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JOHN S. KEMPER
VICE-PRESIDENT
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January 13, 1984

Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Docket Nos.: 50-352
50-353

Subject: Limerick Generating Station, Units 1 and 2
Structural Steel Fire Resistance

References:
(1) Summary of December 13, 1983 Meeting from L. L . Kintner to Philadelphia Electric dated December 23, 1983.
(2) Letter from J. S. Kemper to A. Schwencer dated January 4, 1984
(3) Telecon between L. Kintner, R. Furguson and R. Eberly (NRC) and G. M. Morley, D. M. Groves and J. L. Phillabaum (PECO) on January 13, 1984

File: GOVT 1-1 (NRC)

Dear Mr. Schwencer:

Reference (1) requested that we provide a comparison between the actual results and results predicted by the Limerick structural steel survivability calculational methodology for NRC sponsored tests performed at Underwriters Laboratories as published in NUREG/CR-3192. Reference (2) provided the comparison summary of the correlation of our Heat Balance Model with Experiment No. 3 and Test No. 1 of the UL Test Results.

Enclosed as Attachment I is the comparison results of our Heat Balance Model with Test No. 1 through Test No. 6 and Experiment No. 3. The comparison summary for Test No. 1 and Experiment No. 3 which were provided by reference (2) have been refined and included in Attachment I.

Included as Attachment II are the results of analysis for the three remaining plant areas which contain safe shutdown equipment and exposed structural steel members. The three areas in Attachment II as promised by reference (2) are the Unit 1 Refueling Floor, Spray Pond Pump Structure, and a Unit 1 Reactor Enclosure pipe chase.

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This letter completes our response to the requests transmitted by reference (1). As agreed upon in the reference (3) conference call we will be prepared to describe alternative fire protection measures (water suppression, encapsulation, steel coating, etc.) considered or in progress at this time; respond to any comments on our correlation of UL test results, Heat Balance Model, or reference (2); and provide any additional information gained from our field review on localized structural steel effects and transient combustibles at the meeting scheduled for 1:00 PM on January 31, 19[illegible]

Sincerely,

John S. Kemper

JLP/gra/011084855

Enclosures

Copy to: See Attached Service List

cc:	Judge Lawrence Brenner	(w/enclosure)
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	Mr. Thomas Gerusky	(w/enclosure)
	Director, Penna. Emergency Management Agency	(w/enclosure)
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	Atomic Safety & Licensing Appeal Board	(w/enclosure)
	Atomic Safety & Licensing Board Panel	(w/enclosure)
	Docket & Service Section	(w/enclosure)
	Martha W. Bush, Esq.	(w/enclosure)
	James Wiggins	(w/enclosure)

Attachment I

Comparison of PECo Heat Balance Model With NUREG/CR-3192

Data for the tests reported on in NUREG/CR-3192 has been received from Sandia National Laboratories; enabling us to complete a comparison between the results of the UL tests and the calculated temperatures from the PECo heat balance model. We have evaluated Tests 1 through 6 and Experiment 3. The results of the comparison are as follows:

Test 1

5 gallons Heptane and non-qualified cables (PE/PVC)
Experimental peak temperatures at 5 minutes
Duration - 15 minutes

Heat release rate	1160 KW Heptane
	1750 KW Cables
	2910 KW Total

PECo Heat Balance Calculated Temperature	- 1284°F
Test 1 Average Room Temp.	- 784°F
Test 1 Temp without lowest level thermocouples	- 1212°F

Test 2

5 gallons Heptane and qualified cables (XLPE)
Experimental peak temperatures at 6 minutes
Duration - 14 minutes

	Case A	Case B
Heat release rate	1160 KW Heptane	1160 KW Heptane
	1234 KW Cables	1410 KW Cables
	2394 KW Total	2570 KW Total

PECo Heat Balance Calculated Temperature	- 1036°F	1106°F
Test 2 Average Room Temp.	- 659°F	
Test 2 Temp without lowest level thermocouples	- 1027°F	

Test 3

5 gallons Heptane and non-qualified cables with ceramic fiber blanket
Experimental peak temperature at 15 minutes
Duration - 20 minutes

Heat release rate	1160 KW Heptane
	1312 KW Cables
	2472 KW Total

PECo Heat Balance Calculated Temperature	- 1261°F
Test 3 Average Room Temp.	- 539°F
Test 3 Temp without lowest level thermocouples	- 753°F

Test 4

5 gallons Heptane and qualified cables with ceramic fiber blanket
Experimental peak temperature at 16 minutes
Duration - 30 minutes

