Fired Heater Safety Review Study

Client: xxx

Project: xxx

1. Executive Summary

This report is based around Fired Heater tag no. H-125F currently installed and in operation at the CLIENT production facility. An internal safety review within CLIENT raised the question about the current safety limits of the heater with such a high process fluid outlet temperature. The purpose of this study was to examine whether the current operation of the heater poses any safety concerns, with particular focus around mechanical integrity and maximum tube metal temperatures.

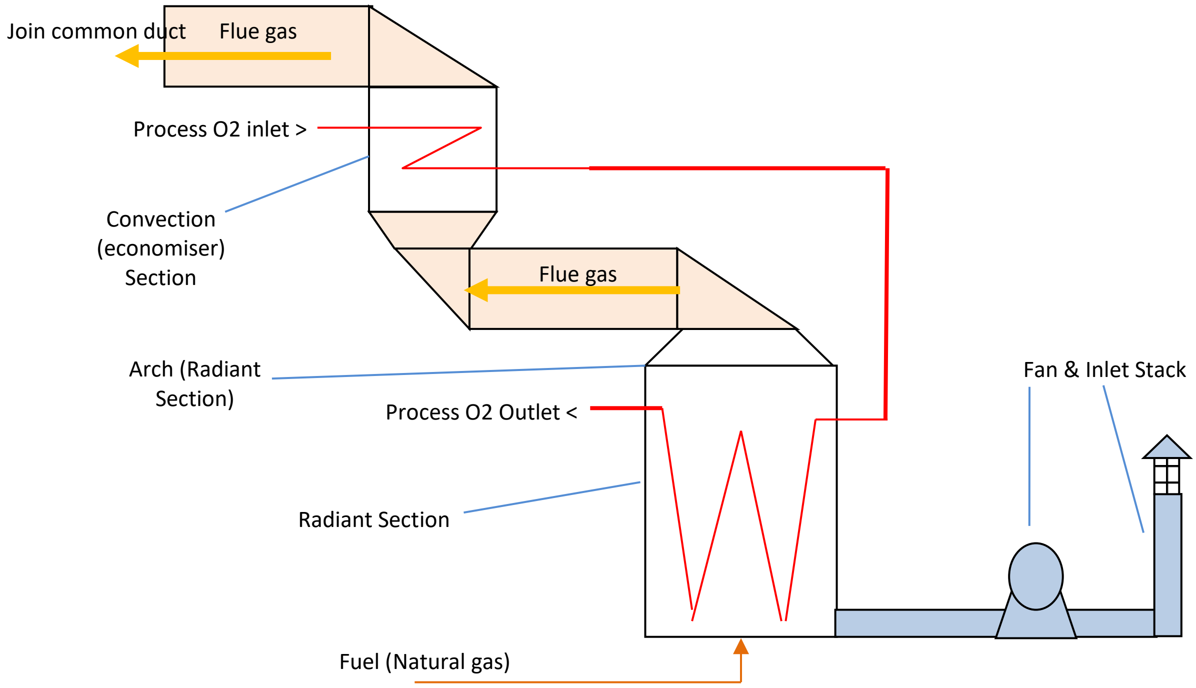
Several heater simulation models were set up and analysed, namely the Rated Duty Case, Design Duty Case, Minimum Duty Case and the Site Data Case 1 and 2. The model calculations closely matched the reported the heater documents provided by CLIENT and the site measurement readings taken from the various heater sections. For example, a datasheet documents provided by CLIENT stated that the calculated max tube temperature was 930 deg C, which generally matches our calculated value of 927 deg C. The design metal temperature of the tube was stated as 1038 deg C which is significantly above the calculated maximum, however the current thickness of the tubes and the original design life intended are both unknown.

API 530 tube wall calculations were also performed to examine what was the minimum thickness requirement for safe operation of the tube. An assumption of 2 mm corrosion of the tube wall was used, which was considered to be a conservative value since the tube material is the very resistant Inconel 600 material, the process fluid is clean oxygen and the fuel gas is clean Natural Gas. Nonetheless, with this corrosion considered, it was demonstrated that the minimum thickness required for operation was below the actual tube wall thickness with the assumed 2mm corrosion, indicating that the tubes are likely to be within an acceptable limit of operation.

