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FIRE PERFORMANCE
OF
FIRE RESISTIVE CONCRETE SLAB ASSEMBLIES
WITH PVC RACEWAYS INSTALLED

A Report To:

CARLON
25701 Science Park Drive
Cleveland, Ohio 44122

Attn: Mr. Charles Forsberg

By

IFT Technical Services, Inc.
2550 Ninth St., #112
Berkeley, CA 94710

Ref: IFT 86-38D

September 1990

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1.0 INTRODUCTION

Poured-in-place concrete slabs are routinely utilized as fire resistive walls and floor/ceiling assemblies. However, the effect of including PVC-ENT (electrical non-metallic tubing) on the fire resistance of these assemblies has not been experimentally evaluated.

For this reason, IFT conducted a research program, including both ASTM E-119 fire testing and mechanical engineering analyses, to develop this needed information.

The objective of this report is to review both the theoretical bases for the safe use of PVC raceways in concrete slabs and to present fire test results.

2.0 DISCUSSION

The use of concrete in fire resistive walls and floor/ceiling assemblies is well accepted and the fire endurance of such assemblies has been verified many times by exposures according to the ASTM E-119 time-temperature curve. In such exposures, test assemblies are subjected to standard conditions which increase from ambient temperatures to 1850° F at two hours and 2000° F after four hours.

Specified failure criteria, upon which performance of these assemblies are judged, include:

- loss of mechanical integrity,
- excessive single-point temperature rise on the back (unexposed) face of the assembly,
- excessive average temperature rise, as measured by multiple thermocouples on the unexposed face,
- passage of hot gases and/or flame capable of igniting combustible materials located on the unexposed side.

With few exceptions, fire testing on concrete slabs has been conducted with assemblies which did not include extraneous cast-in-place materials such as conduit, electrical tubing, pipes, etc. Rather, available fire endurance test results, (ratings for generic fire resistive assemblies, UL listed assemblies and Model Code-Research Committee recommended proprietary floor slab assemblies) specifically exclude use of pipe, tube or conduit with such assemblies without supporting test data. To our knowledge, the impact of occasional runs of

electrical conduit or tubing (whether plastic or metal) has never been reviewed or examined experimentally.

2.1 Structural Review

Since PVC raceways represent a new class of materials, verification that their use will not reduce the expected structural fire performance of concrete slabs is considered here.

The resistance of a concrete slab to weight loading is primarily dependent on reinforcing steel (rebar, mesh, or corrugated sheet) installed in or under the slab. Concrete slabs are designed so that tensile bending stresses are picked up by the steel and compressive bending stresses by concrete. Although tensile and compressive loads producing the bending stresses are equal, there is typically an order of magnitude more concrete available to carry load than steel due to requirements in addition to strength such as fire resistance and the need for a continuous membrane. The result is that the steel is structurally the more stressed component of the two. Installing a PVC raceway in the slab has no effect on the steel if such a raceway meets typical code requirements that its diameter is less than 1/3 slab thickness and installation is near the center of the slab where bending stresses are small or zero. Thus, installing a 1" (or thinner) PVC raceway will not reduce the structural integrity of the 4-1/2" thick slab.

In terms of possible impact of PVC raceway installation on strength properties of slabs which are related to thermal effects, the failure temperatures in the ASTM E-119 test are 325° Fahrenheit plus ambient. Since concrete does not show thermally related loss of strength basically until it reaches substantially higher

temperatures, thermal degradation of strength properties of the concrete due to heating associated with any possible impact of PVC raceway use in a foreseeable fire situation will not occur.

2.2 Thermal Properties

For a slab which includes PVC raceway, the impact of the thermal conductivity of the PVC itself and the air within the raceway on the assembly need to be considered. In both cases, (air and unplasticized PVC), thermal conductivity is lower than that of concrete, i.e., they are better insulators. Consequently, inclusion of the raceway (which includes the air within its interior boundaries) will not degrade the thermal behavior of the slab, and in fact, should improve it locally.

With regard to conduction of heat along PVC raceway, given its low thermal conductivity, it will again be less conductive than the concrete itself. In fact, PVC raceway will not conduct heat to the unexposed face nearly as readily as metallic raceway which is commonly used and is far more conductive than concrete.

Finally, what about the possibility of fire spread along PVC raceway in situations where the raceway installation originates on one side of a slab and transits through it after an offset? Will fire be communicated along its length? Based on theory, we anticipate that such fire spread will not occur because, during its thermal decomposition, PVC will have insufficient oxygen to burn due to the nature of the pyrolyzate gases generated as it decomposes. Also, the level of thermal radiation present within the slab is insufficient to sustain ignition.

Rather, the thermal degradation which occurs leads to development of a "char" in the slab.

In light of the preceding theoretical information, it should be anticipated that PVC raceway would not degrade the performance of concrete test slabs. Experimental verification of these items follows.

3.0 EXPERIMENTAL

The experiments conducted involved fabrication of two 6' by 8' concrete slabs within which runs of Carlon electrical non-metallic tubing (ENT) 1" in diameter were placed. This tubing is manufactured from unplasticized PVC resin and is UL labelled. The first slab was of normal density (145 pcf) concrete, 4-1/2" thick. The second slab was cast using a proprietary metal decking system (VERCO W2 FORMLOK, 20 Ga. decking) with lightweight (110 pcf) concrete. Due to the fluted design of the decking, concrete thickness ranged from 3-1/4" to 5-1/4".

Various configurations of ENT installation were tested according to the ASTM E-119 time/temperature curve. These included "U" shapes upward and downward, and a "dog-leg" offset from the fire side to the unexposed sides. These configurations allowed observation of possible high back-face temperatures in areas where tubing (a.) ran but did not exit the slab, (b.) originated and terminated on the unexposed side or (c.) ran from the fire side to the unexposed face. In this way, the impact of directly exposing the raceway to a fully developed fire which could then spread along its length, (if this were to occur) was also evaluated in two ways. Locations where ENT exited the unexposed side of the slab were instrumented with thermocouples per ASTM E-814 to ensure that high temperatures did not occur there as result of either fire spread or thermal conduction. [The experimental set-up for the test specimens along with thermocouple locations are shown in Figures #1 - 4. Photographs (#1 - 13) are also appended which show preparation and testing of samples.]

Time temperature curves (in addition to those in the test accompanying lab reports) were prepared (Figures 3.1 & 3.2) which demonstrate that temperatures on the unexposed slab face directly over the horizontal runs of ENT were below those of control areas of the slab in various stages of the tests. This is an expression of the thermal conductivity of the ENT installation being lower than the concrete as described earlier.

With regard to ENT exit locations, the PVC-ENT at no time approached temperatures sufficient for either combustion of surrounding material or auto-ignition to occur at those points.

Full copies of test reports prepared by the CABO approved testing agency are attached.

Figure 3.1 Unexposed Face Temperatures: Normal Weight Slab

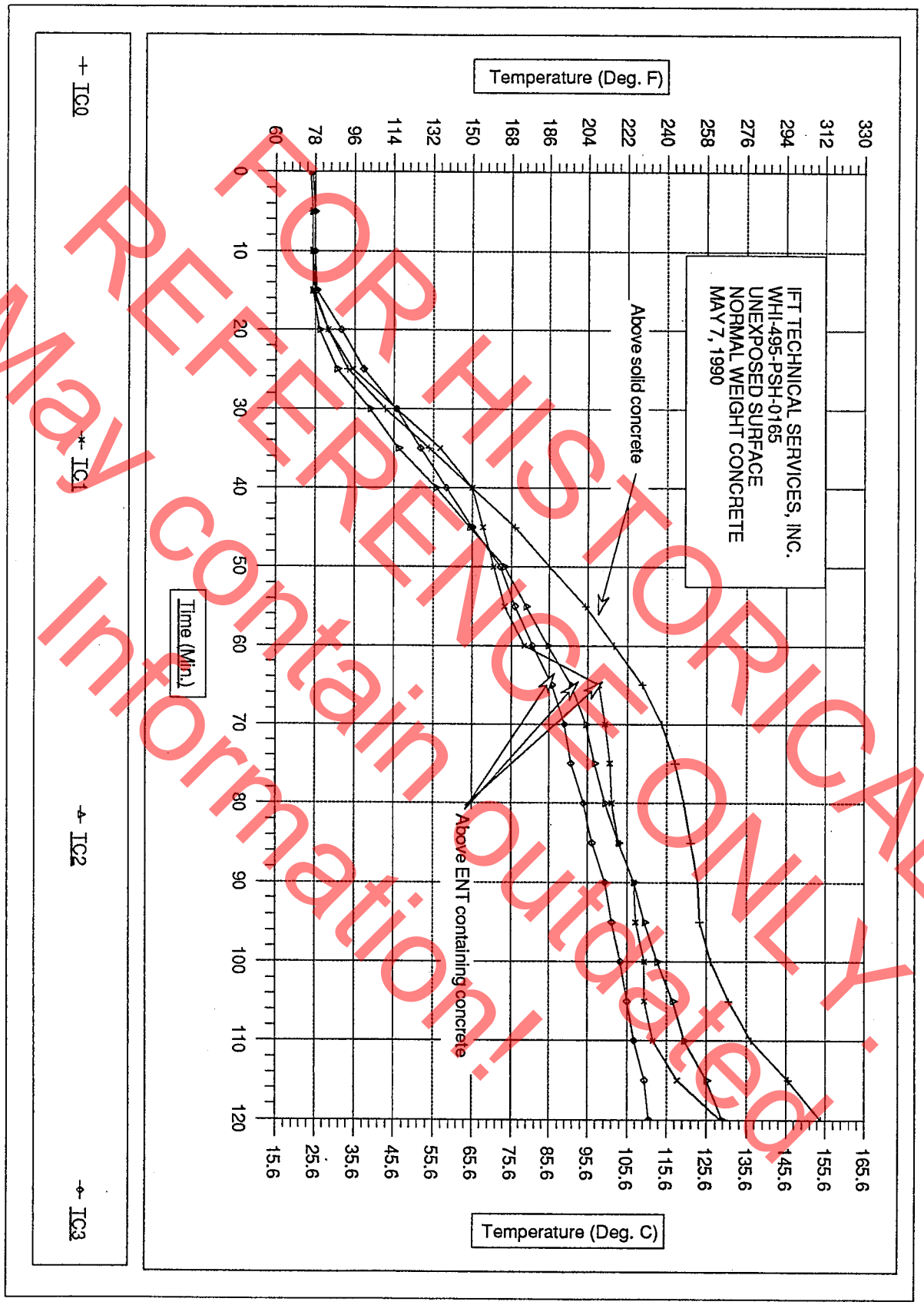
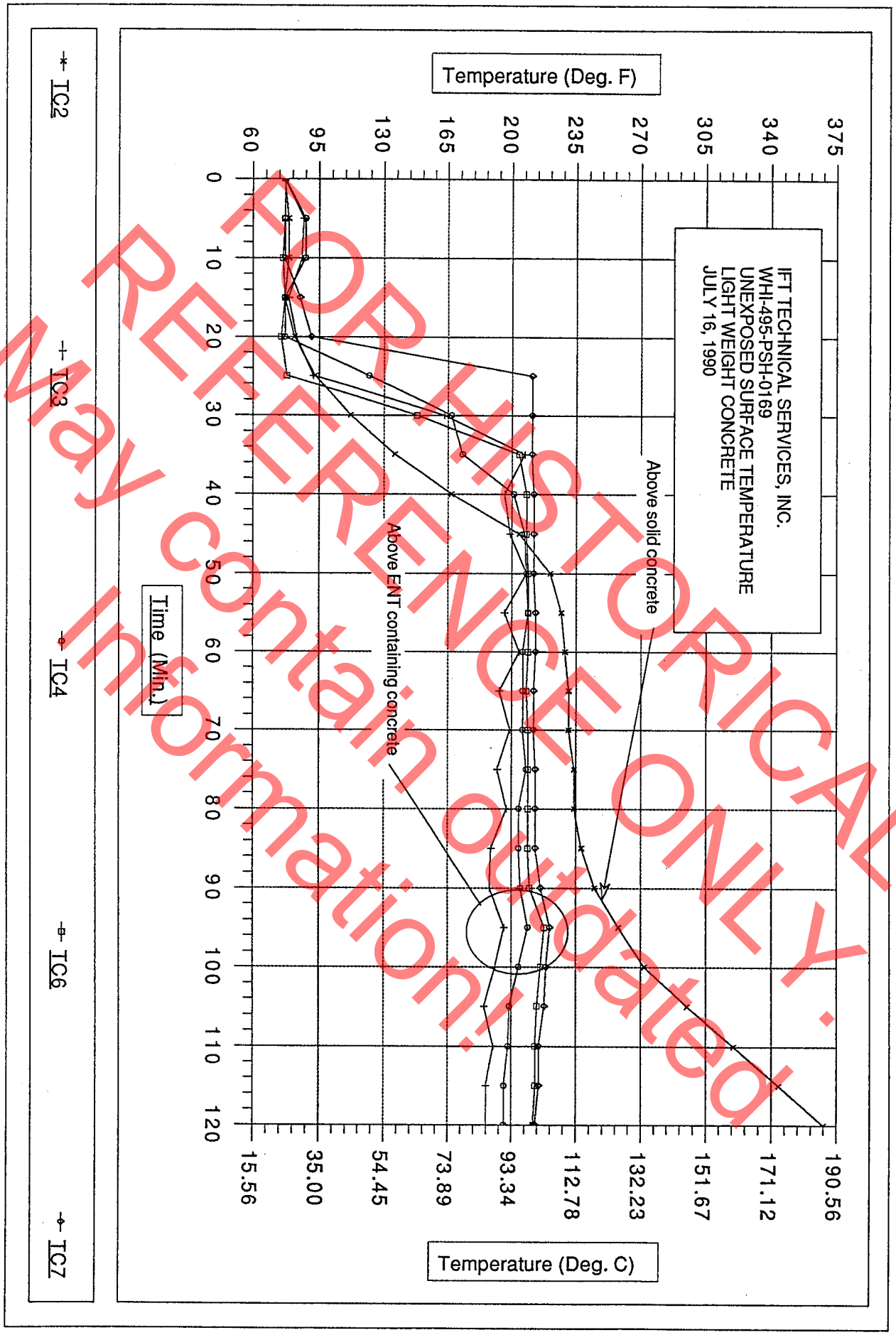


Figure 3.2 Unexposed Face Temperatures: Light Weight Slab



4.0 CONCLUSION

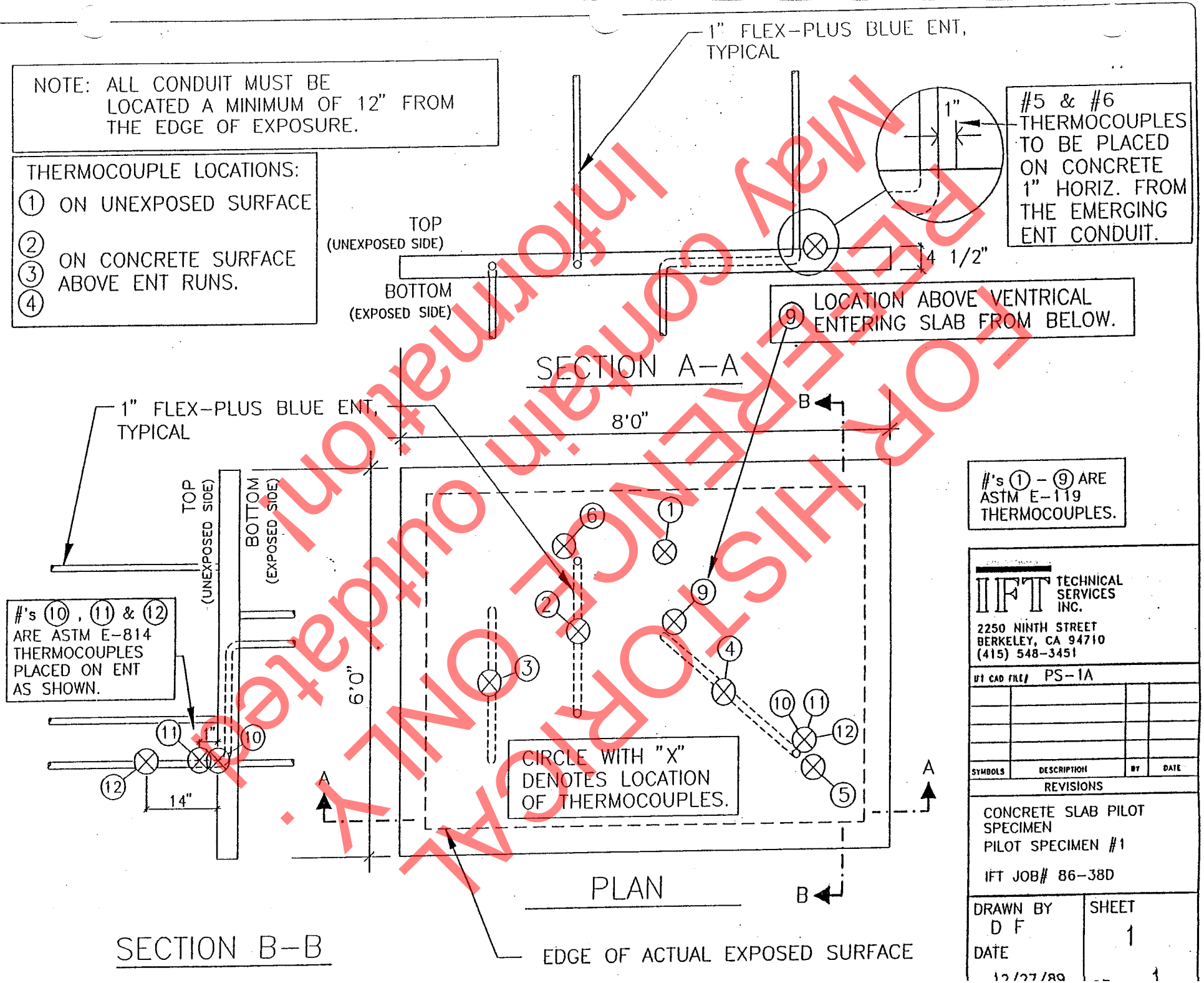
The fire performance two-hour concrete floor slabs which contained PVC electrical non-metallic tubing raceway materials was not compromised due to the presence of these materials based on test criteria found in the E-119 and E-814 standards.