Heat release rate	1160 KW Heptane
	575 KW Cables
	1735 KW Total

PECo Heat Balance Calculated Temperature	- 1094°F
Test 4 Average Room Temp.	- 519°F
Test 4 Temp without lowest level thermocouples	- 742°F

Test 5

5 gallons Heptane and nonqualified coated cables
Experimental peak temperature at 10 minutes
Duration - 20 minutes

Heat release rate	1160 KW Heptane
	1312 KW Cables
	2472 KW Total

PECo Heat Balance Calculated Temperature	- 1261°F
Test 5 Average Room Temp.	- 560°F
Test 5 Temp without lowest level thermocouples	- 789°F

Test 6

5 gallons Heptane and qualified coated cables
Experimental peak temperature at 19 minutes
Duration - 23 minutes

Heat release rate	1160 KW Heptane
	693 KW Cables
	1853 KW Total

PECo Heat Balance Calculated Temperature	- 1028°F
Test 6 Average Room Temp.	- 559°F
Test 6 Temp without lowest level thermocouples	- 774°F

Experiment 3

10 gallons Heptane
Experimental peak temperature at 20 minutes
Duration - 25 minutes

Heat release rate	1160 KW Heptane

PECo Heat Balance Calculated Temperature	- 696°F
Exper 3 Average Room Temp.	- 524°F
Exper 3 Temp without lowest level thermocouples	- 710°F

The above comparisons were made on the following bases:

1. Average temperature calculation: Sandia Laboratories provided thermocouple readings and temperature plots for the six full-scale tests conducted by UL. These readings were used to calculate a volumetric average of the 76 thermocouple locations (Figure 1). In evaluating the data, thermocouples #26 and 28 were not functioning properly, #56 was not included in the data and #31 and 32 were interchanged. To replace #26 and 28, thermocouples #102 and 100, respectively, were used (see p. 116, NUREG/CR 3192). The value for #56 was taken to be the average of adjacent thermocouples #44 and 68.

   The test room was divided into the 76 zones shown on Figure 2. Each of these zones was assigned the temperatures of the thermocouple within the zone. Weighted volumetric averaging was then performed by using the following formula.

$$\frac{\sum_{i=1}^{N} T_i \times V_i}{\sum_{i=1}^{N} V_i} = \bar{T}$$

   Where V_i = Each of the 76 volumes shown on Figure 2

   T_i = The thermocouple data for V_i

   All 76 zones were used in calculating the average room temperature. An average temperature for the upper portion of the room was calculated by eliminating the lower layer of thermocouples and their associated volumes. The average temperatures were calculated using the peak temperatures from the test data.

2. <u>Heat Release Rate</u>

   Heptane - Literature values for heat release rates for flammable liquid pool fires generally and heptane specifically vary in the range of 2500 to 3300 kW/m^2. For the Sandia and UL tests, the heat release rate was calculated by taking the total heat value of the fuel divided by the duration of the fire, and is 1966 kW/m^2. The table below shows the heat release rate for the heptane fire using this data.

Heat Release Rate for Heptane Pool Fire

Q	Source
913 kW	Sandia/UL - NUREG/CR-3192
1160 kW	Based on 120,000 BTU/gal - Coulbert Fire Technology Aug. 1977
1530 kW	FMRC-Alpert & Ward, SFPE-TR 83-2

The methodology used for Limerick for pool fires was based on Coulbert's approach. Therefore, for this comparison, the value of 1160 kW was used.

Cables - The heat release rate for the non-qualified PE/PVC was calculated using the mass loss data and heat of combustion similar to the methodology used for Limerick. The FM test data (see EPRI NP-1881) for PE/PVC was used. This yields a heat release rate of 628 kW/m^2 of cable tray.

In the case of the qualified (IEEE 383) XLPE cables, no large scale test data was available similar to that on PE/PVC or hypalon jacket conducted by FMRC. To develop the heat release rate for these cables, the small scale tests outlined in EPRI NP 1200 (see Table S-4) were used as a comparison to develop a heat release rate. Two such values were developed. The first was developed by taking the PE/PVC data from EPRI NP-1881 and multiplying by the ratio of small scale heat release rates from EPRI NP-1200 as follows:

$$628 \text{ kW/m}^2 \times \frac{475 \text{ XLPE}}{589 \text{ PE/PVC}} = 506 \text{ kW/m}^2 \text{ from PE/PVC}$$

The second was developed by taking the hypalon data and multiplying by the ratio of small scale heat release rates as follows:

$$190 \text{ kW/m}^2 \times \frac{475 \text{ XLPE}}{204 \text{ hypalon}} = 443 \text{ kW/m}^2 \text{ from hypalon}$$

These comparisons yield a range of heat release rates for Test 2 of 1234 kW - 1410 kW.

