STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

CLIENT & PROJECT	PAGE 1 OF 13 + 2 pages of Attachments
Private Fuel Storage L. L. C./Private Fuel Storage Facility	
CALCULATION TITLE **Plume and Upper Layer Temperatures in Canister Transfer Building Fire Scenarios**	QA CATEGORY I

CALCULATION IDENTIFICATION NUMBER				OPTIONAL WORK PACKAGE NO.
J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	
05996.02	**Mechanical**	**P-006**	**NA**	**NA**

APPROVALS - SIGNATURE & DATE			REV. NO. OR NEW CALC. NO	SUPERSEDES CALC. NO. OR REV. NO.	CONFIRMATION REQUIRED (X)	
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)			YES	NO
K. Dungan (Risk Technologies) 4-7-00	R. Rudy (Risk Technologies) 4-7-00	F. Collins (S & W) Frank Collins via telecon 4-7-00	0	NA		X

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CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 2
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RECORD OF REVISIONS

Revision 0 - Original Issue

CALCULATION SUMMARY	J.O./W.O./CALCULATION NO. 0599601-P-006	REVISION 0	PAGE 3

CLIENT / PROJECT	QA CATEGORY / CODE CLASS
Private Fuel Storage L.L.C.	QA Category I

SUBJECT / TITLE

Plume and Upper Layer Temperatures in Canister Transfer Building Fire Scenarios

OBJECTIVE OF CALCULATION

The objective of this calculation is to determine plume and upper temperatures in the Canister Transfer Building that would result from a fire fueled by the following scenarios:

1. A 300 gallon pool of diesel fuel that burns for 30 minutes
2. A 200 square foot pool of diesel fuel that burns for 16 minutes.
3. A double axle of tires on the heavy haul trailer (16 tires) that burns for 30 minutes.
4. A combined 200 sq. ft. pool of diesel fuel and a 30 minute tire fire.

CALCULATION METHOD / ASSUMPTIONS

The calculation will utilize the software program FPEtool Version 3.2. This software is a collection of computer simulated procedures providing numerical engineering calculations for predicting the phenomena of a specified fire.

Two sections of the software are utilized; Ceiling Plume Temperature to estimate plume gas temperatures from the height of the flames to the height of the ceiling and Upper Layer Temperature to predict upper-layer gas temperatures in a compartment fire with a door or window aiding as a vent.

Attachment 1 provides an Independent Design Review to verify the accuracy of FPEtool.

See assumptions on page 4.

SOURCES OF DATA / EQUATIONS

1. FPEtool, National Institute of Standards and Technology, Version 3.2.
2. Drawing 0599601-EM-1, Rev. D
3. Drawing 0599601-EM-2, Rev. D
4. Drawing 0599601-EM-3, Rev. D
5. ASTM E-119, Standard Test Methods for Fire Tests of Building Construction and Materials, 1998.

CONCLUSIONS

The results on page 4 show that the reinforced concrete Canister Transfer Building, when exposed to the plume and upper layer temperatures, will not exceed the acceptable exposure temperatures shown in an ASTM E-119 fire resistance test that reached 1399 F in 15 minutes and continued to climb to 1925 F at 180 minutes.

REVIEWER (S) COMMENTS	PREPARER	DATE
	K. Dungan	4-7-00
	REVIEWER / CHECKER R. Rudy	DATE 4-7-00
	INDEPENDENT REVIEWER F. Collins Frank Collins via telecon	DATE 4-7-00

Plume and Hot Layer Calculation

Assumptions:

Plume Temperature Calculations

Ceiling Height - 30 feet
Ceiling area – 10200 sq. ft.
Calculation at plume centerline

Upper Layer Temperature Calculations

Heat Loss Area – walls and ceiling, 80545 sq. ft.
Vents – Door only, to low bay, 30 feet high and 20 feet wide

Results: 9 pages attached

Summary

Fire Scenario	Plume Temp. (F)	Upper Layer Temp. (F)
30 minute pool fire at 21,100 kW	834	324
16 minute pool fire at 38,000 kW	1200	408
Tire fire, double axle at 9000 kW	503	214
16 minute pool and tire fire at 47000 kW for 16 minutes 9000 kW for 14 minutes	1372	459

Software

FPETOOL V3.2

Prepared by: [signature] Date: 4/7/00

Checked by: [signature] Date: 4/7/00

01-04-1980
FPETOOL V3.2

---------- Ceiling plume temperature ----------

A 21100 kW fire LOCATED AWAY FROM WALLS positioned 30.0ft below the ceiling in a space having an ambient (room) temperature of 70 F (21 C), will produce a jet of hot gas impacting on the ceiling over the fire that has a temperature of:

834 F 445 C

Unless the room or space involved has ceiling vents to remove the hot gases that accumulate at the ceiling, a hot gas layer will eventually build up sufficiently to cause the temperature to rise above that indicated by this formula.