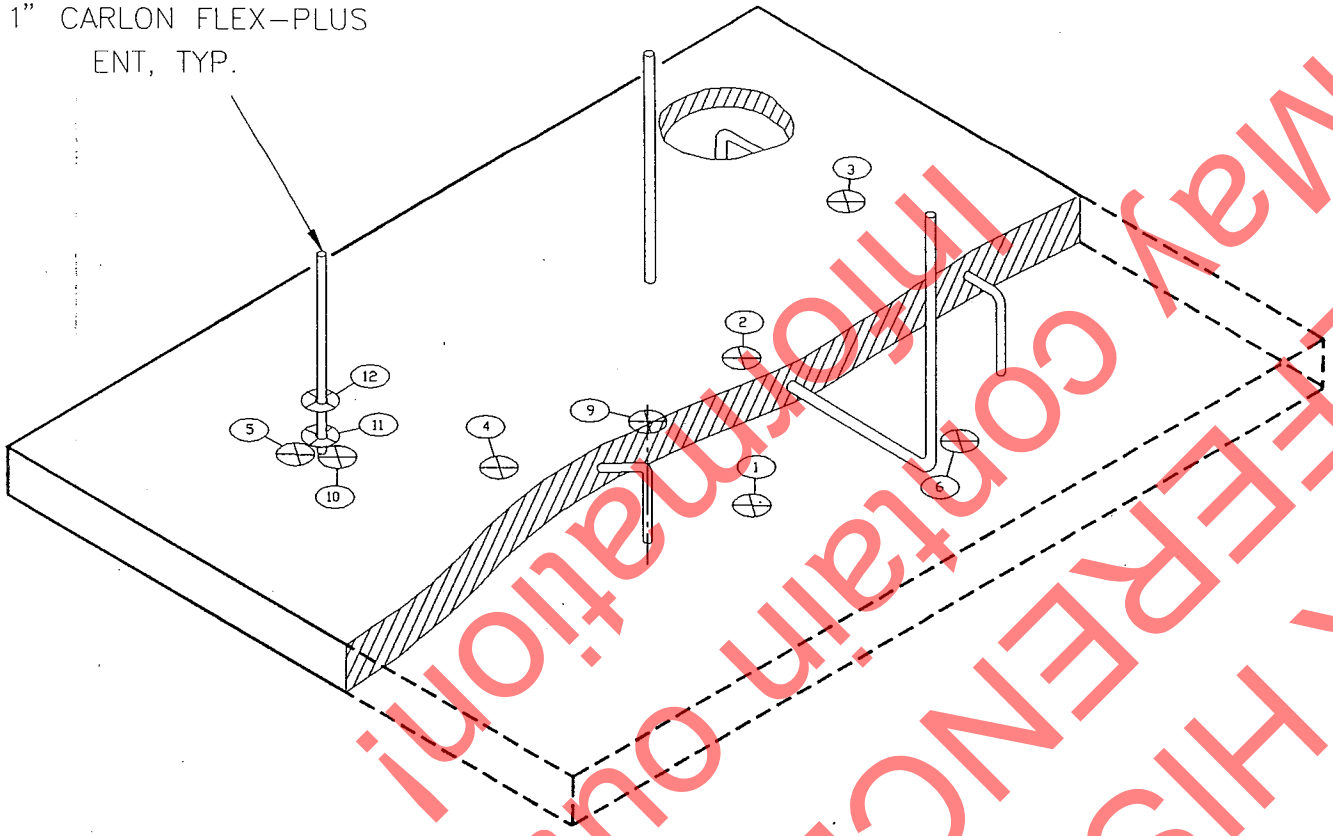
The tests were conducted at the Warnock-Hersey International fire test facility, (Pittsburg, CA) which is an approved independent third-party testing laboratory, accredited by CABO, ICBO, BOCA and SBCCI and a number of cities in the United States. IFT Technical Services, Inc. of Berkeley, California directed the test program. The Warnock-Hersey test reports are attached.

5.0 APPENDICES

Appendix I

Orthographic and Isometric Views of Normal Weight Test Assembly and Specimen Photographs





THERMOCOUPLE LOCATIONS:

(1) ON UNEXPOSED SURFACE.

(2) (3) (4) ON CONCRETE SURFACE ABOVE ENT RUNS.

(5) (6) PLACED ON CONCRETE 1" HORIZONTALLY FROM EMERGING ENT.

(9) ABOVE VERTICAL RUN ENTERING SLAB FROM BELOW.

(10) AT ENT ON SURFACE.

(11) 1" ABOVE SLAB ON ENT.

(12) 14" ABOVE SLAB ON ENT.

CONCRETE SLAB PILOT SPECIMEN - PILOT SPECIMEN #1

NOTE: 1) ALL CONDUIT MUST BE LOCATED A MINIMUM OF 12" FROM THE EDGE OF EXPOSURE
2) CIRCLE WITH "X" DENOTES LOCATION OF THERMOCOUPLE
3) ASTM E-119 6" PADS ARE USED FOR THERMOCOUPLES #1-#9
4) ASTM E-814 2" PADS ARE USED FOR THERMOCOUPLES #10-#12

IFT TECHNICAL SERVICES INC.
2250 NINTH STREET
BERKELEY, CA 94710
(415) 548-3451

SYMBOLS	DESCRIPTION	BY	DATE

REVISIONS

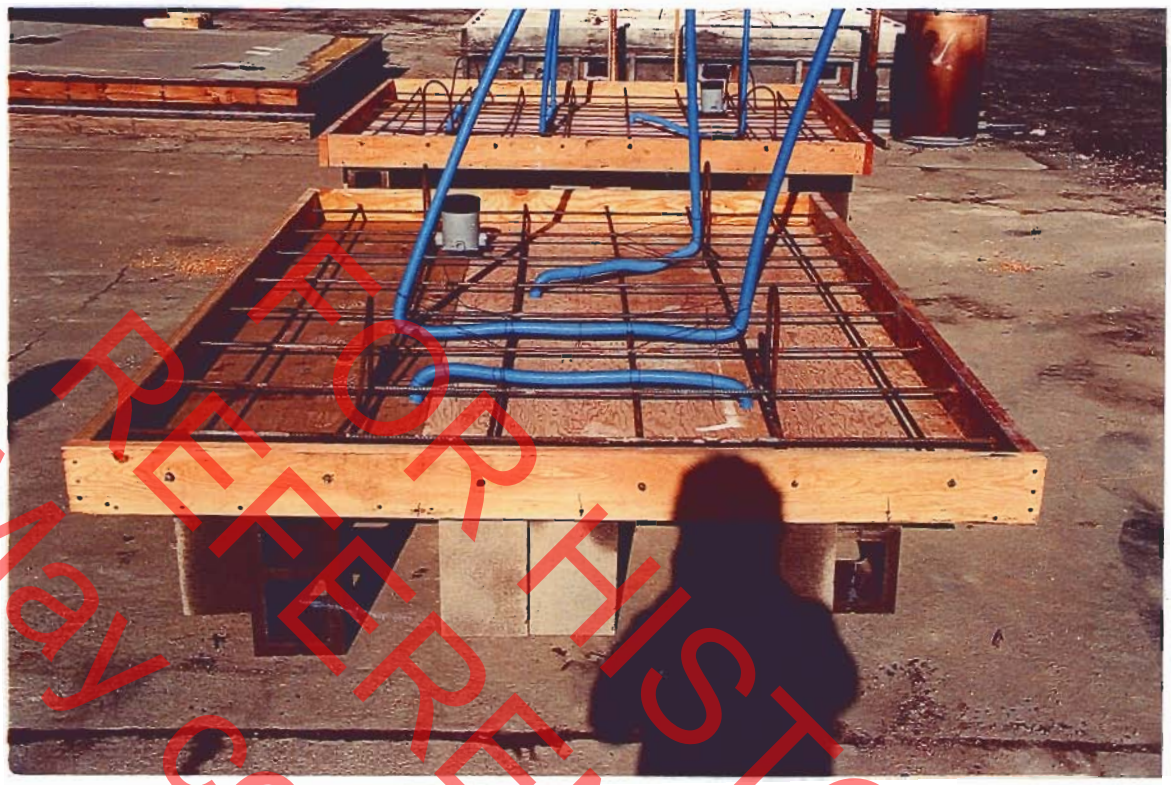
CARLON

TEST NO. WHI-495-PSH-0165
TEST DATE 5-07-90
DWG NO. PS1A-ISO

DRAWN BY	SHEET
D.REID	
DATED 8-07-90	1 OF 1

1. Rebar placed in form.

2. ENT installed.

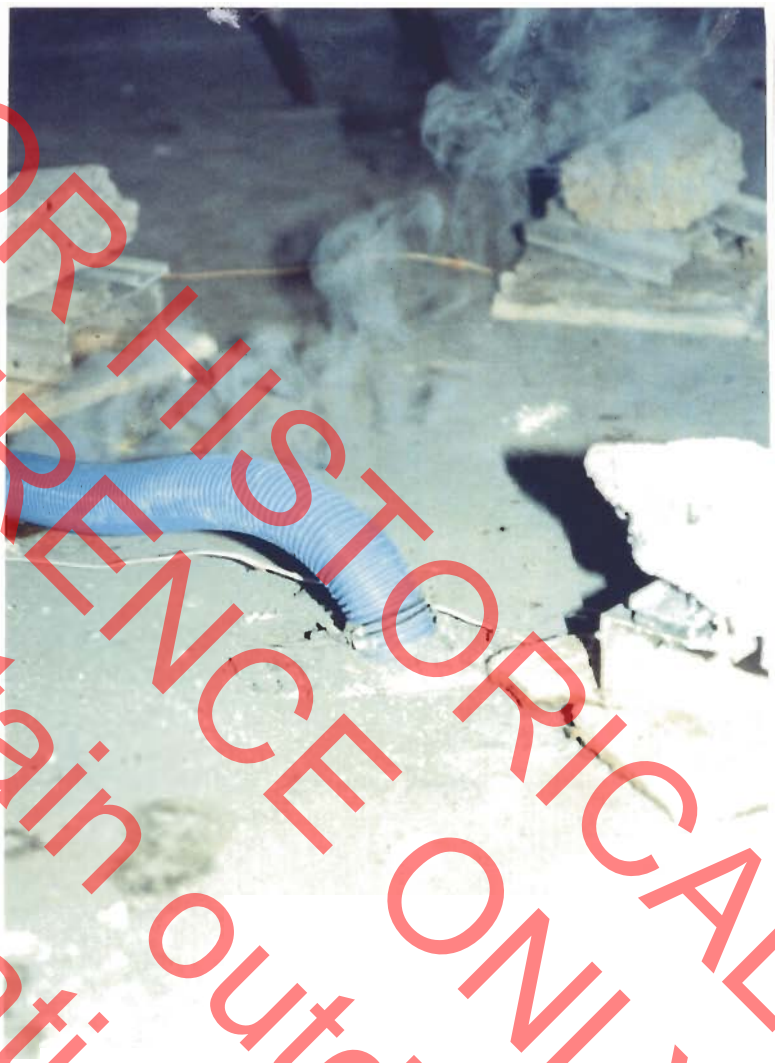


3. Ready for concrete application.

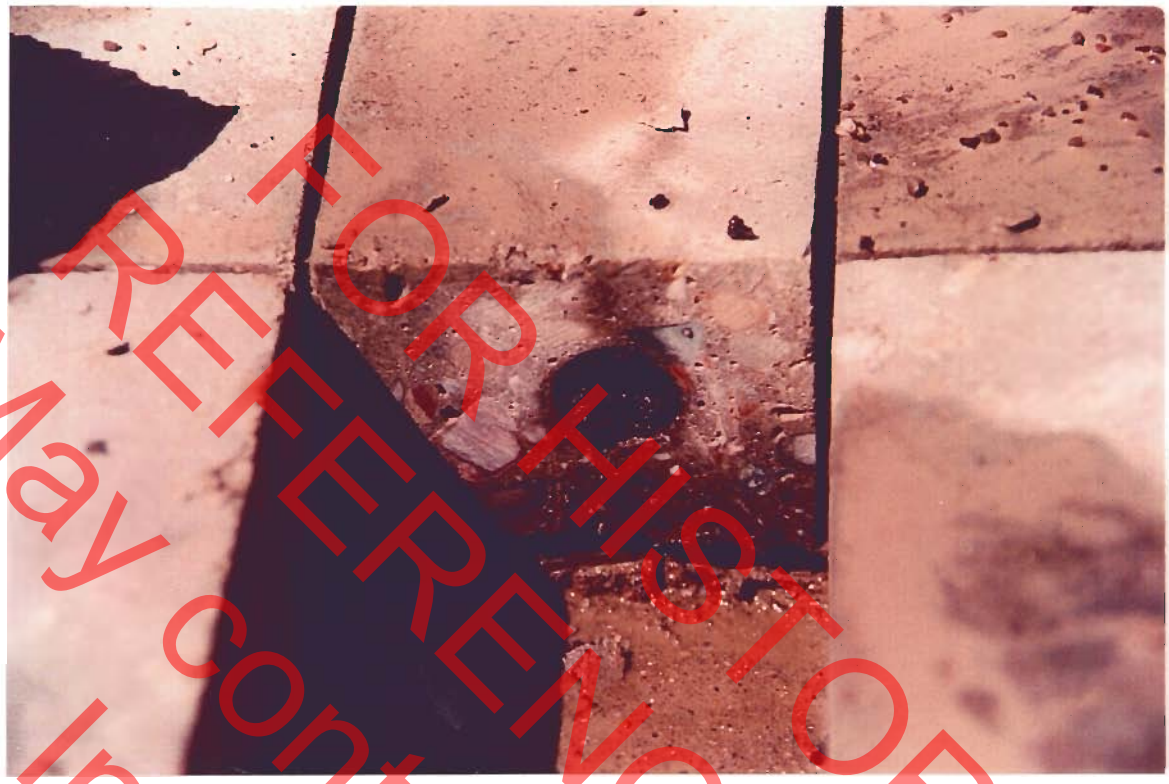
4. ENT on exposed (furnace) side of slab prior to test.

5. Thermocouple instrumentation, unexposed side.

6. Ready to test. All thermocouples in place.



7. ENT during test.



8. Post Test. Cross-section through ENT. Pyrolyzed residue of ENT in center.

Appendix II

Orthographic and Isometric Views of Light Weight Assembly using Proprietary Metal Pan System and Photographs

E-814 THERMOCOUPLE LOCATIONS:

(12) AT ENT ON SLAB SURFACE.

(13) 1" ABOVE ABOVE SLAB ON ENT.

(14) 14" ABOVE SLAB ON ENT.

NOTES:
1) ALL CONDUIT & BOXES MUST BE LOCATED A MINIMUM OF 12" FROM THE EDGE OF EXPOSURE.
2) CIRCLE WITH "X" DENOTES LOCATION OF THERMOCOUPLE.
3) ASTM E-119 6" PADS ARE USED FOR THERMOCOUPLES #1 THROUGH #8.
4) ASTM E-814 2" PADS ARE USED FOR THERMOCOUPLES #12 THROUGH #14.

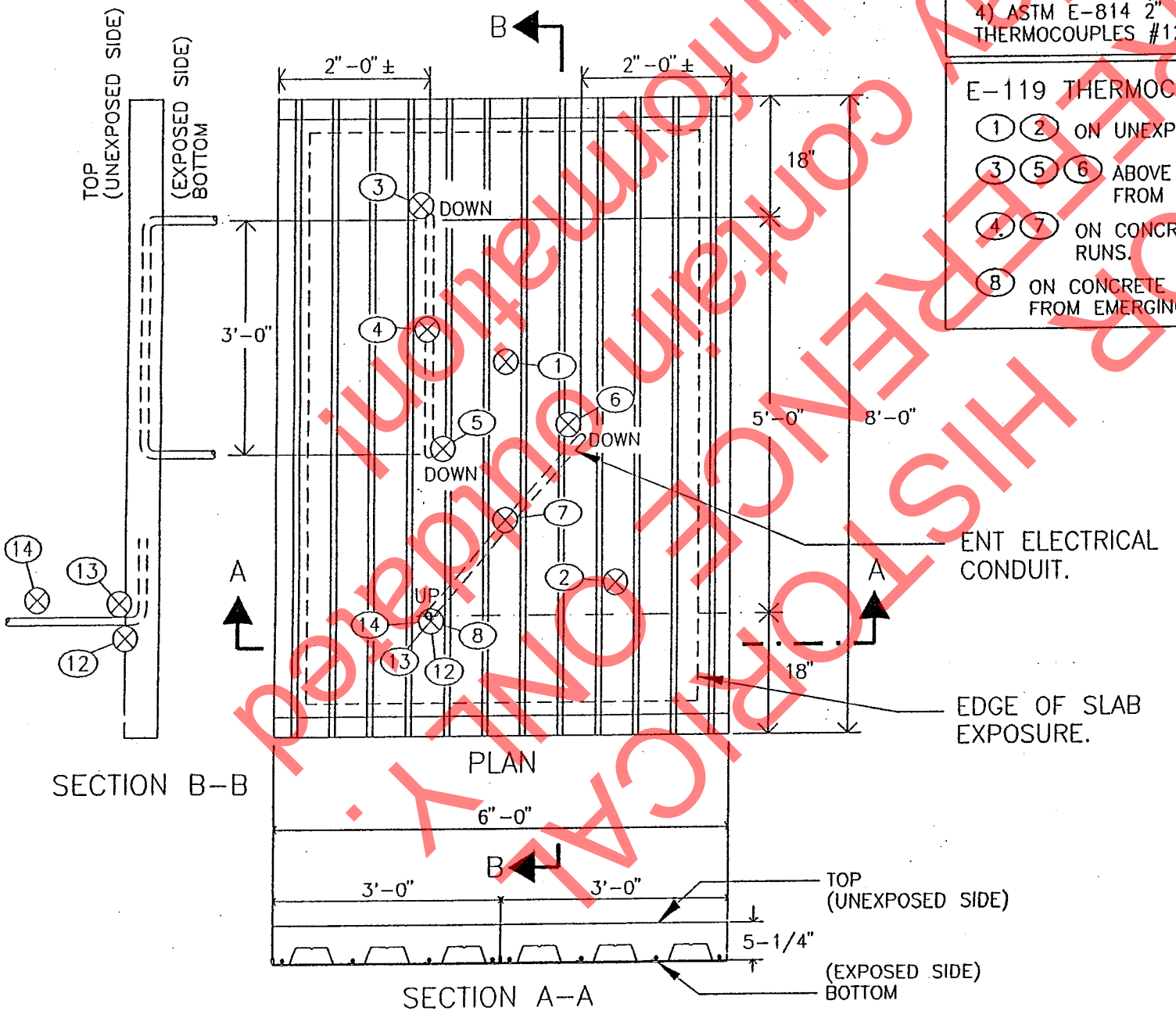
E-119 THERMOCOUPLE LOCATIONS:

(1) (2) ON UNEXPOSED SURFACE

(3) (5) (6) ABOVE VENTRICAL ENTERING SLAB FROM BELOW.

(4) (7) ON CONCRETE SURFACE ABOVE ENT RUNS.

(8) ON CONCRETE SURFACE 1" HORIZONTALLY FROM EMERGING ENT CONDUIT.