In the cases where cable protection schemes were provided (i.e., ceramic fiber insulation or cable coatings) no test data exists regarding heat release rates. To estimate these heat release rates, the duration of the fire for protected cables was compared to that of unprotected cables. The heat release rate was then developed by multiplying the heat release rate of the unprotected cables by the ratios of fire duration.

3. Fire duration: The fire duration was determined from the thermocouple readings in the fire plume (Nos. 13, 14, 15, and 16 on Figure 1). When the temperature of these thermocouples dropped sharply, the fire was assumed to be completed.

Summary

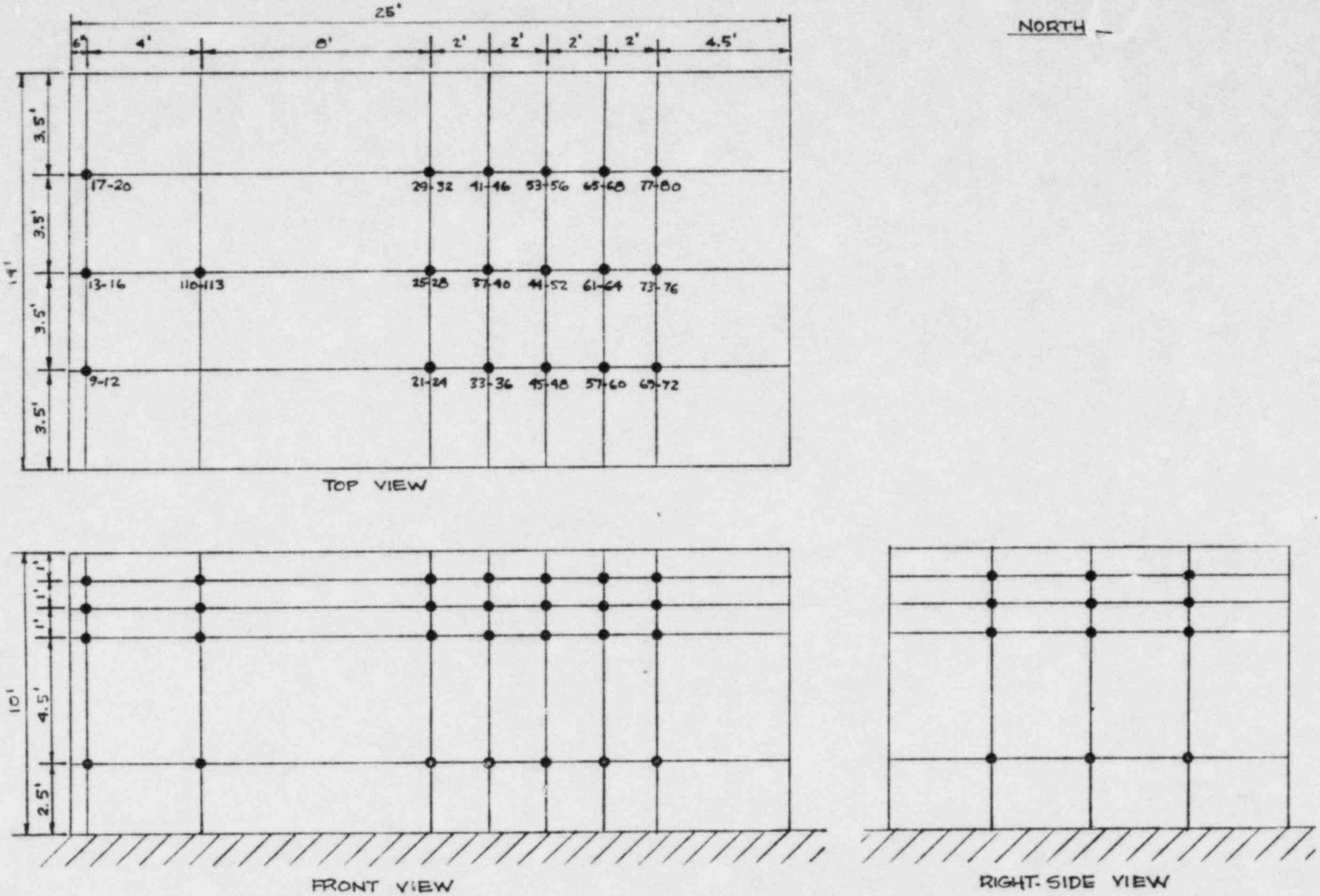
The results of the work undertaken to compare the test data of the UL test fires analyzed by Sandia National Laboratories in NUREG/CR-3192 with the analysis of identical fires using the PECo heat balance mode indicate that the model predicts temperatures which are higher than the weighted volumetric average temperatures obtained from the test data. Note that the calculated average temperatures from the test data are based on instantaneous maximum peak values.

