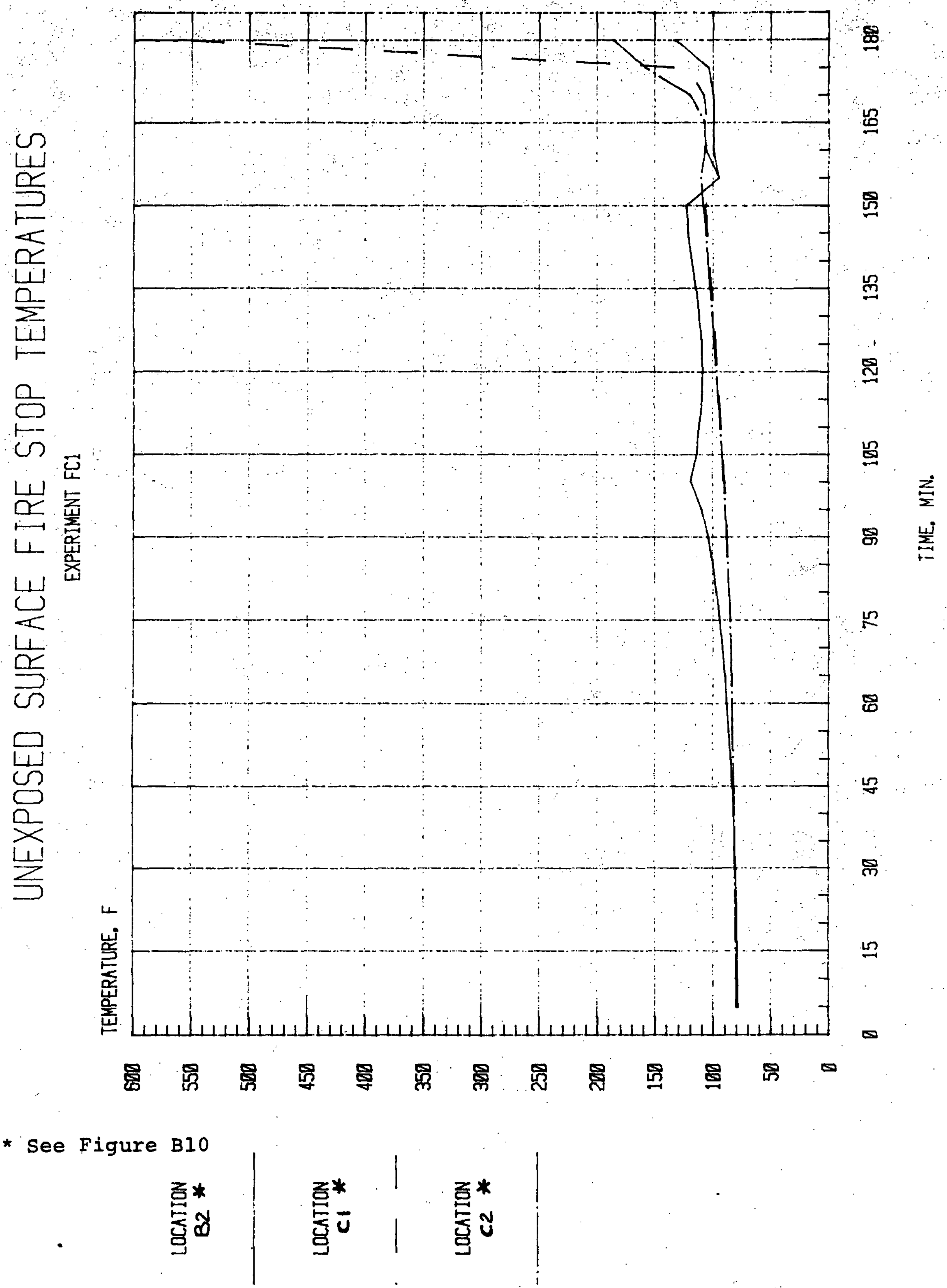


Figure C28 - Unexposed Surface Temperatures of Fire Stop Material



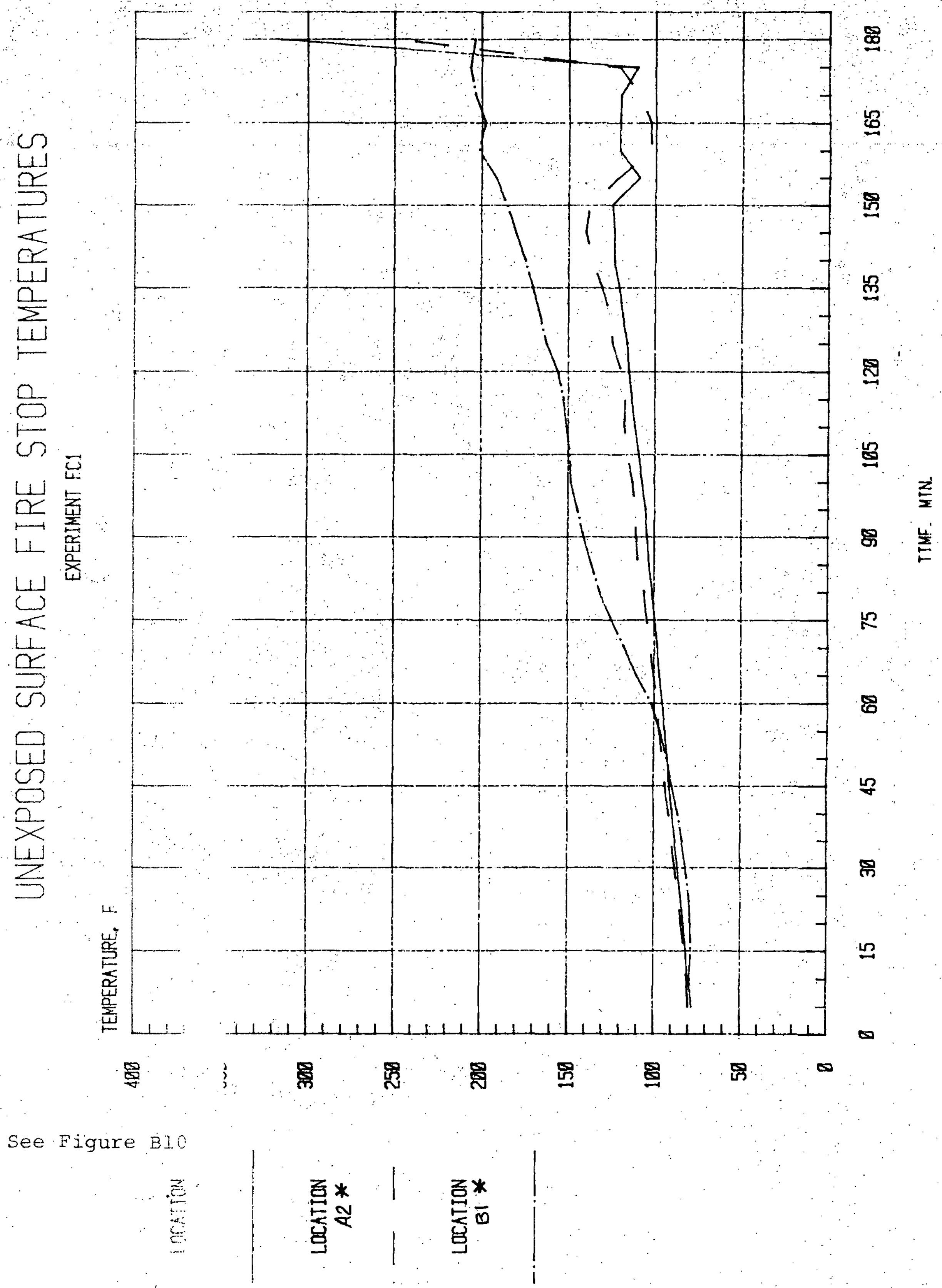
* See Figure B9

Figure C29 - Unexposed Surface Temperatures of Fire Stop Material



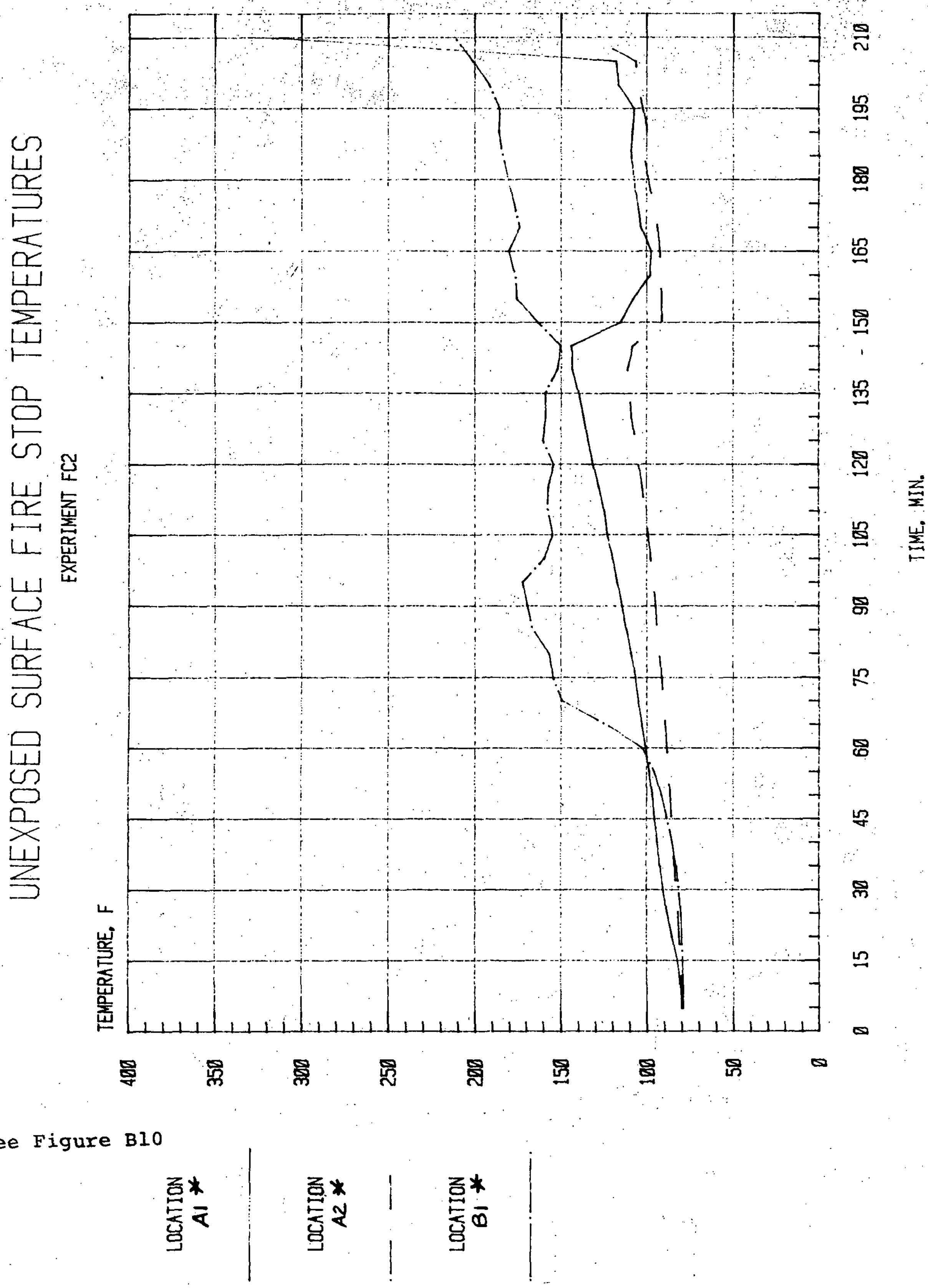
* See Figure B10

Figure C30 - Unexposed Surface Temperatures of Fire Stop Material



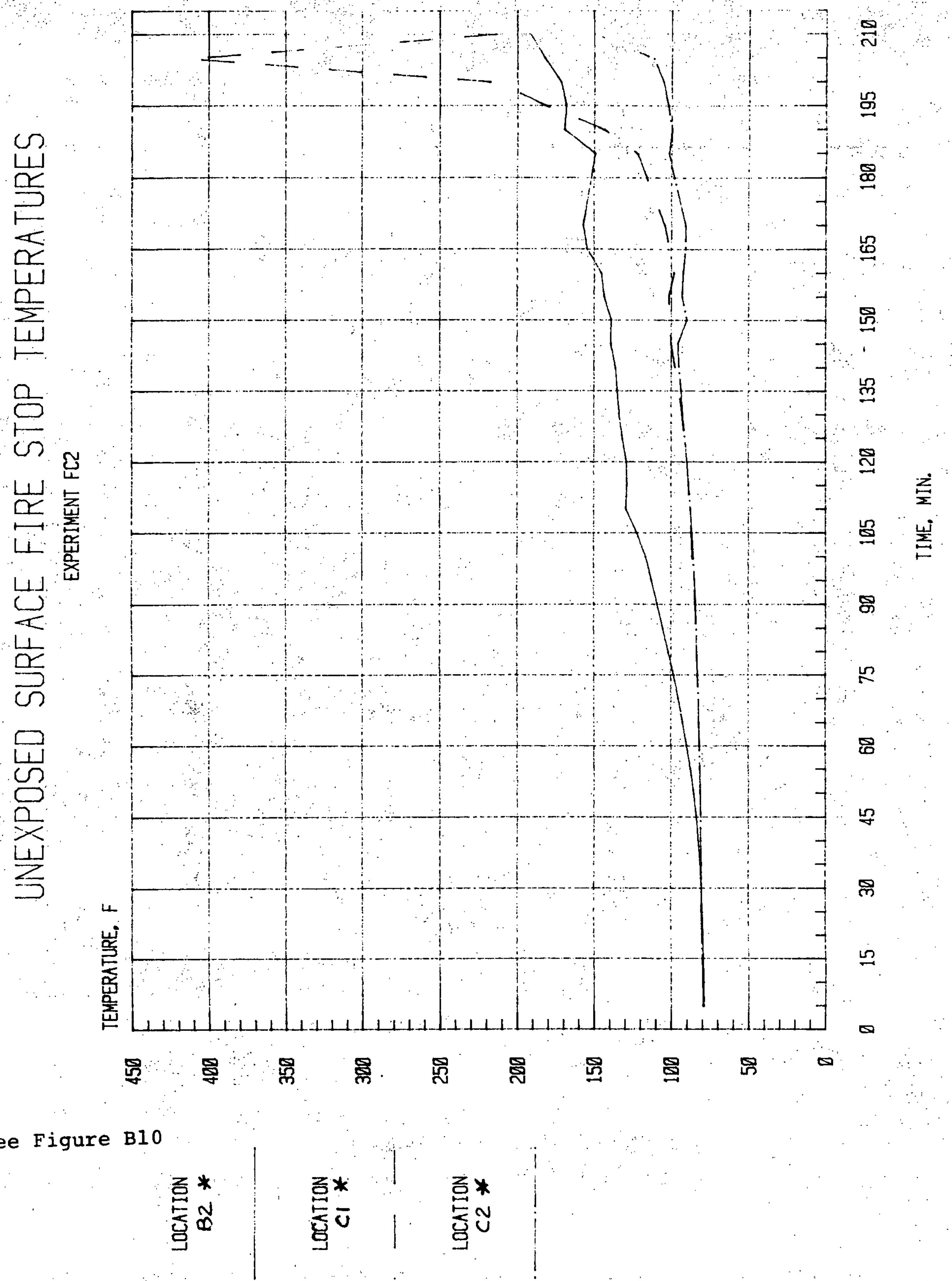
* See Figure B10

Figure C31 - U xposed Surface Temperatures of Fire Stop Material



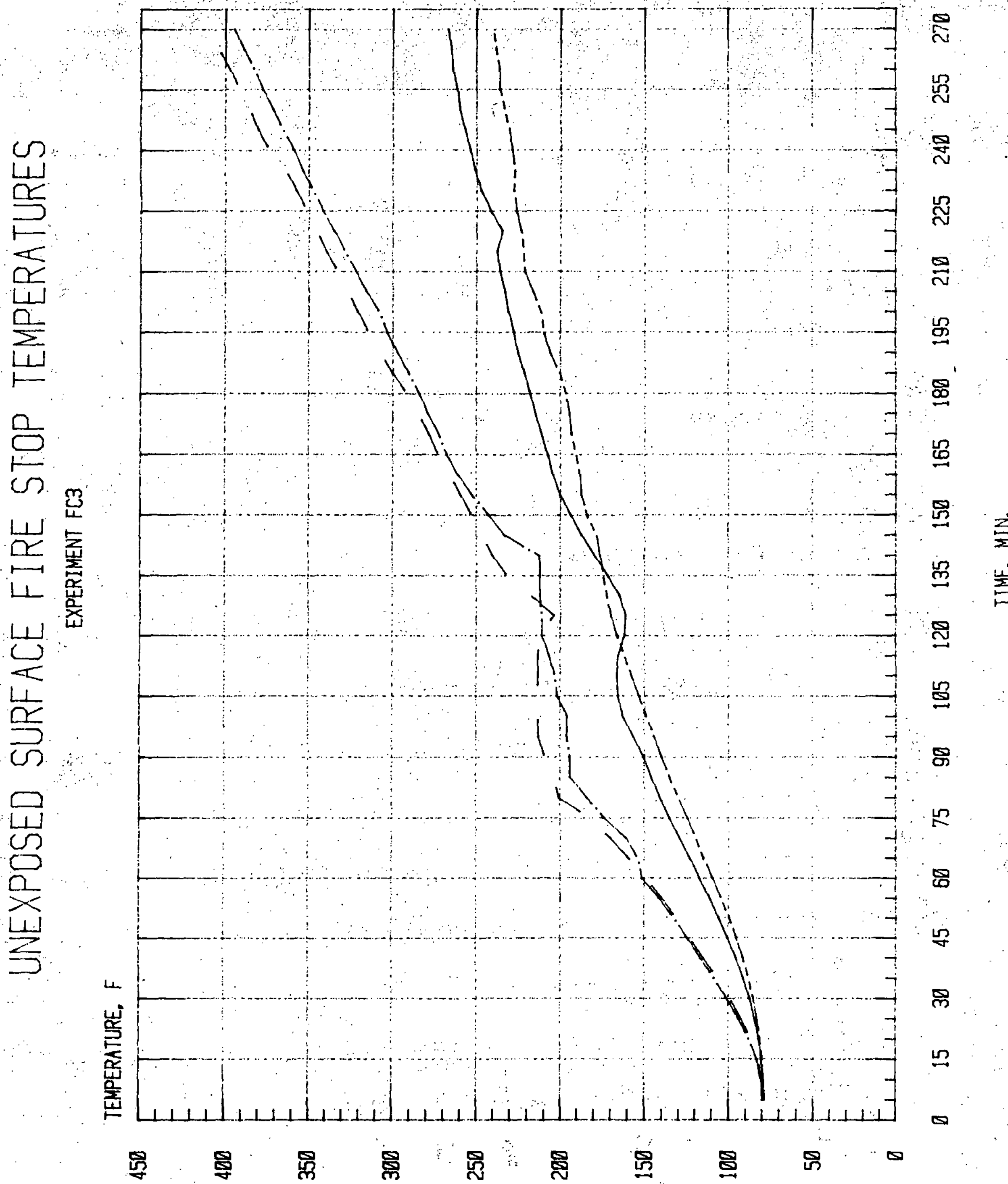
* See Figure B10