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BERKELEY, CA 94710
(415) 548-3451

IFT CAD FILE# PS-3A

SYMBOLS	DESCRIPTION	BY	DATE
	REVISIONS		

CONCRETE SLAB PILOT SPECIMEN
PILOT SPECIMEN #3A
IFT JOB# 86-38D

DRAWN BY D F
DATE 4/13/88

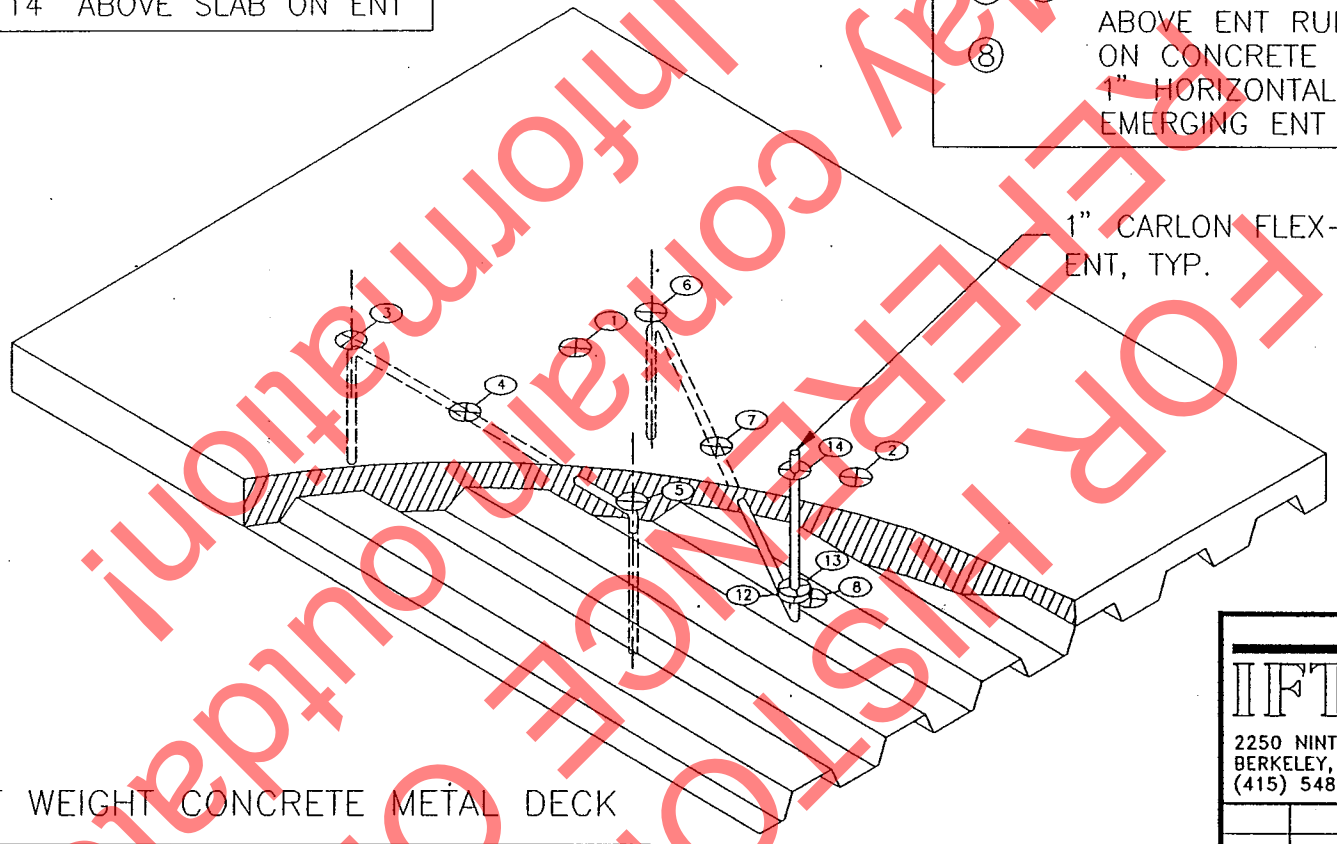
SHEET 1

E-814 THERMOCOUPLE LOCATIONS:

(12) AT ENT ON SLAB SURFACE
(13) 1" ABOVE SLAB ON ENT
(14) 14" ABOVE SLAB ON ENT

E-119 THERMOCOUPLE LOCATIONS

(1) (2) ON EXPOSED SURFACE..
(3) (5) (6) ABOVE VERTICAL RUN ENTERING SLAB FROM BELOW.
(4) (7) ON CONCRETE SURFACE ABOVE ENT RUNS.
(8) ON CONCRETE SURFACE 1" HORIZONTALLY FROM EMERGING ENT CONDUIT.



ENT IN LIGHT WEIGHT CONCRETE METAL DECK

NOTES:
1) ALL CONDUIT MUST BE LOCATED A MINIMUM OF 12" FROM THE EDGE OF EXPOSURE.
2) CIRCLE WITH "X" DENOTES LOCATION OF THERMOCOUPLE.
3) ASTM E-119 6" PADS ARE USED FOR THERMOCOUPLES #1 THROUGH #8.
4) ASTM E-814 2" PADS ARE USED FOR THERMOCOUPLES #12 THROUGH #14.

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SYMBOLS	DESCRIPTION	BY	DATE

REVISIONS

CARLON

TEST NO. WHI-495-PSH-0169
TEST DATE 7-16-90
DWG. NO. PS3A-ISO

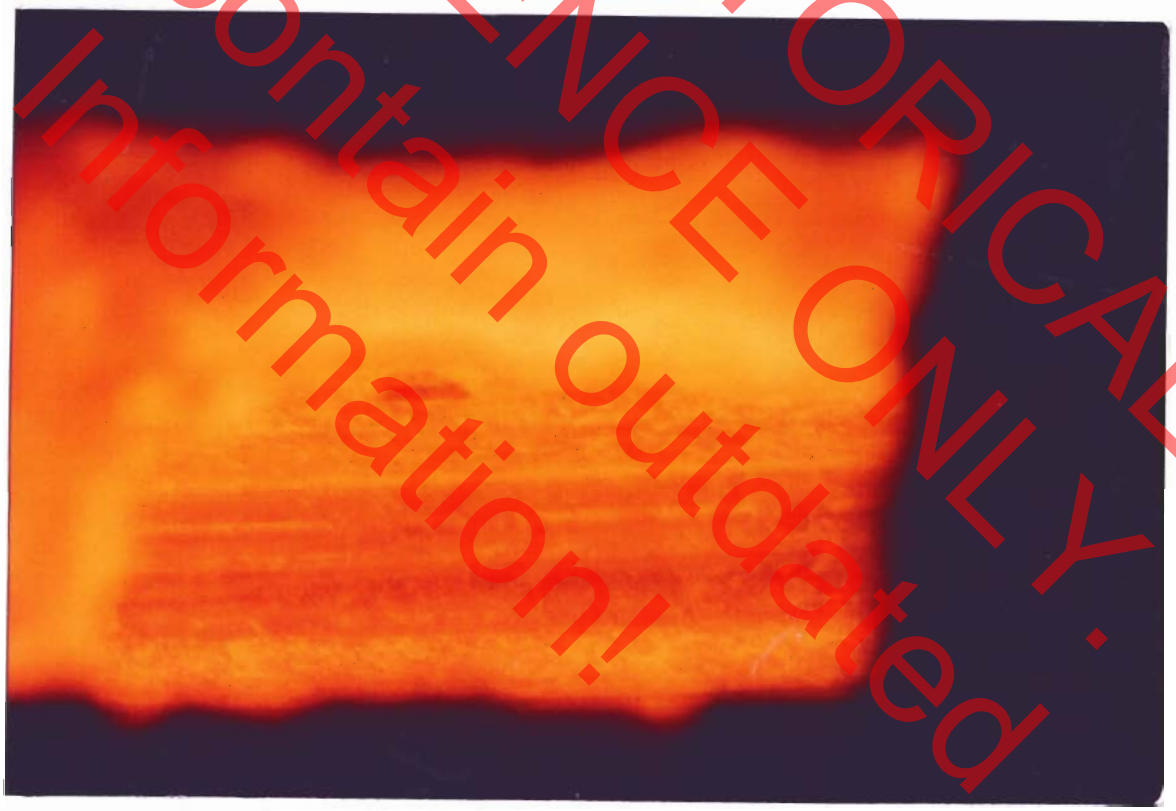
DRAWN BY	SHEET
D.REID	1
DATED 8-25-90	OF 1

Appendix II Photographs: Lightweight concrete slab prepared on metal pan system

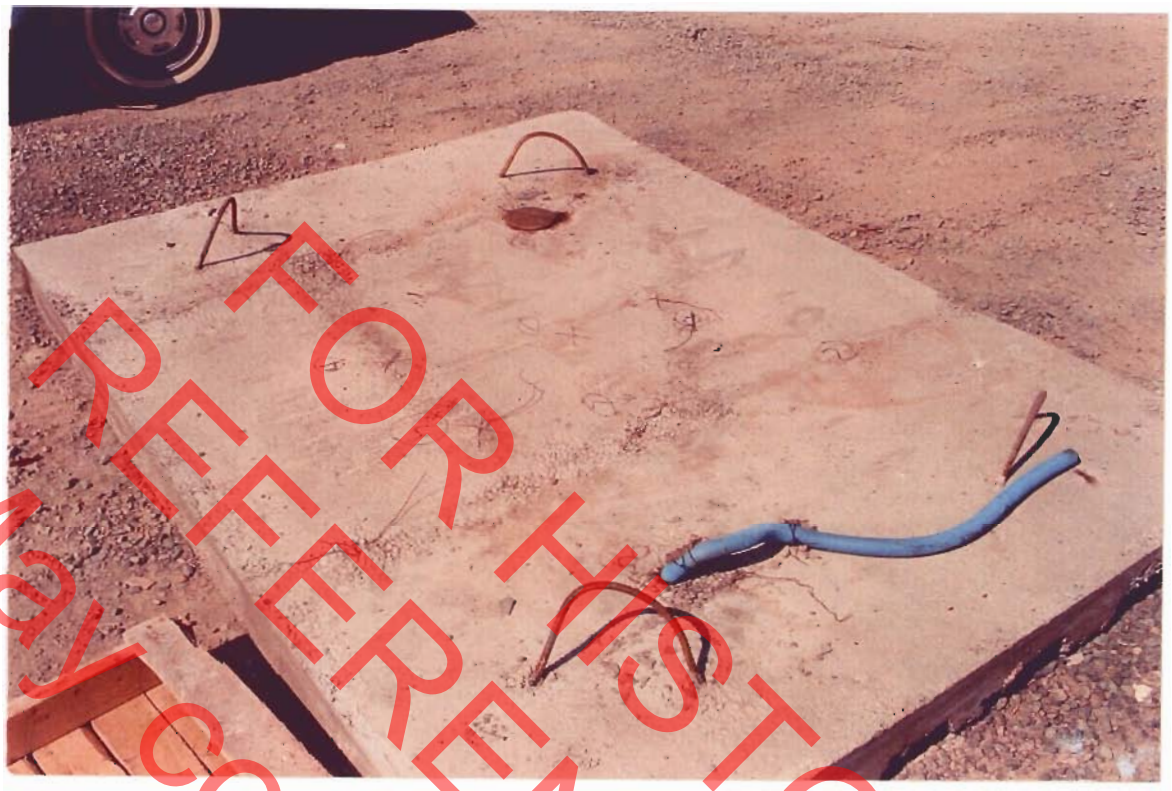
1. ENT installed ready for concrete application.

2. As per photo #1.

3. Lightweight slab test instrumented with thermocouples on furnace.



4. Furnace view of decking.



5. Post test.

Appendix III

Warnock Hersey Report

Two-Hour Fire Performance

of

Fire Resistive Concrete Slab Assemblies

with PVC Raceways installed using

Normal Weight Slab

Warnock Hersey

1101 LOVERIDGE ROAD, PITTSBURG, CA 94565
TEL. (415) 432-7344 FAX 415-432-3576

REPORT OF THE PILOT SCALE FIRE ENDURANCE TEST OF AN UNRESTRAINED 6' BY 8' BY 4-1/2" THICK, REINFORCED CONCRETE SLAB WITHOUT AN APPLIED LOAD, AND WITH 1" DIAMETER, PVC, FLEXIBLE, ENT CONDUIT RUNS

CLIENT

IFT TECHNICAL SERVICES INC.
2250 NINTH STREET NORTH
SUITE 112
BERKELEY, CALIFORNIA 94710

REPORTED BY

WARNOCK HERSEY INTERNATIONAL, INC.
1101 LOVERIDGE ROAD
PITTSBURG, CALIFORNIA 94565

FILE NUMBER: WHI-495-PSH-0165
WORK ORDER NUMBER: 50611-C7-030320
DATE TESTED: MAY 7, 1990

TABLE OF CONTENTS PAGES

INTRODUCTION

On May 7, 1990, the Pittsburg, California, fire testing laboratory of Warnock Hersey International, Inc., conducted a pilot scale horizontal, 122 minute fire endurance test. The test assembly consisted of a 6' by 8' by 4-1/2" thick, reinforced concrete slab having 3 horizontal runs of Carlon 1" diameter, flexible PVC, ENT conduit within the slab. One of the runs emerged to the exposed face at both ends. A second run emerged to the unexposed face at both ends. A third run emerged to opposite faces at the ends. Horizontal runs of conduit were wire tied to the #4 rebar before the concrete was poured and positioned to be covered above or below with a minimum of 1" thick concrete. After conditioning on the furnace to dry the slab, the test was conducted without an applied load in accordance with the furnace temperature and unexposed surface temperature rise requirements of ASTM E 119 and ASTM E 814. The test assembly was unrestrained. A hose stream test was not conducted. The test assembly also contained a confidential RESERVED construction involving unexposed surface thermocouples #7, 8 and 13, documented in a separate report.

The pilot scale test assembly reported herein met the unexposed surface temperature rise requirements of ASTM E 119 for a 2 hour rating and also developed a 120 minute 'F' rating and a 120 minute 'T' rating (without hose stream) at a negative furnace pressure of 0.01" water per ASTM E 814.

The test was conducted for IFT Technical Services Inc., of Berkeley, California.

TEST MATERIALS

One inch inside diameter, flexible PVC, ENT conduit, manufactured by CARLON, UL labeled as electric, non-metallic tubing. Issue #958, E73317

1/2" diameter steel reinforcement rods (#4 Rebar).

0.060" diameter steel tie wire.

3000 psi, ready mixed, normal weight concrete.

TEST ASSEMBLY CONSTRUCTION
(Refer to Figures #1 through #3)

Wood forms were constructed for the slab as shown in Figure #1. Number 4 Rebar was placed 12" o.c., in both directions at mid-slab thickness of the form. The conduit runs were placed as shown in Figure #2 and wire tied to the #4 rebar at slab entry points and mid-run locations. The conduit was placed to extend 12" from the exposed surface of the slab into the furnace and 36 inches from the unexposed surface of the slab.

Ready mixed concrete was poured, making sure that the concrete was 1" minimum thickness above and below the conduit. After troweling, the slab was cured for 28 days. Wood forms were then removed. Fiberglass insulation was placed around the conduit penetrations on the exposed surface for protection of the conduit while the slab was dried on the test furnace. The assembly was dried at a furnace temperature of 170 degrees Fahrenheit for a period of seven days. The temporary insulation was removed from the conduit on the exposed surface. After cooling, this completed construction and conditioning of the test assembly.

At the request of the client, the unexposed surface of the assembly was fitted with thermocouples as shown in Figure #3. Thermocouples #1 through #6 and #9 used 6" square pads conforming to the requirements of ASTM E 119. Thermocouples #10 through #12 used 2" square pads conforming to the requirements of ASTM E 814. Thermocouples #7, #8, and #13 are RESERVED.

THE FIRE ENDURANCE TEST

The test assembly was placed in position of top of the horizontal furnace (refer to Figure #4). Unexposed surface thermocouples #0 through #13 were connected to an automatic strip chart recorder for purposes of recording temperatures during the test. These temperatures are included with this report as Figure #6- Unexposed Surface Temperatures. Data from Figure #6 are summarized at 5 minutes intervals in Figure #10 and illustrated graphically in Figure #11.

A pressure tap was installed eight inches below the center of the slab in the furnace chamber. This pressure tap was attached to a pressure gauge. Readings from the pressure gauge were monitored for controlling furnace pressure by adjusting dampers in the furnace exhaust stacks during the test. Periodic readings were recorded and are included with this report as Figure #7- Furnace Pressures.

The fire test was started after igniting the natural gas burners. Temperatures within the furnace were monitored with 6 thermocouples attached to a second automatic strip chart recorder. The furnace temperatures were controlled by adjusting fuel rates to follow the time/temperature curve specified in the test standards and pre-drawn on the recorder chart. These temperatures and the standard time/temperature curve are included with this report as Figure #5-Furnace Temperatures. Data from Figure #5 are summarized at 5 minute intervals in Figure #8 and illustrated graphically in Figure #9.

Periodic observations were made and recorded of conditions on the exposed and unexposed faces of the test assembly. These observations are included with this report.

The fire endurance test was conducted for a period of 122 minutes. At this time, the furnace was extinguished and the test assembly was moved into position for photographs, cooling and examination.

FIRE TEST OBSERVATIONS

ELAPSED TIME	EXPOSED FACE
1 min.	The conduit is melting and issuing flames.
5 min.	The conduits continue to issue flames and form an ash which falls to the furnace floor.
15 min.	No visible changes are evident.
30 min.	Flames from all conduits have receded. The slab is developing a deep red glow.
45 min.	Dampers have been adjusted to develop a less negative pressure in the furnace chamber, resulting in smoky combustion and poor temperature control. There are no visible changes on the test assembly.
60 min.	Furnace temperatures are back under control. There are no visible changes on the test assembly.
75 min.	No visible changes are evident.
90 min.	No visible changes are evident.
105 min.	No visible changes are evident.
120 min.	No visible changes are evident.
122 min.	No visible changes are evident. The test has been stopped at the request of the client.

FIRE TEST OBSERVATIONS (continued)

ELAPSED TIME	UNEXPOSED FACE
1 min.	Light smoke is issuing from the conduits.
5 min.	Smoke from the conduits has receded.
15 min.	No visible changes are evident.
30 min.	Smoke and steam are issuing from the slab at the point of entry of the conduits. The conduits are softening and deforming.
45 min.	No visible changes are evident.
60 min.	Steaming has receded. No other visible changes are evident.
75 min.	Light smoke has resumed issuing from the slab around the conduits. The slab has sagged about 3" at the center. No other visible changes are evident.
90 min.	No visible changes are evident.
105 min.	No visible changes are evident.
120 min.	No visible changes are evident.
122 min.	No visible changes are evident. The fire test is being terminated at the request of the client. The assembly is being removed from the furnace for photographs, cooling and examination.

CONCLUSIONS

The pilot scale horizontal assembly, as described and tested herein, meets the unexposed surface temperature rise requirements of ASTM E 119 for a 2 hour rating and meets the requirements of ASTM E 814 for 120 minute 'F' and 'T' ratings(without hose stream).

The maximum temperature rise on the unexposed surface at 120 minutes elapsed time per ASTM E 119 was 244 degrees Fahrenheit. This occurred on the slab at #6 thermocouple, 1" from a point where the conduit emerged to the unexposed surface from a conduit run where both ends emerged to the unexposed surface. Number 1 thermocouple was located on the slab at a distance of 15 inches from any of the conduit and recorded a temperature rise of 234 degrees Fahrenheit at 120 minutes elapsed time.

The maximum temperature rise on the unexposed surface at 120 minutes elapsed time per ASTM E 814 was 143 degrees Fahrenheit at #10 thermocouple.

