DEVELOPMENT OF INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW FLASHPOINT FUELS (IGF CODE)

Calculation on thermal radiation hazard distance of LNG pool fire for bunkering station

Submitted by China

SUMMARY

Executive summary: This document provides detailed information of the calculation on thermal radiation hazard distance of LNG pool fire for bunkering station

Strategic direction: 5.2

High-level action: 5.2.1

Planned output: 5.2.1.2

Action to be taken: Paragraph 3

Related document: CCC 1/4/3

Background

1 China proposes to modify paragraph 11.3.7 of the draft IGF Code in paragraph 3 Fire protection of the bunkering station of the annex to document CCC 1/4/3, with a view to improving the fire protection requirements for the bunkering station.

2 By using the well-established Solid Flame Model, China has conducted analysis and calculations on LNG pool fire in a drip tray, and proposed fire protection requirements for bunkering station based on calculation results. For details, please refer to the annex.

Action requested of the Sub-Committee

3 The Sub-Committee is invited to note the information provided in this document while discussing document CCC 1/4/3.

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ANNEX

Calculation on thermal radiation hazard distance of LNG pool fire for bunkering station

Introduction

1. This document calculates the thermal radiation hazard distance of LNG pool fire that occurs in the drip tray below a bunkering connection to provide basis for fire separation of superstructures/deck houses facing the bunkering connection located on open deck.

2. The calculation of thermal radiation hazard distance was conducted based on simplified Solid Flame Model.

Solid Flame Model of LNG pool fire \[1\][2]

3. The model takes into consideration the geometric dimension of the fire and environmental conditions (wind speed, temperature and humidity, etc.). In this model, flame shape is selected as a circular cylinder, which has a diameter equivalent to the base diameter of the fire. When wind comes, the flame tilts in different angles. (See figure 1).

\[ q'' = EF \tau \] (1)

where,

- E = Average emissive power over the entire surface of the selected shape of the equivalent fire.

- F = Mean view factor between the geometry that represents the fire and the heat receiving object located at a specified distance from and orientated in a specified angle to the fire.

- \( \tau \) = Wave length independent radiant heat transmissivity of the atmosphere between the object and the fire.
5 It is generally assumed that the emissive power of the flame is in the range of 220 ± 50 kW/m² for pool fire of general scale. Atmospheric transmissivity of radiant heat can be calculated by the following equation:

\[
\tau = 1.3989 - 0.0565 \ln \left\{ \frac{p_{w}^{\text{sat}}(T_{a})RH}{100} \right\}
\]

(2)

where, \( \tau \) = Atmospheric transmissivity

\( s \) = Distance through atmosphere (m)

\( p_{w}^{\text{sat}}(T_{a}) \) = Saturated water vapor pressure (N/m²)

\[
\left( \frac{11.526 + 1441.4 \times 0.3281}{T_{a}} \right)
\]

where, \( T_{a} \) = Air temperature (K)

\( RH \) = Relative humidity (%)

6 Visible fire plume length (L) for a fire of diameter D is calculated by the following Thomas equation:

\[
\frac{L}{D} = AF_{r}^{1/3} \left( U^{*} \right)^{1}
\]

(3)

with, \( A, p, q \) being correlation constants determined empirically from test data and

\[
F_{r} = \frac{m^{*}}{\rho_{a} \sqrt{gD}} = \text{Froude Number Dimensionless burning rate},
\]

\[
U^{*} = \frac{U_{\text{wind}}}{\left\{ \frac{m^{*}}{\rho_{a} gD} \right\}^{1/3}} = \text{Dimensionless wind speed},
\]

\( U_{\text{wind}} \) is the wind speed of 10 m high. The tilt angle \( \theta \) in the wind-direction depends upon \( U^{*} \); if \( U^{*} \leq 1 \), \( \cos(\theta) = 1 \); if \( U^{*} > 1 \), \( \cos(\theta) = \frac{1}{\sqrt{U^{*}}} \).

The parameter values in this calculation are selected according to standard EN1473:2007[3].
Analysis and calculation on LNG pool fire in a drip tray

Dimension calculation on drip tray

7 The bunkering connection is one of the sources that lead to LNG leakage, a low temperature resistant drip tray should be installed below it to hold the LNG when leakage occurs. Under the assumption that the bunkering speed of LNG is 60 $\text{m}^3/\text{h}$, when LNG leaks at the bunkering connection, the response time of emergency cut-off valve is taken as 30 s, then the maximum leakage volume can be up to 0.5 $\text{m}^3$. In this case, a cubical drip tray of $1 \text{ m} \times 1 \text{ m} \times 0.6 \text{ m}$ in size can hold all the LNG leaked, the equivalent diameter of the bottom area is taken as 1.41 m.

LNG pool fire model of drip tray

8 It is assumed that the wind speed is 2 m/s, temperature is 20°C, air humidity is 50%, and air density is 1.2 kg/m$^3$, $E = 270 \text{ kW/m}^2$. If the spilled LNG is ignited, according to calculation, the flame length is $L = 6.19 \text{ m}$, flame length of horizontal projection is $H = 4.19 \text{ m}$.

9 In the worst scenario, a thermal radiation value 15 kW/m$^2$ is selected as the acceptable criterion for steel structure such as superstructures$^{[3]}$, according to calculation, the thermal radiation hazard distance of the pool fire is $X = 8.7 \text{ m}$, we take 10 m as the hazard distance of bunkering connection based on considerations of the equivalent circle radius of the drip tray and certain safety margin.

Proposal of fire prevention for bunkering connection

10 For a bunkering connection located on open deck:

.1 when the horizontal distance between the bunkering connection and the superstructure is not more than 10 m, the boundary of machinery spaces of category A, accommodation, control stations and high fire risk spaces facing the bunkering connection shall be shielded with A-60 class divisions spreading at least 10 m on both sides along the horizontal projection point of the bunkering connection. When the bulkhead along both sides of the horizontal projection point of the bunkering connection is not more than 10 m, the heat insulation can be of the length of the actual length of the bulkhead (see figures 2.a and 2.b). Besides, such heat insulation shall spread up to bridge deck or the actual height of the boundary; and

.2 if the horizontal distance between the bunkering connection and the superstructures is more than 10 m, the insulation standard may be reduced to class A-0 (see figure 2.c).
Figure 2.a: Distance between superstructure and bunkering connection facing the side bulkhead is not more than 10 m

Figure 2.b: Distance between superstructure and bunkering connection facing the end bulkhead is less than 10 m

Figure 2.c: Distance between superstructure and bunkering connection is more than 10 m

Figure 2: Schematic representation of LNG pool fire in a drip tray under the bunkering connection on open deck
References:

