CHAPTER 5
ESTIMATING RADIANT HEAT FLUX FROM FIRE TO A TARGET FUEL ABOVE GROUND LEVEL IN PRESENCE OF WIND (TILTED FLAME)
SOLID FLAME RADIATION MODEL

Version 1805.1
(English Units)

The following calculations estimate the full-scale cable tray heat release rate.
Parameters in YELLOW CELLS are Entered by the User.
Parameters in GREEN CELLS are Automatically Selected from the DROP DOWN MENU for the Cable Type Selected.
All subsequent output values are calculated by the spreadsheet and based on values specified in the input parameters. This spreadsheet is protected and secure to avoid errors due to a wrong entry in a cell(s). The chapter in the NUREG should be read before an analysis is made.

Project / Inspection Title: **ENEL E INGENOSTRUM - GUAYEPO**

INPUT PARAMETERS

Mass Burning Rate of Fuel (m")	0,045	kg/m^2-sec
Effective Heat of Combustion of Fuel ($\Delta H_{c,eff}$)	44400	kJ/kg
Empirical Constant ($k\beta$)	2,1	m^{-1}
Fuel Area or Dike Area (A_{dike})	6,68	ft^2
Distance between Fire and Target (L)	13,69	ft
Wind Speed or Velocity (u_w)	590,551	ft/min
Ambient Air Temperature (T_a)	81,50	°F
Gravitational Acceleration (g)	9,81	m/sec^2
Ambient Air Density (ρ_a)	1,17	kg/m^3

Calculate

Note: Air density will automatically correct with Ambient Air Temperature (T_a) Input

THERMAL PROPERTIES DATA

BURNING RATE DATA FOR FUELS

Fuel	Mass Burning Rate m" (kg/m^2-sec)	Heat of Combustion $\Delta H_{c,eff}$ (kJ/kg)	Constant $k\beta$ (m^{-1})
Methanol	0,017	20.000	100
Ethanol	0,015	26.800	100
Butane	0,078	45.700	2,7
Benzene	0,085	40.100	2,7
Hexane	0,074	44.700	1,9
Heptane	0,101	44.600	1,1
Xylene	0,09	40.800	1,4
Acetone	0,041	25.800	1,9
Dioxane	0,018	26.200	5,4
Diethy Ether	0,085	34.200	0,7
Benzine	0,048	44.700	3,6
Gasoline	0,055	43.700	2,1
Kerosine	0,039	43.200	3,5
Diesel	0,045	44.400	2,1
JP-4	0,051	43.500	3,6
JP-5	0,054	43.000	1,6
Transformer Oil, Hydroca	0,039	46.000	0,7
561 Silicon Transformer F	0,005	28.100	100
Fuel Oil, Heavy	0,035	39.700	1,7
Crude Oil	0,0335	42.600	2,8
Lube Oil	0,039	46.000	0,7
Douglas Fir Plywood	0,01082	10.900	100
User Specified Value	Enter Value	Enter Value	Enter Value

Reference: *SFPE Handbook of Fire Protection Engineering*, 3rd Edition, 2002, *Page 3-26.*

Select Fuel Type
Diesel
Scroll to desired fuel type then
Click on selection

ESTIMATING RADIATIVE HEAT FLUX TO A TARGET FUEL IN PRESENCE OF WIND

Reference: *SFPE Handbook of Fire Protection Engineering, 3rd Edition, 1995, Page 3-276*.

SOLID FLAME RADIATION MODEL IN PRESENCE OF WIND

$$q'' = EF_{1\text{->}2}$$

Where
q'' = incident radiative heat flux on the target (kW/m^2)
E = emissive power of the pool fire flame (kW/m^2)
$F_{1\text{->}2}$ = view factor between target and the flame in presence of wind

Pool Fire Diameter Calculation

$$A_{dike} = \pi D^2/4$$

$$D = \sqrt{(4\ A_{dike}/\pi)}$$

Where
A_{dike} = surface area of pool fire (m^2)
D = pool fire diameter (m)

D = 0,89 m

Pool Fire Radius Calculation

$$r = D/2$$

Where
r = pool fire radius (m)
D = pool fire diameter (m)

r = 0,44 m

Flame Emissive Power Calculation

$$E = 58\ (10^{-0.00823\ D})$$

Where
E = emissive power of the pool fire flame (kW/m^2)
D = diameter of the pool fire (m)

E = 57,03 kW/m^2

View Factor Calculation in Presence of Wind

$$\pi F_{1\text{->}2,H} = \tan^{-1}(b+1/b-1)^{0.5} - (a^2 + (b+1)^2 - 2(b+1+ab\,\mathrm{Sin}\,\theta)/(AB)^{0.5}\tan^{-1}(A/B)^{0.5}((b-1)/(b+1))^{0.5} + \mathrm{Sin}\theta/(C)^{0.5}(\tan^{-1}((ab-(b^2-1)\mathrm{Sin}\theta)/((b^2-1)(C))^{0.5}) + \tan^{-1}((\mathrm{Sin}\theta(b^2-1))/(b^2-1)^{0.5}(C)^{0.5})$$

$$\pi F_{1\text{->}2,V} = (a\,\mathrm{Cos}\theta/(b-a\,\mathrm{Sin}\theta))(a^2+(b+1)^2-2b(1+a\,\mathrm{Sin}\theta))/(AB)^{0.5}(\tan^{-1}(A/B)^{0.5}((b-1)/(b+1))^{0.5} + \mathrm{Cos}\theta/(C)^{0.5}((\tan^{-1}(ab-(b^2-1)\mathrm{Sin}\theta)/((b^2-1)(C))^{0.5} + \tan^{-1}(b^2-1)\mathrm{Sin}\theta/((b^2-1)^{0.5}(C)^{0.5}))) - (a\mathrm{Cos}\theta)/(b-a\,\mathrm{Sin}\theta)(\tan^{-1}(b-1/b+1)^{0.5}$$