FIGURE #1- FORMING AND REINFORCEMENT DETAILS

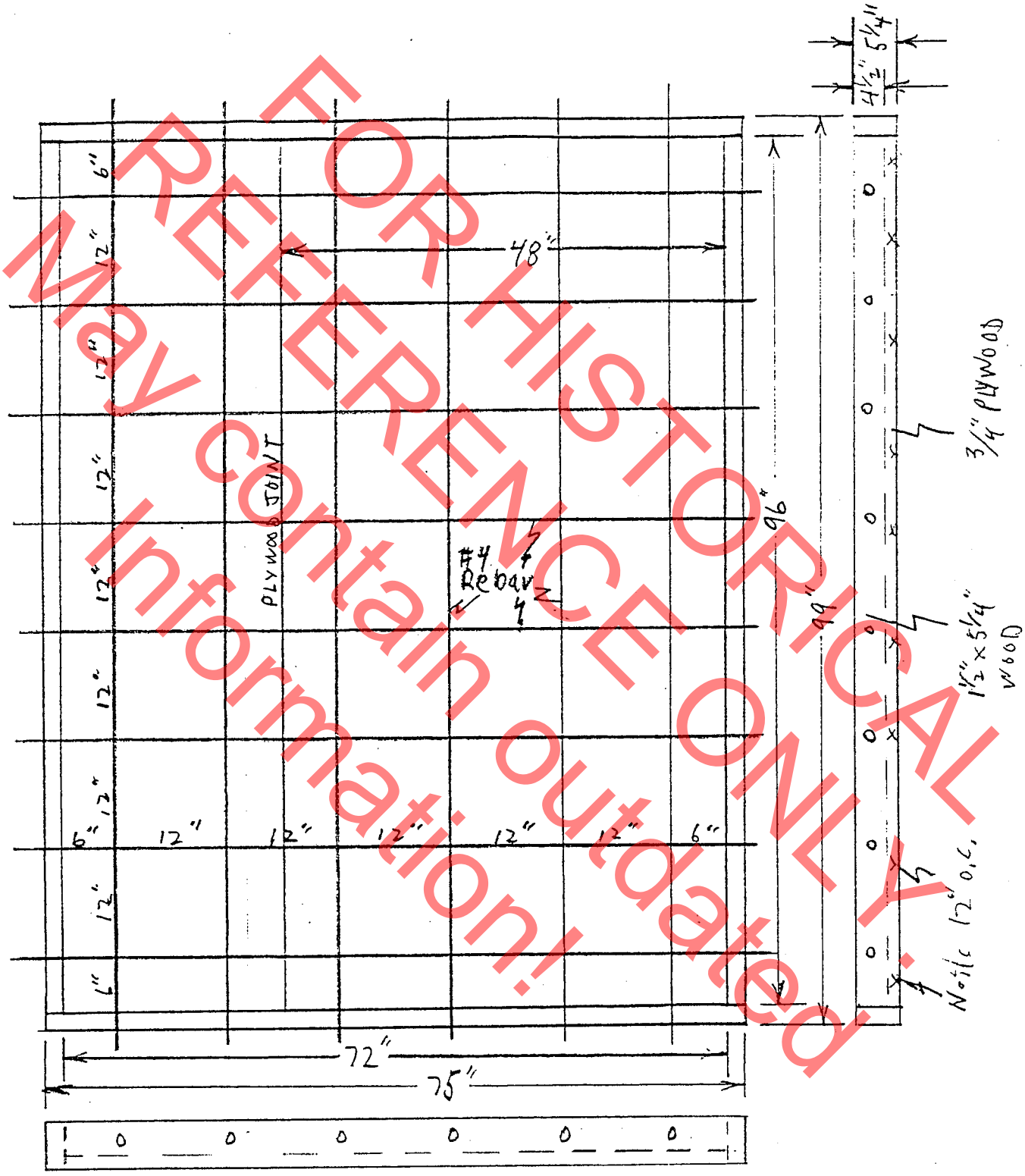


FIGURE #2- CONDUIT RUN PLACEMENT AND SLAB DIMENSIONS

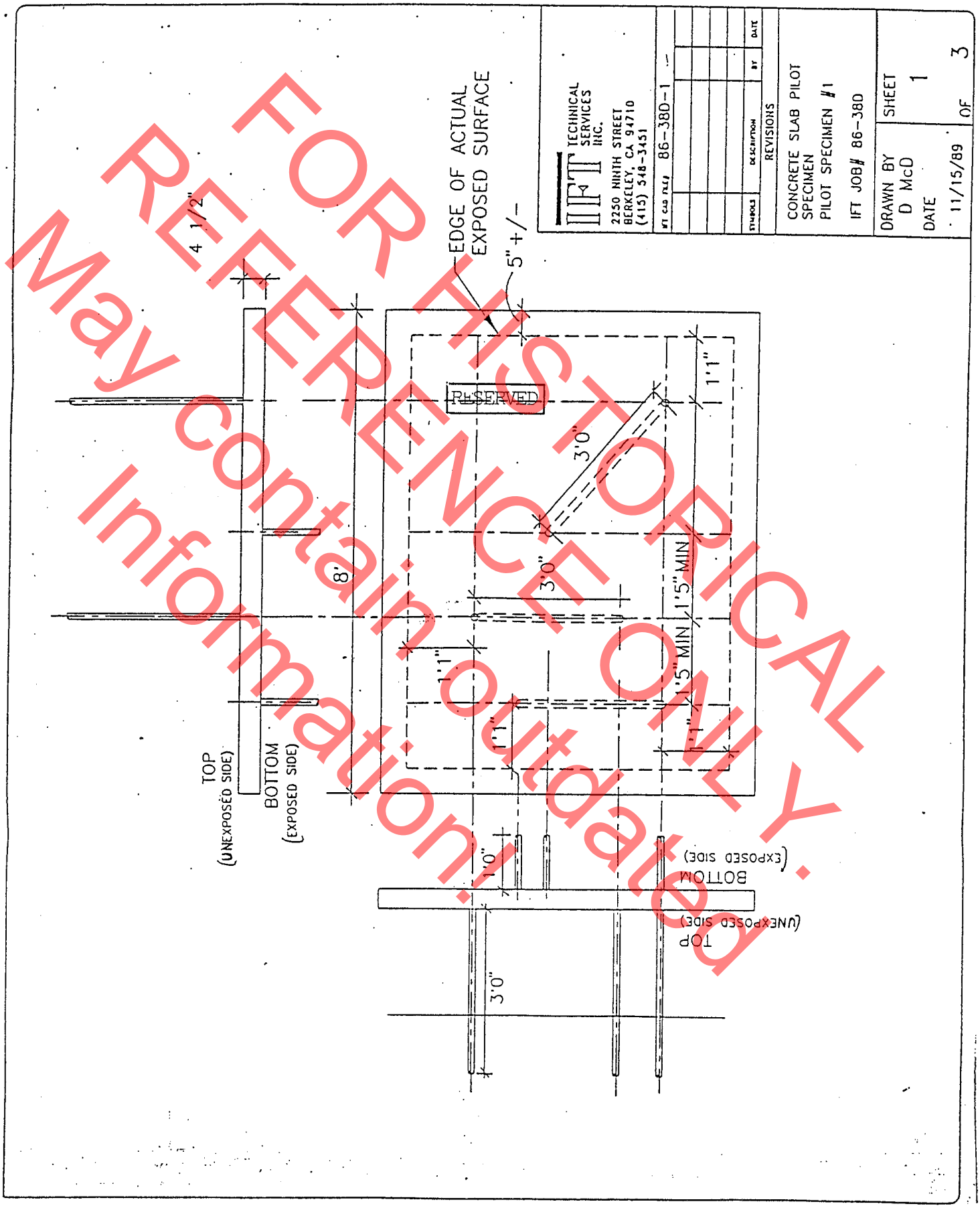


FIGURE #3-- UNEXPOSED SURFACE THERMOCOUPLE PLACEMENT

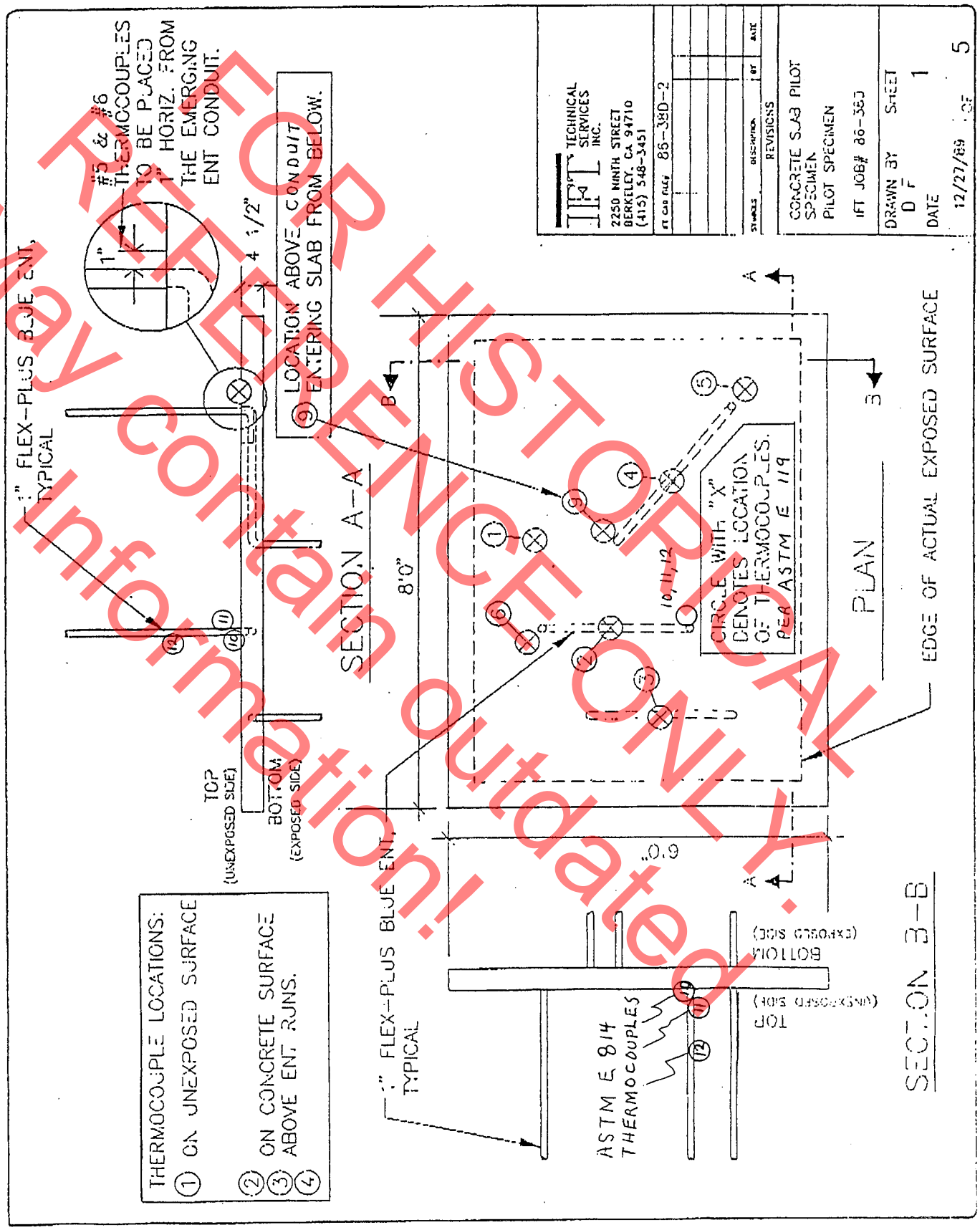


Figure # 4- HORIZONTAL FURNACE DETAIL

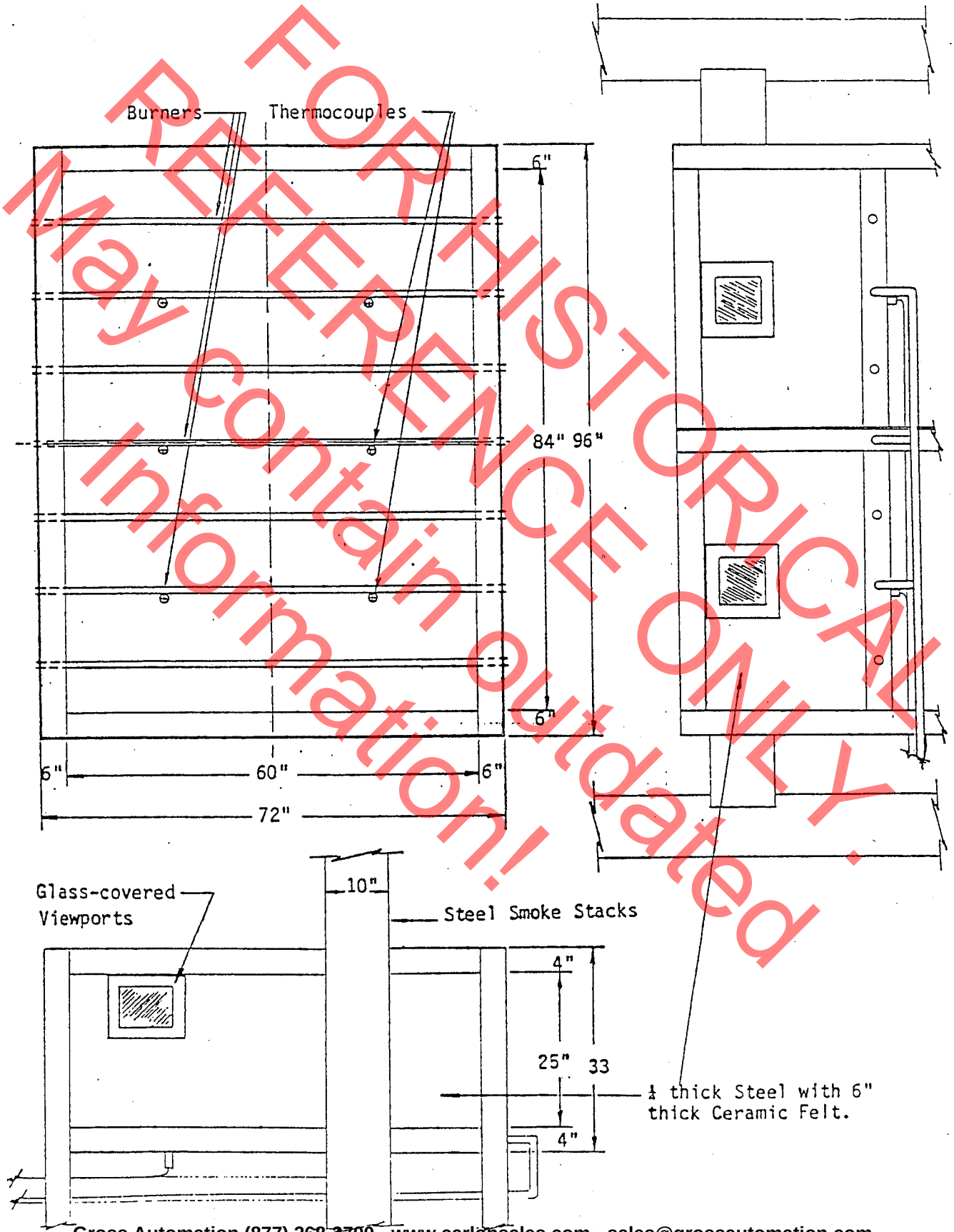


FIGURE #5- FURNACE TEMPERATURES (SECTION 1)

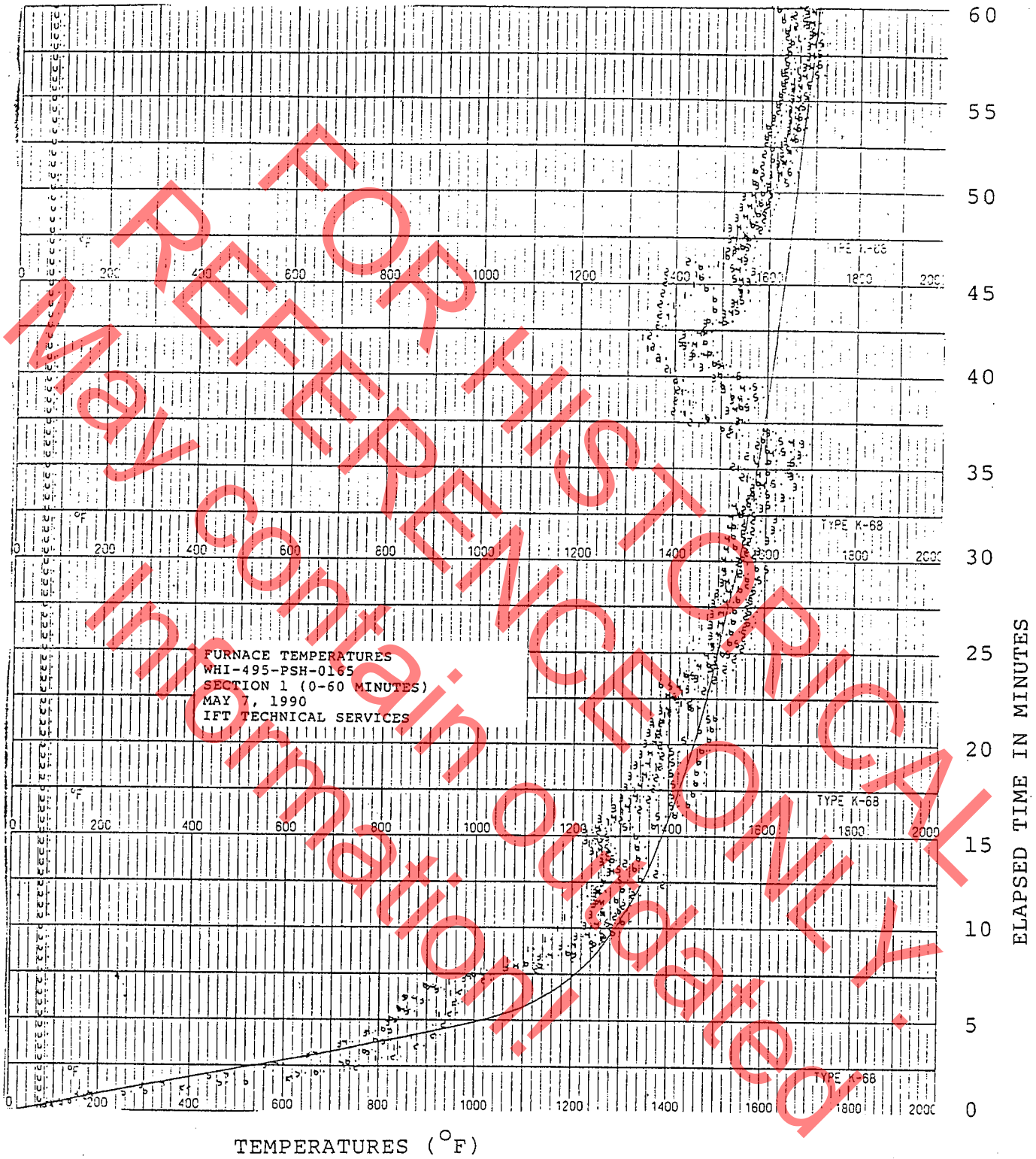


FIGURE #5- FURNACE TEMPERATURES (SECTION 2)

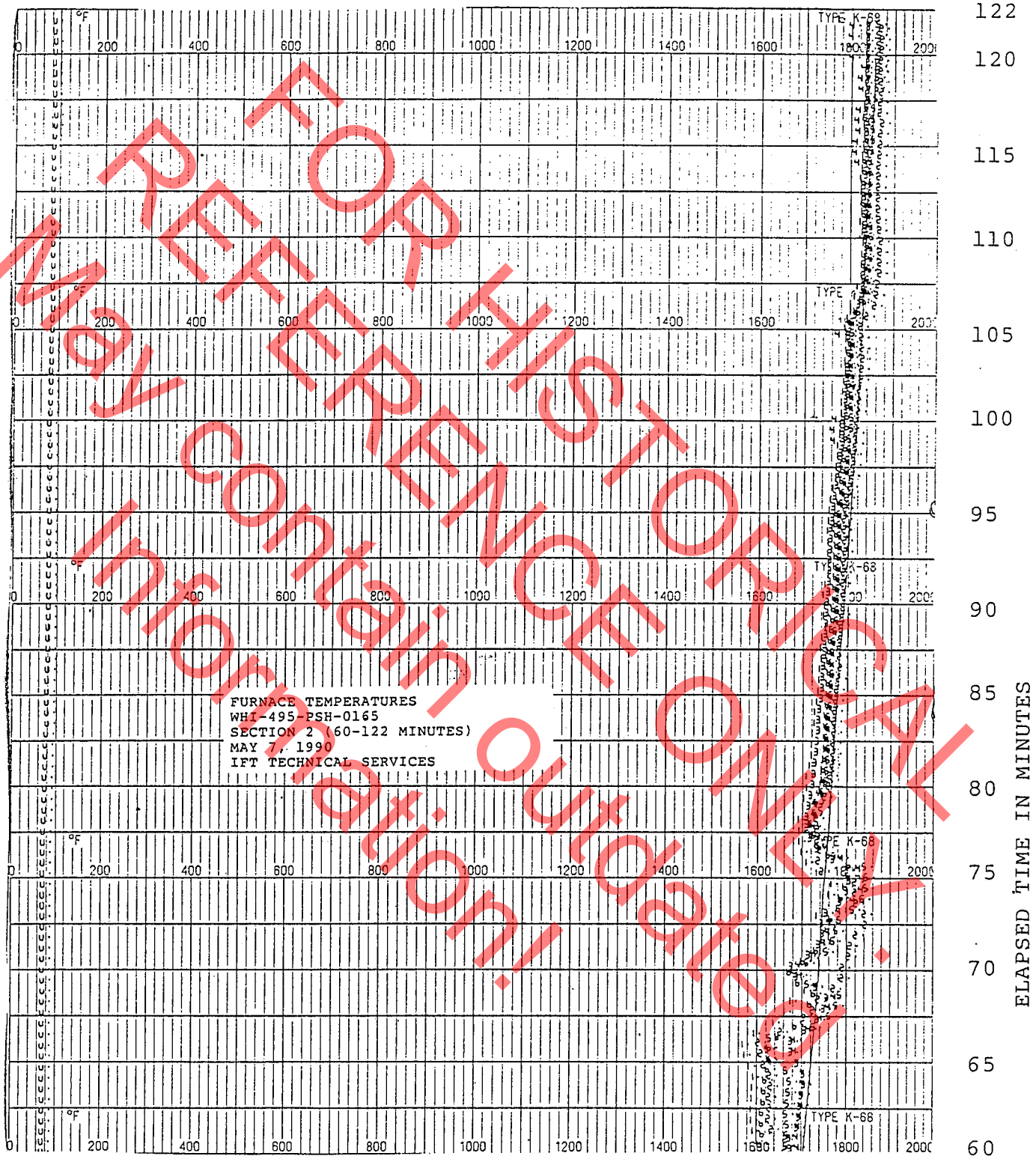


FIGURE #6- UNEXPOSED SURFACE TEMPERATURES (SECTION 1)

