ATTACHMENT B

THERMOCOUPLE READINGS

FROM TEST [2]

						JOB NO 0218-023	PAGE B1
0	RPC	7-9-92	BCH	7-10-92	ABB ASEA BROWN BOVERI ABB IMPELL CORPORATION	CALC NO 0210-50-0075	OF 5
REV	BY	DATE	CHECKED	DATE			

Project No 93543C Scheme 2 6/17/92

Time (min)	E119 Std (°F)	Furnace Avg (°F)	Ckt Int #1 (volts)	Ckt Int #2 (volts)	Ckt Int #3 (volts)	Ckt Int #4 (volts)
0	[illegible]	87	4.8397	5.6864	5.7277	4.8833
1	254	173	4.8391	5.6870	5.7282	4.8833
2	440	439	4.8399	5.6871	5.7283	4.8839
3	627	791	4.8403	5.6871	5.7283	4.8839
4	813	874	4.8403	5.6871	5.7283	4.8839
5	1000	838	4.8403	5.6871	5.7283	4.8839
6	1060	842	4.8403	5.6876	5.7283	4.8839
7	1120	1018	4.8403	5.6876	5.7283	4.8839
8	1180	1195	4.8403	5.6876	5.7283	4.8845
9	1240	1249	4.8410	5.6876	5.7289	4.8845
10	1300	1247	4.8410	5.6876	5.7289	4.8845
11	1327	1230	4.8410	5.6876	5.7289	4.8851
12	1346	1296	4.8408	5.6881	5.7288	4.8849
13	1364	1376	4.8414	5.6881	5.7288	4.8849
14	1380	1373	4.8408	5.6881	5.7288	4.8849
15	1395	1324	4.8414	5.6881	5.7288	4.8849
16	1410	1366	4.8414	5.6881	5.7288	4.8849
17	1423	1448	4.8414	5.6881	5.7293	4.8855
18	1436	1419	4.8419	5.6886	5.7293	4.8855
19	1448	1385	4.8419	5.6886	5.7293	4.8855
20	1459	1469	4.8419	5.6886	5.7293	4.8855
21	1470	1484	4.8419	5.6886	5.7299	4.8861
22	1480	1466	4.8419	5.6886	5.7299	4.8860
23	1490	1495	4.8425	5.6886	5.7299	4.8860
24	1499	1496	4.8425	5.6886	5.7299	4.8860
25	1508	1499	4.8419	5.6886	5.7299	4.8860
26	1517	1500	4.8425	5.6892	5.7299	4.8860
27	1525	1514	4.8425	5.6892	5.7299	4.8866
28	1533	1537	4.8425	5.6892	5.7304	4.8866
29	1541	1556	4.8425	5.6892	5.7299	4.8866
30	1548	1551	4.8430	5.6892	5.7299	4.8866
31	1555	1515	4.8430	5.6892	5.7299	4.8866
32	1562	1563	4.8431	5.6892	5.7305	4.8867
33	1569	1579	4.8431	5.6892	5.7305	4.8872
34	1576	1542	4.8431	5.6892	5.7305	4.8872
35	1582	1578	4.8438	5.6892	5.7305	4.8872
36	1588	1603	4.8438	5.6898	5.7305	4.8872
37	1594	1591	4.8438	5.6898	5.7305	4.8878
38	1600	1590	4.8438	5.6898	5.7305	4.8878
39	1606	1603	4.8438	5.6898	5.7311	4.8878
40	1612	1611	4.8442	5.6898	5.7311	4.8878
41	1617	1617	4.8442	5.6898	5.7311	4.8878

ATTACHMENT B SHT B.2/5
CALC NO 0215-56-0094 R/C

Project No. 93543C   Scheme 2   6/17/92

Time (min)	E119 Std (°F)	Furnace Avg (°F)	Ckt Int #1 (volts)	Ckt Int #2 (volts)	Ckt Int #3 (volts)	Ckt Int #4 (volts)
42	1622	1623	4.8438	5.6898	5.7311	4.8884
43	1627	1627	4.8438	5.6898	5.7311	4.8884
44	1633	1631	4.8444	5.6898	5.7311	4.8884
45	1638	1635	4.8444	5.6898	5.7311	4.8884
46	1642	1637	4.8444	5.6898	5.7311	4.8890
47	1647	1640	4.8444	5.6904	5.7311	4.8890
48	1652	1645	4.8444	5.6904	5.7311	4.8890
49	1656	1645	4.8444	[illegible]	5.7311	4.8890
50	1661	1649	4.8444	5.6904	5.7317	4.8890
51	1665	165[illegible]	4.8450	5.6904	5.7317	4.8890
52	1669	1662	4.8450	5.6904	5.7317	4.8897
53	1674	1671	4.8450	5.6904	5.7317	4.8897
54	1678	1677	4.8450	5.6904	5.7317	4.8897
55	1682	1681	4.8450	5.6904	5.7317	4.8903
56	1686	1684	4.8450	5.6904	5.7317	4.8903
57	1690	1686	4.8450	5.6904	5.7317	4.8897
58	1693	1689	4.8450	5.6904	5.7317	4.8903
59	1697	1693	4.8438	5.6898	5.7317	4.8897
60	1701	1695	4.8414	5.6887	5.7305	4.8879
61			4.8403	5.6887	5.7300	4.8884
62			4.8391	5.6887	5.7300	4.8886
63			4.8403	5.6917	5.7312	4.8914
64			4.8410	5.6957	5.7335	4.8949
65			4.8264	5.6929	5.7335	4.8920
66			4.7997	5.6893	5.7317	4.8890
67			4.7741	5.6870	5.7306	4.8879
68			4.7805	5.6864	5.7294	4.8873
69			4.8258	5.6864	5.7289	4.8867
70			4.8362	5.6858	5.7289	4.8862

Max Temp:

ATTACHMENT ___ SHT ___
CALC NO ___

Project No. 93543C Scheme 2 6/17/92

Time (min)	J-Box Steel Avg	J-Box Steel Max	TC # 1 (°F)	TC # 2 (°F)	TC # 3 (°F)	TC # 4 (°F)	TC # 5 (°F)	TC # 6 (°F)	TC # 7 (°F)
0	93	95	87	87	87	88	88	88	88
1	94	96	87	87	88	88	88	88	88
2	103	107	88	87	88	88	88	88	88
3	113	117	87	87	88	88	88	88	88
4	116	120	87	87	87	88	88	88	88
5	118	121	87	87	88	88	88	88	88
6	120	123	88	87	88	88	88	88	88
7	124	126	88	87	88	88	88	88	88
8	130	132	88	87	88	88	88	88	88
9	138	143	88	87	88	88	88	88	88
10	144	149	88	87	88	88	88	88	88
11	153	156	88	87	88	88	88	88	88
12	160	162	88	87	88	88	88	88	88
13	173	186	88	87	88	88	88	98	88
14	184	204	88	87	88	88	88	88	88
15	197	221	88	87	88	88	88	88	88
16	210	242	88	88	88	88	88	88	88
17	221	259	88	88	88	88	88	88	88
18	237	280	88	88	88	88	88	88	88
19	252	298	88	88	88	88	88	88	88
20	269	316	88	88	88	88	88	89	88
21	293	352	88	88	88	88	89	89	89
22	312	362	89	88	88	88	89	89	89
23	319	364	89	88	88	88	89	89	89
24	323	382	89	88	89	89	89	89	89
25	340	409	89	89	89	89	89	90	89
26	350	427	90	89	89	89	90	90	89
27	354	439	90	89	89	89	90	90	90
28	368	463	91	89	89	90	90	91	90
29	392	505	91	90	90	90	91	91	90
30	407	527	92	90	90	90	91	91	90
31	419	539	93	90	91	91	92	92	91
32	428	532	93	91	91	91	92	92	91
33	440	534	94	91	92	92	93	93	92
34	432	513	95	92	93	92	93	93	92
35	440	501	96	92	94	93	94	94	93
36	437	477	97	93	95	93	95	95	93
37	441	471	98	94	96	94	96	95	94
38	450	472	100	95	97	95	97	96	94
39	458	484	101	96	98	96	97	97	95
40	471	510	102	96	99	97	98	98	96
41	478	526	104	98	101	97	99	99	96

ATTACHMENT B SHT B 4/5
CALC NO. 0218-[illegible]

Project No. 93543C Scheme 2 6/17/92

Time (min)	J-Box Steel Avg	J-Box Steel Max	TC # 1 (°F)	TC # 2 (°F)	TC # 3 (°F)	TC # 4 (°F)	TC # 5 (°F)	TC # 6 (°F)	TC # 7 (°F)
42	483	538	106	99	102	98	100	100	97
43	480	538	107	101	103	100	101	101	98
44	477	531	109	102	105	101	102	102	99
45	473	522	111	104	107	102	103	103	100
46	465	507	113	105	108	103	105	104	101
47	457	502	115	107	110	104	106	105	101
48	450	497	117	109	112	105	107	106	102
49	440	484	120	112	114	107	108	107	103
50	431	468	122	114	116	108	110	109	104
51	419	447	125	116	119	110	111	110	105
52	408	428	128	118	121	111	113	111	106
53	407	424	131	121	124	113	115	113	107
54	398	410	134	123	127	115	116	114	109
55	393	408	138	126	130	116	118	115	110
56	386	400	142	129	132	118	119	117	111
57	387	393	146	131	135	120	121	118	112
58	388	398	149	134	138	122	123	119	113
59	399	409	153	137	141	123	125	120	115
60	392	405	156	140	145	125	126	122	116
61									
62									
63									
64									
65									
66									
67									
68									
69									
70									
Max Temp:	483	539	156	140	145	125	126	122	116