To perform calculations for these comparisons required that assumptions be made for burn rates and heat releases because no data was available for some of the materials being burned. The input to the Limerick and Peach Bottom calculations have been gathered from test data and were not based upon assumptions.

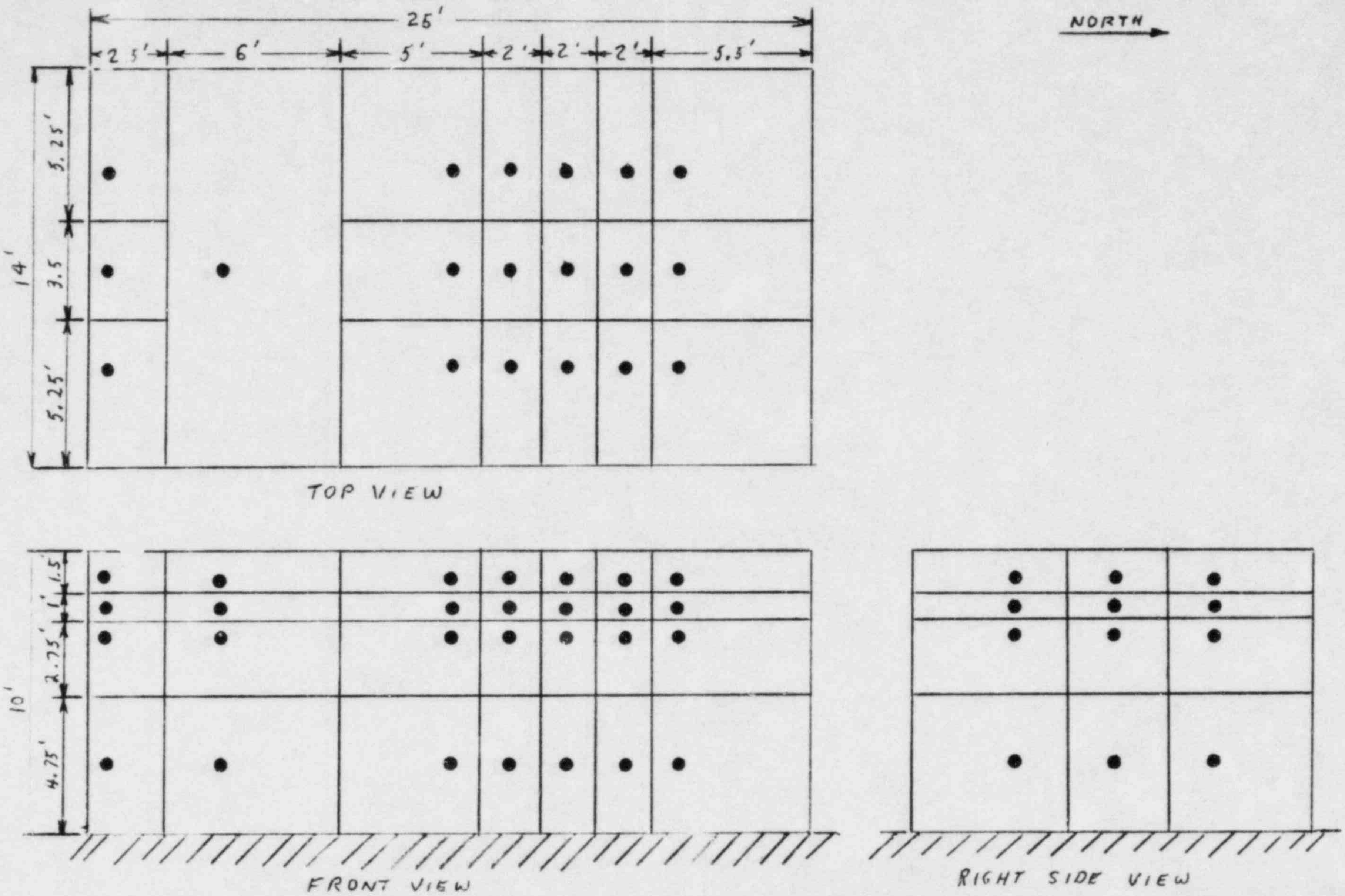
The heat balance methodology is not intended for use as a tool for calculating a preuse temperature that results from a fire. The intended application is that of a conservative screening device in the process of determining the survivability of structural steel during a fire. In addition to using the heat balance model to determine overall room or area temperatures localized effects of fires on the structural steel are evaluated. This is accomplished by looking at the plumes of the hypothesized fires. Once temperatures are obtained from these devices steel temperatures are calculated by using the methodology presented by Stanzak as submitted with our calculations.