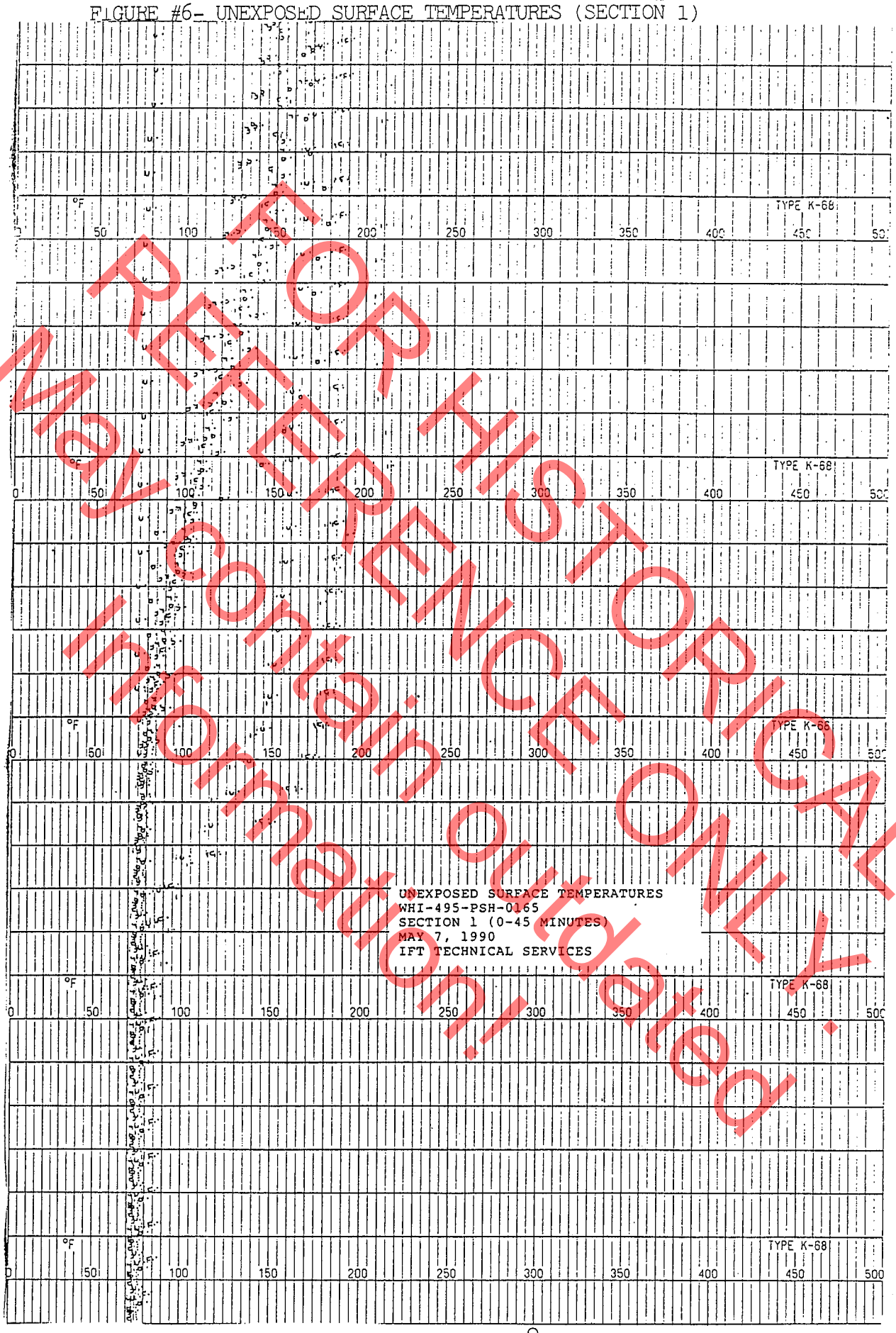


FIGURE #6- UNEXPOSED SURFACE TEMPERATURES (SECTION 2)

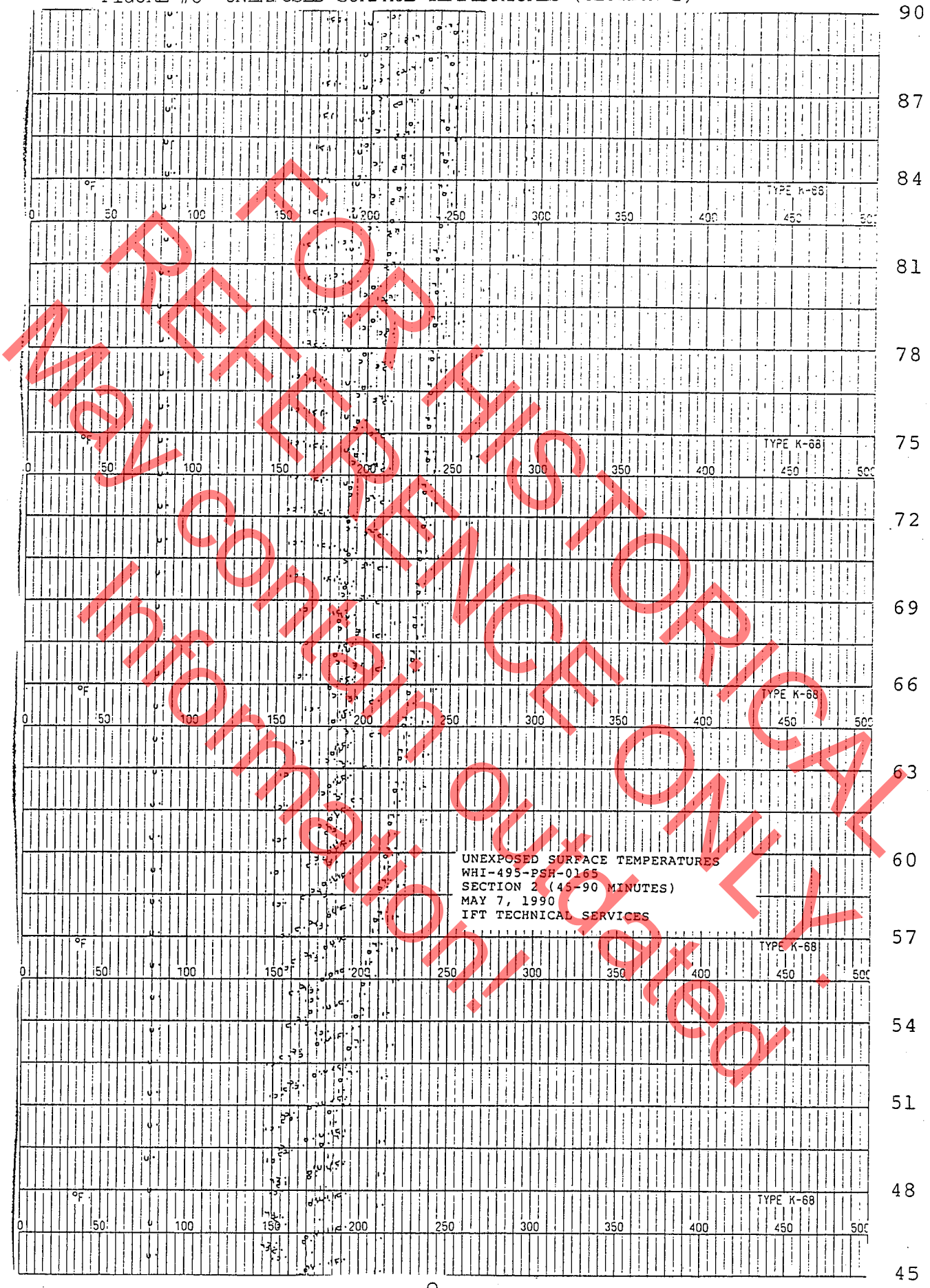


FIGURE #6- UNEXPOSED SURFACE TEMPERATURES (SECTION 3)

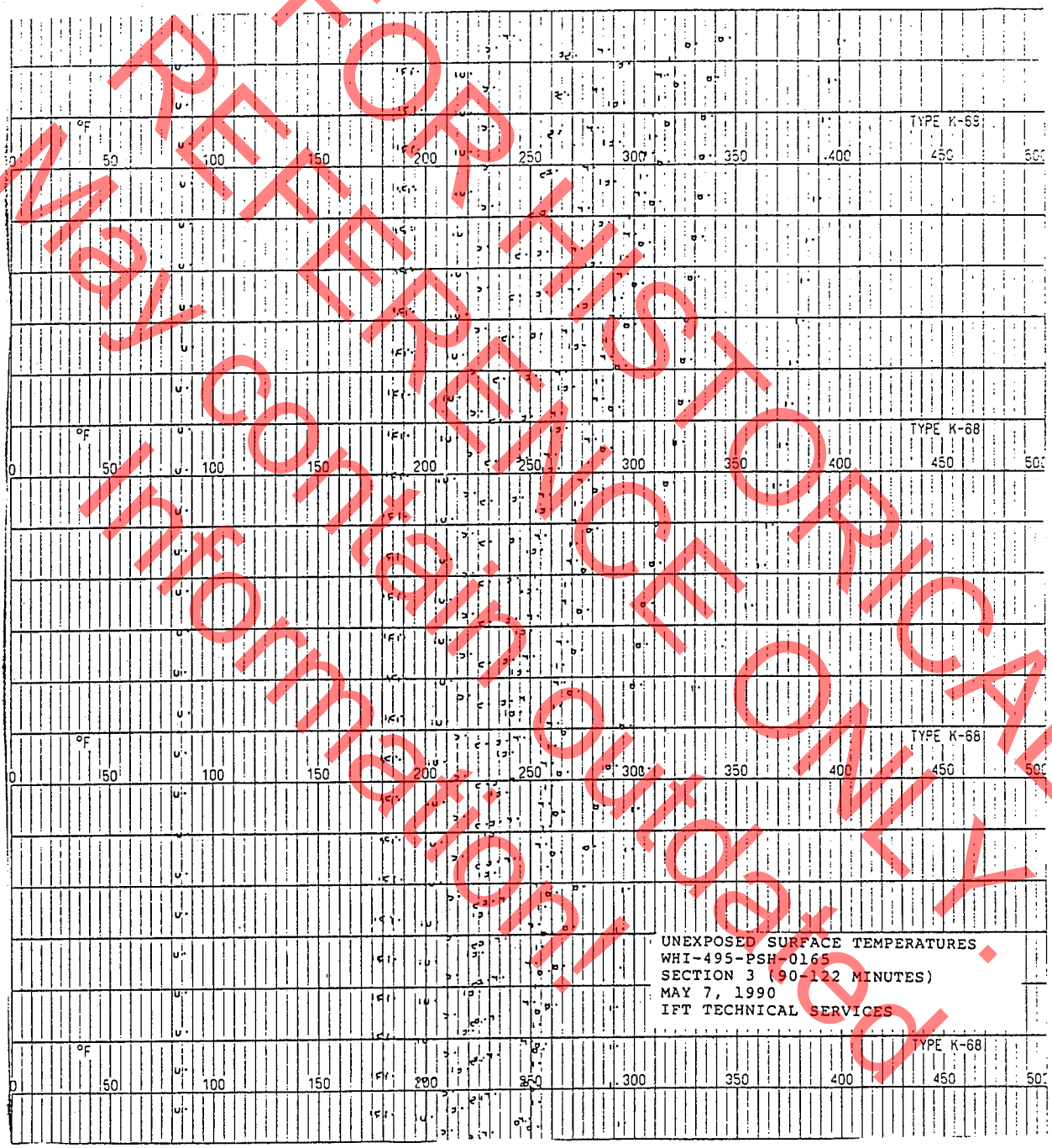


FIGURE #7
FURNACE PRESSURES
(negative inches of water)

ELAPSED TIME (minutes)	READING
15	0.005
30	0.005
45	0.005
60	0.005
75	0.010
90	0.010
105	0.010
120	0.010

IFT TECHNICAL SERVICES, INC.
WHI-495-PSH-0165
MAY 9, 1990

Furnace Temperature (Deg. F)

Time (Min.)	TC0	TC1	TC2	TC3	TC4	TC5	TC6
0	85	85	85	85	85	85	85
5	85	910	950	830	840	850	840
10	85	1180	1300	1240	1270	1290	1325
15	85	1240	1270	1240	1270	1325	1390
20	85	1400	1400	1370	1390	1450	1500
25	85	1450	1570	1500	1510	1560	1540
30	85	1560	1560	1560	1530	1590	1570
35	85	1550	1545	1665	1600	1675	1620
40	85	1420	1420	1500	1545	1555	1515
45	85	1450	1395	1575	1555	1540	1470
50	85	1605	1615	1590	1615	1650	1580
55	85	1660	1640	1660	1680	1690	1635
60	90	1605	1680	1680	1710	1680	1630
65	90	1600	1630	1710	1710	1640	1640
70	90	1690	1810	1690	1710	1730	1720
75	90	1780	1840	1820	1850	1850	1820
80	90	1720	1775	1740	1760	1770	1760
85	95	1740	1790	1755	1775	1775	1775
90	97	1760	1805	1770	1790	1790	1790
95	100	1770	1805	1780	1800	1795	1790
100	100	1790	1835	1800	1820	1820	1810
105	100	1800	1840	1820	1820	1820	1820
110	100	1840	1890	1850	1850	1865	1850
115	100	1840	1890	1850	1830	1870	1850
120	100	1850	1890	1855	1815	1880	1855

Figure #8 - Five Minute Interval Summary of Furnace Temperatures

Figure #9 - Five Minute Interval Graph of Furnace Temperatures

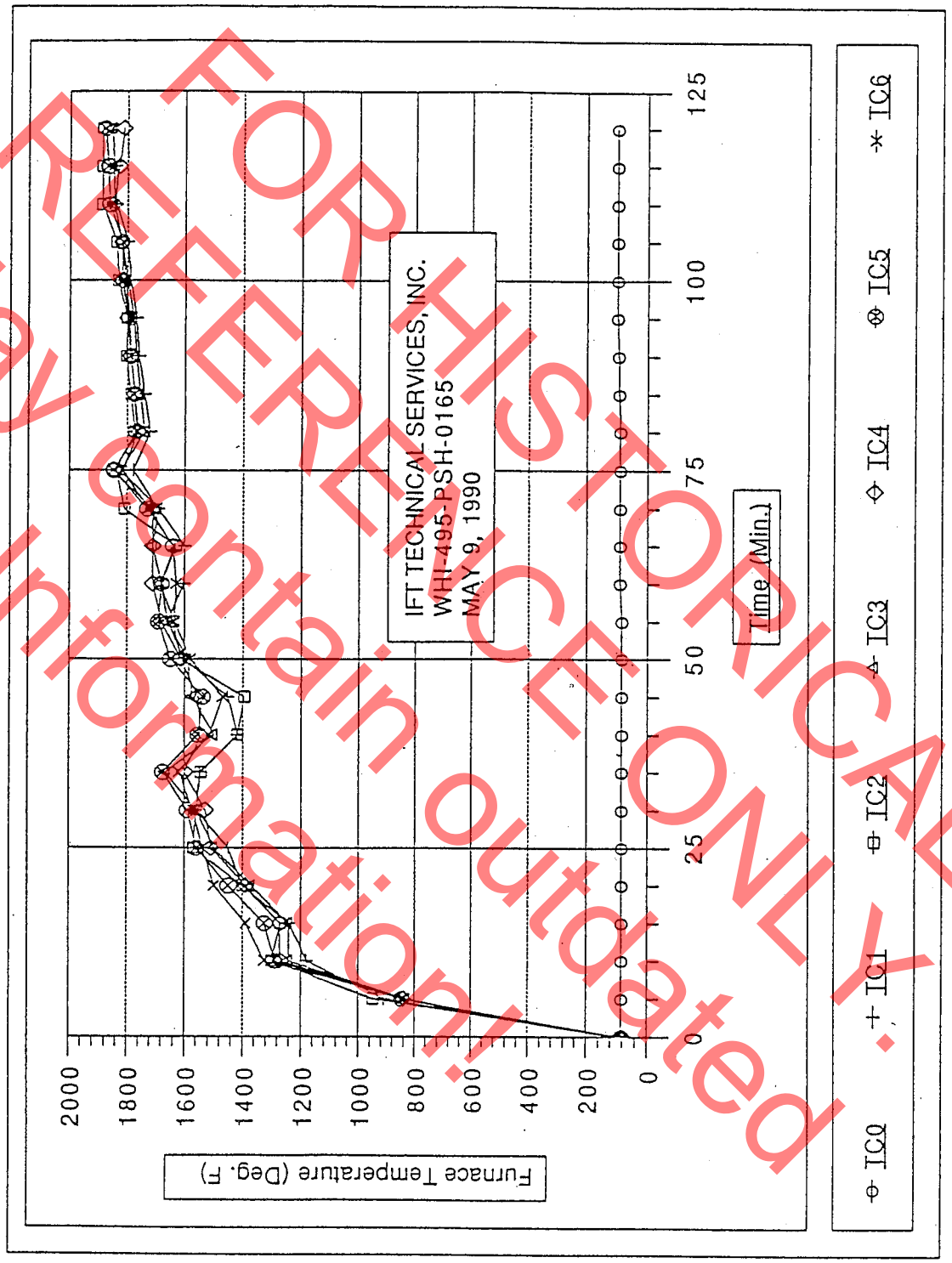


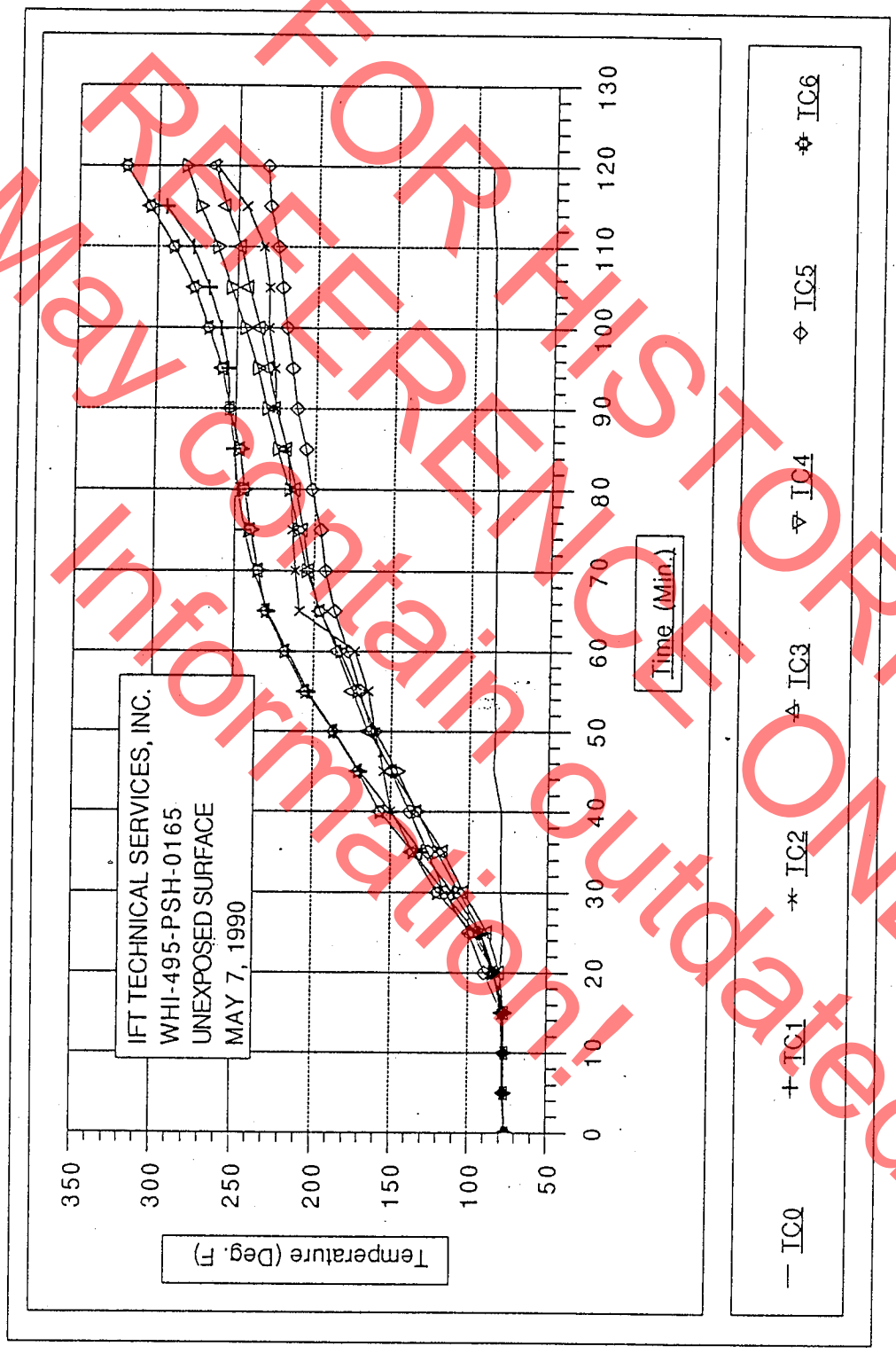
Figure #10 - Five Minute Interval Summary of Un-Exposed Surface Temperatures

IFT TECHNICAL SERVICES, INC.
WHI-495-PSH-0165
UNEXPOSED SURFACE
MAY 7, 1990

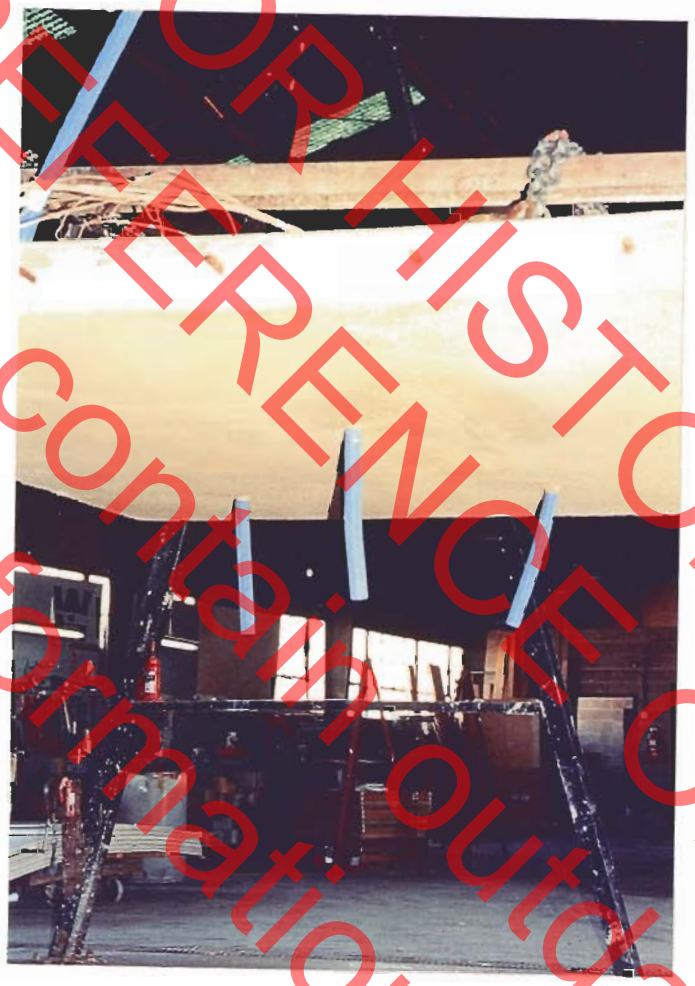
Temperature (Deg. F)

Time (Min.)	TC0	TC1	TC2	TC3	TC4	TC5	TC6	TC9	TC10	TC11	TC12
0	76	76	76	76	76	77	76	76	78	82	84
5	79	77	77	77	77	78	77	77	80	86	88
10	79	77	77	77	77	78	77	77	80	86	88
15	80	78	77	77	77	79	79	79	92	95	98
20	80	84	84	80	83	90	85	85	150	181	180
25	78	93	95	88	92	100	97	96	160	188	186
30	80	110	115	103	106	115	120	116	164	187	189
35	80	130	135	116	120	126	136	136	168	188	190
40	80	150	150	133	133	138	157	157	170	190	189
45	85	170	155	149	146	150	171	175	178	190	193
50	84	186	160	165	160	163	187	195	185	192	193
55	85	203	165	175	172	170	205	208	187	190	194
60	85	216	174	185	183	178	218	219	190	191	194
65	85	229	209	196	196	187	230	230	195	194	195
70	85	238	212	203	205	193	235	235	194	182	180
75	85	244	214	207	210	196	240	240	192	177	175
80	84	248	215	212	216	202	244	242	194	178	170
85	86	251	218	218	224	206	247	245	198	180	176
90	87	254	225	225	231	212	254	250	203	185	181
95	87	255	226	230	237	215	259	253	205	185	183
100	87	260	230	236	245	219	268	260	210	189	187
105	88	268	230	243	254	222	277	270	212	190	188
110	88	278	234	248	263	225	290	281	215	192	190
115	90	295	245	258	274	230	305	297	220	195	194
120	90	310	264	265	283	232	320	313	221	198	195
Temperature Change	14	234	188	189	207	155	244	237	143	116	111

Figure #11 - Five Minute Interval
Graph of Unexposed Surface Temperatures



PHOTOGRAPH #1
THE WOOD FORM WITH CONDUIT AND REBAR INSTALLED



PHOTOGRAPH #2
A REVERSE SIDE VIEW OF THE FORM WITH CONDUIT INSTALLED

PHOTOGRAPH #3
A VIEW OF POURING CONCRETE IN THE FORMS

PHOTOGRAPH #4
THE EXPOSED SURFACE BEFORE THE START OF THE TEST

PHOTOGRAPH #5
THE UNEXPOSED SURFACE BEFORE THE START OF THE TEST

PHOTOGRAPH #6
THE UNEXPOSED SURFACE AT 83 MINUTES ELAPSED TIME

PHOTOGRAPH #7
THE UNEXPOSED SURFACE AT 108 MINUTES ELAPSED TIME

PHOTOGRAPH #8
THE UNEXPOSED SURFACE AT 120 MINUTES ELAPSED TIME

PHOTOGRAPH #9
THE UNEXPOSED SURFACE AT 122 MINUTES ELAPSED TIME

PHOTOGRAPH #10
THE EXPOSED SURFACE AFTER THE TEST WAS COMPLETED

SIGNATURE PAGE

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Report Writer
Date:

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Billy D, Brittain, Ch.E.
Manager, Fire Testing Laboratory
Date:

REGISTERED PROFESSIONAL ENGINEER
GEORGE E. MEYER
PP 179
FIRE PROTECTION
STATE OF CALIFORNIA

REVIEWED BY:

George E. Meyer, Ch.E., P.E.
Vice President, International Operations and
Chief Engineer, USA
Date: 28 Aug 90

PHOTOGRAPH #11
THE UNEXPOSED SURFACE AFTER THE TEST WAS COMPLETED

Appendix IV

Warnock Hersey Report

Two-Hour Fire Performance
of
Fire Resistive Concrete Slab Assemblies
with PVC Raceways installed using
Lightweight Slab

Warnock Hersey

1101 LOVERIDGE ROAD, PITTSBURG, CA 94565
TEL 415/432-7344 FAX 415/432-9578

REPORT OF THE PILOT SCALE FIRE ENDURANCE TEST OF 1" DIAMETER, PVC, FLEXIBLE, ENT CONDUIT RUNS IN AN UNRESTRAINED 6' BY 8' BY 5-1/4" THICK, REINFORCED CONCRETE/CORRUGATED STEEL DECK FLOOR/CEILING ASSEMBLY WITHOUT AN APPLIED LOAD

CLIENT

IFT TECHNICAL SERVICES, INC.
2250 NINTH STREET NORTH
SUITE 112
BERKELEY, CALIFORNIA 94710
U.S.A.

REPORTED BY

WARNOCK HERSEY INTERNATIONAL, INC.
1101 LOVERIDGE ROAD
PITTSBURG, CALIFORNIA 94565
U.S.A.

FILE NUMBER: WHI-495-PSH-0169
WORK ORDER NUMBER: 50611-C7-030320
DATE TESTED: JULY 16, 1990

TABLE OF CONTENTS

INTRODUCTION

On July 16, 1990, the Pittsburg, California, fire testing laboratory of Warnock Hersey International, Inc., conducted a pilot scale horizontal, 120 minute fire endurance test. The test assembly consisted of a 6' by 8' by 5-1/4" thick, reinforced concrete/corrugated steel deck, floor/ceiling assembly having two runs of Carlon 1" diameter, flexible PVC, ENT conduit within the slab. One run emerged to the exposed face at both ends. The other run emerged to opposite faces at the ends. Each run of conduit was wire tied to the welded wire reinforcement before the concrete was poured and positioned to be covered above or below with a minimum of 1" thick concrete. After conditioning on the furnace to dry the slab, the test was conducted without an applied load in accordance with the furnace temperature and unexposed surface temperature rise requirements of ASTM E 119 and ASTM E 814. The test assembly was unrestrained. A hose stream test was not conducted. The test assembly also contained a confidential RESERVED construction involving unexposed surface thermocouples #9, 10 and 11, documented in a separate report.

The pilot scale test assembly reported herein met the unexposed surface temperature rise requirements of ASTM E 119 for a 2 hour rating and also developed a 120 minute 'F' rating and a 120 minute 'T' rating per ASTM E 814 (without hose stream) at a negative furnace pressure of 0.01" water.

The test was conducted for IFT Technical Services Inc., of Berkeley, California.

TEST MATERIALS

One inch inside diameter, flexible PVC, ENT conduit, manufactured by CARLON, UL labeled as electric, non-metallic tubing. Issue #958, E73317

6" by 6" by 8 gauge welded wire reinforcement

2" high fluted 16 ga. steel decking, 36" wide by 96" long, supplied by Verco Industries

0.060" diameter steel tie wire

Ready-mixed, lightweight aggregate concrete, 110 pcf dried density

TEST ASSEMBLY CONSTRUCTION
(Refer to Figure #1)

Wood forms were constructed for the assembly shown in Figure #1. The assembly was constructed using the materials shown on Page 4. The conduit runs were placed as shown in Figure #1 and wire tied to the welded wire reinforcement at slab entry points and mid-run locations. The conduit was placed to extend 12" from the exposed surface of the slab into the furnace and 36 inches from the unexposed surface of the slab.

Ready-mixed lightweight aggregate concrete was poured, making sure that the concrete was 1" minimum thickness above and below the conduit. After troweling, the slab was cured for 28 days. Wood forms were then removed. Fiberglass insulation was placed around the conduit penetrations on the exposed surface for protection of the conduit while the slab was dried on the test furnace. The assembly was dried at a furnace temperature of 170 degrees Fahrenheit for a period of seven days. The temporary insulation was removed from the conduit on the exposed surface. After cooling, this completed construction and conditioning of the test assembly.

At the request of the client, the unexposed surface of the assembly was fitted with thermocouples as shown in Figure #1. Thermocouples #1 through #8 used 6" square pads conforming to the requirements of ASTM E 119. Thermocouples #12 through #14 used 2" square pads conforming to the requirements of ASTM E 814. Thermocouples #9, #10, and #11 are reported separately for a RESERVED construction.

THE FIRE ENDURANCE TEST

The test assembly was placed in position of top of the horizontal furnace (refer to Figure #2). Unexposed surface thermocouples #0 through #14 were connected to an automatic strip chart recorder for purposes of recording temperatures during the test. These temperatures are included with this report as Figure #4- Unexposed Surface Temperatures. Data from Figure #4 are summarized at 5 minutes intervals in Figure #8 and illustrated graphically in Figure #9.

A pressure tap was installed eight inches below the center of the slab in the furnace chamber. This pressure tap was attached to a pressure gauge. Readings from the pressure gauge were monitored for controlling furnace pressure by adjusting dampers in the furnace exhaust stacks during the test. Periodic readings were recorded and are included with this report as Figure #5- Furnace Pressures.

The fire test was started after igniting the natural gas burners. Temperatures within the furnace were monitored with 6 thermocouples attached to a second automatic strip chart recorder. The furnace temperatures were controlled by adjusting fuel rates to follow the time/temperature curve specified in the test standards and pre-drawn on the recorder chart. These temperatures and the standard time/temperature curve are included with this report as Figure #3-Furnace Temperatures. Data from Figure #3 are summarized at 5 minute intervals in Figure #6 and illustrated graphically in Figure #7.

Periodic observations were made and recorded of conditions on the exposed and unexposed faces of the test assembly. These observations are included with this report.

The fire endurance test was conducted for a period of 121 minutes. At this time, the furnace was extinguished and the test assembly was moved into position for photographs, cooling and examination.

FIRE TEST OBSERVATIONS

ELAPSED TIME	EXPOSED FACE
3 min.	The conduit has melted with ashes flush to the steel decking.
6 min.	The concrete has delaminated from the steel decking at the north and south ends. Steam is issuing through the seam at the center of the assembly.
10 min.	No visible changes are evident. There continues to be no flaming from the exposed surface.
15 min.	No visible changes are evident.
20 min.	No visible changes are evident.
30 min.	No visible changes are evident.
38 min.	Conduit ash has fallen to the furnace floor. The steel decking is glowing orange, and appears to have sagged about 2" at the center.
45 min.	No visible changes are evident.
60 min.	No visible changes are evident.
75 min.	No visible changes are evident.
90 min.	No visible changes are evident.
105 min.	No visible changes are evident.
120 min.	No visible changes are evident.
121 min.	No visible changes are evident. The fire endurance test is being stopped and the assembly set aside for photographs, cooling and examination.

FIRE TEST OBSERVATIONS (continued)

ELAPSED TIME	UNEXPOSED FACE
3 min.	Popping noises are audible. No visible changes are evident.
6 min.	Light smoke is issuing from the conduit.
10 min.	No visible changes are evident.
15 min.	Additional popping noises are audible.
21 min.	The slab has separated from the deck by 1/2" at the center of the north and south ends and up to 1" at each of the four corners.
30 min.	No visible changes are evident.
39 min.	Steam emissions are increasing from the concrete materials at various locations.
45 min.	No visible changes are evident.
60 min.	The concrete has sagged about 1-1/2" at the center.
75 min.	No visible changes are evident.
90 min.	No visible changes are evident.
105 min.	No visible changes are evident.
120 min.	No visible changes are evident.
121 min.	No visible changes are evident. The fire endurance test is being stopped and the assembly set aside for photographs, cooling and examination.

CONCLUSIONS

The pilot scale horizontal assembly, as described and tested herein, meets the unexposed surface temperature rise requirements of ASTM E 119 for a 2 hour rating and meets the requirements of ASTM E 814 for 120 minute 'F' and 'T' ratings (without hose stream).

The maximum temperature rise on the unexposed surface at 120 minutes elapsed time per ASTM E 119 was 291 degrees Fahrenheit. This occurred on the slab at #2 thermocouple, 15" from any conduit run or emerging point.

The average temperature rise on the unexposed surface per ASTM E 119 at 120 minutes elapsed time was 146 degrees Fahrenheit.

The maximum single point temperature rise on the unexposed surface at 120 minutes elapsed time per ASTM E 814 was 183 degrees Fahrenheit at #13 thermocouple.