Figure C32 - Unexposed Surface Temperatures of Fire Stop Material



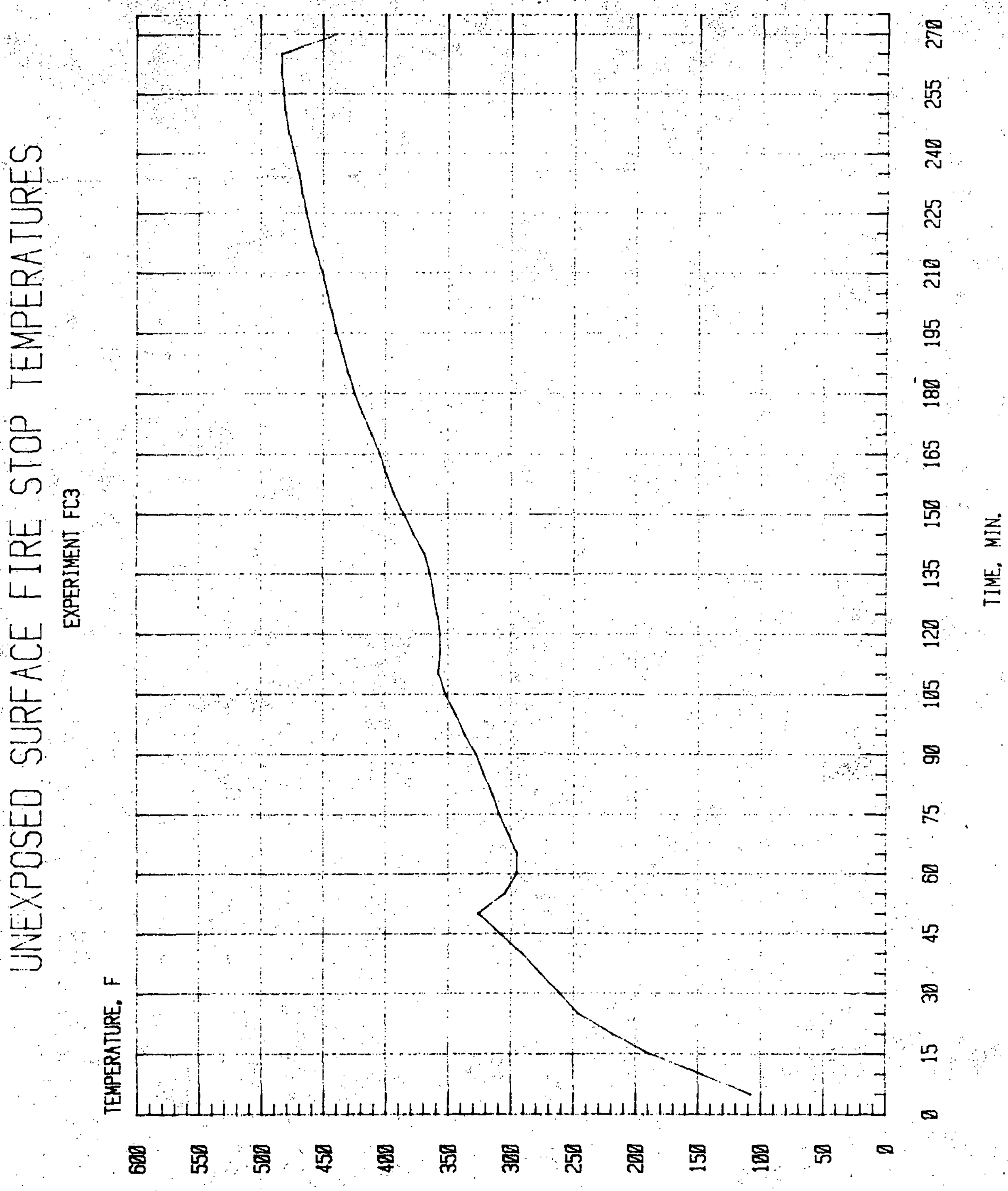
* See Figure B10

Figure C33 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B11

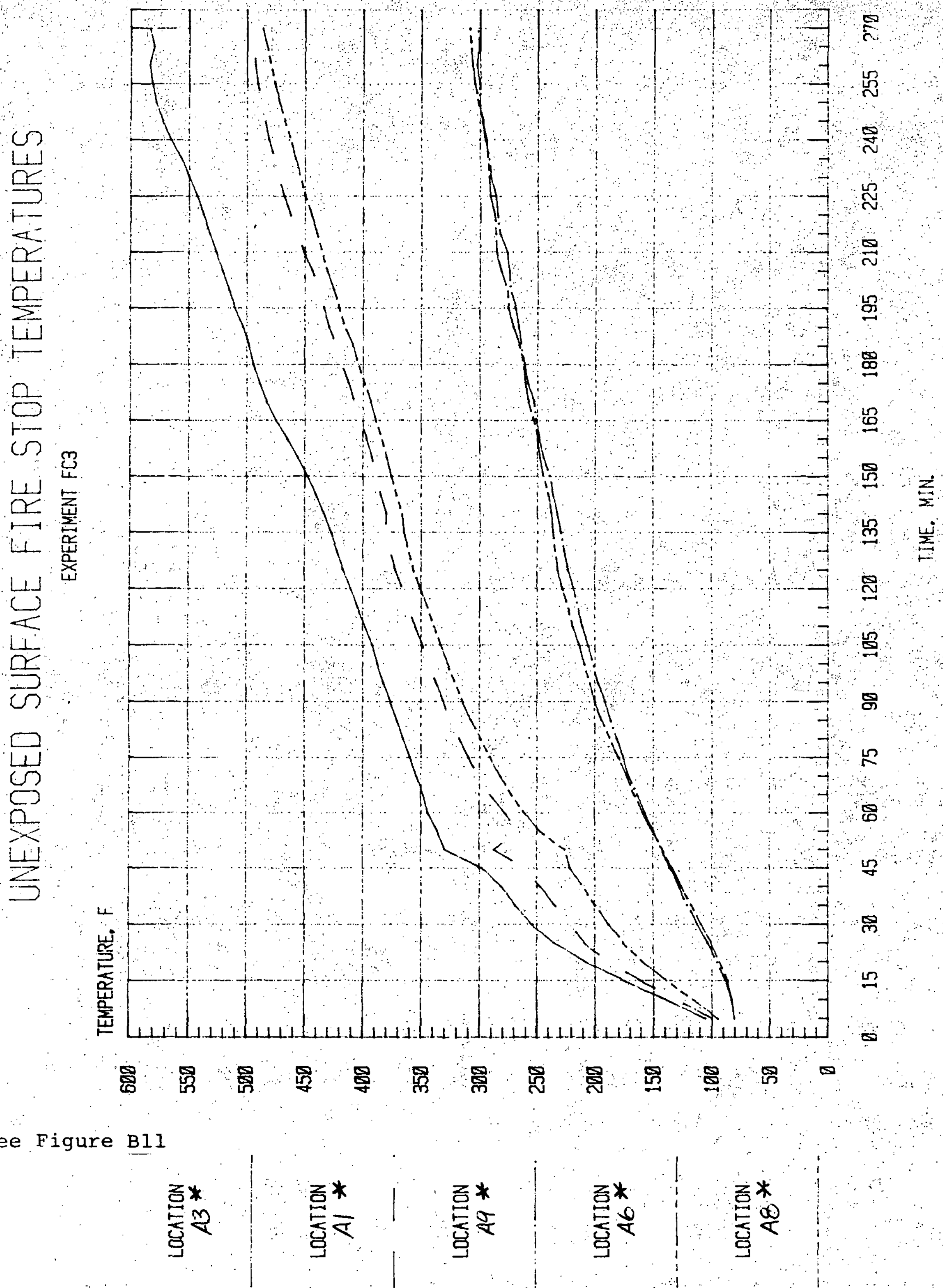
Figure C34 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B11

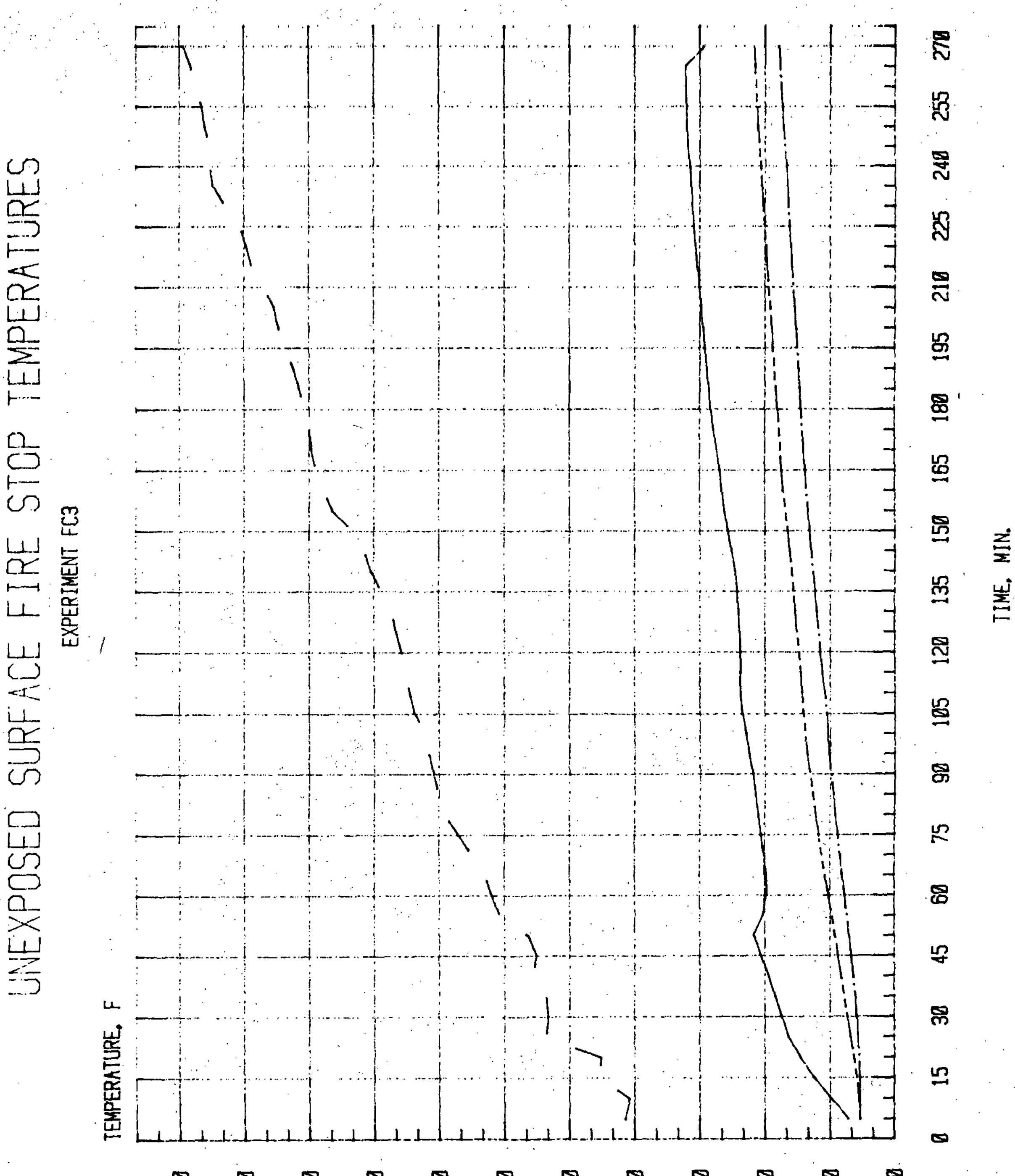
LOCATION
A3 *

Figure C35 - Unexposed Surface Temperatures of Fire Stop Material

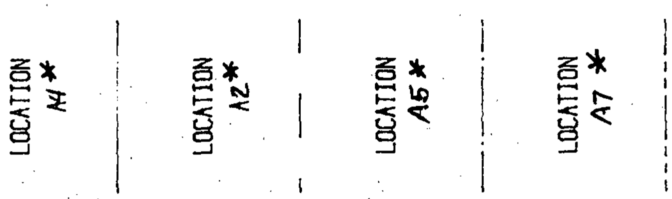


* See Figure B11

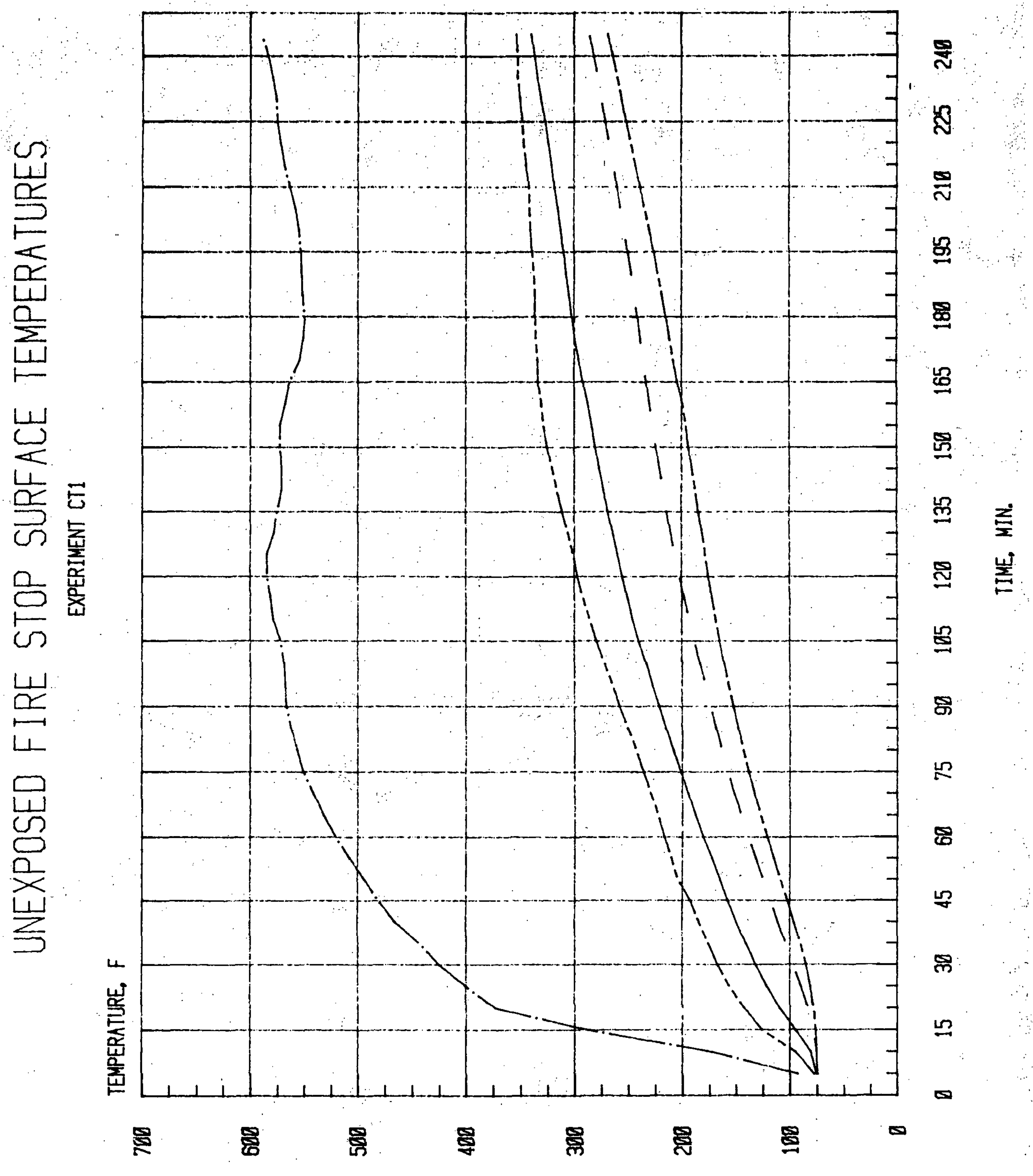
Figure C36 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B11