The temperature will start to rise if a fire of 21100 kW lasts more than approximately
160 seconds (2.7 minutes).

01-04-1980
FPETOOL V3.2

---------- Ceiling plume temperature ----------

A 38000 kW fire LOCATED AWAY FROM WALLS positioned 30.0ft below the ceiling in a space having an ambient (room) temperature of 70 F (21 C), will produce a jet of hot gas impacting on the ceiling over the fire that has a temperature of:

1200 F 649 C

Unless the room or space involved has ceiling vents to remove the hot gases that accumulate at the ceiling, a hot gas layer will eventually build up sufficiently to cause the temperature to rise above that indicated by this formula.

The temperature will start to rise if a fire of 38000 kW lasts more than approximately
131 seconds (2.2 minutes).

01-04-1980
FPETOOL V3.2

---------- Ceiling plume temperature ----------

A 9000 kW fire LOCATED AWAY FROM WALLS positioned 30.0ft below the ceiling in a space having an ambient (room) temperature of 70 F (21 C), will produce a jet of hot gas impacting on the ceiling over the fire that has a temperature of:

503 F 262 C

Unless the room or space involved has ceiling vents to remove the hot gases that accumulate at the ceiling, a hot gas layer will eventually build up sufficiently to cause the temperature to rise above that indicated by this formula.

The temperature will start to rise if a fire of 9000 kW lasts more than approximately
212 seconds (3.5 minutes).

01-04-1980
FPETOOL V3.2
---------- Ceiling plume temperature ----------
A 47000 kW fire LOCATED AWAY FROM WALLS positioned 30.0ft below the ceiling in a space having an ambient (room) temperature of
70 F (21 C), will produce a jet of hot gas impacting on the ceiling over the fire that has a temperature of:

1372 F 745 C

Unless the room or space involved has ceiling vents to remove the hot gases that accumulate at the ceiling, a hot gas layer will eventually build up sufficiently to cause the temperature to rise above that indicated by this formula.

The temperature will start to rise if a fire of 47000 kW lasts more than approximately
122 seconds (2.0 minutes).

01-04-1980
FPETOOL V3.2
---------- Ceiling plume temperature ----------
A 47000 kW fire LOCATED AWAY FROM WALLS positioned 30.0ft below the ceiling in a space having an ambient (room) temperature of
70 F (21 C), will produce a jet of hot gas impacting on the ceiling over the fire that has a temperature of:

1372 F 745 C

Unless the room or space involved has ceiling vents to remove the hot gases that accumulate at the ceiling, a hot gas layer will eventually build up sufficiently to cause the temperature to rise above that indicated by this formula.

The temperature will start to rise if a fire of 47000 kW lasts more than approximately
122 seconds (2.0 minutes).

01-04-1980
FPETOOL V3.2
----------Upper layer temperature----------

Run title: 30 minute pool fire
Room surfaces are:

surface #	Area ft^2	Thickness in	Material Name
1	80545.0	12.0	CONCRETE

Fire room openings:
Door: 30.0 ft. high by 20.0 ft. wide.
The room has no window or other vent except the door.

Time (sec)	Rate of heat release (BTU/sec)	(kW)	Upper level smoke temperature (degrees F)	(degrees C)
30	20019	21100	199	93
60	20019	21100	215	101
90	20019	21100	225	107
120	20019	21100	232	111
150	20019	21100	238	115
180	20019	21100	244	118
210	20019	21100	248	120
240	20019	21100	252	122
270	20019	21100	256	124
300	20019	21100	259	126
330	20019	21100	262	128
360	20019	21100	265	129
390	20019	21100	267	131
420	20019	21100	270	132
450	20019	21100	272	133
480	20019	21100	274	135
510	20019	21100	276	136
540	20019	21100	278	137
570	20019	21100	280	138
600	20019	21100	282	139
630	20019	21100	284	140
660	20019	21100	286	141
690	20019	21100	287	142
720	20019	21100	289	143
750	20019	21100	290	143
780	20019	21100	292	144
810	20019	21100	293	145
840	20019	21100	294	146
870	20019	21100	296	147
900	20019	21100	297	147
930	20019	21100	298	148
960	20019	21100	299	149
990	20019	21100	301	149
1020	20019	21100	302	150
1050	20019	21100	303	151
1080	20019	21100	304	151
1110	20019	21100	305	152
1140	20019	21100	306	152
1170	20019	21100	307	153
1200	20019	21100	308	153
1230	20019	21100	309	154
1260	20019	21100	310	154