$a = H_f/r$
$b = R/r$
$A = a^2 + (b+1)^2 - 2a(b+1)\sin\theta$
$B = a^2 + (b-1)^2 - 2a(b-1)\sin\theta$
$C = 1 + (b^2-1)\mathrm{Cos}^2\theta$
$F_{1\text{->}2,max} = \sqrt{(F^2_{1\text{->}2,H} + F^2_{1\text{->}2,V})}$

Where
$F_{1\text{->}2,H}$ = horizontal view factor
$F_{1\text{->}2,V}$ = vertical view factor
$F_{1\text{->}2,max}$ = maximum view factor
R = distance from center of the pool fire to edge of the target (m)
H_f = height of the pool fire flame (m)
r = pool fire radius (m)
θ = flame tilt or angle of deflection (radians)

Distance from Center of the Pool Fire to Edge of the Target Calculation

R = L+r

Where
R = distance from center of the pool fire to edge of the target (m)
L = Distance between fire and target
r = pool fire radius (m)

R= 4,62 m

Heat Release Rate Calculation

$$Q = m''\Delta H_{c,eff}(1 - e^{-k\beta\,D})\,A_{dike}$$

Where
Q = pool fire heat release rate (kW)
m" = mass burning rate of fuel per unit surface area (kg/m^2-sec)
ΔH_c = effective heat of combustion of fuel (kJ/kg)
A_{dike} = surface area of pool fire (area involved in vaporization) (m^2)
$k\beta$ = empirical constant (m^{-1})
D = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

Q = 1048,21 kW

Pool Fire Flame Height Calculation

$$H_f = 55\ D\ (m''/\rho_a\ (\sqrt{g\ D}))^{0.67}\ (u^*)^{-0.21}$$

Where
H_f = nondimensional wind velocity
m'' = mass burning rate of fuel (kg/m^2-sec)
D = pool fire diameter (m)
ρa = ambient air density (kg/m^3)
g = gravitational acceleration (m/sec^2)
u^* = nondimensional wind velocity

H_f = 1,96 m

Nondimensional Wind Velocity Calculation

$$u^* = u_w/(g\ m''\ D/\rho_a)^{1/3}$$

Where
u^* = nondimensional wind velocity
u_w = wind velocity (m/sec)
g = gravitational acceleration (m/sec^2)
m'' = mass burning rate of fuel (kg/m^2-sec)
D = pool fire diameter (m)
ρa = ambient air density (kg/m^3)

u^* = 4,324

Flame Tilt or Angle of Deflection Calculation

$COS\ \theta = 1$ for $u^* \le 1$
$COS\ \theta = 1 / \sqrt{(u^*)}$ for $u^* \ge 1$

Since $u^* \ge 1$

θ= ACOS(1/(u*)^0.5) = 1,069 Rad 61,25 degree

$a = H_f/r =$	4,40
$b = R/r =$	10,39
$A = a^2 + (b +1)^2 - 2a$ (	61,17
$B = a^2 + (b - 1)^2 - 2a$ (	35,05
$C = 1 + (b^2 - 1) Cos^2$(	25,73

		F_{H1}	F_{H2}	F_{H3}	F_{H4}	F_{H5}	F_{H6}
$F_{1\to2,H} =$	0,005	0,834	0,996	0,876	0,173	-0,741	1,061
$F_{1\to2,V} =$	0,027	F_{V1}	F_{V2}	F_{V3}	F_{V4}	F_{V5}	F_{V6}
$F_{1\to2,\ max} = \sqrt{(F^2_{1\to2,H} +}$	0,028	0,324	1,039	0,876	0,095	-0,741	1,061

RADIATIVE HEAT FLUX CALCULATION IN PRESENCE OF WIND

$$q'' = EF_{1\text{->}2}$$

Answer	**q" =**	**0,14 Btu/ft^2-sec**	**1,60 kW/m^2**

NOTE:

The above calculations are based on principles developed in the SFPE Handbook of Fire Protection Engineering, 3rd Edition, 2002. Calculations are based on certain assumptions and have inherent limitations. The results of such calculations may or may not have reasonable predictive capabilities for a given situation and should only be interpreted by an informed user. Although each calculation in the spreadsheet has been verified with the results of hand calculation, there is no absolute guarantee of the accuracy of these calculations. Any questions, comments, concerns and suggestions or to report an error(s) in the spreadsheets, please send an email to David.Stroup@nrc.gov or Naeem.Iqbal@nrc.gov.

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