ATTACHMENT B SHT B.45
CALC NO 2218-SQ-0396 R10

Enclosure 3

FIGURE 7.1

2EP-5.08
REVISION 3
PAGE 1 OF 1

CALCULATION TITLE PAGE

TEXAS UTILITIES ELECTRIC CO. / CPSES UNIT 2	PAGE 1 TOTAL NO. OF PAGES 29
CALCULATION TITLE (Indicative of the Objective): Calculation of Thermal Response for Sprinkler and Raceway Supports	CALCULATION CLASSIFICATIONS: ☒ CLASS I or II ☐ NON-SAFETY

CALCULATION IDENTIFICATION

ORGANIZATION:	CALCULATION NUMBER TYPE	CALCULATION NUMBER NUMBER	
SWEC	FPT 2	2-FP-0042	
WPST NUMBER — — — — — (OR) WPN 5 6 K	COMPUTER OUTPUT YES ☐ NO ☒ ATTACHED YES ☐ NO ☒	SYSTEM/SUB-SYSTEM (Generic) N/A	

APPROVALS - PRINT NAME, SIGN, AND DATE: PREPARER(S)	CHECKER(S)/ REVIEWER(S)	APPROVAL(S)/ INDEPENDENT REVIEWER(S)	REV. NO.	SUPPLEMENTS/ SUPERSEDES (TYPE/NUM./REV.)	CONFIRMATION REQUIRED YES	CONFIRMATION REQUIRED NO
F. [illegible] Collins [signature] 7-10-92	E J SANDERS [signature] 7-10-92	E J SANDERS [signature] 7-10-92	0	N/A	X see pages 4+5 +28	

DISTRIBUTION:

FILE BOOK NO 11-1 / C-28 SWEC
E. SANDERS BOS 245/9 SWEC
F. COLLINS BOS 245/9 SWEC
R. DIBLE MECH C-28 SWEC

FIGURE 7.4
COMPUTER OUTPUT/CROSS REFERENCE

ORGANIZATION: SWEC JOB NO. 01631.02

CALC NO.: 2-FP-0042 REV. 0 PAGE 2

COMPUTER RUN UNIQUE IDENTIFIER					
1JOB DATE	PROG. NAME2	VERSION/LEVEL2	LIBRARY NAME2	COMPUTER 1JOB NUMBER*	ADD/ DELETE
		N/A			

*or unique identification number
1) Mandatory
2) Optional, as appropriate

CROSS REFERENCE

CALC. TYPE	CALC. NUMBER	REVISION	ADD/DELETE
FPT2	2-FP-0081	0	ADD
FPT2	2-FP-00[illegible]5	2	ADD
FPT2	2-FP-0019	1	ADD
FPT2	2-FP-0030	0	ADD
FPT2	2-FP-0032	0	ADD
FPT2	2-FP-0035	0	ADD
MEC2	2-ME-0282	0	ADD
FPT2	2-FP-0085	1	Add
IMFP	0210-063-0043	6	Add
IMFP	0210-063-0003	[illegible]	Add

SUPPLEMENTS

DO EXISTING SUPPLEMENTS APPLY TO NEW REVISION? N/A ☐ YES ☐ NO

STONE & WEBSTER ENGINEERING CORPORATION

REVIEW STATEMENT FOR CALCULATIONS

CALCULATION IDENTIFICATION NUMBER			PAGE 3
CALCULATION NO.	REVISION NO.	CALC. CHANGE NOTICE NO.	OF 29
2-FP-0042	0	N/A	

REVIEW OF THIS CALCULATION WAS BASED ON THE METHODS BELOW

		INITIAL UPON COMPLETION
1) REVIEW OF:		
A) INPUTS TO ASSURE THAT THEY HAVE BEEN PROPERLY SELECTED AND CORRECTLY USED IN THE CALCULATION. (CHECK ONE)		
i) LIMITED REVIEW (PROVIDE JUSTIFICATION)	[ ]	N/A
ii) LINE BY LINE REVIEW	[X]	EJS
B) ASSUMPTIONS TO ASSURE THEIR VALIDITY AND NEED FOR LATER CONFIRMATION.	[X]	EJS
C) METHODOLOGY TO ASSURE THE APPROPRIATENESS OF THE OVERALL APPROACH, ITS IMPLEMENTATION, AND THE CORRECTNESS OF THE SPECIFIC EQUATIONS UTILIZED. (CHECK ONE)		
i) LIMITED REVIEW (PROVIDE JUSTIFICATION)	[ ]	N/A
ii) LINE BY LINE REVIEW	[X]	EJS
D) RESULTS TO ASSURE REASONABLENESS AND ACCURACY.	[X]	EJS
E) IF ALTERNATE CALCULATION IS PERFORMED TO VERIFY C) AND D) CHECK HERE AND ATTACH CALCULATION AS AN APPENDIX	[ ]	N/A
2) CHECK OF CALCULATION (CHECK ONE)		
A) COMPLETE NUMERICAL CHECK	[X]	EJS
B) NUMERICAL CHECK OF CRITICAL ITEMS (STATE ITEMS AND JUSTIFICATION BELOW)	[ ]	N/A
3) ADMINISTRATIVE CHECK OF FORMAT AND CONTENT	[X]	EJS

4) COMMENTS/JUSTIFICATION

REVIEW METHODS SELECTED AS INDICATED ABOVE

E.J. SANDERS [signature] — INDEPENDENT REVIEWER — DATE 7-10-92

[signature] — SUPERVISOR CONCURRENCE — DATE 7/10/92

SATISFACTORY COMPLETION OF REVIEW (CALCULATION IS APPROVED FOR ISSUE)

E.J. SANDERS [signature] — CHECKER — DATE 7-10-92

E.J. SANDERS [signature] — REVIEWER — DATE 7-10-92

E.J. SANDERS [signature] — INDEPENDENT REVIEWER — DATE 7-10-92

TABLE OF CONTENTS

* CONFIRMATION REQUIRED

1.0 Objectives

The objectives of this calculation are:

1) To determine the response time for sprinkler actuation for a transient combustible (hydrocarbon) fire, a "C" curve fire and a "E-119" fire.

2) To determine the time for a raceway support under dead weight load conditions to fail (reach 1200°F) for a transient combustible fire, a "C" curve fire and a "E-119" fire.

3) Determine the heat release rate for each type of fire.

4) Determine the cooling effect from a single sprinkler on a square foot basis.

5) Compare the above results to demonstrate that a design basis fire will not cause failure of a raceway support.

6) Evaluate as-built configurations, administrative controls, etc. for rooms without sprinkler protection which contain protected raceways (i.e. Thermo-Lag and/or Firezone "R" cable) to determine the acceptability of raceway supports under fire conditions.

This calculation provides input to calculation 2-FP-0085, "Raceway and Firezone R Cable Supports Analysis" (Ref. 3.32) which will be revised to incorporate the results of this calculation.*

* CONFIRMATION REQUIRED

2.0 Assumptions

2.1 Sprinklers at CPSES are Grinnell Model F950 rated at 212°F. This is the worst case sprinkler based on Ref. 3.1, 3.2, 3.3 and 3.4. These references are representative sprinkler system hydraulic calculations for the Unit 2 Safeguards Building where Thermo-Lag and/or "Firezone "R"' cable is installed. The 212°F rating is the highest temperature rating for sprinklers in any of these areas.

2.2 Based on Ref. 3.5, the sprinkler's Response Time Index (RTI) is 285 $ft^{1/2} \bullet S^{1/2}$ which is the worst case.

2.3 Per Ref. 3.8, 1 lb. of combustible material equates to 8,000 BTUs.

2.4 All sprinklers will be assumed to be installed at the ceiling level (worst case for response time). Based on the presence of sprinklers installed below major obstructions (such as grouped cable trays) in the plant per NFPA 13 (Ref. 3.20), this is a conservative assumption.

2.5 Sprinklers are assumed to be spaced 10 ft. on centers. This gives a radial distance from the center of a 10' by 10' arrangement of 7.07 ft. The fire will be assumed in the center of the spacing. Based on the congestion around cable trays and the presence of cable tray sprinklers in the plant, this is a very conservative assumption.

