# CHAPTER
# 10
# THE RADIANT HEAT FLUX OF HORIZONTAL JET FLAMES

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## 10.1 INTRODUCTION

Accidental gaseous fuel releases in the industry can cause dangerous jet flames, endangering nearby installations. According to the statistics from a previous study of Gómez-Mares et al. (2008) all jet fires induced at least one more serious occurrence (Liu et al., 2019). Two potential factors are leading to accident escalation involving jet fire occurrence; the radiation heat release and flame impingement (Wang et al., 2021). For the prediction of radiation heat, there are four models available namely as point source model (PSM), solid flame model (SFM), multi-point source model (MPSM), and line source model (LSM) (Ab Aziz et al., 2019). The accuracy of the radiant heat prediction from various release conditions using PSM, SFM, and MPSM was detailed out by Hankinson and Lowesmith (2012). In 2016, a new model called LSM was developed by Zhou and Jiang (2016) that addresses the inadequacies of MPSM for radiant heat release prediction in the near-field. Even though LSM could predict the radiant heat release very well in near and far-field, however, it was dictated later, it could result in underprediction for a horizontal buoyant jet flame (Changchun et al., 2019*;* Ekoto et al., 2014*)* which is a focus in this study. The equation that governs the LSM model is as illustrated in Equation 10.1;

$$Q_R = \int_{L_f}^{L} \frac{\tau E'}{4\pi S^2} \cos \emptyset \, dz \qquad (10.1)$$

The emissivity, $E'$ is the infinitesimal volume of flame with the corresponding point located on the jet centreline, which is equal to $2\pi bE''$ indicates it is proportional to the square of the flame radius, *b*. The value can be calculated using a theoretical model that is based on the flame shape dimension (width and length).

$$E' = E'_o \left(\frac{b}{b_o}\right)^2 \qquad (10.2)$$

Integrating the emissivity value over the flame length leads to total radiant heat output;

$$E'_o = \frac{x_R \dot{Q}}{\int_{L_f}^{L_p} \left(\frac{b}{b_o}\right)^2 dz} \qquad (10.3)$$

Details of the LSM derivation can be found in the literature (Zhou & Jiang, 2016; Zhou et al., 2016). For a horizontal buoyant jet flame, two regions were usually recognized, a buoyancy-controlled and momentum-controlled region (Changchun et al., 2019). As the initial momentum is conserved after exiting the nozzle, buoyancy takes over and causes the flame to bend upwards in the buoyancy-controlled zone. Thus, for a buoyant jet flame, both the momentum-controlled and the buoyancy-controlled region should be accounted for radiant heat prediction. It was inferred from the previous study (Ekoto et al., 2014), instead of using projected flame length $(L_p)$, the trajectory flame length $(L_t)$ could be used as a basis for radiant heat prediction. The theory of trajectory flame length was first developed by Peters and Gottgens (1991) which was later in the event of a stagnant environment, a closed analytic solution for the trajectory of the buoyant jet flame centerline was successfully derived by Gore and Jian (1993). The equation of integrated mass conservation, momentum conservation, and mixture fraction conservation of a curvilinear coordinated that were developed and used by other few studies later that account for buoyancy correction of horizontal jet flame (Changchun et al., 2019; Ekoto et al., 2014; Kim et al., 2009; Liu et al., 2019). Other than using theoretical estimation, the flame trajectory could also be estimated using a flow visualization approach (Liu et al., 2019). Smith et al. (2005) employed graphic software to compute the flame trajectory by identifying the chord line along the flame volume. Another study established the flame centerline using an infrared picture contour and LNG as fuel (Zhang et al., 2019). In a subsequent investigation, the trajectory line was defined as the central point of the horizontal jet flame width, and a recommended correlation for flame trajectory was presented as follows (Tao et al., 2016)

$$\frac{L_t}{d} = aQ^{*2/5} \tag{10.4}$$

Based on Equations 10.1–10.4, the flame trajectory, lift-off distance, and flame length ratio are all relevant parameters to be measured in this study to further be used for radiant heat prediction. Thus, this study attempt to compare the validity of LSM based on flame projection and flame trajectory, and thus extend the validity which is not only limited to free jet fire scenario but also on impinging jet fire.

## 10.2 METHOLOGICAL APPROACH IN HORIZONTAL JET FLAMES

This section outlines the systematic approach employed to investigate horizontal jet flames. The methodology involves several key steps such as detailed description of the experimental configuration, release condition and data processing.

A flexible high-pressure hose was connected to a 1-m horizontal pipeline that acts as a stagnation chamber upon release of gaseous fuel to a pressurized gas supply. Figure 10.1 shows the experimental setup