C37 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B12

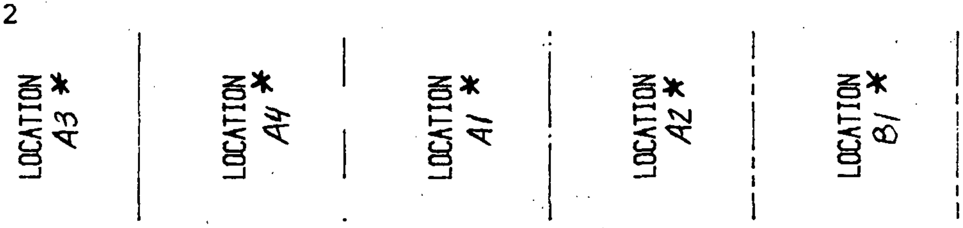
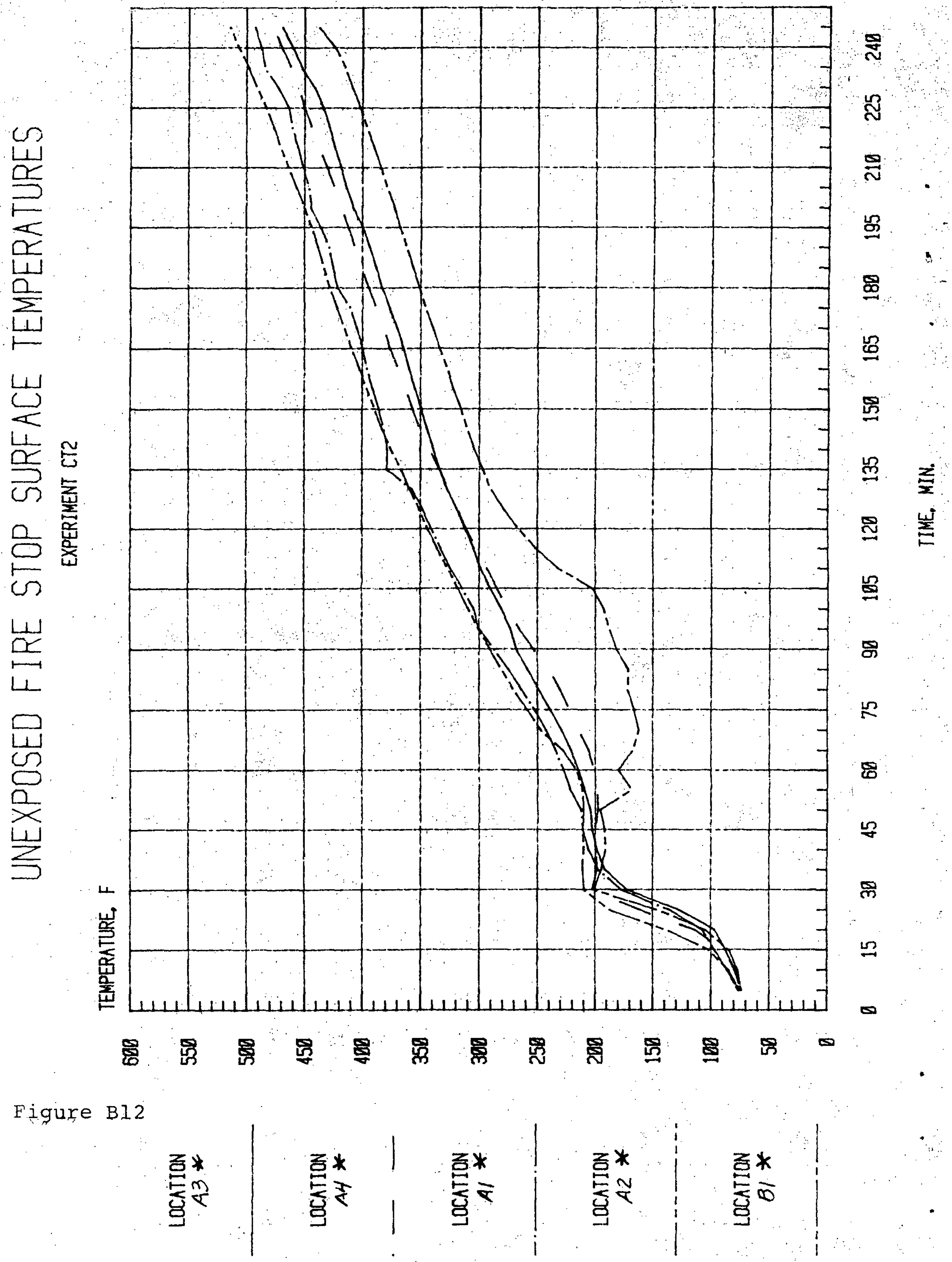
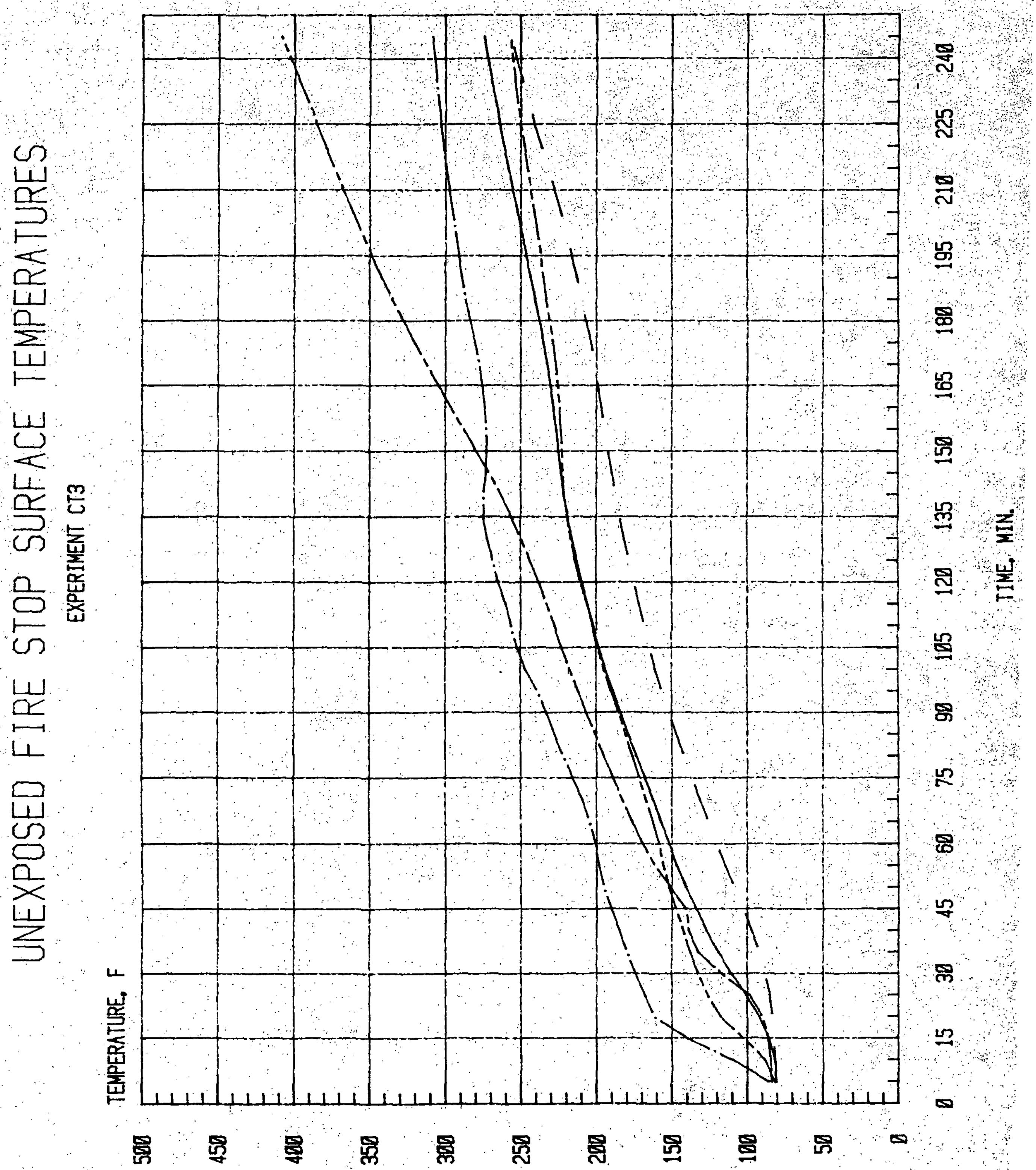


Figure C38 - Unexposed Surface Temperatures of Fire Stop Material

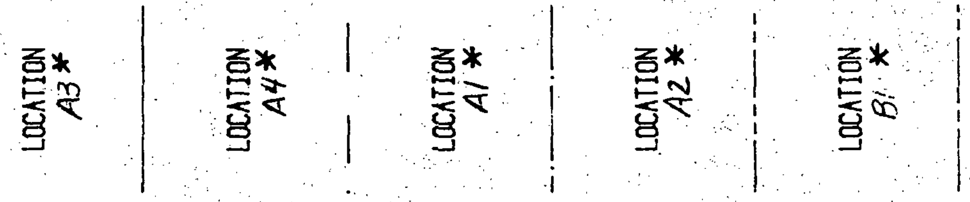


* See Figure B12

Figure C39 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B12



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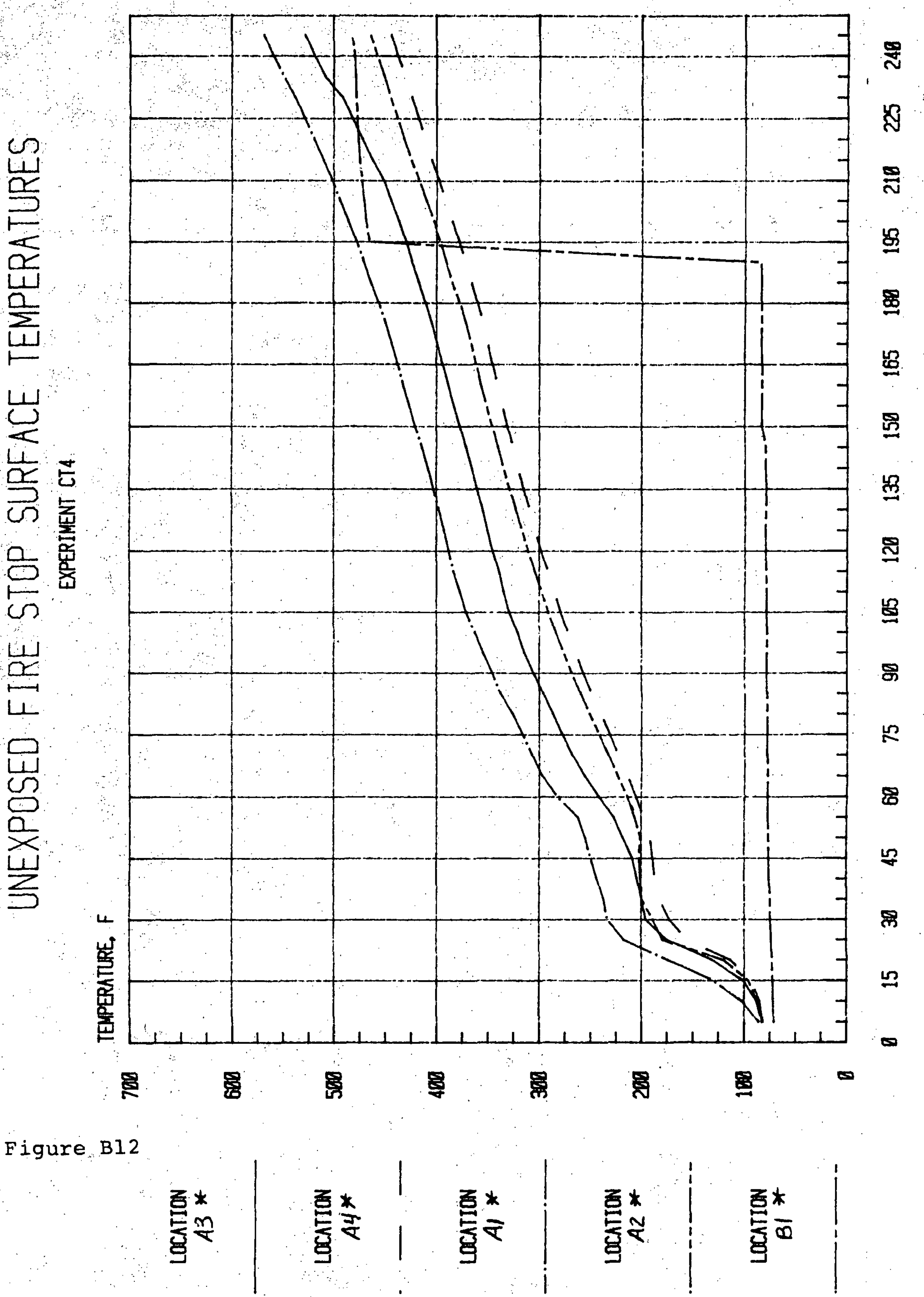

* See Figure B12

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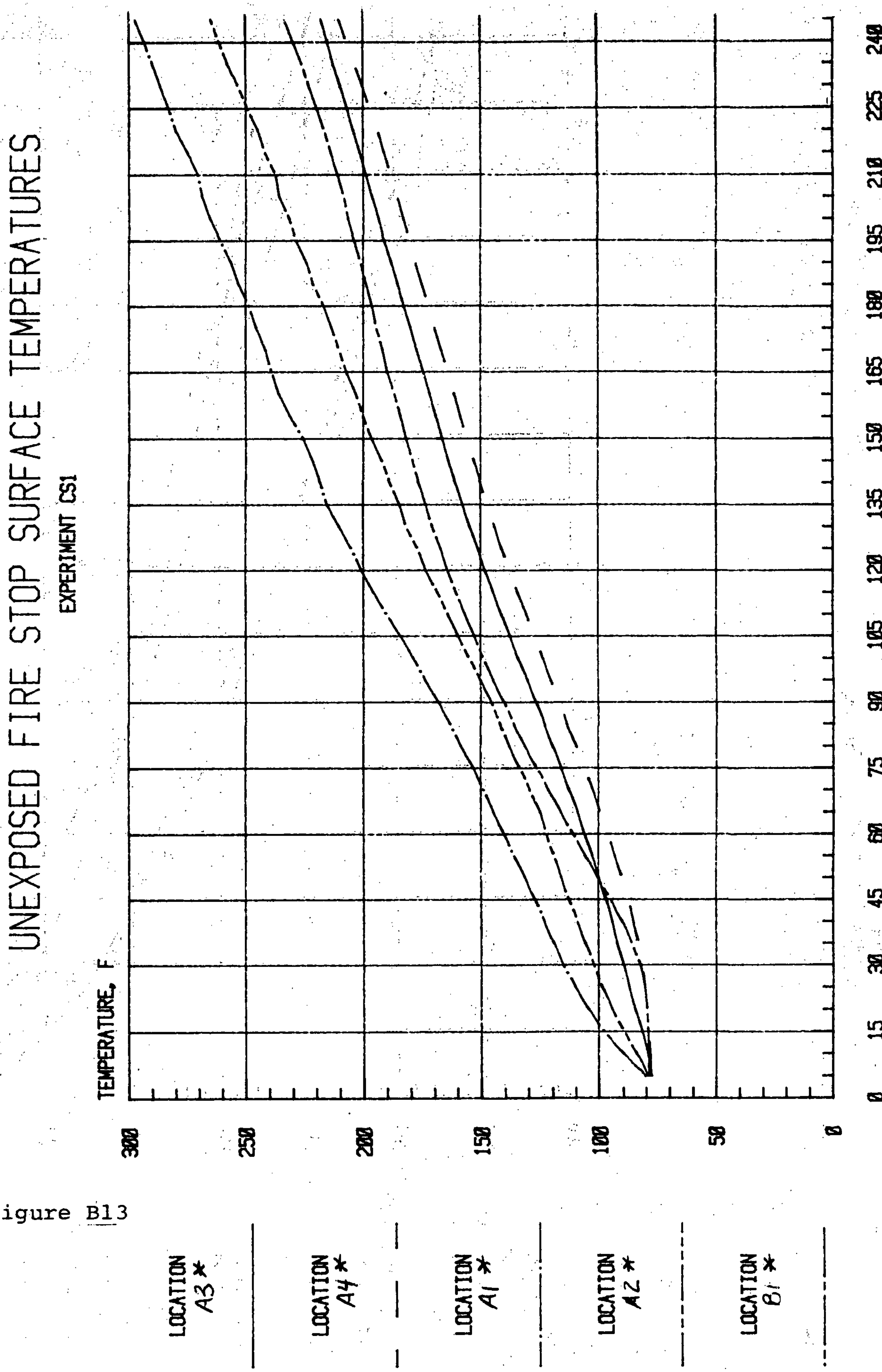
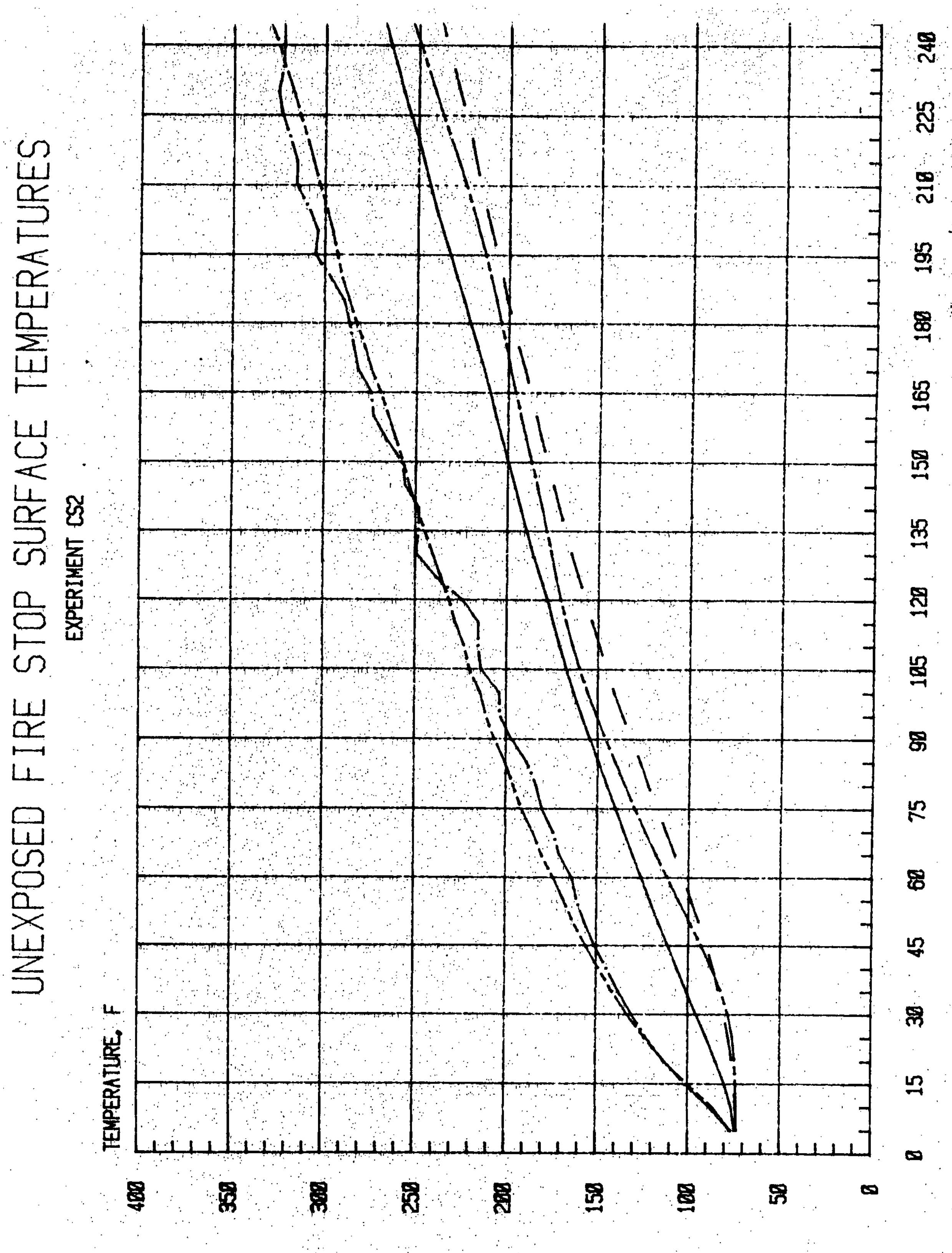


* See Figure B13

Figure C42 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B13

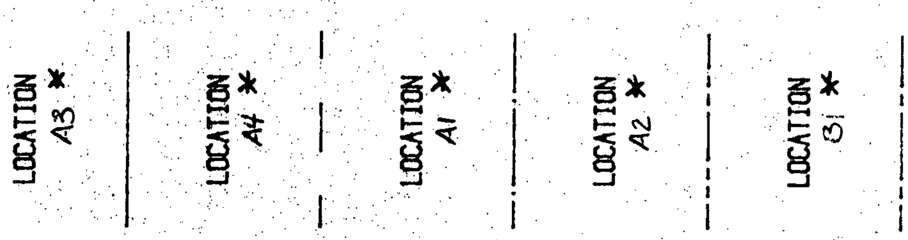
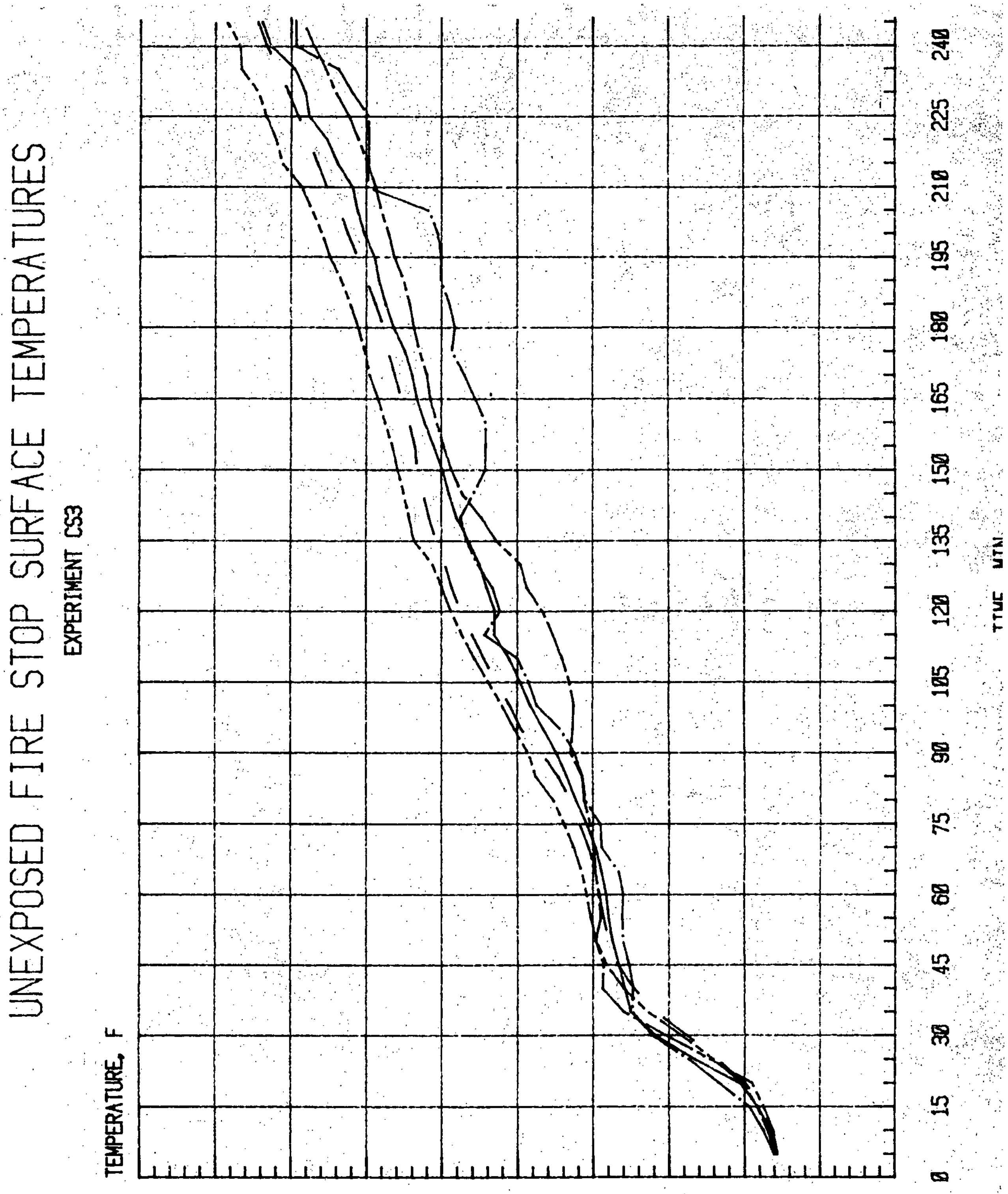
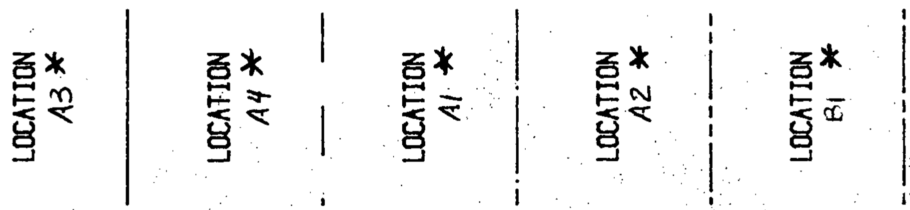


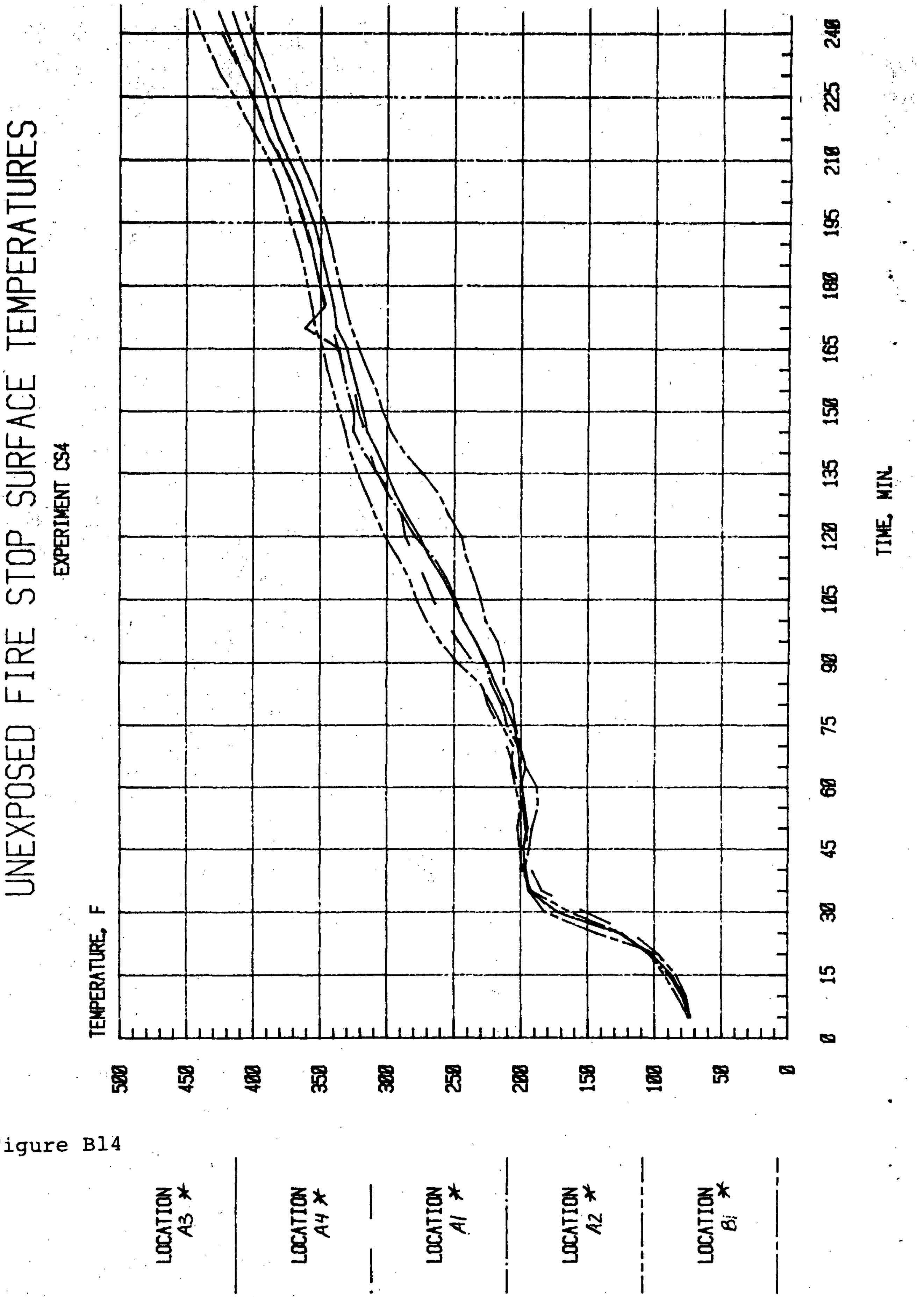
Figure C43 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B14