This report demonstrates that no significant safety concerns have been identified from our analysis and the heater is currently operating within its design limits. However, this report does make some recommendations in terms of maintenance in order to improve the safe operation of the heater.

2. Introduction

This report examines oxygen heater H-125F at the CLIENT Pigment production facility in Stallingborough. The maximum design requirement of the heater is to heat 2.15 kg/s oxygen from 16 deg C to 895 deg C. The heater consists of a radiant and convection ('economiser') section with a flue gas exit duct shared with a neighbouring heater. A Forced Draft (FD) fan is also utilised with a single burner in the radiant floor.



The convection section is not mounted on top of the radiant section, but instead is supported on a separate support framework adjacent to the radiant section.

Site Data Measurements

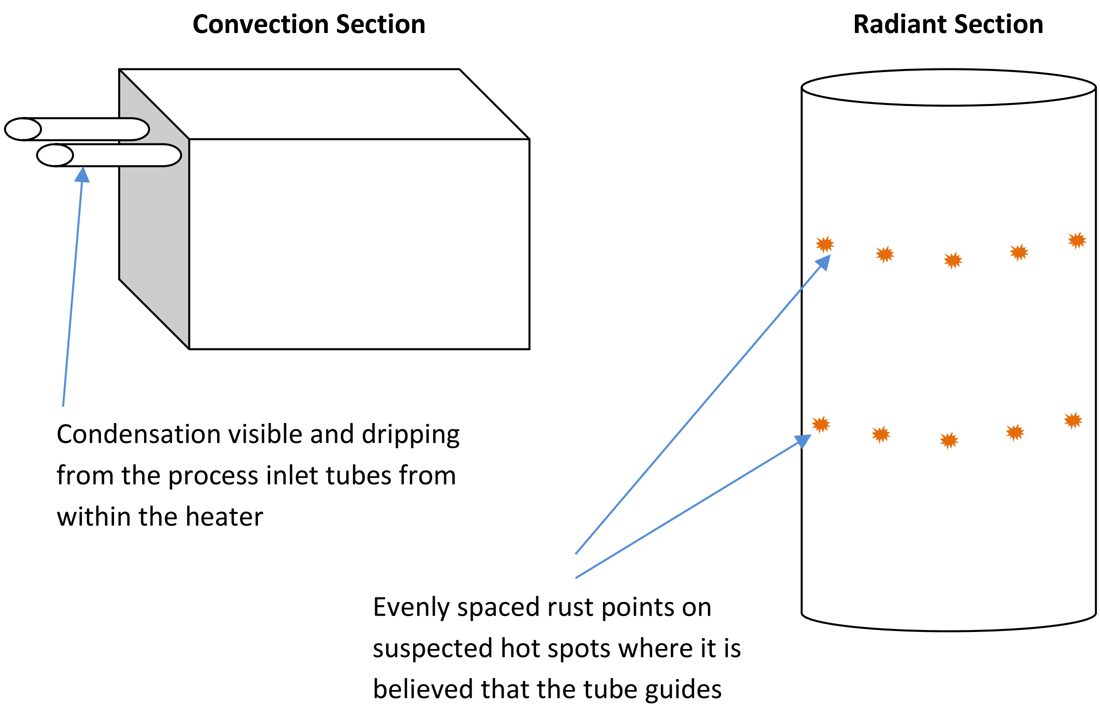
Description	Low Rate	High Rate	
O2 inlet	16	13	deg C
O2 outlet @ Convection	1076	1079	deg C
O2 outlet @ Radiant	822	843	deg C
Flue gas @ Convection outlet	171	201	deg C
Arch temperature	906	977	deg C
Combustion air flow rate	1,954	3,735	m3/hr
Oxygen Process flow rate	3,908	9,340	Kg/hr
Fuel gas Flow rate	138	307	Nm3/hr

Note: Values have been averaged if more than one measurement reading was provided

3. Site Visit – Visual Inspection

Whilst our visual inspection of the heater in operation did not raise any severe safety concerns, we have noted the following key aspects of concern:

- Flue gas condensation at the upper convection rows (process inlet tubes)
- Dirty observation doors (viewing of burner or flame was severely impaired)
- External rust/corrosion at suspected hot spots where the radiant tube supports/guides are believed to contact the steel casing/frame of the heater