1290	20019	21100	311	155
1320	20019	21100	312	156
1350	20019	21100	313	156
1380	20019	21100	314	157
1410	20019	21100	315	157
1440	20019	21100	315	157
1470	20019	21100	316	158
1500	20019	21100	317	158
1530	20019	21100	318	159
1560	20019	21100	319	159
1590	20019	21100	320	160
1620	20019	21100	320	160
1650	20019	21100	321	161
1680	20019	21100	322	161
1710	20019	21100	323	161
1740	20019	21100	323	162
1770	20019	21100	324	162

01-04-1980
FPETOOL V3.2
----------Upper layer temperature----------

Run title: 16 minute pool fire, 10 gpm
Room surfaces are:

surface #	Area ft^2	Thickness in	Material Name
1	80545.0	12.0	CONCRETE

Fire room openings:
Door: 30.0 ft. high by 20.0 ft. wide.
The room has no window or other vent except the door.

Time (sec)	Rate of heat release (BTU/sec)	(kW)	Upper level smoke temperature (degrees F)	(degrees C)
30	36053	38000	261	127
60	36053	38000	284	140
90	36053	38000	299	148
120	36053	38000	310	155
150	36053	38000	319	160
180	36053	38000	327	164
210	36053	38000	334	168
240	36053	38000	340	171
270	36053	38000	345	174
300	36053	38000	350	177
330	36053	38000	354	179
360	36053	38000	358	181
390	36053	38000	362	184
420	36053	38000	366	186
450	36053	38000	369	187
480	36053	38000	373	189
510	36053	38000	376	191
540	36053	38000	379	193
570	36053	38000	381	194
600	36053	38000	384	196
630	36053	38000	387	197
660	36053	38000	389	198
690	36053	38000	391	200
720	36053	38000	394	201
750	36053	38000	396	202
780	36053	38000	398	203
810	36053	38000	400	205
840	36053	38000	402	206
870	36053	38000	404	207
900	36053	38000	406	208
930	36053	38000	408	209
960	18074	19050	284	140
990	95	100	77	25

01-04-1980
FPETOOL V3.2
----------Upper layer temperature----------

Run title: Tire fire, double axle
Room surfaces are:

surface #	Area ft^2	Thickness in	Material Name
1	80545.0	12.0	CONCRETE

Fire room openings:
Door: 30.0 ft. high by 20.0 ft. wide.
The room has no window or other vent except the door.

Time (sec)	Rate of heat release (BTU/sec)	(kW)	Upper level smoke temperature (degrees F)	(degrees C)
30	8539	9000	143	62
60	8539	9000	152	67
90	8539	9000	158	70
120	8539	9000	162	72
150	8539	9000	165	74
180	8539	9000	168	76
210	8539	9000	171	77
240	8539	9000	173	78
270	8539	9000	175	80
300	8539	9000	177	81
330	8539	9000	179	82
360	8539	9000	180	82
390	8539	9000	182	83
420	8539	9000	183	84
450	8539	9000	185	85
480	8539	9000	186	85
510	8539	9000	187	86
540	8539	9000	188	87
570	8539	9000	189	87
600	8539	9000	190	88
630	8539	9000	191	88
660	8539	9000	192	89
690	8539	9000	193	89
720	8539	9000	194	90
750	8539	9000	195	90
780	8539	9000	196	91
810	8539	9000	196	91
840	8539	9000	197	92
870	8539	9000	198	92
900	8539	9000	199	93
930	8539	9000	199	93
960	8539	9000	200	93
990	8539	9000	201	94
1020	8539	9000	201	94
1050	8539	9000	202	94
1080	8539	9000	203	95
1110	8539	9000	203	95
1140	8539	9000	204	95
1170	8539	9000	204	96
1200	8539	9000	205	96
1230	8539	9000	206	96
1260	8539	9000	206	97

1290	8539	9000	207	97
1320	8539	9000	207	97
1350	8539	9000	208	98
1380	8539	9000	208	98
1410	8539	9000	209	98
1440	8539	9000	209	98
1470	8539	9000	210	99
1500	8539	9000	210	99
1530	8539	9000	211	99
1560	8539	9000	211	99
1590	8539	9000	211	100
1620	8539	9000	212	100
1650	8539	9000	212	100
1680	8539	9000	213	100
1710	8539	9000	213	101
1740	8539	9000	214	101
1770	8539	9000	214	101

01-04-1980
FPETOOL V3.2
----------Upper layer temperature----------

Run title: Pool and tire fire
Room surfaces are:

surface #	Area ft^2	Thickness in	Material Name
1	80545.0	12.0	CONCRETE

Fire room openings:
Door: 30.0 ft. high by 20.0 ft. wide.
The room has no window or other vent except the door.