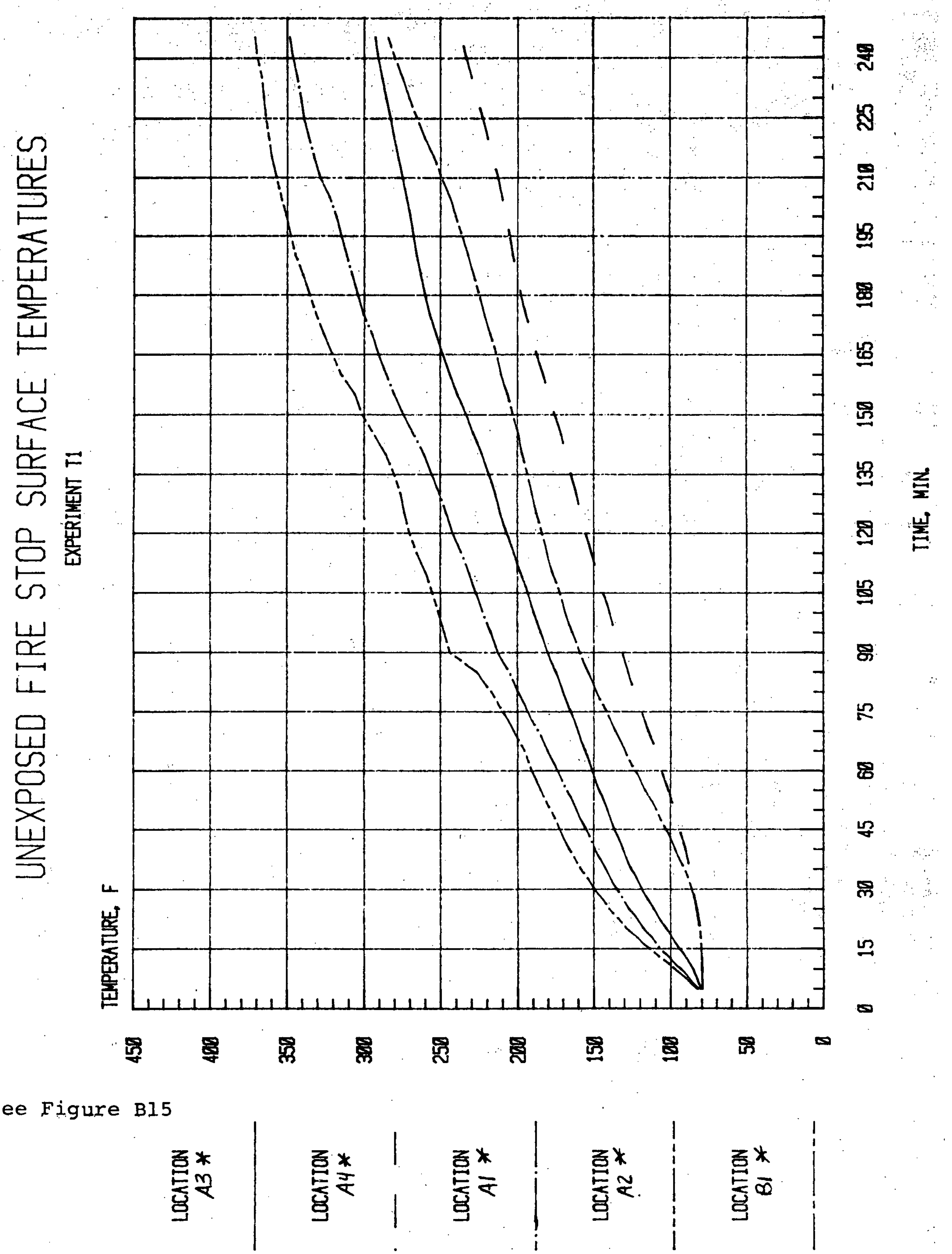


C44 - Unexposed Surface Temperatures of Fire Stop Material



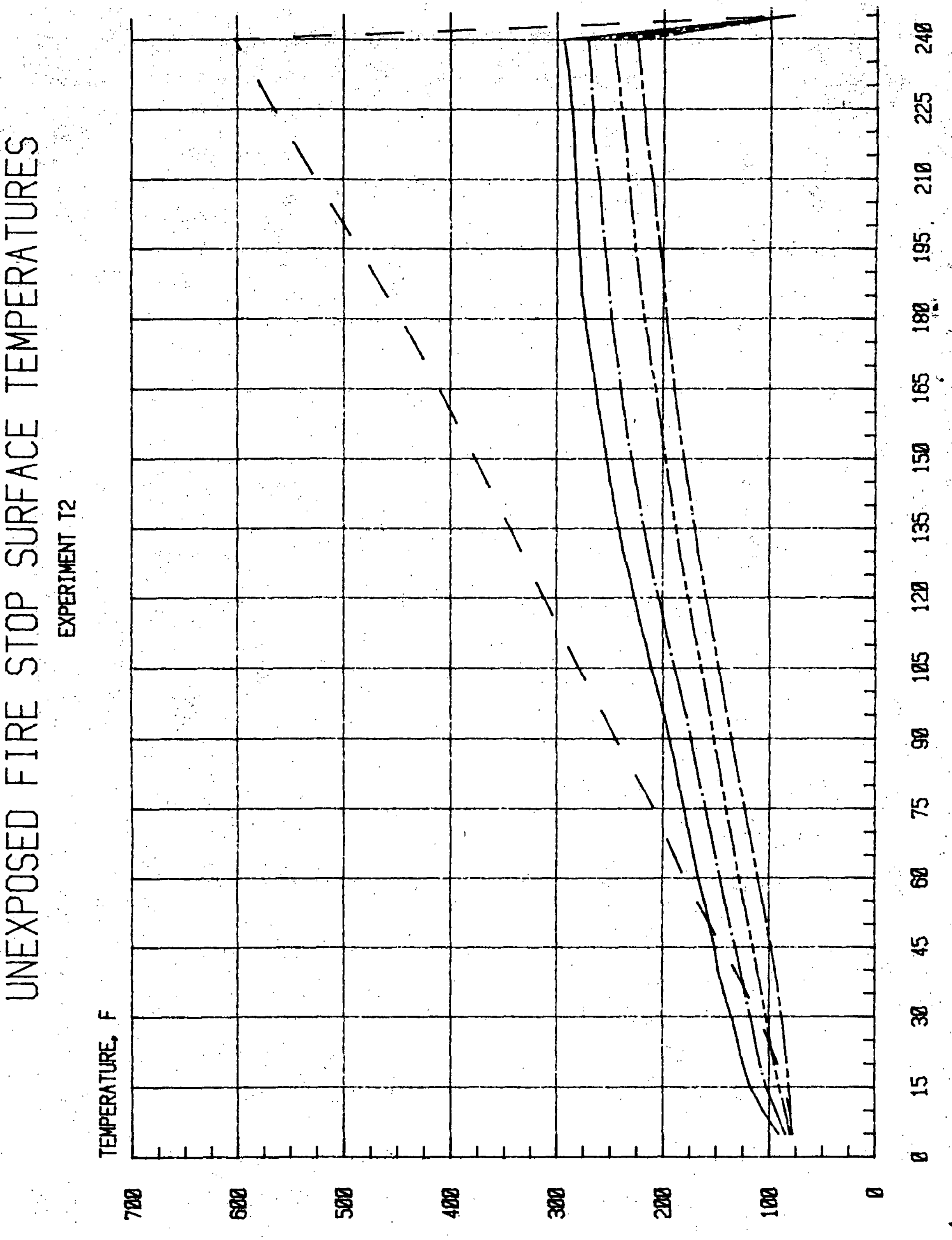
* See Figure B14

Figure C45 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B15

Figure C46 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B15

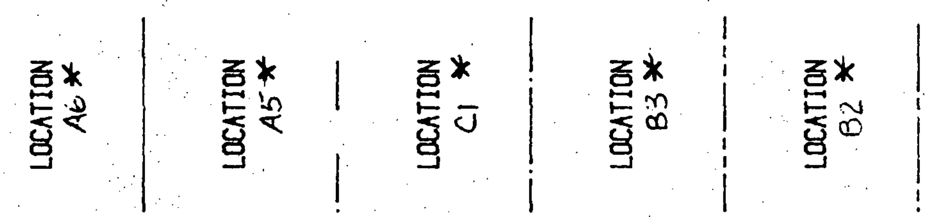
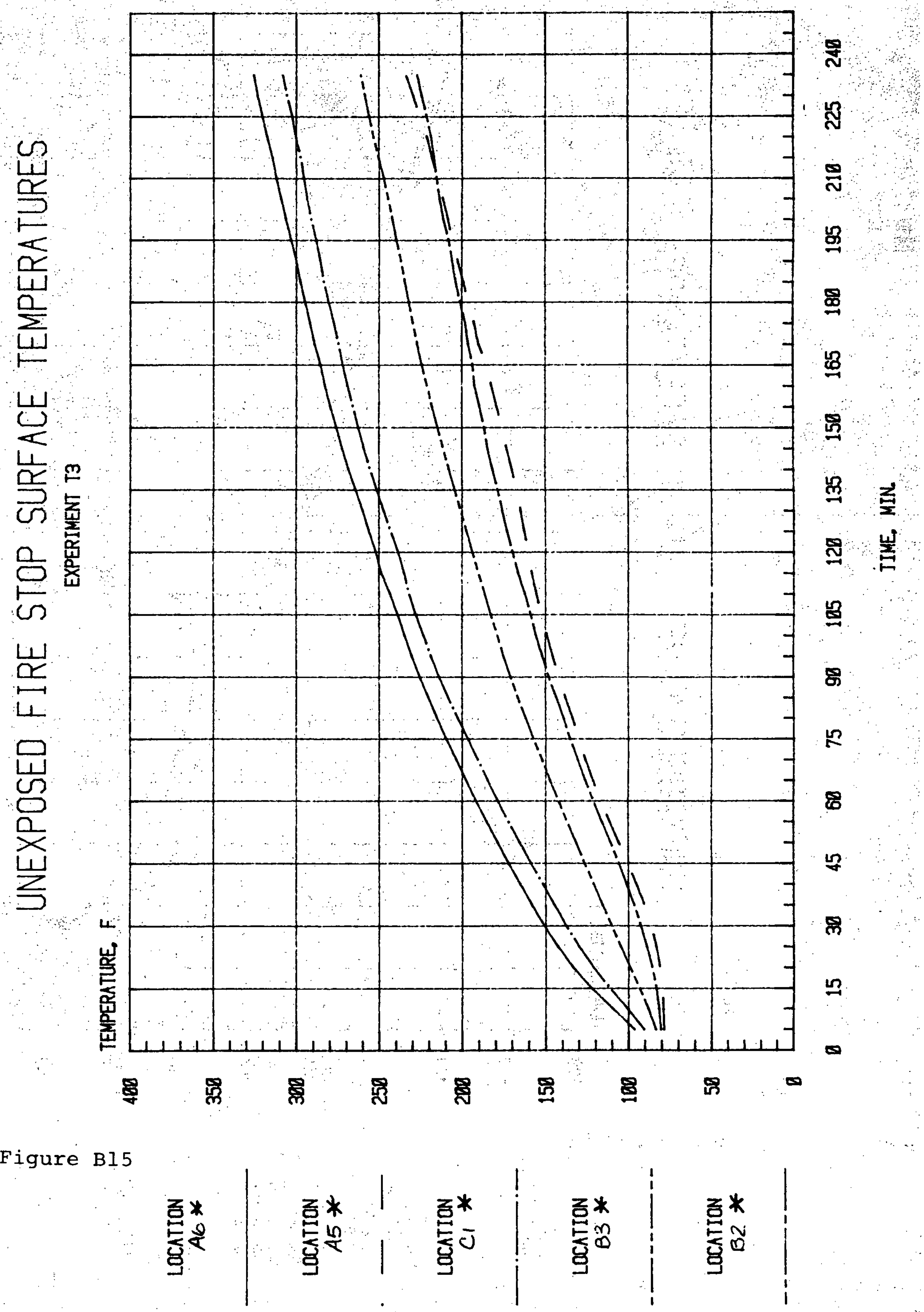
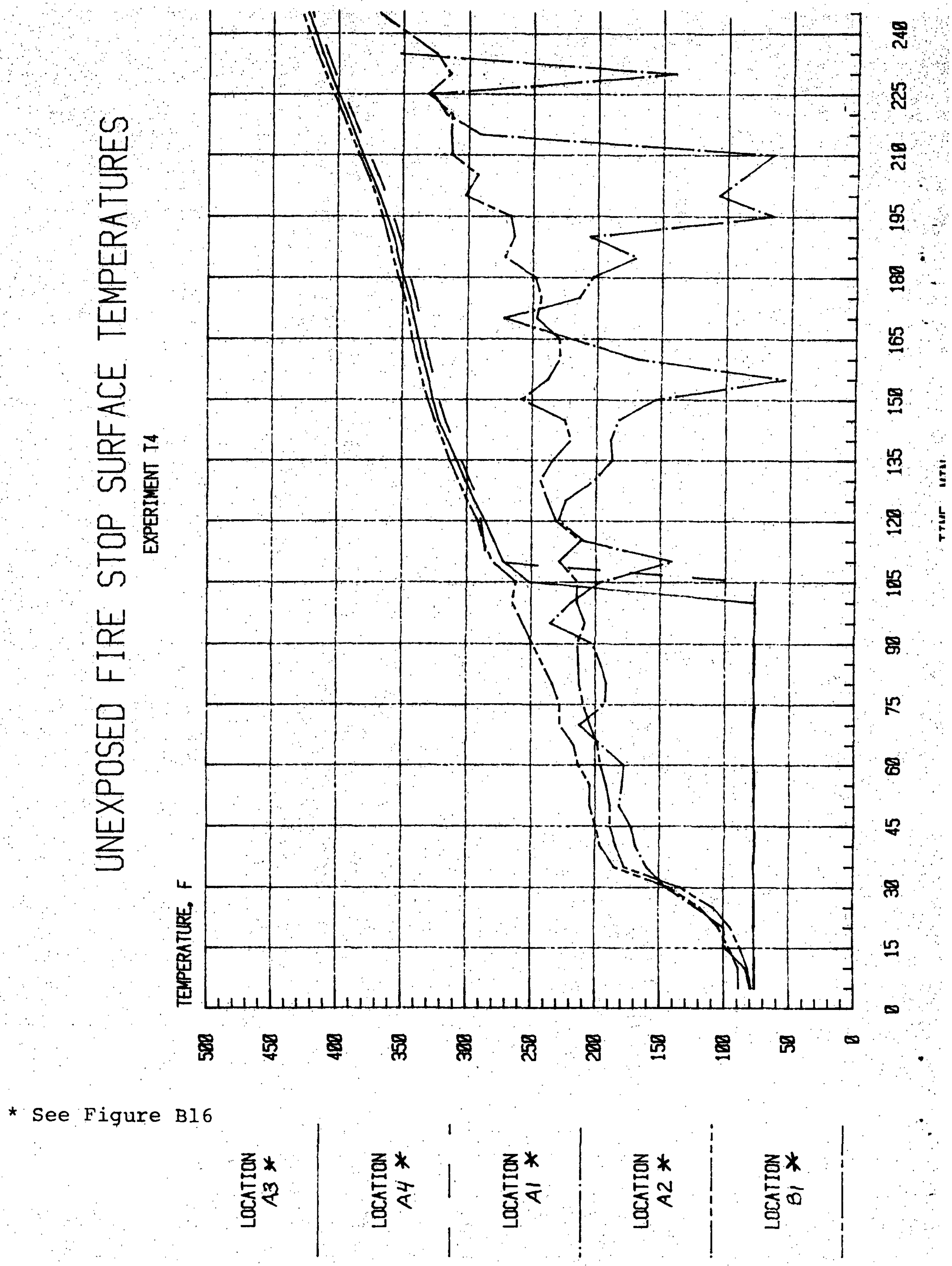


Figure C47 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B15

Figure C48 - Unexposed Surface Temperatures of Fire Stop Material



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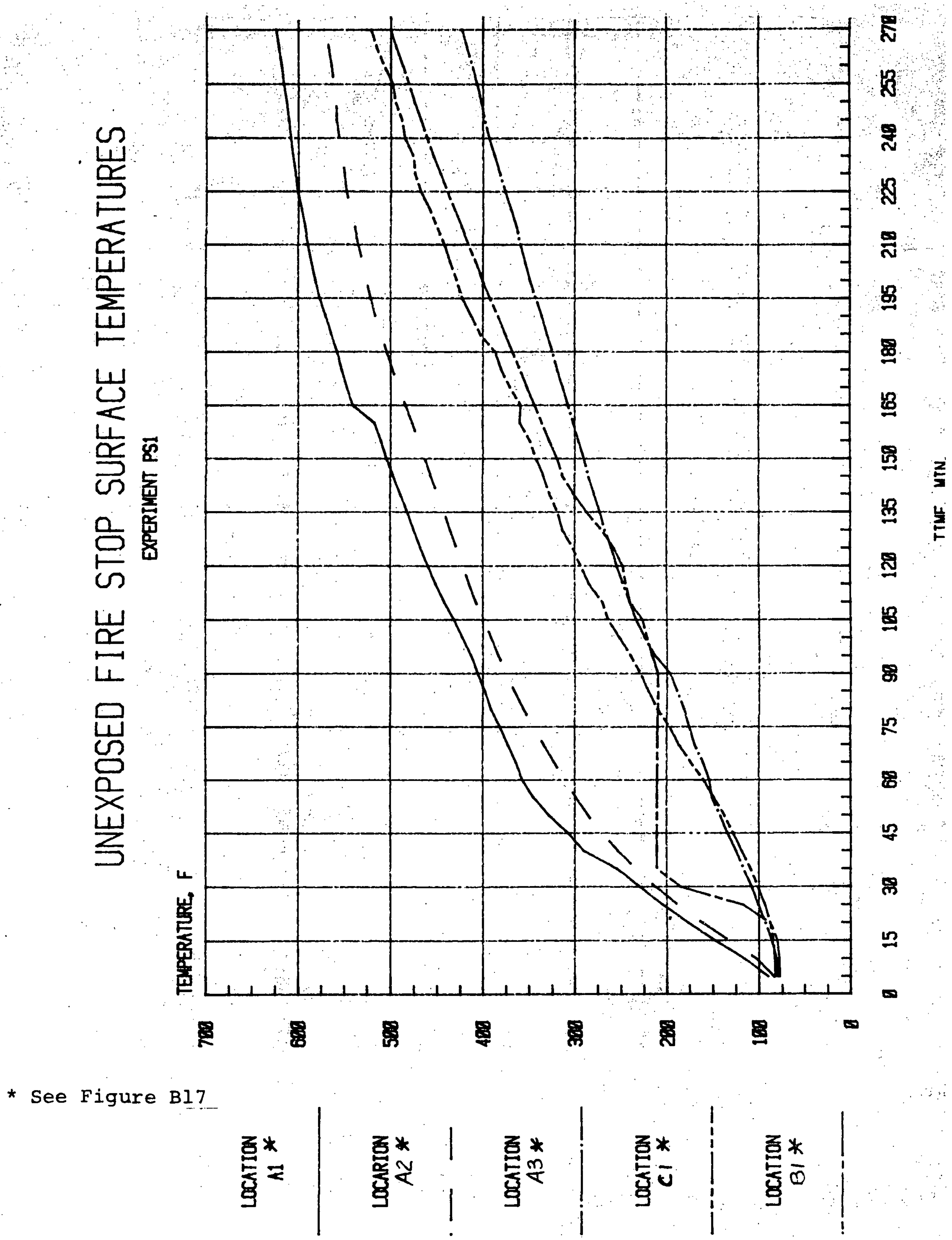

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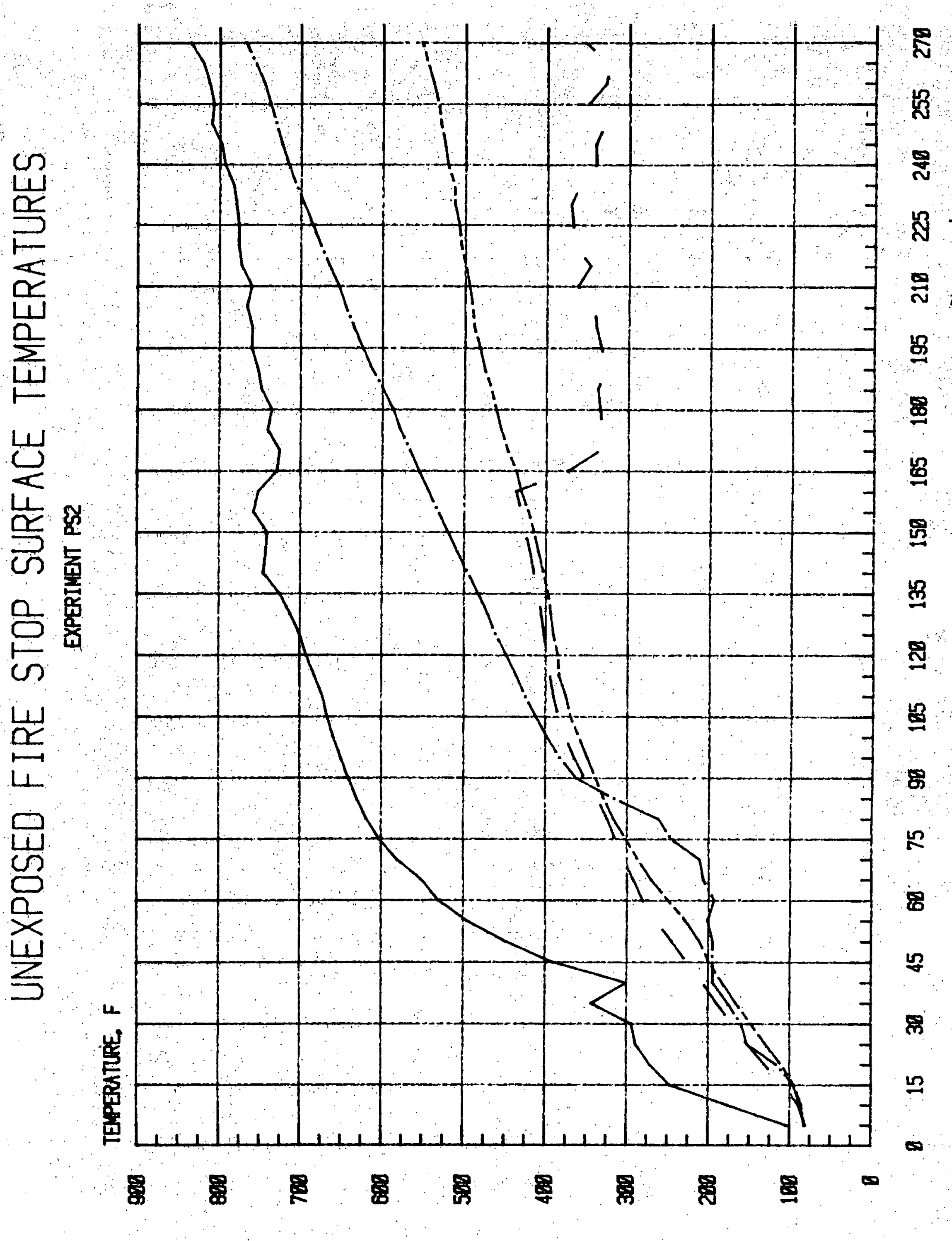
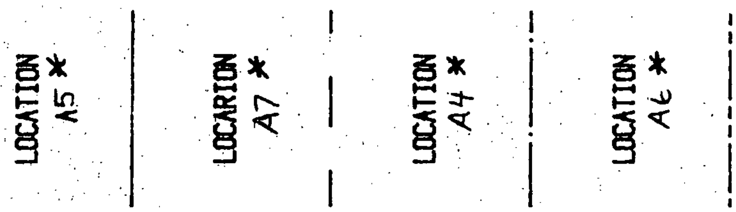