4. Methodology

Based on the site data received and heater design documents from CLIENT Pigment, it was necessary to model 8 separate operation cases in total, as listed below:

- Rated Duty Case
- Design Duty Case
- Minimum Duty Case
- Site Data 1 (Low case)
- Site Data 2 (High case)
- Rated Duty Case (with O2 and N2 at 87% and 12.5% respectively)
- Design Duty Case (with O2 and N2 at 87% and 12.5% respectively)
- Minimum Duty Case (with O2 and N2 at 87% and 12.5% respectively)

Note: The 'Datasheet For Miscellaneous Items' document states process fluid can contain up to 12.5% N2

The heater was designed to consider up to 12.5% N2 content in the process fluid. It is understood that the heater is operated today with 0% N2. Thus, the reminder of this report will focus on the 100% O2 process flow cases only.

Fired Heater Simulation Inputs:

The summary of our HeaterSIM Fired Heater Simulation Technology model and calculation is as follows (please see our attached heater datasheet for further details):

Mechanical Data

c	Mol %
Heater Design Configuration:	Vertical Cylindrical
Radiant Height:	8
Radiant Tube Effective Length:	6.759m
Convection Effective Length:	3.654m
Radiant Tube Material	Inconel 600
Convection tube material	304 SS / Inconel 600 (refer to datasheet)

4.1. Process Data

c	Rated	Design	Min	Site 1 (Low)	Site (High)
O2 Process flow (kg/h)	7,750	6,000	3,000	3,908	9,340
O2 Inlet Temperature deg C	-31	-29	10	16	13
O2 outlet temperature deg C	895	895	895	822	843
Fuel Type	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
Excess Air %	15%	15%	15%	15%	15%
Ambient Air Temperature	15.5	15.5	15.5	15.5	15.5

5. Fired Heater Simulation Results:

5.1. Combustion conditions

Item	Rated	Design	Min	Site 1 (Low)	Site (High)
Total Heat Absorbed, MW	2.025	1.568	0.784	0.887	2.188
Heat Release, MW	2.213	1.69	0.875	0.937	2.413
Calculated Efficiency, %	91.4	92.6	89.6	94.5	90.5
Excess Air, %	15	15	15	15	15
Flue gas flow rate, kg/s	0.9	0.7	0.4	0.4	1.0
Flue gas temp. at arch, °C	965	940	907	844	945
Flue gas temp. leaving convection, °C	156	123	179	78	175
Max Tube Temp. deg C	927	917	902	834	885
Lowest Tube Temp *	77	62	65	57	99
Combustion Air flow, kg/s	0.88	0.67	0.33	0.37	0.96
Avg. Radiant Flux W/m2	17,938	13,984	7,015	8,444	20,127

*Lowest tube temperature in contact with flue gas, indicating the likely hood for flue gas condensation on the tubes

Calculated flue gas composition

Component	Mol % (wet basis)
CO2	8.55
H2O	17.23
N2	71.74
O2	2.48
SO2	0.00

Flue gas dew point: 57.2 deg C

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

General Analysis of Results

The HeaterSIM Fired Heater Technology Simulation model calculations are in close agreement with the design documents and also the site data provided for both the high and low operating cases. It is clear that both the high and Low operating cases are within the heater's design limits according to our simulation. Whilst the simulations carried out have not highlighted any excessive temperatures beyond the heater's design limits, they have highlighted the strong likelihood of flue gas condensation on the convection tubes within the heater.

