**STONE & WEBSTER ENGINEERING CORPORATION**

# CALCULATION TITLE PAGE

| CLIENT & PROJECT | PAGE 1 OF 6 |
|---|---|
| **Private Fuel Storage L. L. C./Private Fuel Storage Facility** | |
| CALCULATION TITLE<br>**Radiant Heat Flux Calculations for Canister Transfer Building Heavy Haul Vehicle Tire Fire** | QA CATEGORY I |

| CALCULATION IDENTIFICATION NUMBER | | | | |
|---|---|---|---|---|
| J.O. OR W.O. NO. | DIVISION & GROUP | CURRENT CALC. NO. | OPTIONAL TASK CODE | OPTIONAL WORK PACKAGE NO. |
| **05996.02** | **Mechanical** | **P-007** | **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) [signature] 4-7-00 | R. Rudy (Risk Technologies) [signature] 4-7-00 | D. Lewis (S & W) [signature] 4-10-00 | 0 | NA | | X |
| | | | | | | |
| | | | | | | |
| | | | | | | |

## DISTRIBUTION

| GROUP | NAME & LOCATION | COPY SENT (X) | GROUP | NAME & LOCATION | COPY SENT (X) |
|---|---|---|---|---|---|
| RECORDS MGT. FILES (OR FIRE FILE IF NONE) | JOB BOOK R4.2<br>FIRE FILE | ORIG.<br>x | | | |

## RECORD OF REVISIONS

**Revision 0** - Original Issue

| CALCULATION SUMMARY | J.O./W.O./CALCULATION NO. 0599601-P-007 | REVISION 0 | PAGE 3 |
|---|---|---|---|

**CLIENT / PROJECT**
Private Fuel Storage L.L.C.

**QA CATEGORY / CODE CLASS**
QA Category I

**SUBJECT / TITLE**
Radiant Heat Flux Calculations for Canister Transfer Building Heavy Haul Vehicle Tire Fire

**OBJECTIVE OF CALCULATION**

The objective of this calculation is to determine the peak radiant heat flux that would be given off by a set of burning tires to see what affect it would have on the spent fuel shipping cask and tires on an adjacent axle. The calculation will determine:

1. The radiant heat flux from the flame of 8 burning tires.
2. The affect of the heat flux on the shipping cask.
3. The affect of the heat flux on an adjacent axle of tires.

**CALCULATION METHOD / ASSUMPTIONS**

Method: The calculation will utilize typical radiant heat transfer formulas to determine the radiant heat flux of the burning tires.

Assumptions:

1. From Ref. 1 (a typical heavy haul trailer), use trailer tire size 255/70R x 22.5 16PR Radials. These tires are 10 in. wide x 36.5 in. high. Therefore, a double axle set of dual tires will be approximately 1m high x 1 m wide x 3 m long.
2. Use heat release rate of 1500 kW/m$^2$ for burning tires. This is conservative based on similar fuels listed in Table 5-5.2(a) of Reference 3.
3. Assume closest set of axles on trailer to shipping cask burn to calculate part 2. From Ref. 1, scale 12 ft (3.7 m) from closest axle to nearest edge of shipping cask.
4. From Ref. 1, distance between sets of axle tires is 12 ft (3.7m).

**SOURCES OF DATA / EQUATIONS**

1. Trail King Drawing No. 962620, TK300 Trailer System, 5/24/96.
2. Society of Fire Protection Engineers Handbook, NFPA, 2nd edition.
3. NFPA 204, Guide for Smoke and Heat Venting, 1991.

**CONCLUSIONS**

The results show that the peak radiant heat flux given off by the burning tires of 10.7 kW/m$^2$ to the shipping cask is less than the radiant heat flux from the fire for which the cask is qualified in accordance with 10 CFR 71, which yields 68 kW/m$^2$.

The results also show that the peak radiant heat flux given off by the burning tires of 8 kW/m$^2$ to the adjacent set of axle tires is less than the minimum flux necessary to ignite vulcanized rubber (Similar materials shown in Section 3/Chapter 4 of Reference 2 as ethylene/propylene rubber power cables as 20-23 kW/m$^2$ and for chloroprene rubber conveyor belts as 20 kW/m$^2$ ).

| REVIEWER (S) COMMENTS | | |
|---|---|---|
| | PREPARER K. Dungan | DATE 4-7-00 |
| | REVIEWER / CHECKER R. Rudy | DATE 4-7-00 |
| | INDEPENDENT REVIEWER D. Lewis | DATE 4-10-00 |

Description:

8 - 255/70R 22.5 16PR Radial tires per axle

(10" wide, 36.5" high)

Separation: 12' (3.7m) from tire to next double axle

12' (3.7m) from closest tire to cask edge

Burning characteristics:

Assume heat release rate of 1500 kW/m² floor area for tires, 1m high, 1m wide, 3m long

$$Q_T = (3 \times 1)\,1500 = 4500\text{ kW}$$

Radiative fraction $\chi_r \leq .35$ so maximum radiative heat release

$$Q_R = \chi Q_T = .35 \times 4500 = 1575\text{ kW}$$

Flame emissive flux:

$$E = Q_R / A_f$$

, $A_f$ = flame area envelope = $H_f \times P_f$

$H_f$ = flame height

$P_f$ = flame perimeter = 3+1+3+1 = 8m

Flame Height (per Heskestad eq 6-1 NFPA 204)

$$H_f = -1.02D + .235\,Q_T^{2/5}$$

$$= -1.02(3m) + .235\,(4500)^{.4} = 3.74\text{ m}$$

| | BY | DATE | |
|---|---|---|---|
| PREPARED | KWD | 4-5 | Radiant Heat Flux Calc. |
| CHECKED | RR | 4-6 | |
| APPROVED | | | |

| REVISIONS BY | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| DATE | | | | | |

CLIENT Stone & Webster
PROJECT PFSF
TASK TIRE FIRE
1 ISSUED BY
DATE 4-5-00
NUMBER 1 of 3

$A_f = 3.74\,m \times 8\,m = 30\,m^2$

$E = Q_R / A_f = \frac{1575}{30} = 52.5\,kW/m^2$

Exposure calculations:

$\dot{q}_r = F_{12} E$ , $F_{12}$ = view factor

Case 1 Tire fire exposing shipping cask.

At closest point cask will be 3.7m from edge of flame; greatest point flux will be on portion of cask centered on flame.

$$F_{12} = \frac{2}{\pi}\left[\frac{X}{\sqrt{1+X^2}}\tan^{-1}\frac{Y}{\sqrt{1+X^2}} + \frac{Y}{\sqrt{1+Y^2}}\tan^{-1}\frac{X}{\sqrt{1+Y^2}}\right]$$

$X$ = ½ Flame height / distance to target $= \frac{1.87}{3.7} = .5054$

$Y$ = ½ flame width / distance to target $= \frac{1.5}{3.7} = .4054$

$$F_{12} = \frac{2}{\pi}\left[\frac{.5054}{\sqrt{1+.5054^2}}\tan^{-1}\frac{.4054}{\sqrt{1+.5054^2}} + \frac{.4054}{\sqrt{1+.4054^2}}\tan^{-1}\frac{.5054}{\sqrt{1+.4054^2}}\right]$$

$$= \frac{2}{\pi}\left[.1567 + .1646\right] = .2045$$

$\dot{q}_r = 52.2 \times .2045 = 10.7\,kW/m^2$ peak

| | BY | DATE |
|---|---|---|
| PREPARED | KWD | 4-5 |
| CHECKED | RR | 4-6 |
| APPROVED | | |

| REVISIONS BY | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| DATE | | | | | |

CLIENT Stone & Webster
PROJECT PFSF
TASK TIRE FIRE
1 ISSUED BY
DATE 4-5-00
NUMBER 2 of 3

Case 2 Tire fire exposing adjacent axle

At closest point tire edge will be 3.7m from edge of flame, tire will be at base of flame, worst case is center base.

$$F_{12} = \frac{1}{\pi}\left[\frac{X}{\sqrt{1+X^2}}\tan^{-1}\frac{Y}{\sqrt{1+X^2}} + \frac{Y}{\sqrt{1+Y^2}}\tan^{-1}\frac{X}{\sqrt{1+Y^2}}\right]$$

$X$ = flame height / separation distance $= \frac{3.74}{3.7} = 1.011$

$Y$ = ½ flame width / separation distance $= \frac{1.5}{3.7} = .4054$

$$F_{12} = \frac{1}{\pi}\left[\frac{1.011}{\sqrt{1+1.011^2}}\tan^{-1}\frac{.4054}{\sqrt{1+1.011^2}} + \frac{.4054}{\sqrt{1+.4054^2}}\tan^{-1}\frac{1.011}{\sqrt{1+.4054^2}}\right]$$

$$= \frac{1}{\pi}\left[.1975 + .283\right] = .153$$

$\ddot{q}_{or} = 52.2 \times .153 = 8\ kW/m^2$ peak

| | BY | DATE |
|---|---|---|
| PREPARED | KWD | 4-5 |
| CHECKED | RR | 4-6 |
| APPROVED | | |

| REVISIONS BY | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| DATE | | | | | |

CLIENT Stone & Webster
PROJECT PFSF
TASK TIRE FIRE
1 ISSUED BY
DATE 4-5-00
NUMBER 3 of 3