SIGNATURE PAGE

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Billy D, Brittain, Ch.E.
Manager, Fire Testing Laboratory
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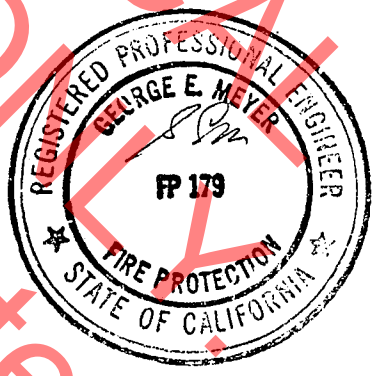
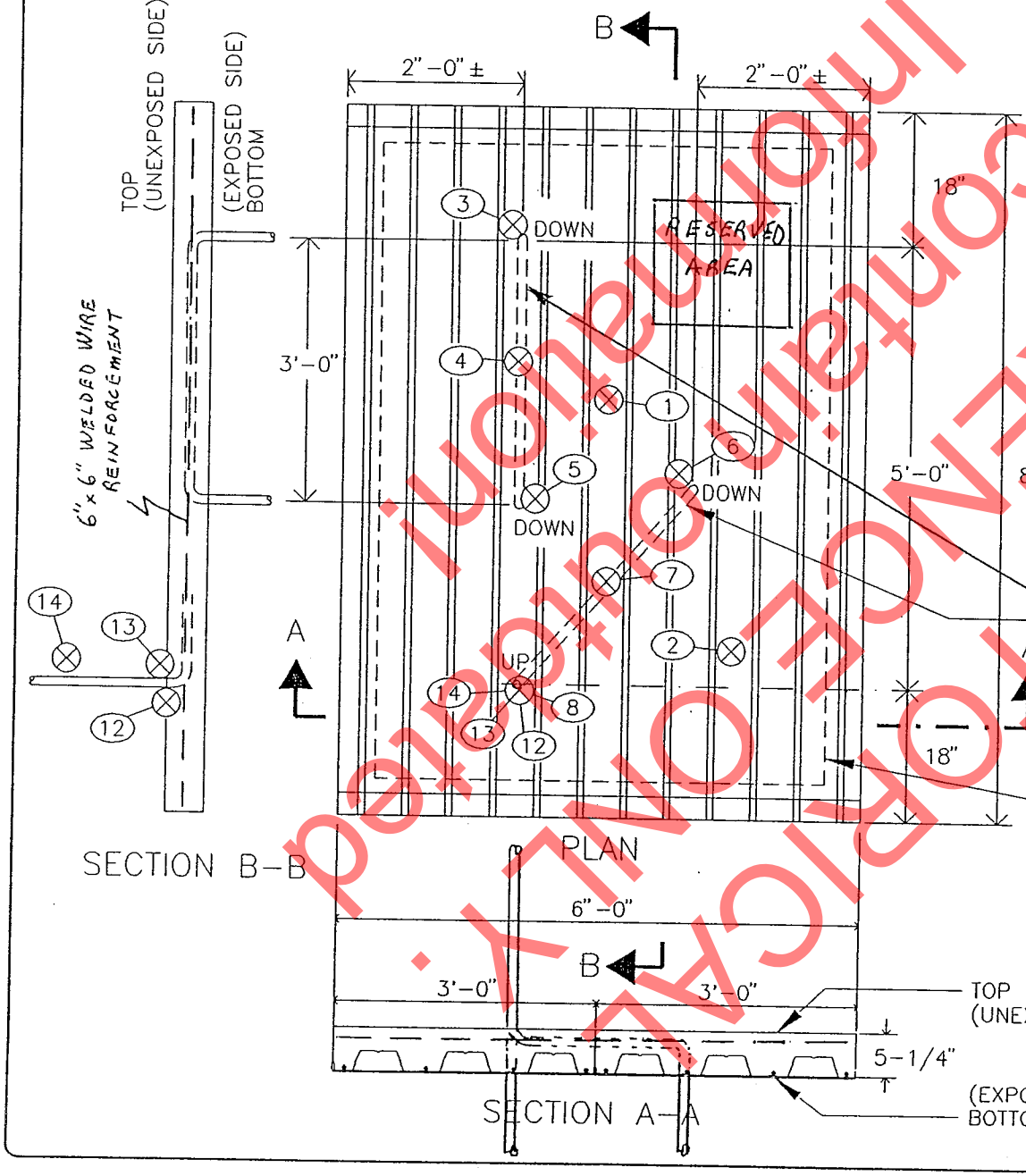
George E. Meyer, Ch.E., P.E.
Vice President, International Operations and
Chief Engineer,USA
Date: 3 Sept. 90



E-8 THERMOCOUPLE LOCATIONS:

(12) AT ENT ON SLAB SURFACE.
(13) 1" ABOVE SLAB ON ENT.
(14) 14" ABOVE SLAB ON ENT.

FIGURE #1 - ASSEMBLY CONSTRUCTION DETAILS AND UNEXPOSED SURFACE THERMOCOUPLE PLACEMENT



NOTES

CIRCLE WITH "X" DENOTES LOCATION OF THERMOCOUPLE.
ASTM E-119 6" PADS ARE USED FOR THERMOCOUPLES #1 THROUGH #8.
ASTM E-814 2" PADS ARE USED FOR THERMOCOUPLES #12 THROUGH #14.

E-119 THERMOCOUPLE LOCATIONS:

(1) (2) ON UNEXPOSED SURFACE
(3) (5) (6) ABOVE VENTRICAL ENTERING SLAB FROM BELOW.
(4) (7) ON CONCRETE SURFACE ABOVE ENT RUNS.
(8) ON CONCRETE SURFACE 1" HORIZONTALLY FROM EMERGING ENT CONDUIT.

IFT TECHNICAL SERVICES INC.
2250 NINTH STREET
BERKELEY, CA 94710
(415) 548-3451

IFT CAD FILE# PS-3A

SYMBOLS	DESCRIPTION	BY	DATE

REVISIONS

CONCRETE SLAB PILOT SPECIMEN
PILOT SPECIMEN

IFT JOB# 86-38D

DRAWN BY D F
DATE 4/13/90

SHEET 1 OF 1

WHI-495-PSH-0169
Page 11 of 26

FIGURE #2 - PILOT SCALE HORIZONTAL FURNACE DETAILS

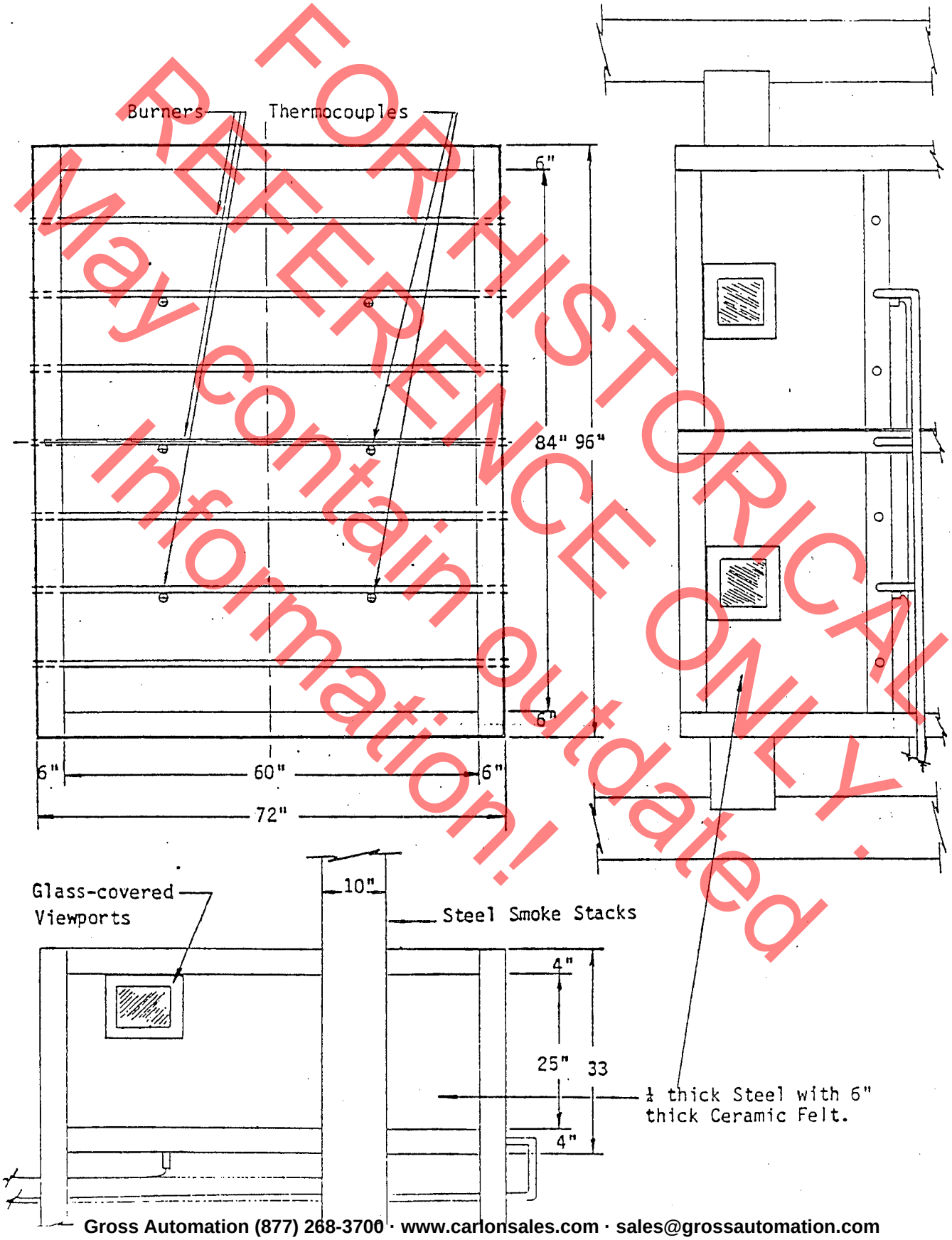
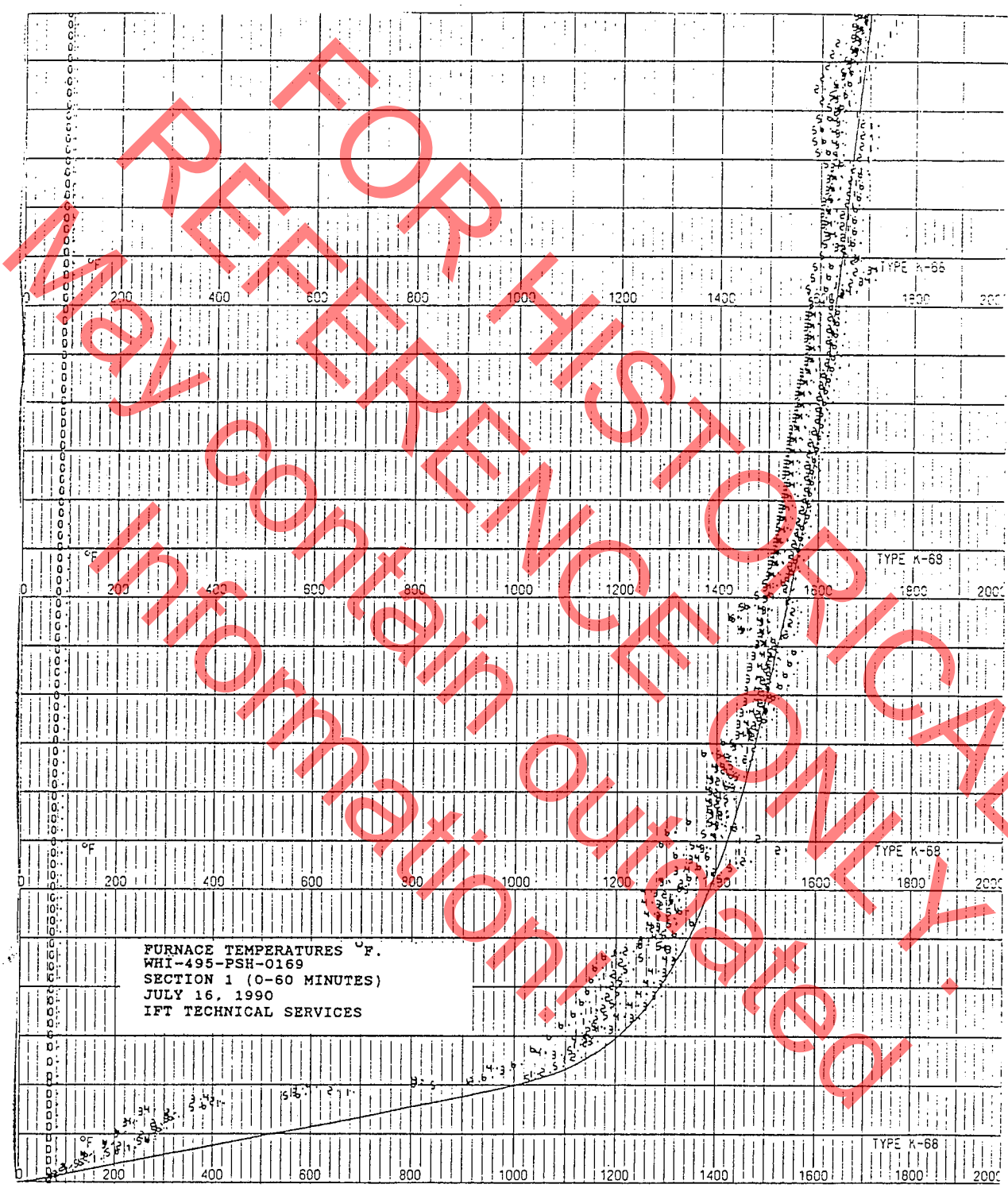


FIGURE #3 - FURNACE TEMPERATURES (SECTION 1)



TEMPERATURES (^{o}F)

FIGURE #3 - FURNACE TEMPERATURES (SECTION 2)

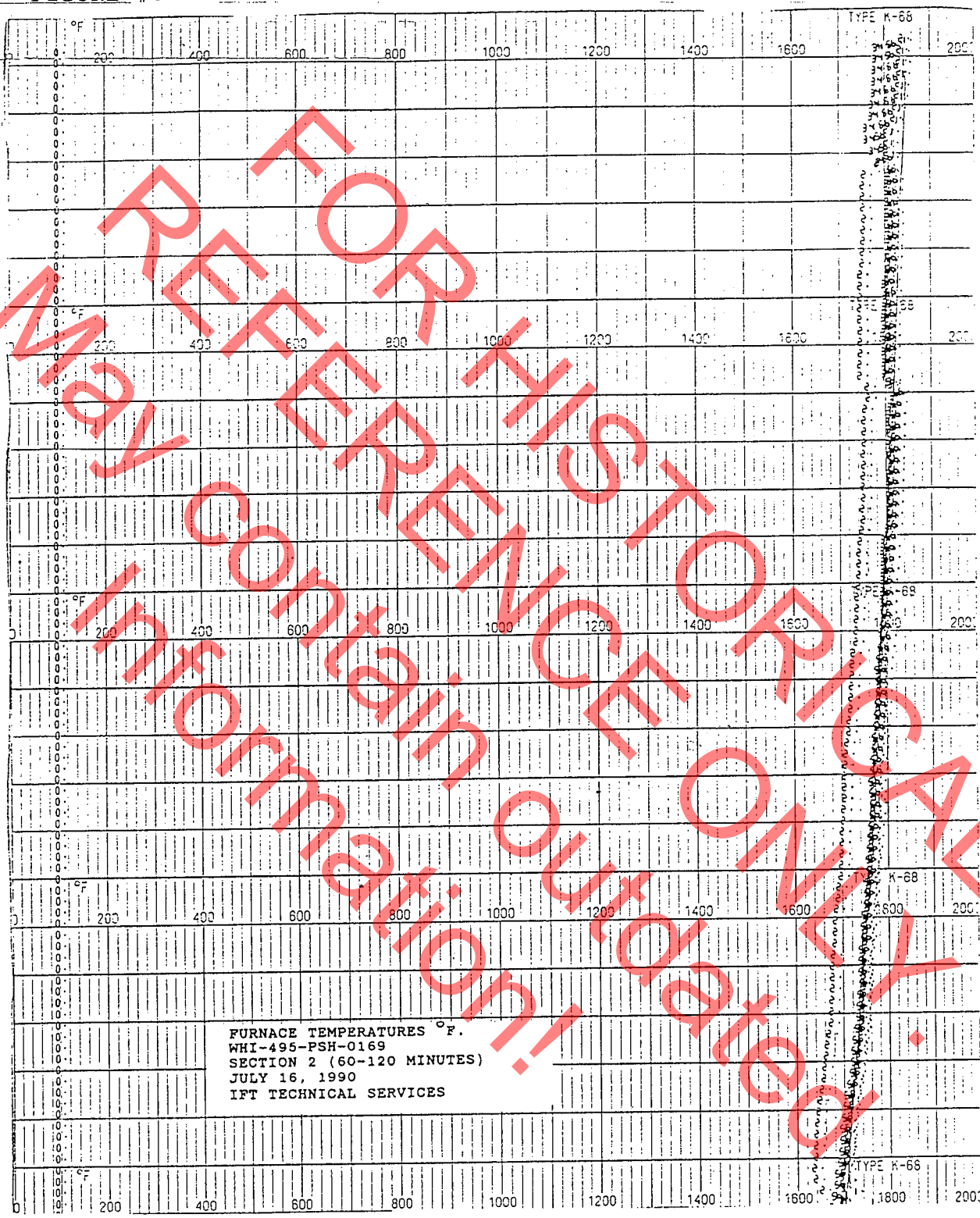


FIGURE #4 - UNEXPOSED SURFACE TEMPERATURES (SECTION 1)

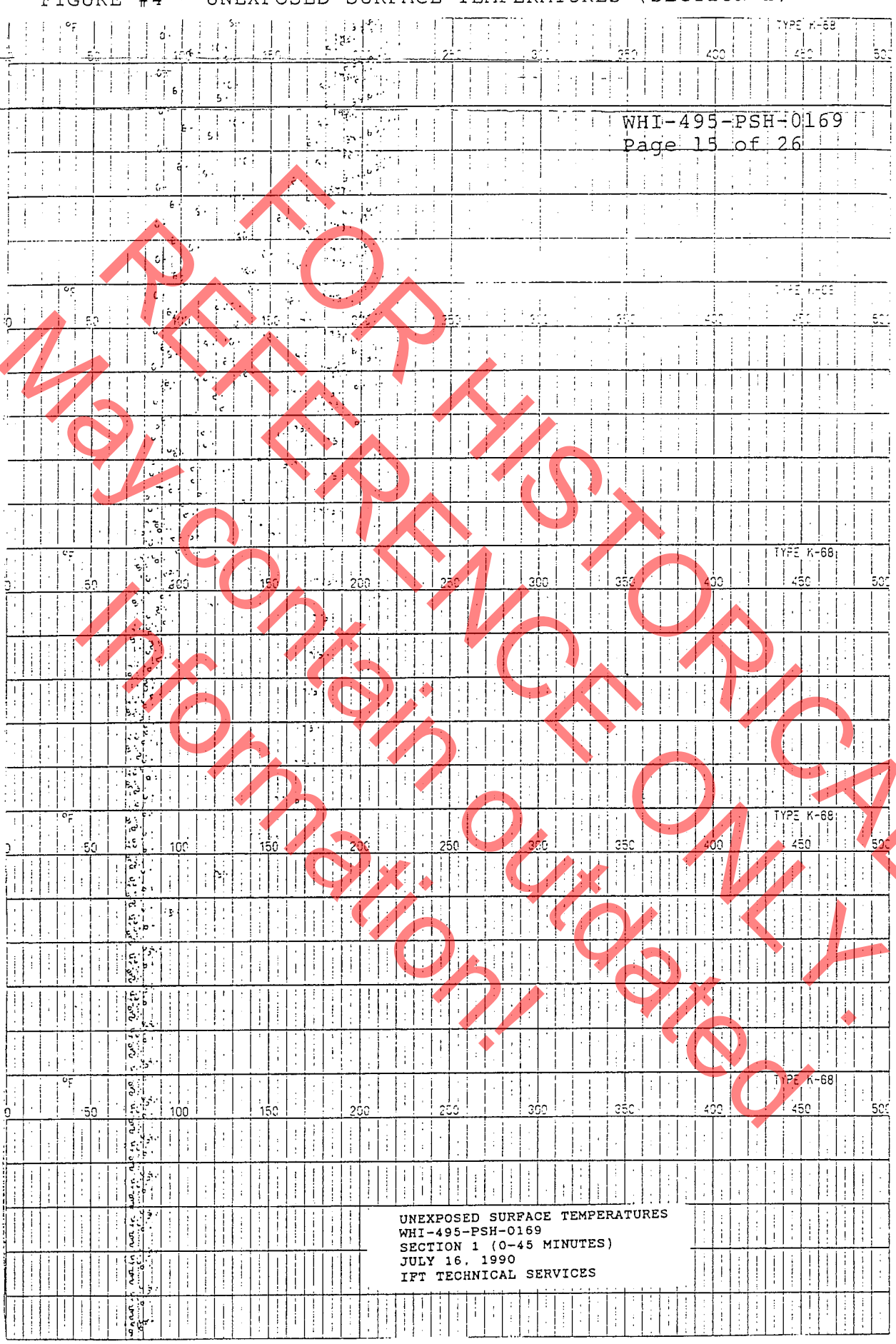


FIGURE #4 - UNEXPOSED SURFACE TEMPERATURES (SECTION 2)