2.6 Failure of the structural steel will be assumed at a steel temperature of 1200°F. The 1200°F (1660°R) is based on the low stresses imposed on the support steel (worst case ~~7~~ 9 ksi per Attachment 2). The supports are constructed of 36 ksi (yield stress) steel and ~~7~~ 9 ksi is less than ~~20%~~ 25% of yield. Based on Ref. 3.8, 1200°F is sufficiently low such that supports loaded to ~~7~~ 9 ksi will still function.

2.7 For transient combustible (hydrocarbon) fires, the adiabatic flame temperature of 1500°K (2240°F) will be used. This is worst case flame (fire) temperature because a fire cannot produce temperatures any higher, and the higher the temperature the sooner the steel reaches 1200°F.

2.8 The raceway support will be assumed to be located 10 ft. off the floor in areas where there is suppression. This assumption is based on the variations of raceway elevations in the plant and is suitably representative for purposes of this analysis considering other conservative assumptions.

2.9 The "C" curve will be used to represent a fire in the plant. This is based on a review of Ref. 3.14 which shows that the majority of the combustible material in the Safeguards Building is cable in tray and per Ref. 3.8, IEEE-383 cable has a flame spread of only approximately 0.1 ft^2/min.

2.10 Ambient air temperature at time zero will be 75°F in accordance with guidance provided by Ref. 3.15.

2.11 Water discharging from the sprinkler will be 80% effective. This is based on Ref. 3.13 and 3.22 with 36% effectiveness in the plume and the cooling effect on vertical plates plus cooling of the burning object (horizontal surface). Also, the burning rate of the object will be reduced by prevention of reradiation.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 8
01531.02	MECH	2-FP-0042, Rev. 0	56Φ	

3.0 References/Inputs

3.1 Sprinkler System Hydraulic Calculation 2-FP-0019, Rev. 1.

3.2 Sprinkler System Hydraulic Calculation 2-FP-0030, Rev. 0.

3.3 Sprinkler System Hydraulic Calculation 2-FP-0032, Rev. 0.

3.4 Sprinkler System Hydraulic Calculation 2-FP-0035, Rev. 0, CCN-0001

3.5 Sprinkler Response Calculation 2-FP-0015, Rev. 2.

3.6 DBD-ME-225, Rev. 2 "Fire Suppression System".

3.7 Heat Transfer by Frank M. White, 1st ed.

3.8 SFPE Handbook of Fire Protection Engineering by the Society of Fire Protection Engineers, 1st ed.

3.9 Heating Ventilation and Air Conditioning by McQuiston, 2nd ed.

3.10 "Methods to Calculate the Response Time of Heat and Smoke Detectors Installed Below Large Unobstructed Ceilings" by Evans, Fire Technology, Volume 22, Number 1.

3.11 "Calculation of Response Time of Ceiling Mounted Fire Detectors" by Alpert, Fire Technology Volume 8.

3.12 Manual of Steel Construction (AISC), 7th ed.

3.13 "Evaluation of Unsprinklered Fire Hazards" by Alpert and Ward, Fire Journal, Volume 7 (1984).

3.14 Unit 2 Safeguards Building Combustible Loading Calculation 2-FP-081, Rev. 0.

3.15 NRC Generic Letter 86-10.

3.16 NFPA — 231C, "Standard for Rack Storage of Materials", 1991 edition.

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 9
01531.02	MECH	2-FP-0042, Rev. 0	560	

3.17 "Correlations of Steel Column Fire Test Data" by Gandhi, Fire Technology, February 1988.

3.18 "On the Evaporation of ~ Sprinkler Water Spray" by Chow, Fire Technology, November 1987.

3.19 "The Fire Resistance of Steel Structures" by Gehri, Fire Technology, Volume 21, Number 1.

3.20 NFPA 13, "Standard for the Installation of Sprinkler Systems" 1991 edition.

3.21 Unit 2 Fire Safe Shutdown Analysis, Calculation 2-ME-0282, Rev. 0.

3.22 "Cooling Water Requirements for the Protection of Metal Surfaces Against Thermal Radiation" by Y. Lev, Fire Technology, August 1989.

3.23 Engineering Assessment Procedure 2-EAP-016, Rev. 0, "Walkdown of Fire Protection Features".

3.24 CPSES Unit 2 Procedure 2EP-5.08, "Project Calculations", Rev. 3 (PCN 04).

3.25 SWEC Procedure 2SW-5.08, "SWEC Calculations", Rev. 1 (PCN 04).

3.26 Crane Technical Paper 410, 24th printing (1988).

3.27 CPSES-9221733, Letter From G.R. Ashley to J.E. Woods dated July 11, 1992. (Transmittal for Attachment 2).

3.28 Calculation 0210-063-0043, Rev. 6, "Maximum Permissible Fire Loading/Non-rated Features Analysis".

3.29 Calculation 0210-063-0003, Rev. 4, "Auxiliary Building As-Built Combustible Loading".

3.30 NUREG-0797 Supplement 21, dated April 1989, "Safety Evaluation Report related to the operation of Comanche Peak Steam Electric Station Units 1 and 2".

3.31 CPSES Procedure STA-729, Rev. 4, "Control of Transient Combustibles Ignition Sources and Fire Watches".

3.32 Calculation 2-FP-0085, Rev. 1, "Raceway and Firezone R Cable Supports Analysis".

4.0 Methodology

4.1 Determine sprinkler response (actuation) time.

a) For a transient combustible (hydrocarbon) fire; calculate the fire size based on the adiabatic flame temperature of 2240°F (1500°k) at the raceway support using the following equation for a fire plume temperature:

$\Delta T = 300(\dot{Q})^{2/3}/H^{5/3}$ (Ref. 3.13)

$\Delta T = (2240 - 75) = 2165°F$

$\dot{Q}$ = Heat Release Rate (fire size) BTU/sec.

H = distance from fuel to support (ft)

Then, calculate the temperature at the ceiling using the following equation for ceiling jet temperature:

$$\Delta T = 92 \frac{\dot{Q}^{2/3}}{r^{2/3}}/H \quad \text{(Ref. 3.11)}$$

Where: r = radial distance from the fire to the sprinkler (7.07 ft)

H = distance from fuel to ceiling.

$\Delta T = Tg - Ta$

Determine the ceiling jet velocity using the following equation:

$$u = \frac{\dot{Q}^{1/3}H^{1/2}}{r^{5/6}} \quad \text{Ref (3.10) (Note 1)}$$

u = ceiling jet velocity (ft/sec) all other terms the same.

Determine sprinkler response time using the following equation:

$RTI = trU^{1/2}/\ln[(Tg - Ta)/(Tg - Tr)]$ (Ref. 3.8)

RTI = Response Time Index ($ft^{1/2}S^{1/2}$)

tr = Response Time (sec)

U = Ceiling jet velocity (ft/sec)

Tg = Ceiling jet temperature (°F)

Ta = Ambient Temperature (°F) (75°F)

Tr = Actuation Temperature (°F)

Note 1: Converted to I-P units

b) Sprinkler response for "C" curve fire. The sprinkler response time will be calculated at various times along the "C" curve using the corresponding temperature at that time as a constant and then determining the response time as before using $RTI = t_r U^{1/2} / \ln[(T_g - T_a)/(T_g - T_r)]$ by adding the "C" curve time and response time together, the sprinkler actuation time will be determined.

c) Sprinkler response for "E" curve fire. The response time will be determined using the above method for a "C" curve fire.

4.2 Cable raceway support thermal response.

a) Determine the smallest (worst case) W/D ratio. The W/D ratio is the ratio of the weight per linear foot of a support divided by the heated perimeter of the support. The smaller the W/D ratio, the faster it will respond (increase in temperature) to the fire plume temperature. By determining the smallest W/D ratio, only one support has to be analyzed for each fire condition.

b) Determine support steel thermal response for a transient combustible (hydrocarbon) fire.

For a hydrocarbon fire, the fire plume temperature will be 2240°F (2700°R) per Assumption 2.7.

For determination of the support thermal response the following equation will be used:

$$\Delta TS = \frac{\alpha}{C_s (W/D)} \times (T_f - T_s) \Delta t \qquad \text{(Ref. 3.8)}$$

This equation will be explained in the body of the calculation.

c) Determine support steel thermal response for a "C" curve fire.

The above equation will be used with the fire temperature being the "C" curve temperature at each time step or if the fire growth rate is slow enough and there is no thermal delay between the support at the fire temperature, then the time for the fire to reach 1200°F will be used.

d) Determine support steel thermal response for a "E" curve fire. The equation used for a hydrocarbon fire will be used except the fire temperature will use the following equation:

$$Tf = 620 \log_{10} (0.133t + 1) + To \quad \text{(Ref 3.8)}$$

This equation will be explained in the body of the calculation.

4.3 Determine heat release rates.

a) For a hydrocarbon fire the $\dot{Q}$ determined in 5.1.a will be used to determine a fire size (pool size) for a gasoline fire and the quantity of gasoline required to cause the support to reach 1200°F will be determined.

b) Heat release rate for a "C" curve fire.

The $\dot{Q}$ will be determined by calculating the total BTU/sq. ft. from the "C" curve and then dividing by the time to sprinkler actuation or support yield to determine release rates.

c) Heat release rate for a "E" curve fire.

