# Fired Heater Simulation

# Study Report

**Client: xxx**

**Project: xxx**

# 1. Executive Summary

This report is based around Fired Heater H-10114, which is one of four identical units currently installed and in operation at the CLIENT production facility. In 2020, an operator was injured when flame and hot flue gas egressed the heater at the observation door location whilst the operator was observing the flame during burner adjustment/maintenance activity. Due to the seriousness of this incident and the major safety hazard that exists, CLIENT have held several safety review meetings in order to identify the cause and solution for the problem.

One of these meetings was attended by HeaterSIM and it was identified that a likely contributing factor for the flue gas/flame egressing at the observation door location resulted from high pressure inside the firebox, which may have been exaggerated due to the presence of a large internal restricting cone inside the heater.

HeaterSIM had advised that the presence of such a restricting cone inside the heater was very unusual and could contribute towards creating higher pressures in the radiant section, since the flue gas exit route was restricted. Presumably, such considerations would have been made at the design stage, thus the cone would not be excessively large in relation to the maximum possible duty of the heater. However, modern fired heaters designed in accordance with API 560 Fired Heater Design Standard would not be designed with such a restriction anywhere inside the heater.

Consequently, this report is as a result of CLIENT's request to carry out a simulation of the heater operating without the cone; as a relatively easy solution to minimise potential overpressure would be to simply remove the restricting cone and continue operating the heater without it.

The subsequent heater simulation results have shown that the heater would be able to operate satisfactorily and achieve the desired duty without the restricting cone. The heater simulation software was not able to produce a model for the heater operating with the cone, thus no direct comparative analysis could be carried out.

One other unusual feature of the heater currently installed is the presence of vertical convection studded tubes in the stack. The HeaterSIM Fired Heater Simulation Technology was used to model and analyse the results.

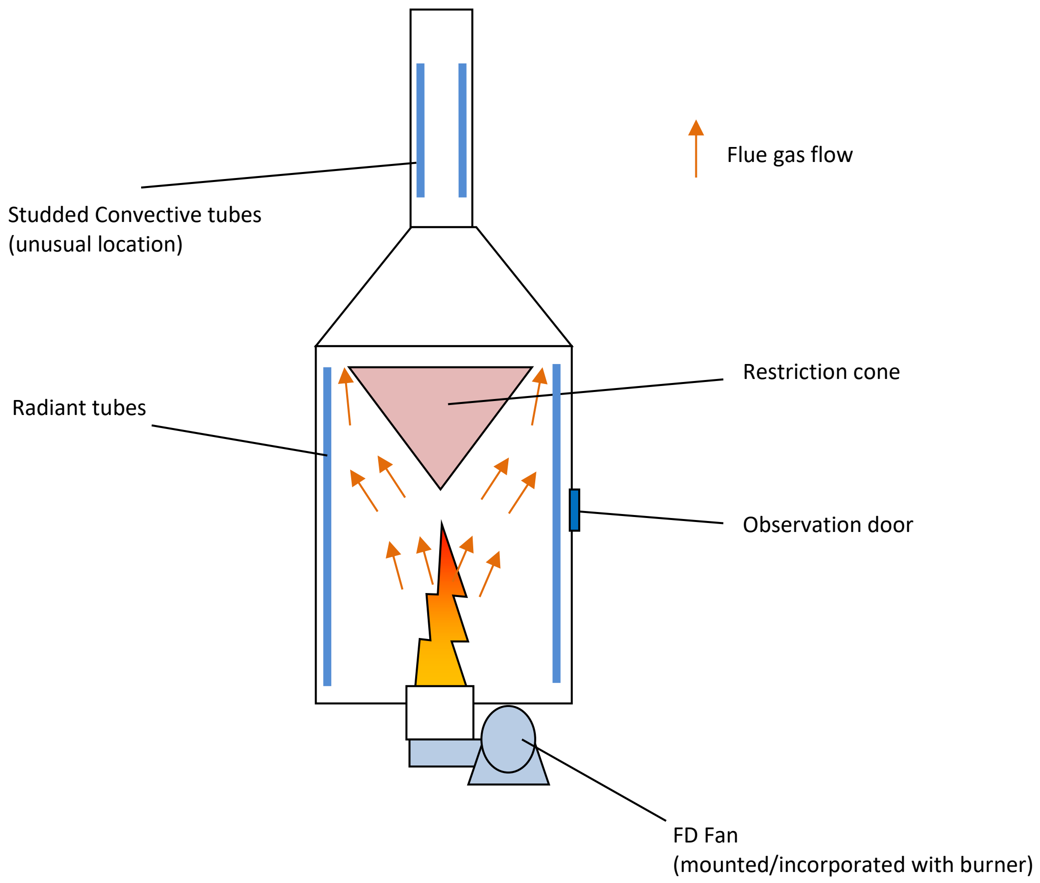
The simulations conducted confirmed safe operation and delivery of the required duty of the heater without the cone installed.

## 2. Introduction

The aim of this report is to detail the results of the API 560 Fired Heater Simulation performed to model the heater H-10114 without the restricting cone, which is currently installed within the operating Fired Heater at site.

This restricting cone is likely to contribute to over-pressurisation of the radiant section at higher firing duties, as the flue gas flow path through the heater is significantly reduced in comparison to modern API 560 fired heater configurations. Thus, the major objective of the analysis was to determine the operating characteristics of the heater without the cone, whilst examining whether such characteristics were suitable for safe operation and delivery of the required duty.