* See Figure B17



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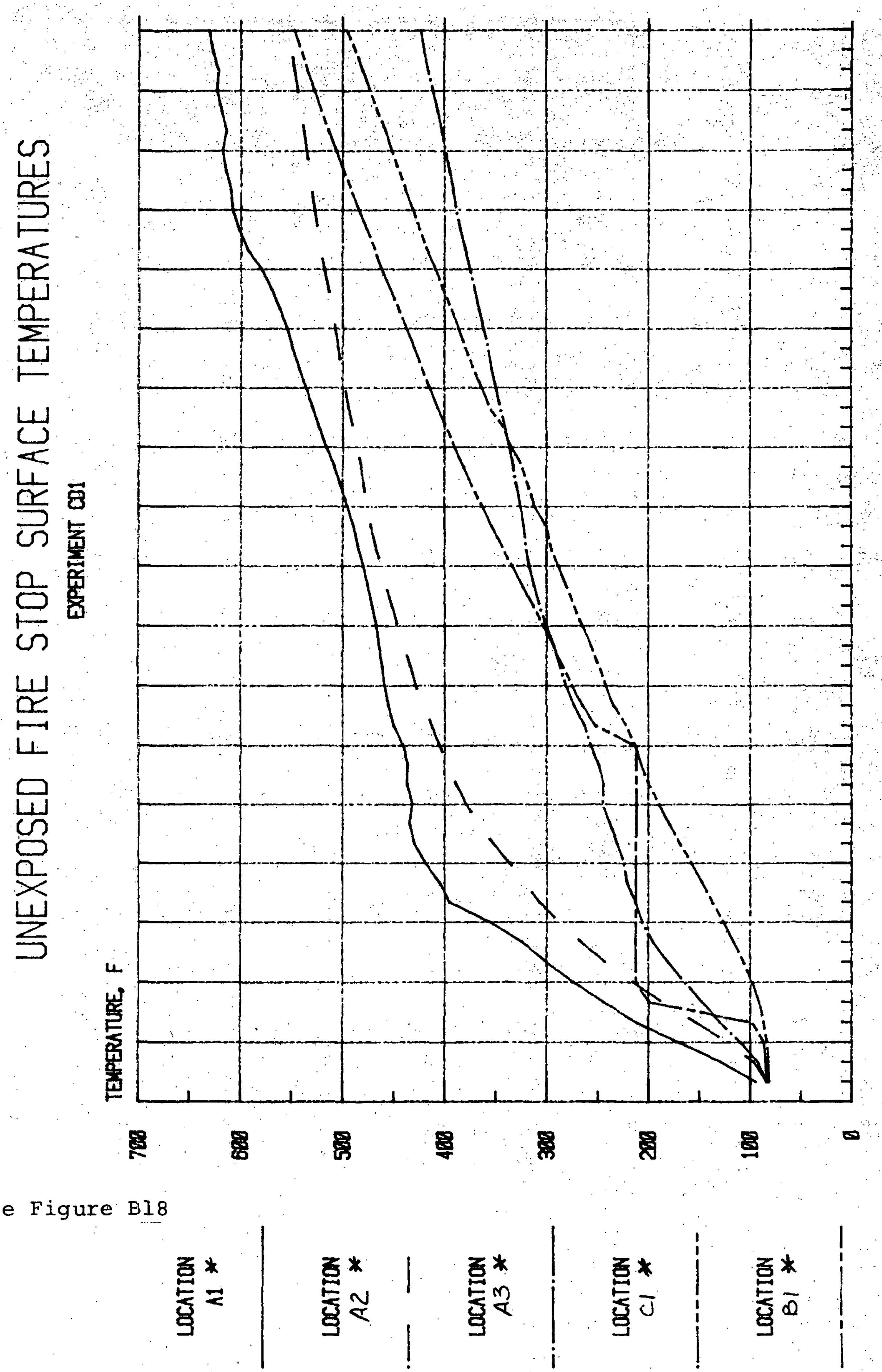
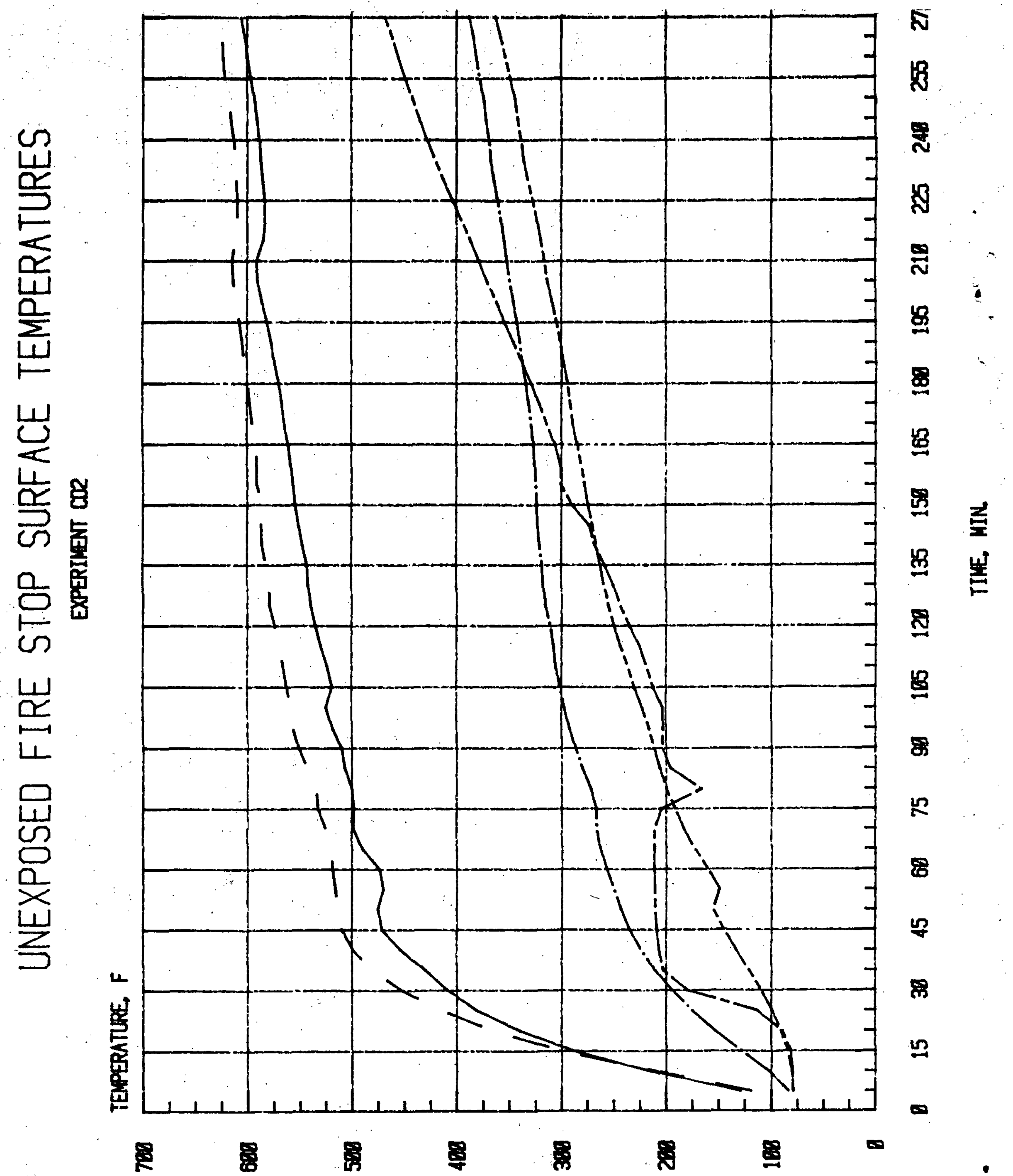
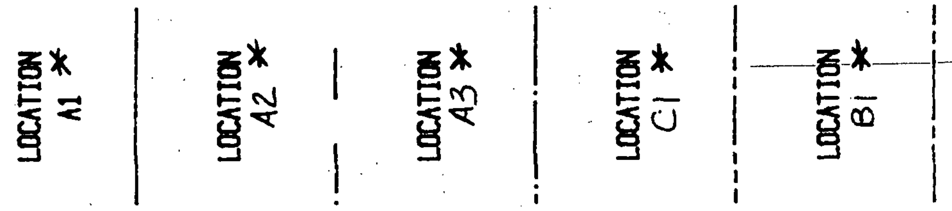


* See Figure B18

Figure C52 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B18



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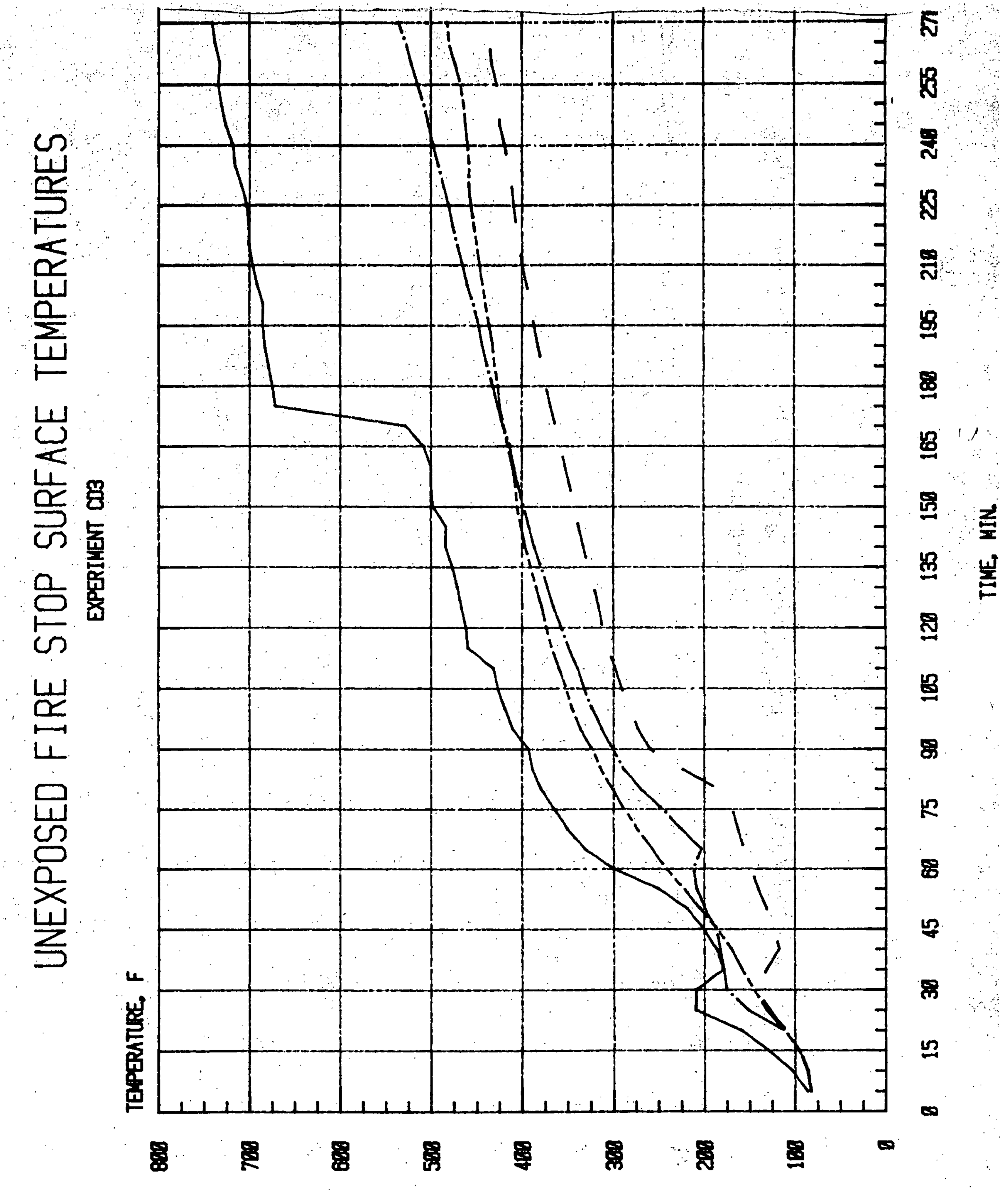
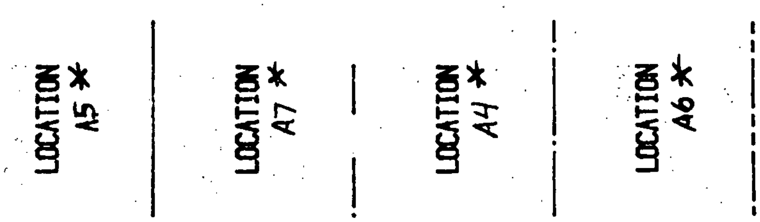


* See Figure B19



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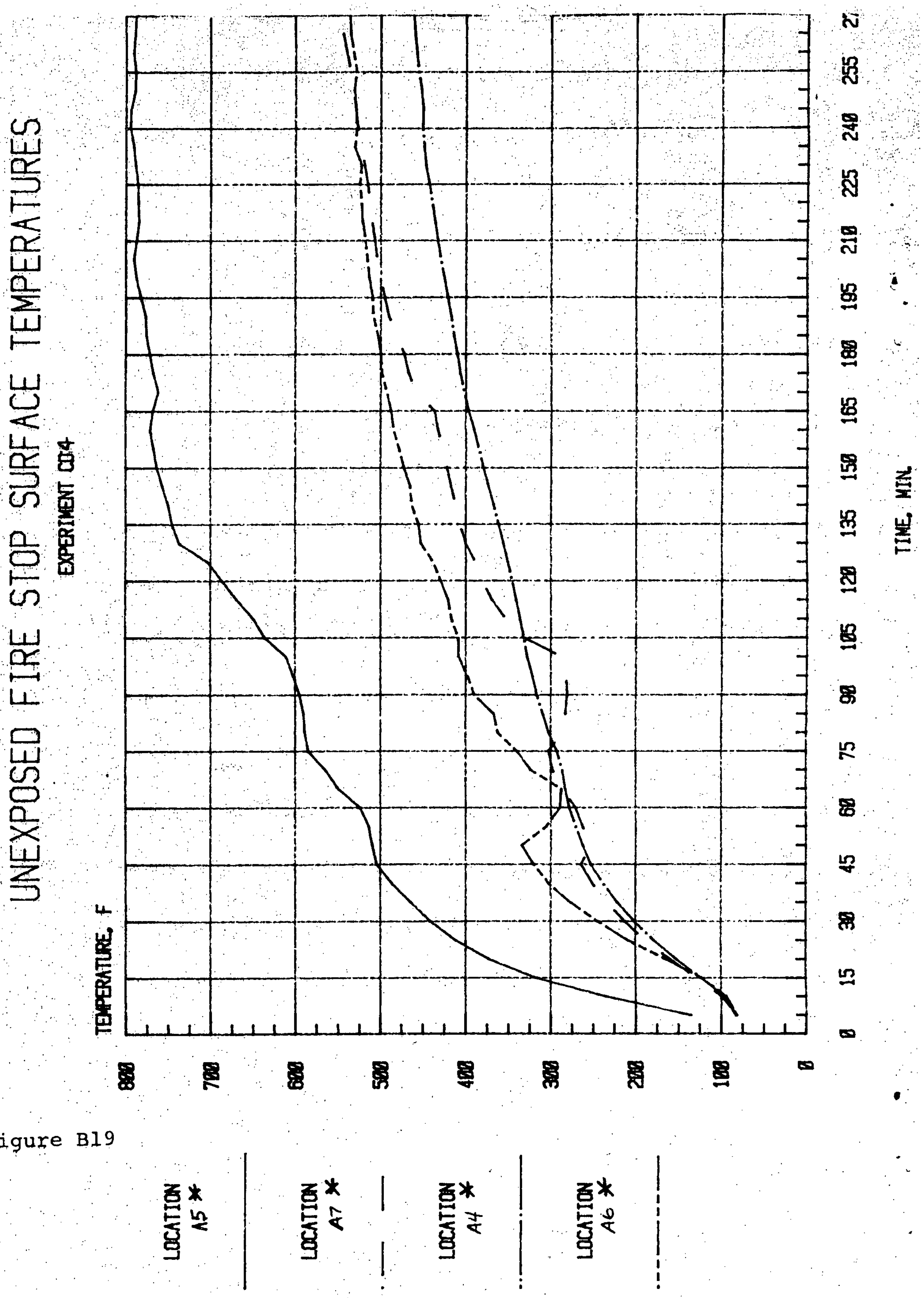
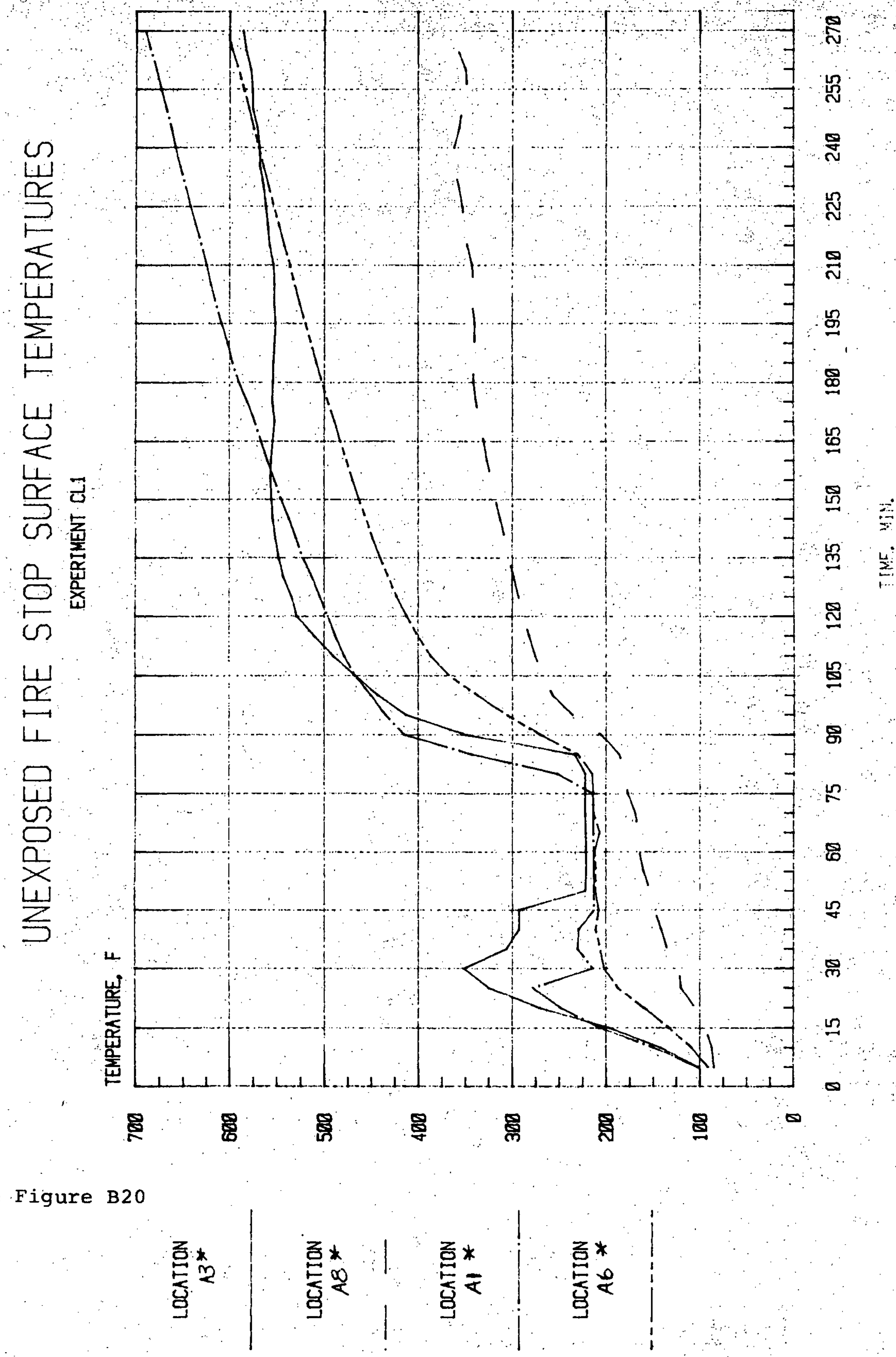