The same approach as for a "C" curve fire will be used.

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4.4 Determine cooling effect of a sprinkler on a per square foot basis and cooling effect on reducing plume temperature for a hydrocarbon fire.

The cooling effect will be based on the design density of the suppression system and the effective BTU value per lbm of water.

In addition, the cooling effect on a support will be addressed by determining the cooling effect of the water on the support by placing the design density of the suppression system (multiplied by the effectiveness of the sprinkler) on the smallest side of the support.

4.5 Compare the results of the above to demonstrate that the supports will not fail.

In addition, review the rooms without suppression to determine the effects on the support from a fire.

5.0 Body of Calculation

5.1 Sprinkler Response Time

a) Transient combustible (hydrocarbon) fire

1) $\Delta T = 300\ (\dot{Q})^{2/3}/H^{5/3}$ (Fire Size)

$2165 = 300\ (\dot{Q})^{2/3}/(10)^{5/3}$

$Q = \underline{6131}$ BTU/sec

2) $\Delta T = 92\ (\dot{Q}/r)^{2/3}/H$ (ceiling jet temperature)

$\Delta T = 92\ (6131/7.07)^{2/3}/20$

$\Delta T = 418°F$

$Tg = 418 + 75°F = \underline{493°F}$

3) $U = \dfrac{\dot{Q}^{1/3}\ H^{1/2}}{r^{5/6}}$ (ceiling jet velocity)

$U = \dfrac{(6131)^{1/3}\ (20)^{1/2}}{(7.07)^{5/6}} = \underline{16\ ft/sec}$

$RTI = tr\ U^{1/2}/\ln\ [(Tg - Ta)/(Tg - Tr)]$ (Response Time)

$285 = tr\ (16)^{1/2}/\ln\ [(493 - 75)/(493 - 212)]$

$tr = \underline{28\ sec}$ (Response time in hydrocarbon fire)

b) "C" curve fire

The response time of the sprinkler is based on a constant surrounding temperature and the time to sprinkler actuation is the time to reach that temperature plus the time for the sprinkler to actuate at that temperature.

$RTI = tr\ U^{1/2}/\ln\ [(Tg - Ta)/(Tg - Tr)]$

$U = 4$ ft/sec (from Ref. 3.8)

$RTI = 285\ ft^{1/2}s^{1/2}$ (Assumption 2.2)

$Ta = 75°F$

$Tr = 212°F$

Tg = from Attachment 1 "C" curve

"C" Curve		ACTUATION TIME		TOTAL TIME (MIN.)
Temp (°F)	Time (min.)	(sec.)	(min.)	
260	2	193	3.2	5.2
340	3	104	1.73	4.73
420	4	72	1.2	5.2
500	5	55	.92	5.92

Based on the above table the sprinkler actuation time is approximately 5 min. for a "C" curve fire

c) "E" curve fire

The response time will be based on the same method as the "C" curve fire only using the "E" curve. (Attachment 1)

"E" Curve		Actuation Time		Total Time
Time (min.)	Temp (°F)	(sec.)	(min.)	(min.)
.25	370	89	1.48	1.73
.5	500	55	.92	1.42
1	660	38	.63	1.63

Based on the above table, the sprinkler actuation time is approximately 1.5 min. for a "E" curve fire.

5.2 Cable Raceway Support Thermal Response

a) Determine the smallest (worst case) "W/D" ratio for the four different supports used for raceways (per Attachment 2).

All weights and dimensions are from Ref. 3.12

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

5010.65

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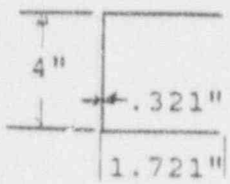
1) <u>C 4 X 7.25</u>

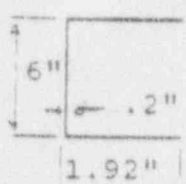
W = 7.25 lbs/ft (Linear)



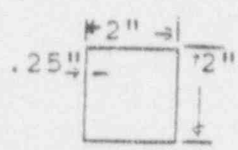
D = (2 X 4") + (4 X 1.721") - (2 X .321") = 14.2"
D = 14.2"/12 = 1.18 ft
W/D = 7.25/1.18 = <u>6.14 lbs/ft²</u>

2) <u>C6 X 8.2</u>

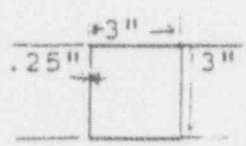
W = 8.2 lbs/ft
D = (2 X 6") + (4 X 1.92") - (2 X .2") = 19.28"
D = 19.28"/12 = 1.6 ft
W/D = 8.2/1.6 = <u>5.13 lbs/ft²</u>



3) <u>Tube steel 2 X 2 X ¼</u>
W = 5.4 lbs
D = (4 X 2") = 8"
D = 8"/12 = .67 ft
W/D = 5.4/.67 = <u>8.1 lbs/ft²</u>



4) Tube steel 3 X 3 X ¼
W = 8.8 lbs/ft
D = (4 X 3") = 12"
D = 12"/12 = 1 ft
W/D = 8.8/1 = <u>8.8 lbs/ft²</u>



Based on the W/D ratios, the C6 X 8.2 is the worst case member.

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b) Determine support steel thermal response for a transient combustible (hydrocarbon) fire (Tf = 2700°R or 2240°F).

$$\Delta Ts = \frac{\alpha}{C_s(W/D)} X (Tf - Ts) \Delta t$$ (Ref. 3.8)

$$\alpha = \alpha r + \alpha c$$ (Ref. 3.8)

where:

$$\alpha r = 4.76 X 10^{-13} X E_f \times \frac{(Tf^4 - Ts^4)}{(Tf - Ts)}$$ (Ref 3.8 & 3.7)

$4.76 X 10^{-13}$ is the Steffan-Boltzmann Constant $(1.7121 X 10^{[illegible]}) \frac{BTU}{hr-ft^2-°R}$ corrected from hrs. to secs.

E_f = .7 based on Ref. 3.8 columns (worst case)

$$\alpha c = 1.46 \frac{BTU}{hr-ft^2-°F}$$ (Ref. 3.7)

converted to sec. $4 X 10^{-4} \frac{BTU}{sec-ft^2-°F(°R)}$

W = weight of steel = 8.2 lbs/ft (for C6 X 8.2)
D = heated perimeter = 1.6 ft
W/D = 5.13 lbs/ft^2

Cs = the specific heat of the steel which ranges from .107 BTU/lbm °F at 0°F to .172 BTU/lbm °F at 1100°F and remains constant above 1200°F. Cs will be modeled by the following equation
$Cs = .107 t(5.9 X 10^{-5} X (Ts - 460°)$

Where:

Ts = the steel temperature in °R

ΔTs = the change in steel temperature at any time step

Δt = time increment in sec.

Tf = the flame temperature = 2700°R

Note: Ts at time 0 = 535°R or 75°F for ambient air conditions (Assumption 2.10).

Table of results of iteration of above equations at 2 sec. intervals:

Note: 2 sec interval was used because of the high (2700°R) Flame Temperature

Time (sec.)	Tf (°R)	Ts_1 (°R)	d	Cs	ΔTs (°R)	Ts_2 (°R)
0	2700	535	0	-	0	535
2	2700	535	8.6×10^{-3}	.111	65	600
4	2700	600	8.8×10^{-3}	.115	62	662
6	2700	662	9.1×10^{-3}	.119	61	723
8	2700	723	9.3×10^{-3}	.122	59	782
10	2700	782	9.6×10^{-3}	.126	57	839
12	2700	839	9.8×10^{-3}	.129	55	894
14	2700	894	1.0×10^{-2}	.133	53	947
16	2700	947	1.0×10^{-2}	.136	52	999
18	2700	999	1.1×10^{-2}	.139	51	1050
20	2700	1050	1.1×10^{-2}	.141	49	1099
22	2700	1099	1.1×10^{-2}	.144	48	1147
24	2700	1147	1.1×10^{-2}	.148	47	1194
26	2700	1194	1.2×10^{-2}	.150	46	1240
28	2700	1240	1.2×10^{-2}	.153	45	1285
30	2700	1285	1.2×10^{-2}	.156	44	1329
32	2700	1329	1.3×10^{-2}	.158	42	1371
34	2700	1371	1.3×10^{-2}	.161	41	1412
36	2700	1413	1.3×10^{-2}	.163	41	1453
38	2700	1453	1.3×10^{-2}	.166	39	1492
40	2700	1492	1.4×10^{-2}	.168	38	1531

Time (sec.)	Tf (°R)	Ts_1 (°R)	α	Cs	ΔTs (°R)	Ts_2 (°R)
42	2700	1531	1.4×10^{-2}	.170	37	1568
44	2700	1568	1.4×10^{-2}	.172	36	1604
46	2700	1604	1.5×10^{-7}	.172	36	1641
48	2700	1641	1.5×10^{-2}	.172	36	1677 (Approx. 1200°F)

The support reaches 1200°F in approximately 47.5 seconds

Preparer's Note: The calculator used, maintains numbers to 10 places. No effort was made to round-off these numbers during the calculation because the accuracy of the analysis was maintained.

c) Determine support steel thermal response for a "C" curve fire.