**Fired Heater Heater Configuration:**



# 3. Methodology

Based on the Fired Heater design documents from CLIENT, a heater model was prepared using the HeaterSIM Fired Heater Technology Fired Heater Simulation software.

The detailed analysis of the process fluid within the heater tubes was not within the scope of this report, as there were no problems reported with the inlet or outlet conditions of the process fluid. Hence, the process fluid physical properties used in preparing the model were 'typical' only, with the focus being on the calculation and results relating to the 'flue gas side' flow and heat transfer characteristics.

**Fired Heater Simulation Inputs:**
The summary of simulation model and calculation is as follows (please see our attached API 560 Fired Heater for further details):

| Description | Input |
|---|---|
| Fired Heater Design Configuration: | Vertical Cylindrical |
| Absorbed Duty (kW) | 535 |
| Process Fluid Flow (kg/h) | 5112 |
| Excess Air, % (*) | 30 |
| Radiant Tube Effective Length (m): | 3.6 |
| Convective tubes Effective Length (m): | 3.9m |
| Tube Material | A106 Gr B |

* The level of excess air is higher than usual for heaters firing Natural Gas fuel. The typical excess air utilised should be between 15-20%, which will provide safe and more efficient operating conditions. Reducing the excess air would also act to lower the load on the stack, hence reduce the likelihood of overpressure within the Fired Heater combustion chamber.

**Limitations in preparing the model**

As mentioned previously, the presence of vertical tubes in the stack is unusual and the HeaterSIM Fired Heater Technology software is unable to model vertical convection tubes in a stack with the flue gas flowing vertically. Hence, the convective tubes were modelled as horizontal tubes whilst the appropriate allowances for the different configuration were considered during the review and analysis.

The restricting cone is also a very unusual feature for a fired heater and the HeaterSIM Fired Heater Technology modelling software is unable to model this feature. Hence, only calculations for the heater without the cone have been carried out.

# 4. Simulation Results:

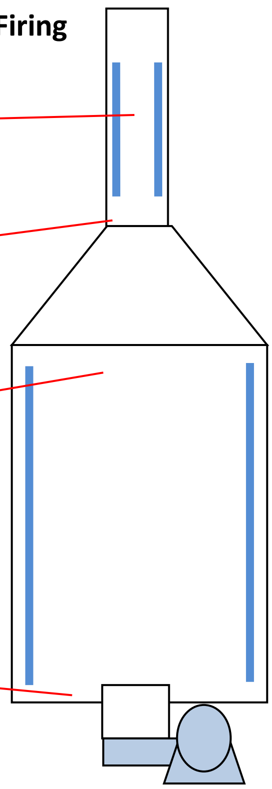
## 4.1. Combustion conditions

| Item | Rated |
|---|---|
| Total Heat Absorbed, kW | 535 |
| Heat Release, kW | 714 |
| Calculated Efficiency, % | 70 |
| Flue gas flow rate, kg/s | 0.34 |
| Flue gas temp. at arch, °C | 694 |
| Flue gas temp. exiting stack, °C | 421 |
| Max Tube Temp. °C | 355 |
| Combustion Air flow, kg/s | 0.32 |
| Avg. Radiant Flux W/m$^2$ | 19,104 |

| Flue Gas Component | Mol % (wet basis) |
|---|---|
| CO2 | 7.64 |
| H2O | 15.53 |
| N2 | 72.40 |
| O2 | 4.42 |

Note 2: Calculated values above based on firing of typical clean Natural gas compositions

### Expected Draft Profile Inside Heater at Max Firing




The maximum heat liberation of the burner is 879 kW. The simulation were also carried out at max burner firing rate (please see results attached for full details.

# 5 Discussion

The HeaterSIM Fired Heater Simulation Technology model and calculations demonstrate that the heater should be able to achieve the required process duty whilst operating safely. In fact, as the removal of the cone will reduce the likelihood of positive pressure within the heater, the overall safety in operation of the heater is expected to be dramatically improved. The calculated radiant temperature at the arch will be 694 °C, which is sufficient to enable the desired duty to be absorbed (at max firing of the burner the arch temperature has been calculated at 744 °C).

As stated, the presence of such a restricting cone is unusual and would not be included in any modern heater designed in accordance with API 560 standards. As such, it is considered that removing the cone will be a positive step towards improving the overall safety of the heater.

The level of excess air is also higher than usual for heaters firing Natural Gas fuel. The typical excess air utilised should be 15-20%, which will provide safe and more efficient operating conditions. It is recommended that the excess air should be reduced to 15-20%, which will also serve to reduce the likelihood of positive pressure within the chamber.

Thus, the simulation conducted illustrates that removal of the cone will not negatively impact heater operation and is expected to significantly improve operational safety minimising the potential reoccurrence of the incident previously experienced on site.

**General Calculation Results:**

The results of the simulation in terms of the other aspects of the heater configuration have not highlighted any problems caused by removal of the cone.

Whilst the HeaterSIM Fired Heater Technology Simulation software utilised is unable to model the cone as currently installed, it is reasonable to expect that the heater's operational efficiency would be reduced upon removal of the cone, as a direct consequence of the lower combustion chamber temperatures expected without the cone.

However, the heater model without the cone illustrates that the heater is expected to achieve its required absorbed duty.