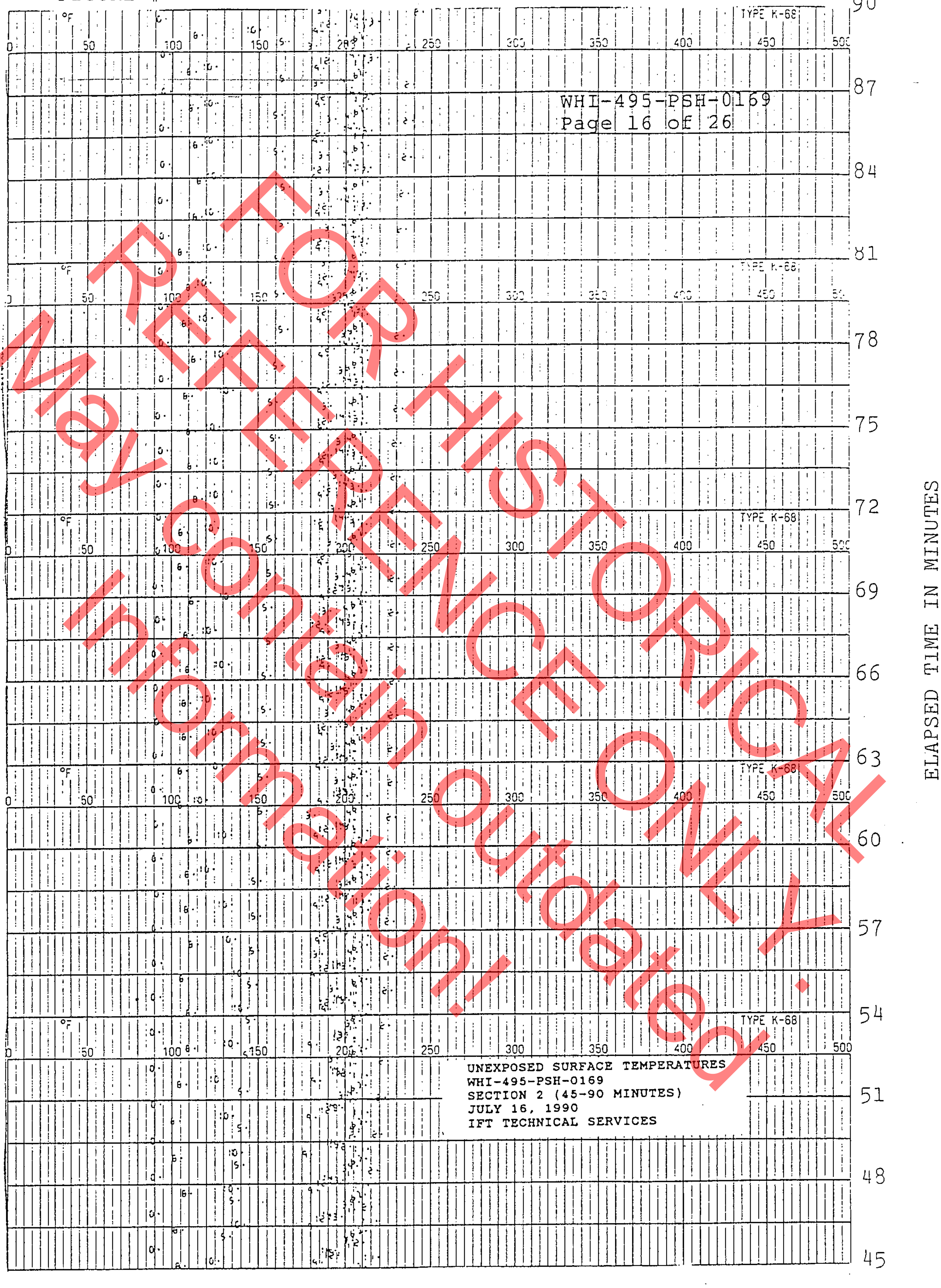


FIGURE #4 - UNEXPOSED SURFACE TEMPERATURES (SECTION 3)

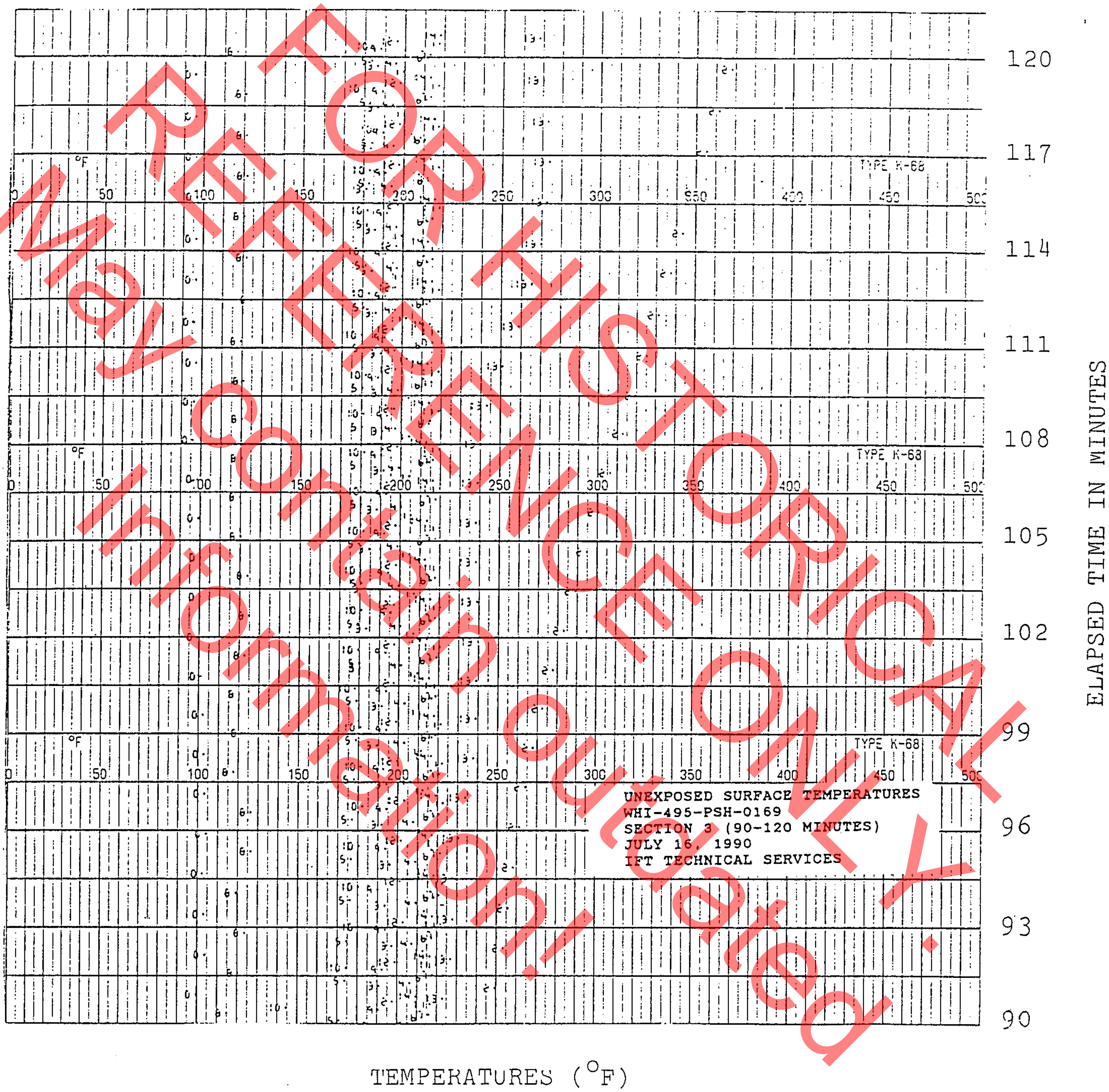


FIGURE #5
FURNACE PRESSURES
(negative inches of water)

ELAPSED TIME (minutes)	READING
15	0.005
30	0.010
45	0.010
60	0.015
75	0.015
90	0.015
105	0.015
120	0.015

FIGURE #6 - FIVE MINUTE INTERVAL SUMMARY OF FURNACE TEMPERATURES

IFT TECHNICAL SERVICES, INC.
WHI-495-PSH-0169
FURNACE TEMPERATURE
JULY 16, 1990

Temperature (Deg. F)

Time (Min.)	TC0	TC1	TC2	TC3	TC4	TC5	TC6
0	82	82	82	82	82	82	82
5	82	688	658	583	617	859	862
10	83	1182	1209	1305	1276	1213	1168
15	88	1344	1344	1308	1307	1422	1362
20	89	1419	1415	1401	1397	1449	1438
25	91	1504	1500	1473	1488	1519	1542
30	95	1548	1559	1510	1512	1493	1522
35	98	1590	1590	1543	1558	1552	1599
40	101	1618	1616	1571	1582	1578	1631
45	102	1638	1660	1660	1675	1593	1633
50	102	1678	1670	1620	1635	1638	1696
55	105	1688	1646	1650	1649	1630	1678
60	108	1777	1711	1709	1703	1690	1701
65	108	1730	1661	1628	1629	1620	1633
70	110	1750	1691	1758	1758	1747	1759
75	110	1761	1700	1766	1767	1761	1774
80	114	1779	1719	1782	1783	1780	1795
85	115	1792	1733	1792	1795	1790	1807
90	114	1802	1750	1802	1808	1806	1819
95	113	1804	1767	1812	1818	1822	1837
100	117	1809	1769	1822	1827	1825	1843
105	117	1815	1762	1810	1812	1813	1832
110	118	1830	1770	1820	1828	1828	1840
115	118	1833	1821	1790	1803	1815	1820
120	118	1857	1852	1798	1812	1828	1838
Maximum Temp. Change	36	1775	1770	1740	1746	1746	1756

FIGURE #7 - FIVE MINUTE INTERVAL GRAPH OF FURNACE TEMPERATURES

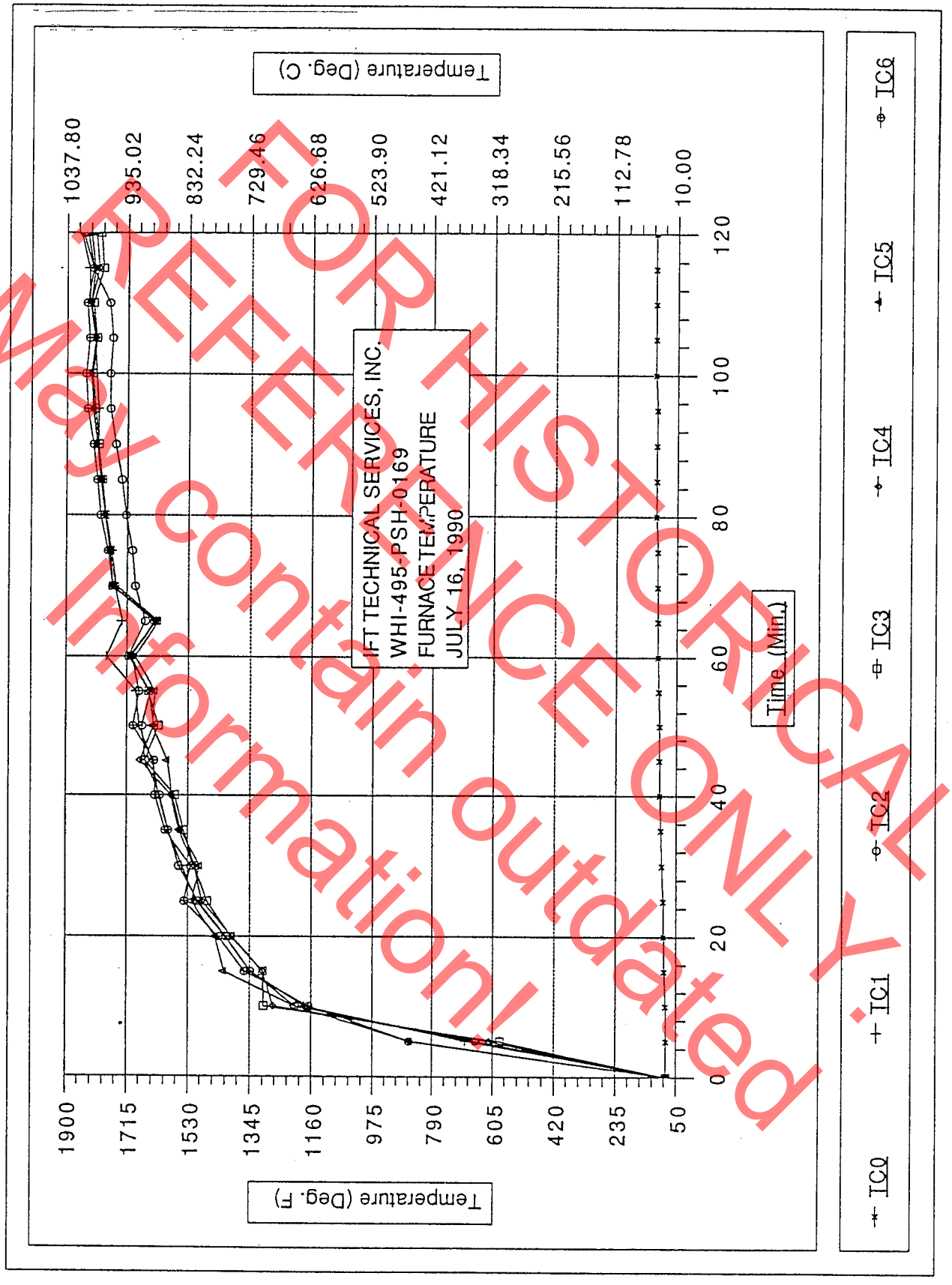


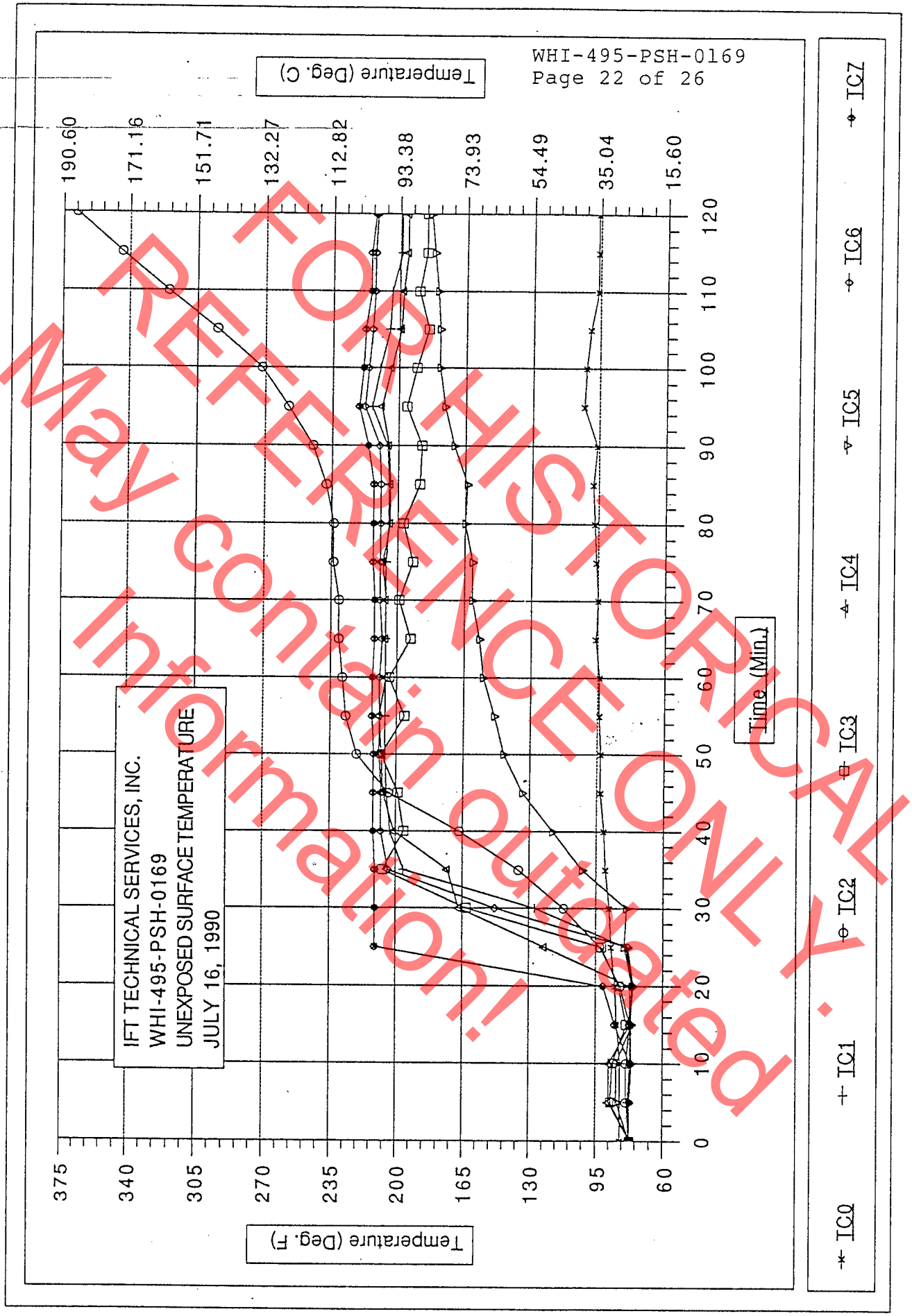
FIGURE #8 - FIVE MINUTE INTERVAL SUMMARY OF UNEXPOSED SURFACE TEMPERATURES

IFT TECHNICAL SERVICES, INC.
WRI-495-PSH-0169
UNEXPOSED SURFACE TEMPERATURE
JULY 16, 1990

Temperature (Deg. F)

Time (Min.)	TC0	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC12	TC13	TC14
0	82	77	77	77	77	77	77	77	80	85	77
5	82	78	79	87	88	84	77	77	78	85	77
10	82	77	79	86	88	84	76	77	74	78	77
15	84	76	77	79	77	76	77	85	78	127	125
20	85	76	82	83	77	76	75	91	86	177	174
25	87	79	93	92	122	80	78	211	100	186	180
30	88	127	112	163	167	79	148	211	118	190	186
35	90	196	136	207	173	102	204	211	166	182	187
40	91	203	167	196	201	118	208	212	198	193	190
45	93	205	204	199	207	134	208	212	196	197	194
50	93	206	221	208	208	144	209	212	194	198	196
55	94	206	227	196	209	149	209	213	193	203	200
60	94	206	229	204	206	155	209	213	194	205	202
65	96	206	231	193	206	157	208	212	196	205	202
70	95	206	231	199	206	161	209	212	191	206	203
75	96	206	234	192	208	161	209	213	194	210	206
80	97	205	234	197	204	165	209	213	192	211	207
85	98	205	238	189	204	164	209	213	187	215	206
90	96	206	245	188	205	171	210	216	197	222	210
95	103	214	258	196	209	176	218	221	202	231	217
100	102	210	272	191	204	179	216	219	197	239	216
105	100	205	295	185	199	179	214	218	198	237	214
110	96	204	320	190	198	180	213	215	196	251	214
115	96	199	344	186	196	182	213	215	197	283	216
120	96	199	368	186	196	184	212	213	196	268	217
120 MIN. TEMP. CHANGE	14	122	291	109	119	107	135	136	116	183	140

FIGURE #9 - FIVE MINUTE INTERVAL GRAPH OF UNEXPOSED SURFACE TEMPERATURES



PHOTOGRAPH #1
THE UNEXPOSED SURFACE BEFORE THE START OF THE TEST

PHOTOGRAPH #2
THE UNEXPOSED SURFACE AT 16 MINUTES ELAPSED TIME

PHOTOGRAPH #3
THE UNEXPOSED SURFACE AT 121 MINUTES ELAPSED TIME

PHOTOGRAPH #4
THE EXPOSED FACE AFTER THE FIRE ENDURANCE TEST WAS COMPLETED