DMG:mtk 1/13/84-1

FIGURE 1



THERMOCOUPLE LOCATION FOR UL TESTS 1-6



VOLUMETRIC SUBDIVISION OF UL TEST ROOM

FIGURE 2

CASE NO.: 1
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 1
CASE DESCRIPTION:

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CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	2910

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	386.992
2	515.835
3	614.939
4	698.583
5	772.325
6	839.021
7	900.372
8	957.490
9	1011.14
10	1061.90
11	1110.17
12	1156.31
13	1200.56
14	1243.14
15	1284.23

CASE NO.: 2-A
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 2
CASE DESCRIPTION:

****

CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	2394

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	331.506
2	437.426
3	518.902
4	587.674
5	648.308
6	703.153
7	753.606
8	800.579
9	844.706
10	886.448
11	926.156
12	964.101
13	1000.49
14	1035.52

CASE NO.: 2-8
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 2
CASE DESCRIPTION:

****

CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	2570

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	350.438
2	464.172
3	551.659
4	625.503
5	690.607
6	749.494
7	803.664
8	854.097
9	901.473
10	946.290
11	988.922
12	1029.66
13	1068.73
14	1106.33

CASE NO.: 3
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 3
CASE DESCRIPTION:

****

CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	2472

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	339.897
2	449.280
3	533.419
4	604.439
5	667.054
6	723.690
7	775.791
8	824.297
9	869.864
10	912.969
11	953.973
12	993.156
13	1030.74
14	1066.90
15	1101.80
16	1135.56
17	1168.27
18	1200.05
19	1230.95
20	1261.04

CASE NO.: 4
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 4
CASE DESCRIPTION:

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CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	1735

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	260.524
2	337.229
3	396.223
4	446.019
5	489.926
6	529.642
7	566.181
8	600.201
9	632.162
10	662.397
11	691.160
12	718.646
13	745.013
14	770.385
15	794.869
16	818.552
17	841.505
18	863.795
19	885.476
20	306.594
21	927.192
22	947.305
23	966.967
24	986.207
25	1005.05
26	1023.52
27	1041.64
28	1059.42
29	1076.90
30	1094.07

CASE NO.: 5
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 5
CASE DESCRIPTION:

****

CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	2472

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	339.897
2	449.280
3	533.419
4	604.439
5	667.054
6	723.690
7	775.791
8	824.297
9	869.864
10	912.969
11	953.973
12	993.156
13	1030.74
14	1066.90
15	1101.80
16	1135.56
17	1168.27
18	1200.05
19	1230.95
20	1261.04

CASE NO.: 6
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL TEST 6
CASE DESCRIPTION:

****

CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	1853

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	273.248
2	355.178
3	418.194
4	471.386
5	518.287
6	560.711
7	599.741
8	636.080
9	670.218
10	702.514
11	733.236
12	762.595
13	790.757
14	817.858
15	844.010
16	869.305
17	893.821
18	917.629
19	940.786
20	963.343
21	985.343
22	1006.82
23	1027.82

CASE NO.: 7
BUILDING:
ELEVATION AND AREA DESCRIPTION: UL EXPERIMENT 3
CASE DESCRIPTION:

CEILING/WALL THICKNESS (FT.)	CEILING/WALL MATERIAL	AO SQ. FT.	HO FT.	AW SQ. FT.	Q KW
0.7	CONCRETE BLOCK	32	8	1130	1160

FIRE IS FUEL CONTROLLED

FIRE DURATION (MIN.)	GAS TEMPERATURE (DEG. F)
1	198.387
2	249.668
3	289.088
4	322.356
5	351.689
6	378.222
7	402.632
8	425.360
9	446.712
10	466.913
11	486.130
12	504.494
13	522.111
14	539.065
15	555.425
16	571.250
17	586.587
18	601.483
19	615.971
20	630.084
21	643.848
22	657.290
23	670.430
24	683.288
25	695.881