From Attachment 1, a "C" curve fire takes approximately 42 minutes to reach 1200°F. Due to the slow growth rate of fire temperature, the support temperature will closely follow the fire temperature. Therefore; 42 minutes will be used as the time to reach 1200°F for a "C" curve fire.

d) Determine support steel thermal response for an "E" curve fire.

The method will be the same as that for a transient combustible (hydrocarbon) fire except that Tf will be calculated using the following equation:

$$Tf = 620 \log_{10} (.133 t + 1) + To \quad \text{(Ref. 3.8)}$$

Where: Tf = Fire Temperature

t = Duration time in seconds

To = ambient temperature at Time = 0
To = 535°R or 75°F (Assumption 2.10)

Due to the duration time ΔT = 30 sec. will be used. As before, W/D = 5.13, Cs same as used above.

Time (sec.)	Tf (°R)	Ts_1 (°R)	d	Cs	ΔTs (°R)	Ts_2 (°R)
0	535	535	0	-	0	535
30	967	535	1.0×10^{-3}	.111	23	558
60	1126	558	1.3×10^{-3}	.113	38	596
90	1225	596	1.5×10^{-3}	.115	49	645
120	1297	645	1.8×10^{-3}	.118	57	702
150	1354	702	2.0×10^{-3}	.121	63	765
180	1401	765	2.2×10^{-3}	.125	66	831
210	1441	831	2.5×10^{-3}	.129	69	900
240	1475	900	2.8×10^{-3}	.133	70	970
270	1507	970	3.1×10^{-3}	.137	70	1040
300	1534	1040	3.3×10^{-3}	.141	69	1109
330	1559	1109	3.7×10^{-3}	.145	66	1175
360	1582	1175	4.0×10^{-3}	.149	63	1238
390	1603	1238	4.3×10^{-3}	.153	60	1298
420	1623	1298	4.6×10^{-3}	.156	56	1354
450	1641	1354	4.9×10^{-3}	.160	52	1406
480	1658	1406	5.2×10^{-3}	.163	47	1453
510	1674	1453	5.5×10^{-3}	.166	53	1496
540	1690	1496	5.8×10^{-3}	.168	39	1535
570	1704	1535	6.1×10^{-3}	.170	35	1570
600	1718	1570	6.3×10^{-3}	.172	32	1602
630	1731	1602	6.6×10^{-3}	.172	29	1631
660	1742	1631	6.8×10^{-3}	.172	26	1657
690	1755	1657	7.0×10^{-3}	.172	23.	1680

The support reaches 1200°F in approximately 660 sec. or 11 min.

Preparer's Note: The calculator used, maintains number to 10 places. No effort was made during the calculation to round-off these numbers because the accuracy of the analysis was maintained.

5.3 Determine heat release rates.

a) For transient combustible (hydrocarbon) fire

$\dot{Q}$ = 6131 BTU/sec (from 5.1.a)

Calculate total heat release before sprinkler actuates and support yields

Sprinkler time 28 sec. (5.1.a)
Support time 47.5 sec. (5.2.b)

Q sprinkler = 6131 BTU/sec X 28 sec. = 17 X 10^4 BTU
Q support = 6131 BTU/sec X 47.5 sec. = 29 X 10^4 BTU

From Ref. 3.8, gasoline has a heat value of 43.7 MJ/kg or 18789 BTU/lbm

Gas mass sprinkler = 17 X 10^4/18789 = 9 lbm or 1.5 gals.
Gas mass support = 29 X 10^4/18789 = 15.4 lbm or 2.6 gals.

Determine diameter of fire.

Where:

$\dot{M}'' = \dot{M}''_{\infty} (1 - e^{-kBD})$ (Ref. 3.8)

Where: $\dot{M}''$ is the mass burn rate
$\dot{M}''_{\infty}$ is the mass ideal burn rate
-kB = extinction - absorption coefficient
D = the diameter of the fire

and

$\dot{Q} = \Delta hc \times \dot{M}'' \times A$

Where: A = Area of pool or $\frac{\pi D^2}{4}$

Δhc = heat of combustion

$\dot{Q}$ = heat release rate = 6131 BTU/sec or 6.47 kw

Δhc = 43.7 Mj/kg (Ref. 3.8)
$\dot{M}''_{\infty}$ = 0.055 (Ref. 3.8)
kB = 2.1 (Ref. 3.8)

Therefore,

$$Q = \Delta hc\ \dot{M}''_{\infty}\ (1 - e^{-kBD})\ X\ \frac{\pi D^2}{4}$$

or

$$6.47\ X\ 10^{-3} = 43.7\ X\ 0.055\ (1 - e^{-2.1D})\ X\ \frac{\pi D^2}{4}$$

Solving for D:

D = .123m or .4 ft
Area = .12 ft^2

which equates to a 1 gal. paint can size opening, so the fire size is reasonable.

b) Determine heat release rate for a "C" curve fire.

From Attachment 1, for a fire to last 42 minutes, 5 lbs/ft^2 of combustible or 40,000 BTU/ft^2 must be consumed. This equates into a heat release rate of 40,000 BTU/ft^2 ÷ 42 min. = <u>952 BTU/ft^2 min.</u>

c) Determine the heat release rate for a "E" curve fire.

From Attachment 1, for a fire to last 12 minutes, 2 lbs/ft^2 must be consumed.

This equates into a heat release rate of 16,000 BTU/ft^2 ÷ 12 min. = 1333 BTU/ft^2 min.

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5.4 Determine the effective cooling of a sprinkler

From Reference 3.6, the minimum design density for sprinkler systems is .19 gpm/ft^2.

From Reference 3.26 (steam tables), to raise water from 104°F (max. design temp.) to 212°F and evaporate into steam takes approximately 1100 BTU/lbm or 9130 BTU/gal.

Based on assumption 2.11 the cooling effect would be .8 X 9130 or 7304 BTU/gal. Therefore, the effective cooling would be:

7304 BTU/gal X .19 gpm/ft^2 or 1388 BTU/ft^2/min.

For a transient (hydrocarbon fire) based on assumption 2.5, the area of coverage for one sprinkler would be 100 ft^2 (10′ X 10′ area) and would have a minimum flow of 100 X .19 = 19 gpm or an effective cooling of 19 X 7304 = 13.9 X 10^4 BTU/min or 2313 BTU/sec.

This effectively reduces the fire heat release rate from 6131 BTU/sec to 3818 BTU/sec. This would reduce the fire plume temperature at the support to:

$\Delta T = 300(Q)^{2/3}/H^{5/3}$ (5.1.a)

$\Delta T = 300(3818)^{2/3}/(10)^{5/3}$

$\Delta T = 1579$

$T_f = 1579 + 75 = 1654$°F

which is a 586°F (2240 - 1654) drop in fire plume temperature almost immediately, without crediting the reduction of the (source) fire size that will follow due to lack of reradiation.

Cooling effect on support steel: The smallest possible area of the support exposed for cooling would be 1.92 in. (.16 ft.) ~~or .16ft² per linear foot of support~~, for a cooling effect on the support of:

.16ft X 1388 BTU/ft^2/min = 222 BTU/min. per ft. or 3.7 BTU/sec. per ft.

With a weight of steel of 8.2 lbm/ft., using 1100°F as the steel temperature (Cs = .172 BTU/lbm °F), the support would cool off at a rate of 2.6 °F/sec.

5.5 Comparison of Results

a) For a transient combustible (hydrocarbon) fire

The sprinkler actuates in 28 sec. while the support takes 47.5 sec. to yield. Therefore the sprinkler will cool the support and prevent failure of the support.

b) For a "C" curve fire

The sprinkler actuates in 5 min. while the support takes 42 min. to yield. The sprinklers provide 1388 BTU/ft^2/min. cooling while the fire only produces 952 BTU/ft^2/min. Therefore, the fire will be suppressed long before the support would yield.

c) For a "E" curve fire

The sprinkler actuation time is 1.5 min. while the support takes 11 min to yield. The sprinkler provides 1388 BTU/ft^2/min. cooling while the fire only produces 1333 BTU/ft^2/min of heat. Therefore the fire will be suppressed before the support would yield.

d) Evaluation Of Rooms Without Sprinkler Protection

1) Room 2-066 (Fire Zone 2SA1C)

This room contains Firezone 'R' cable only (no Thermo-lagged raceways). Review of the Unit 2 Fire Safe Shutdown Analysis (Ref. 3.21) has determined that this cable is not required for safe shutdown. The safe shutdown (cable) separation concern relative to this cable is outside Room 2-066 in the corridor (Room 2-070). This corridor is located in a separate fire area (2SB4) which has sprinkler protection. Therefore, a support failure in this room would not affect safe shutdown. Accordingly, based on the hazards in the area (Ref. 3.14) and administrative controls (Ref. 3.31), this configuration does not require further analysis.

2) Room 2-074A (Fire Zone 2SO3)

This room contains Firezone 'R' cable only (no Thermo-lagged raceways). Review of the Unit 2 Fire Safe Shutdown Analysis (Ref. 3.21) has determined that this cable is not required for safe shutdown. The safe shutdown concern relative to this cable is outside Room 2-074A in the corridor (Room 2-070). This corridor is located in a separate fire area (2SB4) which has sprinkler protection. Therefore, a support failure in this room would not affect safe shutdown. Accordingly, based on the hazards in the area (Ref. 3.14) and administrative controls (Ref. 3.31), these configurations do not require further analysis.

3) Rooms X-172 and X-173 (Fire Zone AA21a) and Room X-208 (Fire Zone AA21c)

Due to the requirement to protect the supports for a distance of 9 in. from the protected raceway for heat path, field walkdown per Ref. 3.23 has confirmed that the supports are completely protected with Thermo-Lag. Therefore, based on the hazards in the area (Ref. 3.29) and administrative controls (Ref. 3.31), these configurations do not require further analysis.

4) Room X-165 (Fire Zone AA21a)

There are only two (2) Thermo-Lagged conduits in this room (Ref. 3.23) and the first support is approximately 6 ft. off the floor with the majority of the support protected for heat path (9 in.) Room X-165 is designated as a "NO STORAGE" room (Ref. 3.31) and has a maximum permissible loading of 37,300 BTU/ft^2 per Ref. 3.28. The actual combustible loading for this fire zone is 10,500 BTU/ft^2 (Ref. 3.29) which is well below the 40,000 BTU/ft^2 required for the support to yield based on the "C" curve. Based on the low combustible loading, the fact that the majority of the support is protected which acts as a heat sink and the administrative controls already in place, the configuration is acceptable and does not require further analysis.

5) Room X-219A (Fire Zone AA21d)

Room X-219A is the same as Room X-165 based on Ref. 3.23 except that the actual combustible loading for this fire zone is 17,000 BTU/ft^2 with a maximum permissible loading of 37,300 BTU/ft^2. Based on this low combustible loading and the reasons listed for Room X-165, the configuration is acceptable.

6) Room X-174 (Fire Zone AA21a)

Room X-174 is the laundry hold-up room. This room contains both Firezone 'R' cable and Thermo-Lagged raceways. The actual combustible loading in the fire zone is 10,500 BTU/ft^2. Although the room is currently designated as a "NO STORAGE AREA", (Ref. 3.31) and the maximum permissible loading for the entirity of Fire Zone AA21a established at 37,300 BTU/ft^2 (Ref. 3.28), the maximum permissible loading for this room will be set at 11,000 BTU/ft^2.*

Based on the existing limitations on storage and transient combustible controls in place, which will be further reinforced as described above, and previous regulatory acceptance (Ref. 3.30) the configuration does not require further analysis.

* CONFIRMATION REQUIRED

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6.0 Conclusions

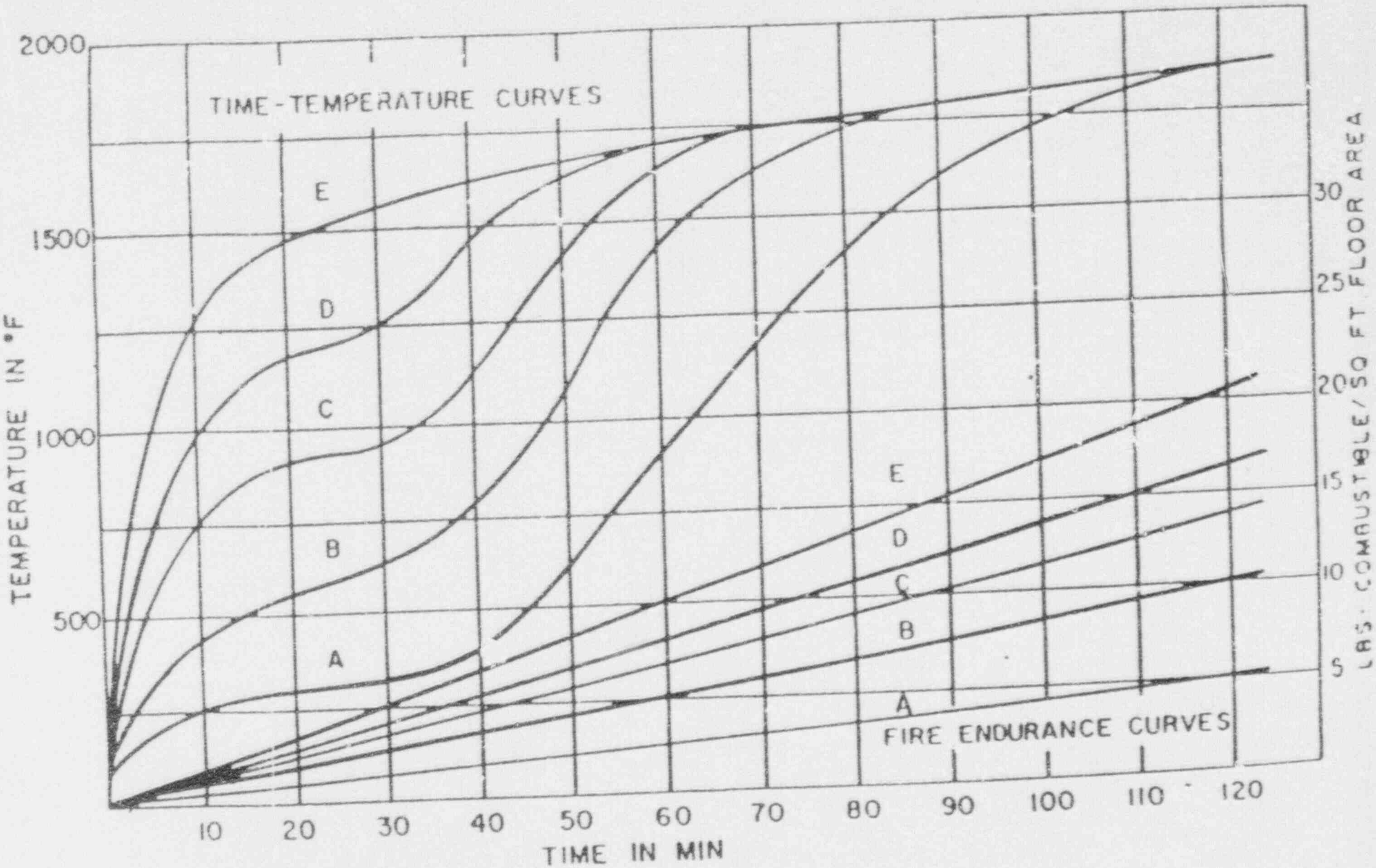
For all areas provided with sprinkler system protection and containing unprotected raceway supports (except for 9" heat path protection), a design basis fire will result in suppression system actuation which will in turn suppress the fire prior to support yield.

In Rooms 2-066 and 2-074A, the Firezone 'R' cable is not required for fire safe shutdown. In Rooms X-172, X-173 and X-208 the raceway supports are adequately protected based on the hazards in the area.

In Rooms X-165 and X-219A, the existing level of protection for raceway supports in conjunction with the administrative controls in place provide an acceptable level of protection.

In Room X-174, based on the hazards in the area and the degree of administrative controls (which will be further reinforced as described in Section 5.0) acceptable means are provided to ensure exposed raceway supports will not fail under fire conditions.

ATTACHMENT 1



TAKEN FROM NFPA FIRE PROTECTION HAND BOOK 17 ED

J.U. 0.581.02
2FP-0042 Rev 0

Attachment _

ABB
ASEA BROWN BOVERI

Inter-Office Correspondence

CPSES-9221733
WBS-CF58P
CS-TEC-6033
July 11, 1992

No Response Required

To: Jack Woods C25

Attention: Rick Dible C28

Subject: **Electrical Raceways Representative Dead Weight Stresses**

In accordance with your request, our Electrical Raceway Group has reviewed representative cable tray and conduit support configurations.

Attached is a summary that provides the dead weight stresses and member sizes for the above mentioned configurations(Four pages.).

If you need any further information regarding this matter, please contact Simon Abuyounes at extension 8101.

for

G. R. Ashley IM1
Project Manager
Civil/Structural

GRA:CAJ:lef

Attachment

cc:	CCS	E06
	IRRC File	IM1
	CS-TEC File	IM1
	C. Abou-Jaoude	IM1
	S. Abuyounes	IM1
	C. Banning	IM1
	D. Pandya	IM1
	R. Scavotto	C28

REPRESENTATIVE/ENVELOPE CTH CONFIGURATION

Cable tray hangers used in Unit 2 consist of three main configurations:

Simple cantilever support
Braced cantilever support
Trapeze support

For the three configurations indicated above, the simple cantilever configuration will yield the most critical stresses. This is due to the fact that the representative tier span for trapeze support is less than 5 ft. and the dead load is carried by two posts.