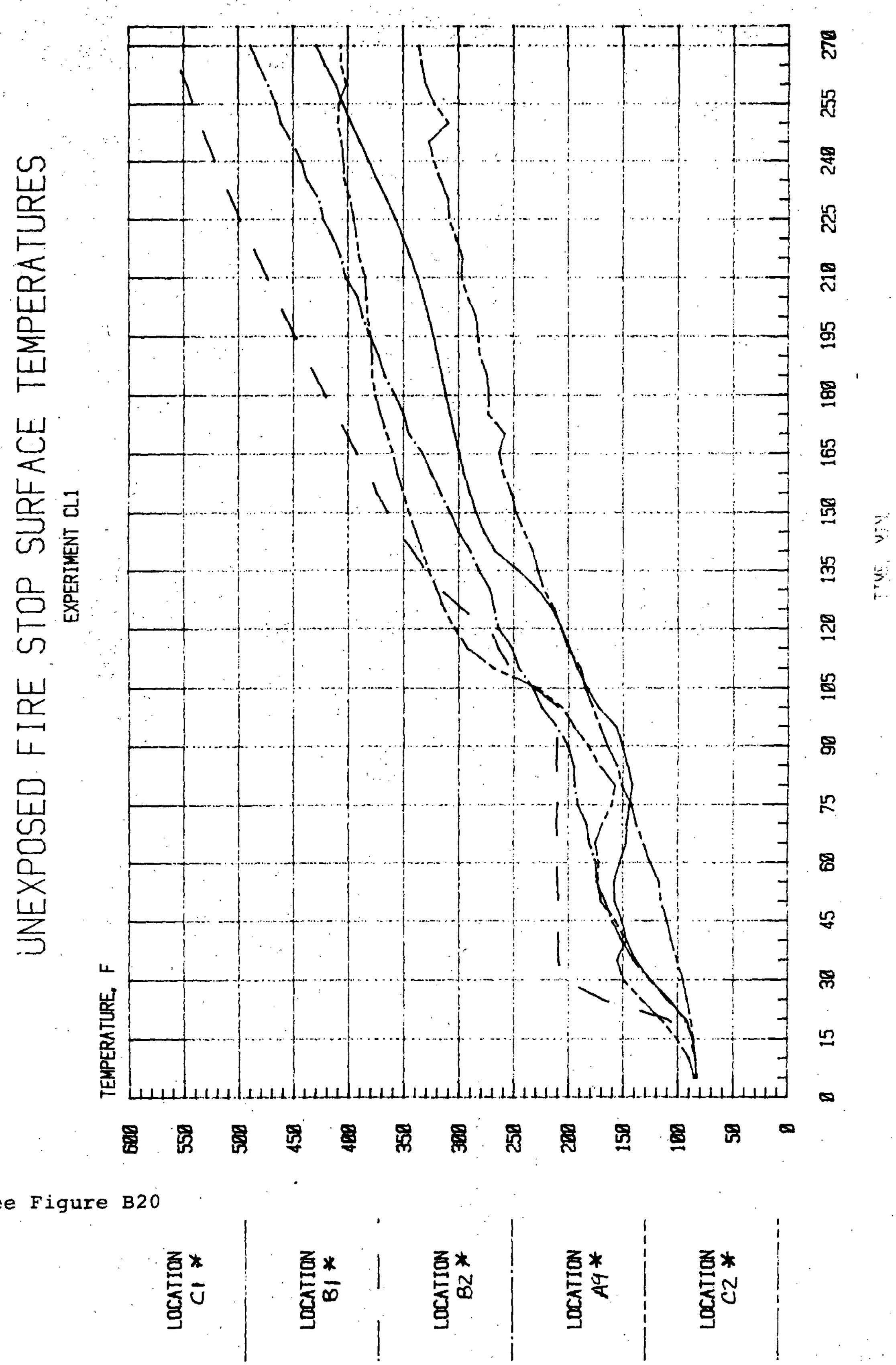
* See Figure B19

Figure C55 - Unexposed Surface Temperatures of Fire Stop Material



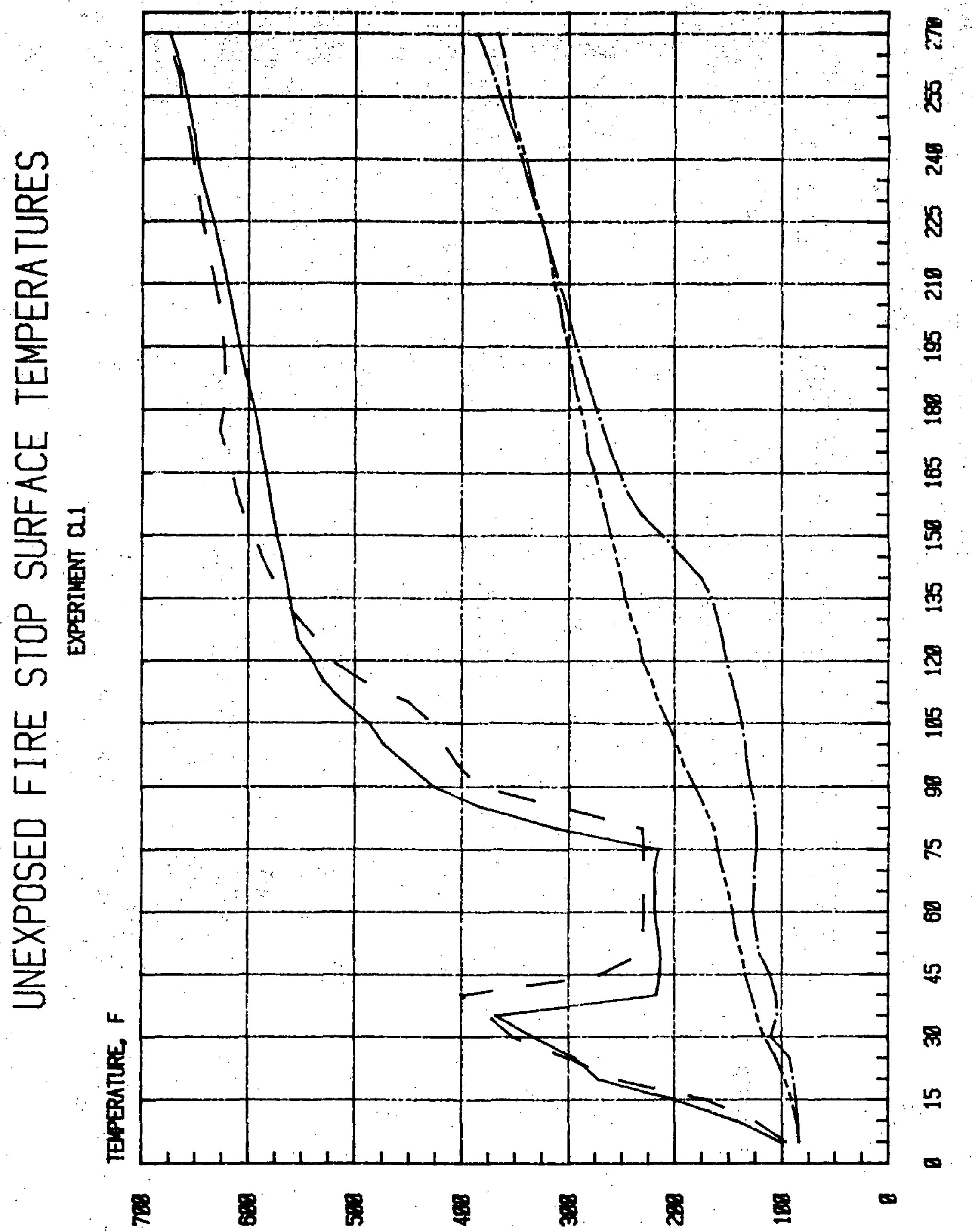
* See Figure B20

Figure C56 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B20

Figure C57 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B20

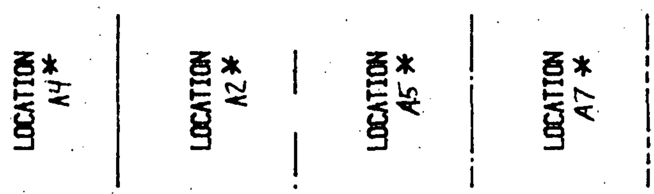
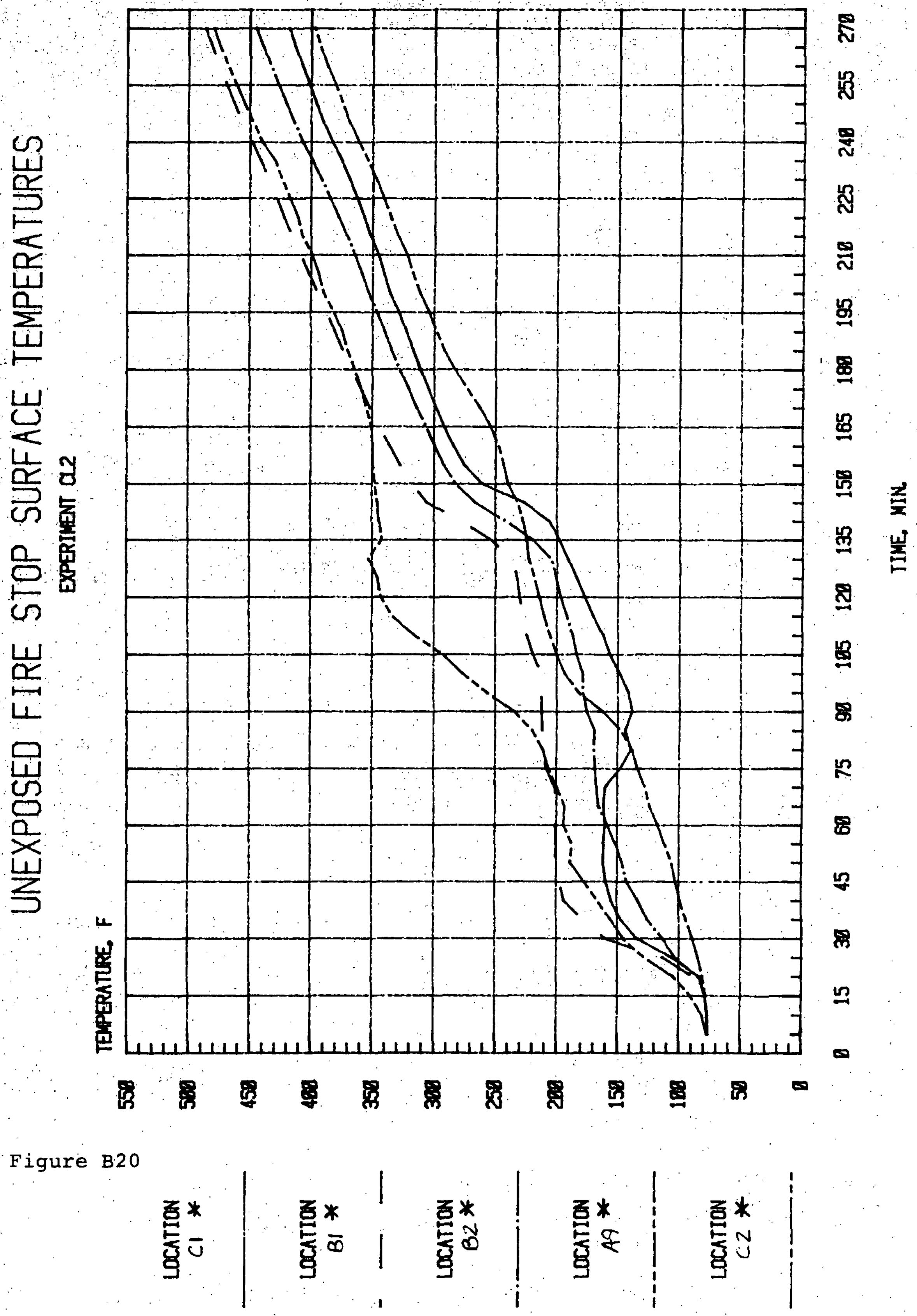
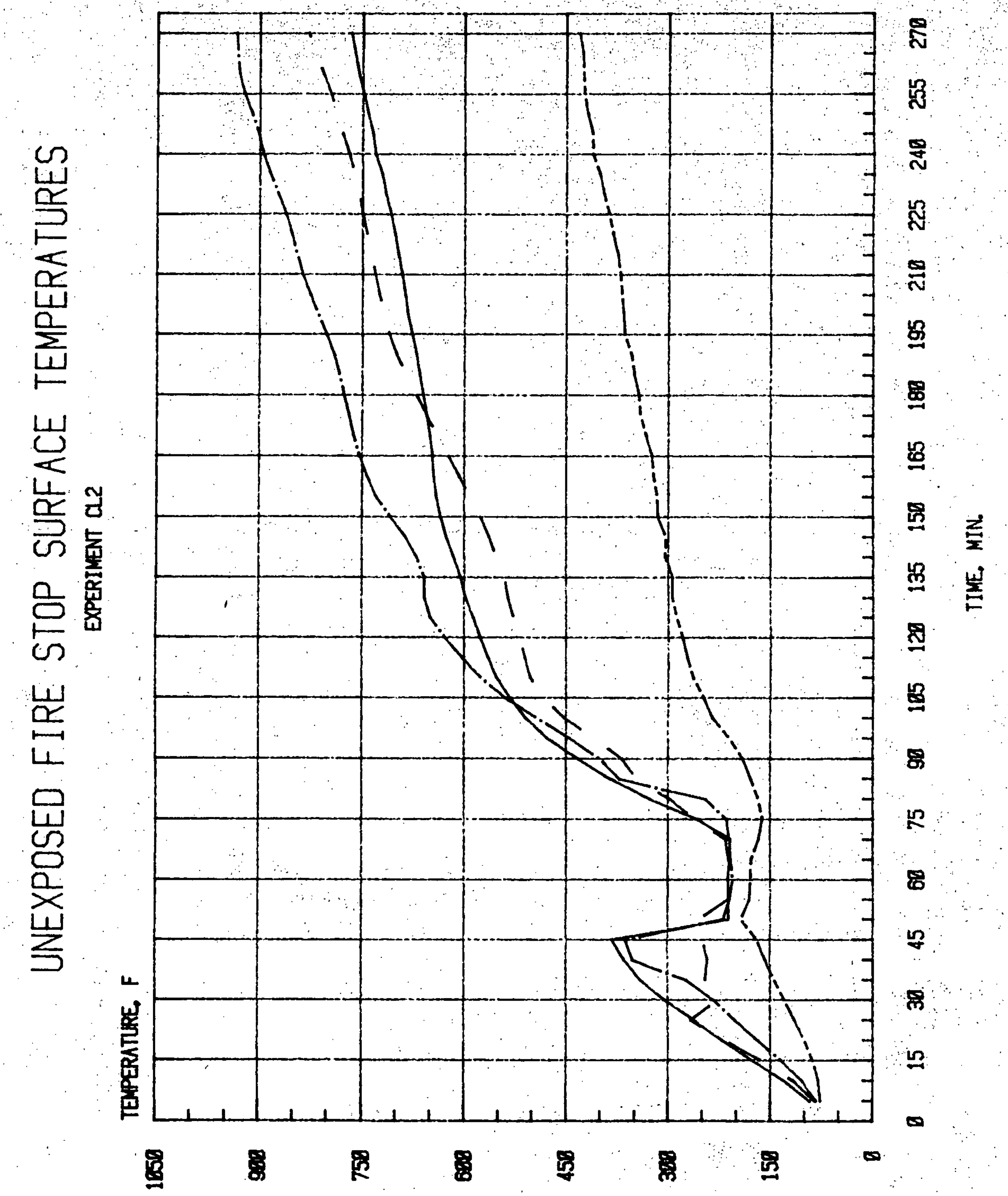