Time (sec)	Rate of heat release (BTU/sec)	(kW)	Upper level smoke temperature (degrees F)	(degrees C)
30	44592	47000	290	143
60	44592	47000	317	158
90	44592	47000	334	168
120	44592	47000	347	175
150	44592	47000	357	181
180	44592	47000	366	186
210	44592	47000	374	190
240	44592	47000	381	194
270	44592	47000	387	197
300	44592	47000	392	200
330	44592	47000	398	203
360	44592	47000	402	206
390	44592	47000	407	208
420	44592	47000	411	211
450	44592	47000	415	213
480	44592	47000	419	215
510	44592	47000	422	217
540	44592	47000	426	219
570	44592	47000	429	220
600	44592	47000	432	222
630	44592	47000	435	224
660	44592	47000	438	225
690	44592	47000	440	227
720	44592	47000	443	228
750	44592	47000	446	230
780	44592	47000	448	231
810	44592	47000	450	232
840	44592	47000	453	234
870	44592	47000	455	235
900	44592	47000	457	236
930	44592	47000	459	237
960	26565	28000	347	175
990	8539	9000	201	94
1020	8539	9000	201	94
1050	8539	9000	202	94
1080	8539	9000	203	95
1110	8539	9000	203	95
1140	8539	9000	204	95
1170	8539	9000	204	96
1200	8539	9000	205	96
1230	8539	9000	206	96
1260	8539	9000	206	97

1290	8539	9000	207	97
1320	8539	9000	207	97
1350	8539	9000	208	98
1380	8539	9000	208	98
1410	8539	9000	209	98
1440	8539	9000	209	98
1470	8539	9000	210	99
1500	8539	9000	210	99
1530	8539	9000	211	99
1560	8539	9000	211	99
1590	8539	9000	211	100
1620	8539	9000	212	100
1650	8539	9000	212	100
1680	8539	9000	213	100
1710	8539	9000	213	101
1740	8539	9000	214	101
1770	8539	9000	214	101

ATTACHMENT 1

IDR Review

FPEtool is a well documented software program. However, it is not presently qualified under S&W Software qualification program. Therefore an alternate method in accordance with S&W EAP 5.3 will be used to verify the calculation and verify the accuracy of FPEtool version 3.2.

The first part of this calculation determines plume temperatures. The FPEtool program uses the plume equation develop by Dr. Alpert and Dr. Ward and documented in Fire Safety Journal No.7 (1984) titled "Evaluation of Unsprinklered Fire Hazards". The plume temperature equation (eq. 1) is:

$$\Delta T = 300(kQ)^{2/3}/H^{5/3}$$

Where: ΔT is the plume temperature rise (°F)
K is a configuration factor for open areas is 1
Q The heat release rate (Btu/s)
H The height of the above the fuel pack (ft)

The following is the results of this equation

Plume Temperatures					
heat release		amb temp	Height	detla temp	Plume temp
q		ta	h	dT	Tp
KW	Btu/s	°F	ft	°F	°F
47,000	44,587	70	30	1,302	1,372
38,000	36,049	70	30	1,130	1,200
21,100	20,017	70	30	764	834
9,000	8,538	70	30	433	503

These results match the results of the calc.

The second part of this calculation determines the hot (upper) gas layer. For a large open space such as the one model here, a reasonable approximation which result in slightly higher temperatures at worst heat release rates (steady state conditions) is to use the ceiling jet temperature equation develop by Alpert and Ward (see above reference) at a radial distance equal to the ceiling height. The ceiling jet equation (eq 2) is:

$$\Delta T = 300(kQ/r)^{2/3}/H$$

Where the terms are the same as above and r is the radial distance from the fire which for this case is 30 ft.

The following is the results of this equation

Ceiling Jet Temperatures						
Heat Release		Amb Temp	height	rad dist	delta temp	Jet Temp
q		ta	h		dt	Tc
kW	Btu/s	°F	ft	ft	°F	°F
47,000	44,587	70	30	30	399	469
38,000	36,049	70	30	30	347	417
21,100	20,017	70	30	30	234	304
9,000	8,538	70	30	30	133	203

The results are slightly higher than the results calculated by FPEtool as expected.

Therefore, the calculation provides reasonable results.