The table shown on the following sheet provide a conservative estimate for the bending stresses due to dead weight.

TABLE 1

TRAY SIZE	SUPPORT TYPE	SUPPORT SPAN	MEMBER SHAPE AND SIZE	TRAY TRIBUTARY SPAN	TRAY WEIGHT (1)	D. W. MOMENT	D. W. STRESS
6X4	CANTILEVER	48 IN	C4X7.25	6 FT	183 LB	9 IN-K	4 KSI
12X4	CANTILEVER	48 IN	C4X7.25	6 FT	321 LB	15 IN-K	7 KSI
18X4	CANTILEVER	48 IN	C6X8.2	6 FT	459 LB	22 IN-K	5 KSI
24X4	CANTILEVER	24 IN	C6X8.2	6 FT	597 LB	14 IN-K	3 KSI
30X4	CANTILEVER	24 IN	C6X8.2	6 FT	735 LB	18 IN-K	4 KSI
36X4	CANTILEVER	24 IN	C6X8.2	6 FT	870 LB	21 IN-K	5 KSI

Based on the above envelope cases, 7 KSI can be considered an upper bound for the bending stresses under dead load. The self weight of the hanger was neglected in the above calculation.

(1) The tray weight was calculated based on 100% fill weight (35 PSF) and thermolag.

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0	[illegible]	7-11-92	KS	7-11-92

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CS-TEC-6033
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REPRESENTATIVE/ENVELOPE CONDUIT SUPPORT CONFIGURATION

Various configurations of conduit supports are used for Unit 2.

The attached sheet provides the bending stresses due to dead weight and thermolag weight, for the worst cases.

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CONDUIT SIZE	SUPPORT TYPE	CANTILEVER LENGTH	MEMBER SIZE	TRIBUTARY CONDUIT SPAN	TRIBUTARY CND WT.W/ THERMOLAG	DEAD WT. MOMENT	DEAD WT. STRESS
3/4" ϕ	CANTILEVER	2'-6"	TS 2x2x1/4	8'-0"	43 #	1.5 IN-K	2.0 KSI
1" ϕ	"	2'-6"	"	9'-6"	60 #	2.0 IN-K	2.7 KSI
1 1/2" ϕ	"	2'-6"		10'-6"	82 #	2.7 IN-K	3.6 KSI
2" ϕ	"	2'-6"	"	12'-7"	119 #	3.8 IN-K	5.0 KSI
3" ϕ	"	2'-6"	TS 3x3x1/4	15'-0"	285 #	8.9 IN-K	4.3 KSI
4" ϕ	"	2'-6"	"	17'-7"	462 #	14.2 IN-K	6.8 KSI
5" ϕ	"	2'-6"	"	19'-6"	618 #	18.9 IN-K	9.0 KSI

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Enclosure 3

FIGURE 7.1

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CALCULATION TITLE PAGE

TEXAS UTILITIES ELECTRIC CO. / CPSES UNIT 2	PAGE 1 TOTAL NO. OF PAGES 34
CALCULATION TITLE (Indicative of the Objective): THERMAL ANALYSIS OF JUNCTION BOX DUE TO ASTM E-119 FIRE TEST	CALCULATION CLASSIFICATIONS: ☑ CLASS I or II ☐ NON-SAFETY

CALCULATION IDENTIFICATION

ORGANIZATION:	CALCULATION NUMBER TYPE	CALCULATION NUMBER NUMBER	
ABB IMPELL	EQQ2	0218-SQ-0095	
WPST NUMBER __ __ __ __ __ (OR) WPN 5 8 P	COMPUTER OUTPUT YES ☐ NO ☑ ATTACHED YES ☐ NO ☑	SYSTEM/SUB-SYSTEM	

APPROVALS - PRINT NAME, SIGN, AND DATE: PREPARER(S)	CHECKER(S)/ REVIEWER(S)	APPROVAL(S)/ INDEPENDENT REVIEWER(S)	REV. NO.	SUPPLEMENTS/ SUPERSEDES (TYPE/NUM./REV.)	CONFIRMATION REQUIRED YES	CONFIRMATION REQUIRED NO
D. Charamelios [signature] 7-10-92	[signature] BRUCE F. HENLEY 7-10-92	[signature] T.P. DESMOND 7-10-92	0	N/A		✓

DISTRIBUTION:

REVISION HISTORY

REVISION	DESCRIPTION
0	ORIGINAL ISSUE

REV	BY	DATE	CHECKED	DATE			
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1.0 INTRODUCTION

THE CONFIGURATION SHOWN IN FIGURE 1.1 WAS THERMO-LAGGED AND SUBJECT TO A ASTM E-119 FIRE TEST AS PART OF THE CPSES FIRE PROTECTION PROGRAM. CONCERNS HAVE BEEN RAISED AS TO THE EFFECT THE JUNCTION BOX AND CONDUIT TUBE STEEL SUPPORTS MIGHT HAVE ACTED AS A HEAT SINK AND LOWERED THE CONDUIT TEST ASSEMBLY TEMPERATURE. STATED ANOTHER WAY, WHAT IS THE SIGNIFICANCE, THERMALLY, OF THE TUBE STEEL SUPPORTS ON THE JUNCTION BOX. SINCE THIS IS A RATHER COMPLICATED TRANSIENT THERMAL ANALYSIS, A CONSERVATIVE STEADY STATE APPROACH WILL BE USED TO QUANTIFY THIS CHANGE IN TEMPERATURE. A SIMPLIFIED MODEL OF THE JUNCTION BOX AND SUPPORT IS USED AND CONSIDERED THE WORST CASE FOR THE TRANSFER OF HEAT INTO THE SUPPORT STEEL. TEMPERATURE READINGS FROM THE TEST

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1.0 INTRODUCTION (CONT'D)

THERMOCOUPLES INDICATE THE HIGHEST TEMPERATURE AT THE JUNCTION BOX AS COMPARED WITH THOSE READINGS ON THE 5"ϕ CONDUIT. FROM THE TEST OUTPUT (ATTACHMENT B), THE INITIAL TEMPERATURE IS 88°F.

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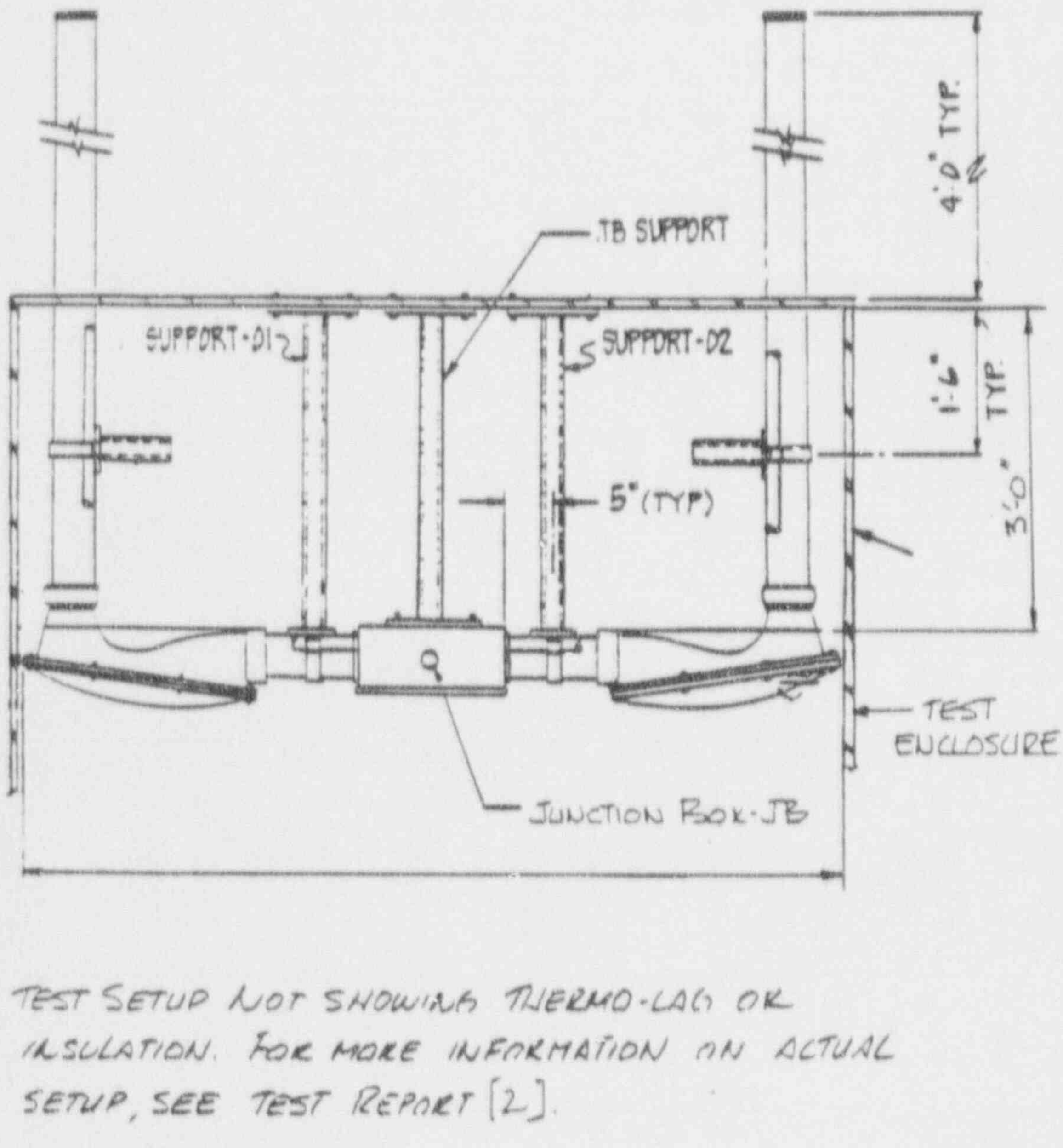
FIG 1.1



TEST SETUP NOT SHOWING THERMO-LAG OR INSULATION. FOR MORE INFORMATION ON ACTUAL SETUP, SEE TEST REPORT [2].

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2.0 METHODOLOGY

The following methodology is used to conservatively estimate the change in temperature of the Junction Box (JB) due to the removal of the TS support steel

1 Although the ASTM-E-119 test method is time/temperature loading (i.e. transient), using a steady state analysis with the JB at the maximum occurred tested temperature is conservative

2 Use the TU approved Wesson Rpt [1] (Attach A) to determine the temperature increase of the Tube Steel (TS) due to the ASTM-E-119 1 hr fire

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2.0 METHODOLOGY

THE FOLLOWING METHODOLOGY IS USED TO CONSERVATIVELY ESTIMATE THE CHANGE IN TEMPERATURE OF THE JUNCTION BOX (JB) DUE TO THE REMOVAL OF THE TS SUPPORT STEEL

1. ALTHOUGH THE ASTM-E-119 TEST METHOD IS TIME/TEMPERATURE LOADING (IE TRANSIENT), USING A STEADY STATE ANALYSIS WITH THE JB AT THE MAXIMUM OCCURRED TESTED TEMPERATURE IS CONSERVATIVE

2. USE THE TU APPROVED WESSON RPT [1] (ATTACH A) TO DETERMINE THE TEMPERATURE INCREASE OF THE TUBE STEEL (TS) DUE TO THE ASTM-E-119 1 HR FIRE

2.0 METHODOLOGY (CONT'D)

3. USING THE TS AS A HEAT SINK, DETERMINE THE HEAT FLUX RATE THROUGH THE TS DUE TO THE TEMPERATURE DIFFERENTIAL BETWEEN THE TS ANCHOR POINT AND THE JB.

4. BASED ON THIS HEAT FLUX OUT OF THE JB, DETERMINE THE TEMPERATURE CHANGE OF THE JB.

3.0 CALCULATION

1. THE WESSON REPORT (ATTACH A) PROVIDES THE FORMULA FOR CALCULATING THE TEMPERATURE RISE OF THE TUBE STEEL (TS) COVERED WITH INSULATION FOR AN ASTM E-119 FIRE.

$$T = \frac{F}{\Delta t^{0.7} w^{0.5}} \left[\frac{t}{23.002} \right]^{\frac{1}{1.3356}}$$

WHERE,

[2]	T = THICKNESS OF INSULATION	= 1.0 in
[1] p A-1	F = HEAT FLUX DUE TO ASTM E-119 FIRE FOR 1 HR	= 245 1000 BTU/hr ft²
[1] p A-1	w = EFFECTIVE HEAT CAPACITY OF TS lbs/ft² OF SURFACE AREA	= 8.80 lbs/ft
[2]	t = DURATION OF FIRE	= 60 min

SUBSTITUTING,

$$1.0 = \frac{245}{\Delta t^{0.7}\, 8.80^{0.5}} \left[\frac{60}{23.002} \right]^{\frac{1}{1.3356}}$$

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REARRANGING,

$$\Delta t = 57°F$$

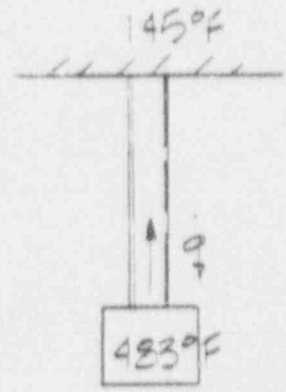
THEREFORE, MINIMUM TEMPERATURE OF TS

$T_{initial} = 88°F$ [2]

$$T_{line} = T_{initial} + T_{FIRE}$$

$$T_{line} = 88° + 57° = \underline{145°F}$$

2 THE HEAT FLUX RATE DUE TO CONDUCTIVITY ALONG THE TUBE STEEL IS,



[3] $$\frac{q}{t} = k A \frac{\Delta t}{L}$$

WHERE,

[4] k = THERMAL CONDUCTIVITY = __30__ BTU / HR FT °F

[5] A = AREA OF TS 3x3x¼ = __2.59__ in² $T_{line} = 483°F$ [2]

Δt = CHANGE IN TEMPERATURE = __338__ °F ← (483-145)

[2] L = LENGTH OF TUBE STEEL = __3.0__ ft

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$$\dot{q} = \frac{30\ BTU}{HR\ Ft\ ^\circ F} \quad \frac{2.59\ in^2\ Ft^2}{144\ in^2} \quad \frac{338\ ^\circ F}{3.0\ Ft}$$

$$\dot{q} = 60.8\ \frac{BTU}{HR}$$

$$Q = \dot{q}\ t = 60.8\ \frac{BTU}{HR}\ 1\ hr = \underline{\underline{61}}\ BTU$$ [3]

3. To determine the heat loss of the Junction Box (JB).

$$Q = m\ C_p\ \Delta t$$ [3]

Where,

Q = Energy, Heat	= 61 BTU	
m = lbm of J.B	= 37.3 lbs	[6]
C_p = Specific Heat	= 0.11 BTU	[4]

Substituting & rearranging,

$$\Delta t = \frac{Q}{m\ C_p} = \frac{61}{37.3\ (.11)} = \underline{\underline{15^\circ F}}$$

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6.0 RESULTS / CONCLUSION

THE RESULTS OF THIS SIMPLIFIED STEADY STATE ANALYSIS SHOW THAT THE CHANGE IN TEMPERATURE OF THE CONDUIT ASSEMBLY, MORE SPECIFICALLY THE JB, DUE TO THE EXISTENCE OF THE SUPPORT STRUCTURE, ARE APPROXIMATELY 15°. THE MAXIMUM TEMPERATURE FOR THE ENTIRE HOUR IS 983°F, THEREFORE THE 15° ADJUSTMENT (Δ) ONLY CORRESPONDS TO ABOUT 3% WHICH IS NOT SIGNIFICANT AT THIS ELEVATED TEMPERATURE

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5.0 REFERENCES

[1] Wesson Rt for TSI, Inc # 11601, 8/3/62

[2] Fire Test, Project No 93543C Scheme 2, 6/17/92

[3] "Heat Transfer", JP Holman, 5th Ed

[4] ASME, Section III, Appendix I, '74

[5] AISC, Manual of Steel Construction, 7th Ed

[6] Drawing 520910 Sht. PESD-4-5, R/CP-1

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ATTACHMENT A

WESSON RPT FOR TSI INC

11601

DATED AUGUST 3, 1981

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WESSON AND ASSOCIATES, INC.
CONSULTING ENGINEERS
510 SOUTH WEBSTER
POSTAL BOX 1082
NORMAN, OKLAHOMA 73070

TELEPHONE 405 364-8077

405 360 2812

3 August 1981

Mr. Rubin Feldman
President
TSI, Inc.
3260 Brannon Avenue
St. Louis, MO 63139

Subject: Engineering Report on Fireproofing Coating Thickness Requirements for Texas Utilities Services, Inc.

Dear Mr. Feldman:

In accordance with your written request, we have conducted the necessary analyses to calculate the fireproofing coating thicknesses required for the various structural st . members being used by Texas Utilities Services, Inc. Calculations have been performed for a One Hour Fire Rating and a Three Hour Fire Rating in accordance with the ASTM - E - 119 Test Method integrated average incident heat fluxes.

Four copies of our Engineering Report on these analyses are attached for your information and/or use. We do not have any objections in your forwarding copies of the enclosed reports to your client, if you desire to do so. It should be noted that the fireproofing coating thickness calculation for the Thermo-Lag 330-1 Subliming Compound material 'does not' include the commonly used 10 percent long term aging and weathering allowance as has been established from the Environmental Test Programs conducted on these materials by various independent and U.S. Governmental Agencies.

If you have any questions on the enclosed report, or if you desire additional information in these regards, please contact us at your convenience.

Sincerely yours,
WESSON AND ASSOCIATES, INC.
[signature]
Dr. H. R. Wesson
President

cc: Project File No. 116 (TUSI)

ATTACHMENT A SHT A.2/16
CALC. NO. C215-SC-0229S R/C