Figure C58 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B20

Figure C59 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B20

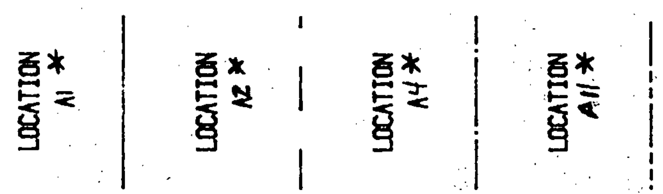
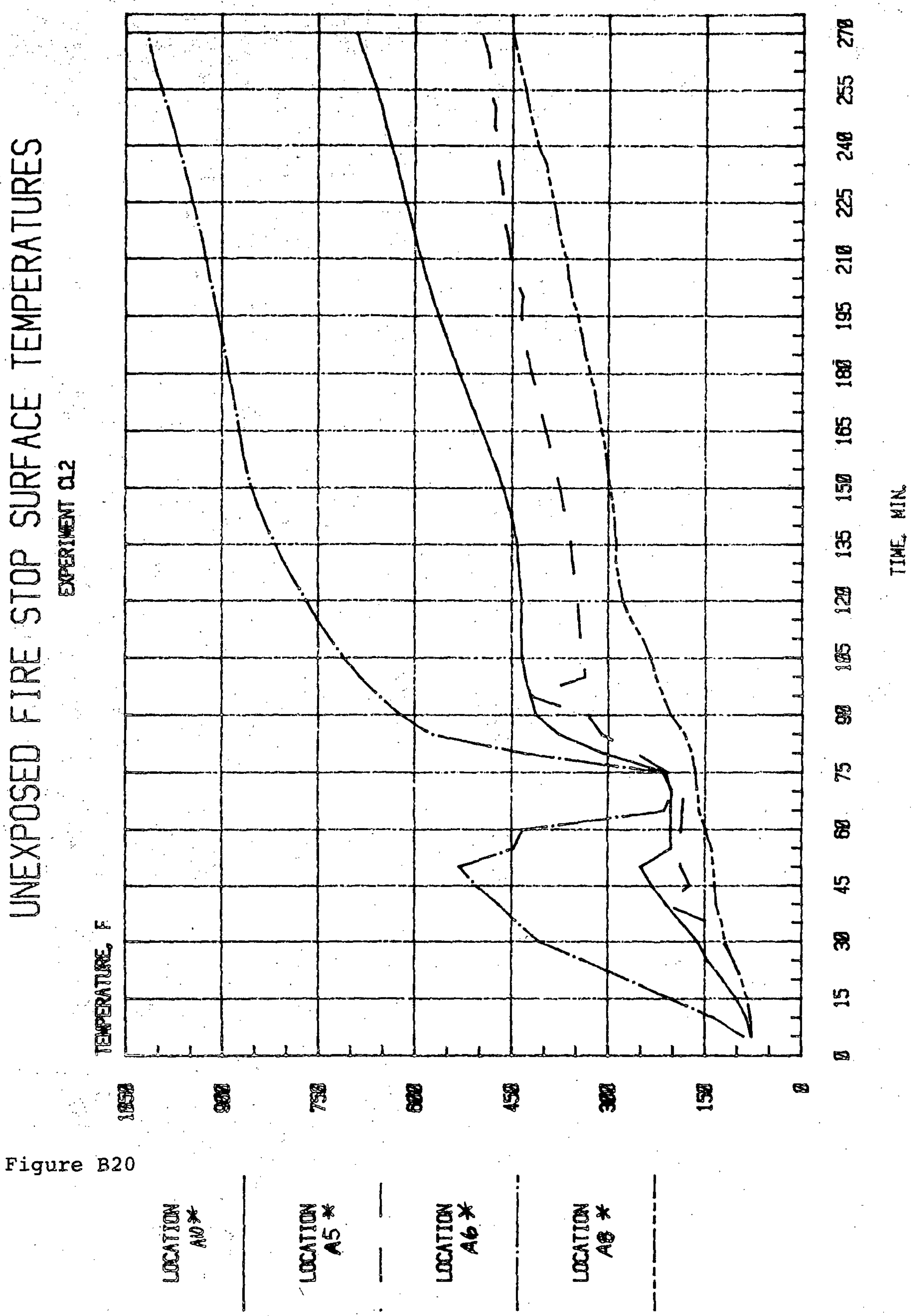
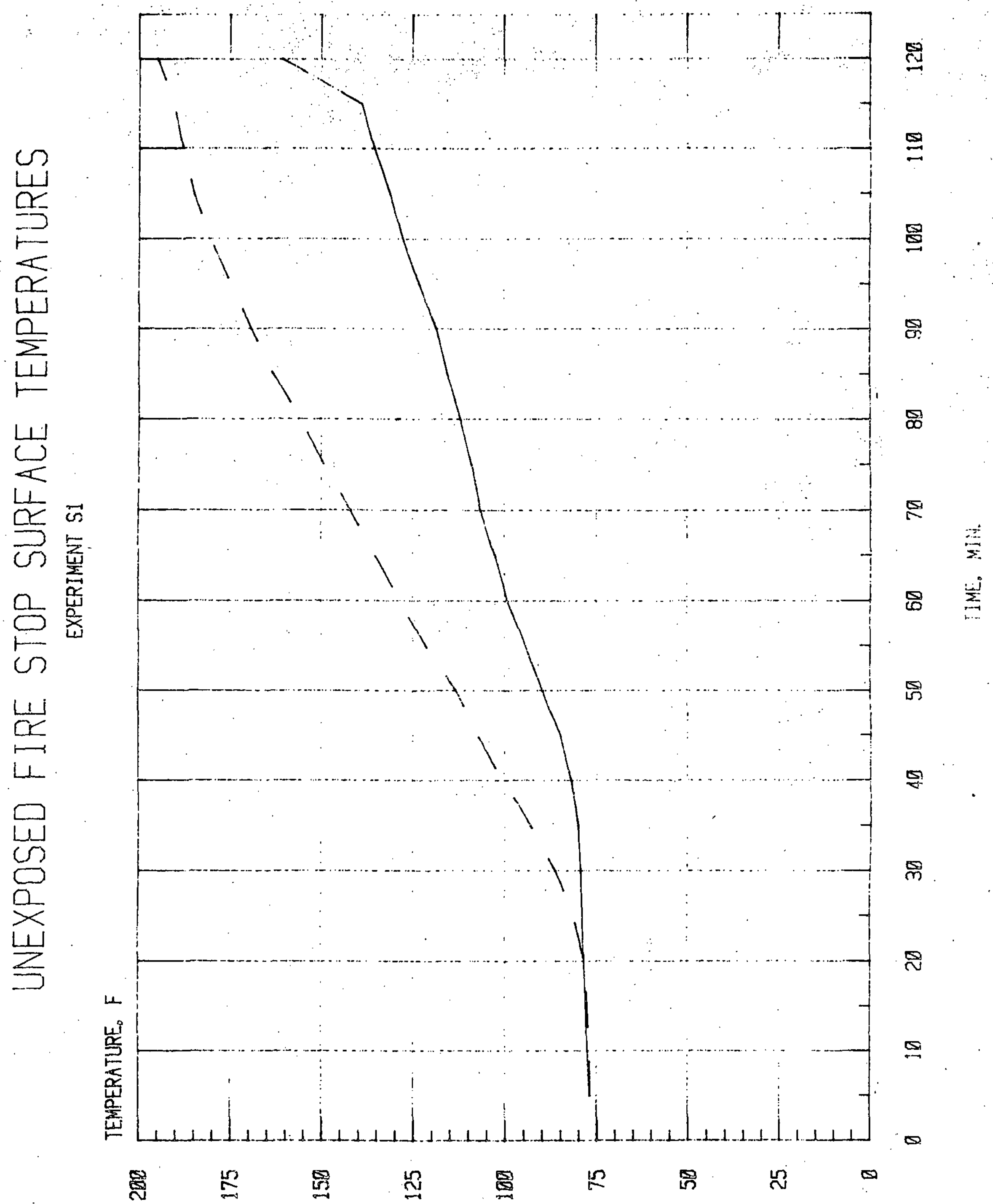


Figure C60 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B20

Figure C61 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B21

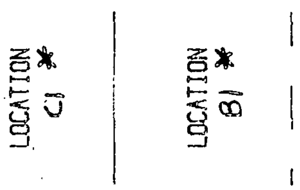
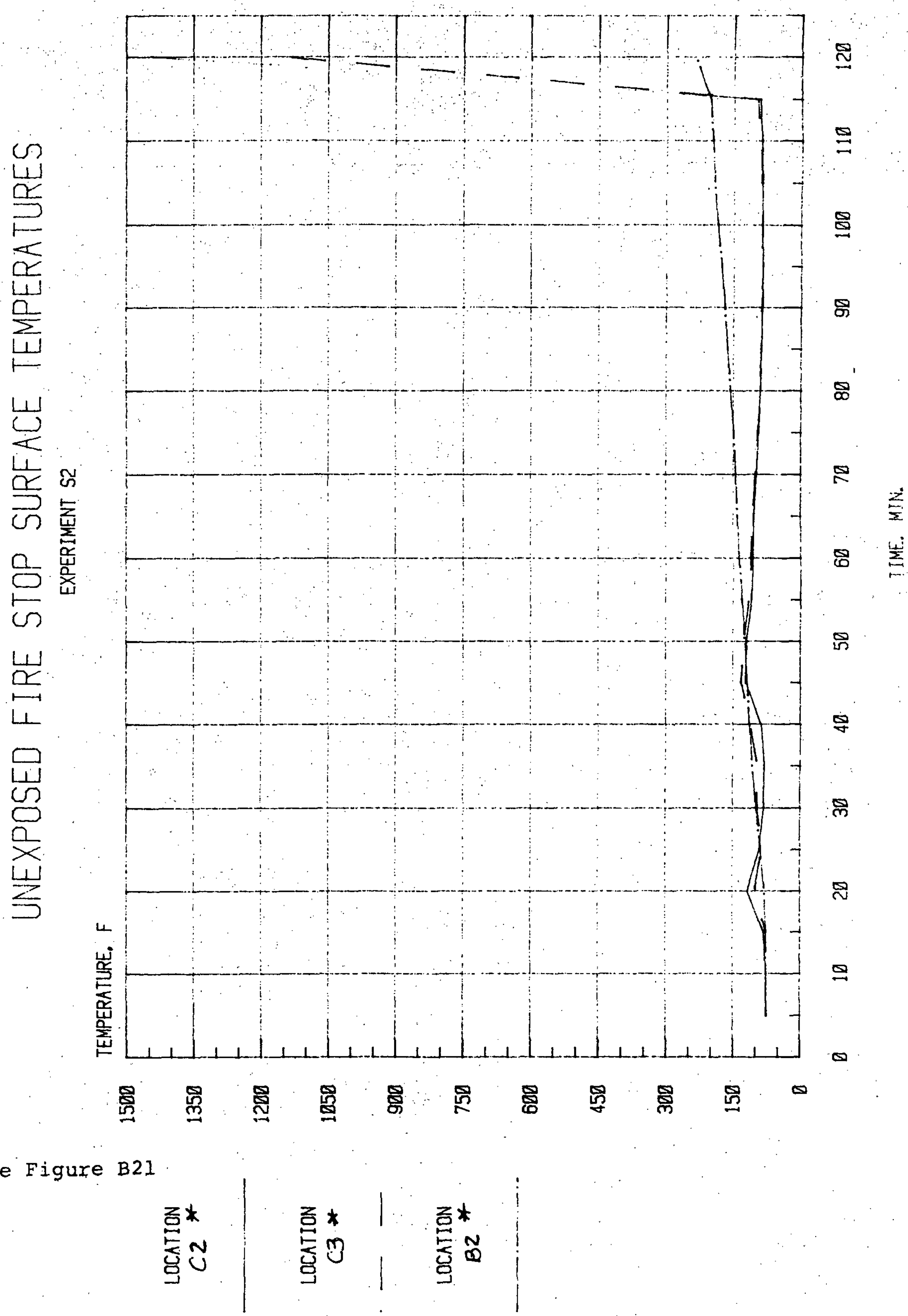
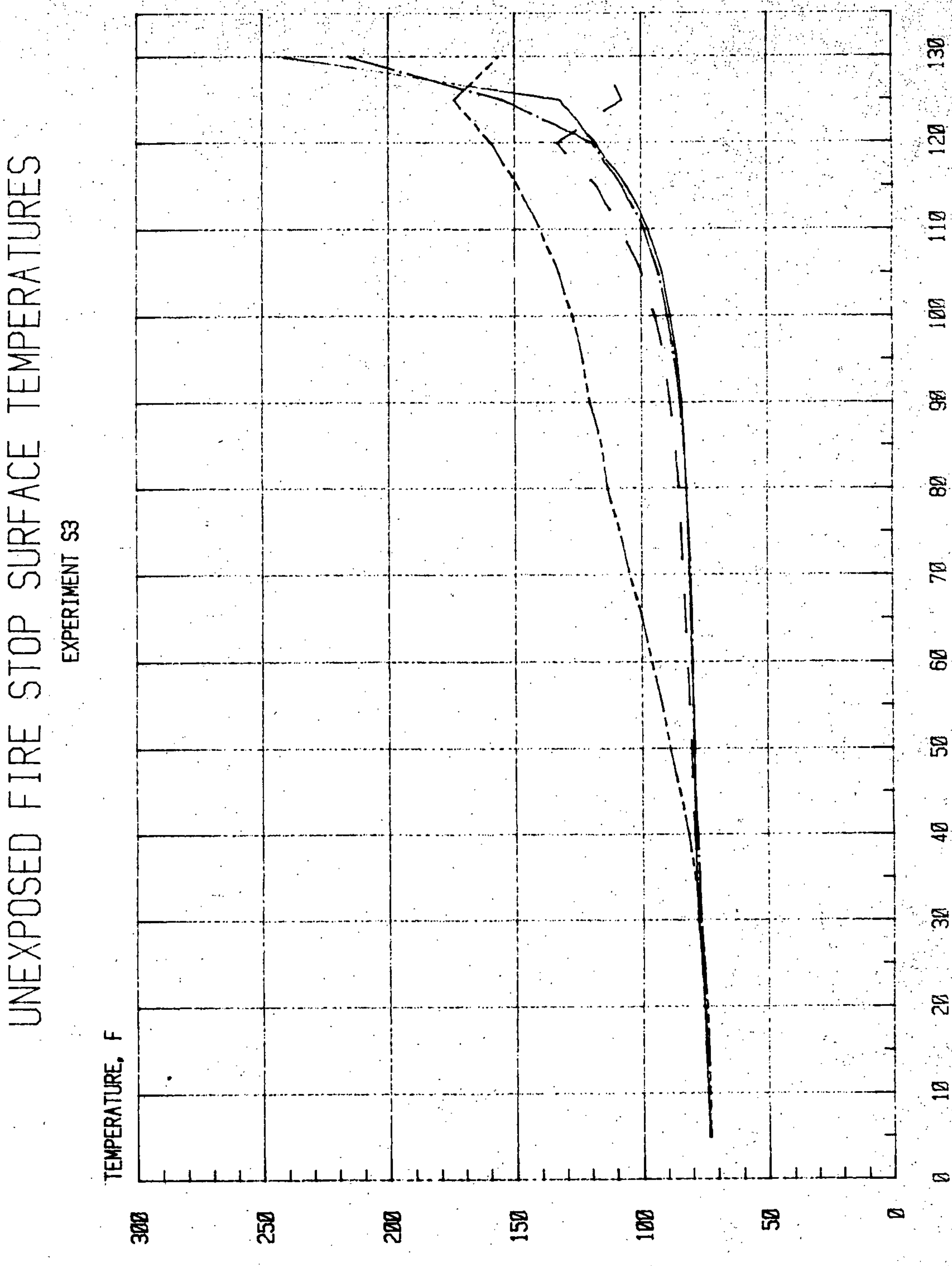


Figure C62 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B21

Figure C63 - Unexposed Surface Temperatures Of Fire Stop Material



* See Figure B21

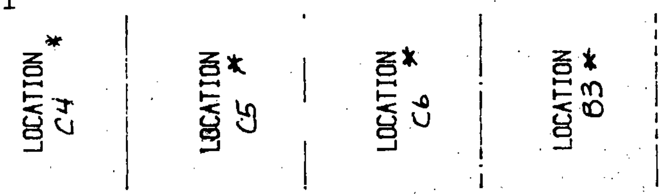
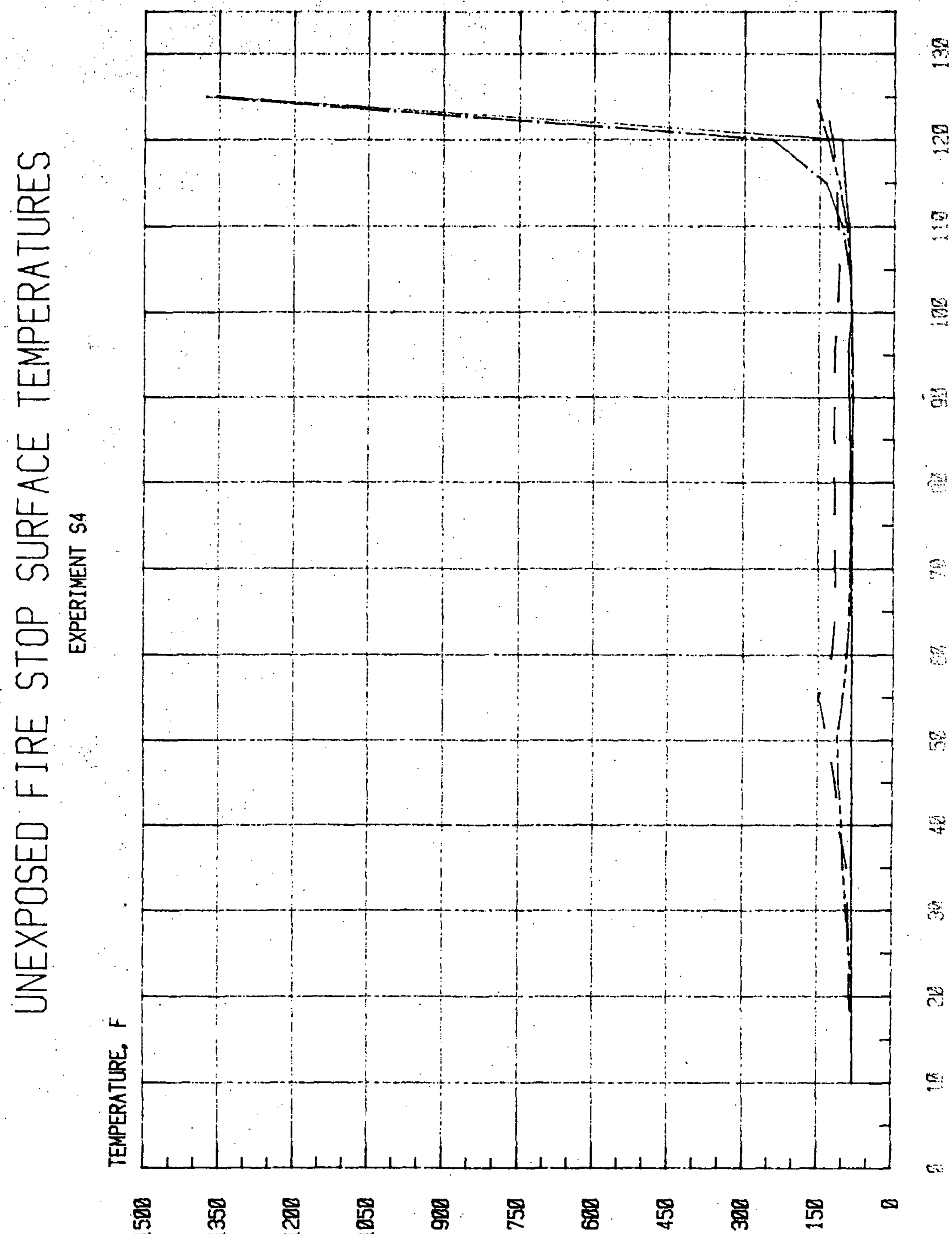


Figure C64 - Unexposed Surface Temperatures of Fire Stop Material



* See Figure B21

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LOCATION C8 *

LOCATION C9 *

LOCATION B4 *

Figure C65 - Unexposed Surface Temperatures of Fire Stop Material

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