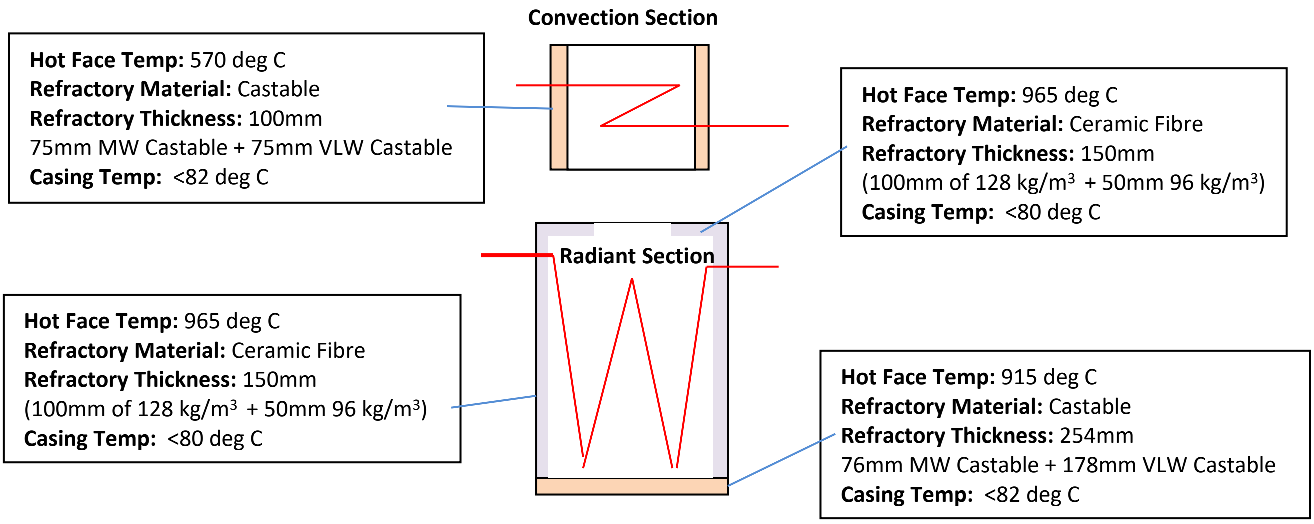
For example, the calculated minimum metal temperature in contact with the flue gas at the upper rows of the connection section is very close to the flue gas dew point temperature. In the Low Case the minimum metal temperature is actually below the dew point which would indicate the occurrence of a significant amount of condensation on the tubes. Indeed, it was noted from our on-site inspection that there was a significant amount of condensation on the process inlet tubes in the convection section.

API 530 Tube Wall Thickness Calculation

Indeed, the maximum tube temperatures calculated should be considered alongside the current thickness of the installed tubes. In the absence of recent thickness check data, it was assumed that the tubes were corroded by 2mm. This was actually a conservative approach as the tube material are either 304 SS or Inconel 600 material, whilst the process fluid and fuel is clean oxygen and natural gas respectively. The calculations demonstrated that the tube thicknesses with a 2 mm corrosion would still be sufficient for safe heater operation (please see attached TWC document).

API 560 Refractory Thickness Calculation Analysis

Refractory calculations were also carried out to ensure that the installed materials and thickness were suitable for safe operation at the max operating case. Our calculations confirm that the refractory and thicknesses installed are suitable for safe operation and compliant with API 560 Fired Heater Standards Refractory Design basis. (please refer to attached refractory calculation sheet for full details).



The refractory design basis: 90 deg C at the floor, 82 deg C at all walls, 27 deg C ambient temperature and 0m/s wind speed

4 Discussion

In accordance with the Fired Heater simulations and calculations performed by HeaterSIM the current operation is within the design limits of the heater. The development of the Fired Heater Simulation Model was based on the data provided by CLIENT Pigment.

Our simulations and calculations are in strong agreement with the measured data collected at site and have demonstrated their reliability and robustness as a method of analysis for the heater currently installed.

Although our analysis have not identified any particular safety concerns in regards to mechanical integrity of the heater, our calculations have identified the strong likelihood for the occurrence of flue gas condensation in the upper rows of the convection ('economiser') section. The calculated flue gas dew point temperature is 57.2 deg C whilst the minimum metal temperature in contact with the flue gas was considerably close to this temperature (actually at 57 deg C in the Low operating case).

The tube wall calculation has demonstrated that the tubes currently in operation are likely to have an adequate wall thickness for safe operation. This conclusion is based on the fact that the tube wall thickness utilised for the new tubes would still be sufficient for safe heater operation despite considering a 2 mm corrosion. It must be noted that corrosion is most likely to occur at the upper convection rows where the occurrence of flue gas condensation is most likely and has also been confirmed by our on-site visual inspection of the heater in operation. As the tube material of the upper rows are A312 TP 304 SS material and the process fluid and flue gas are generally clean, this may not cause significant problems. However, any contamination of the process fluid or fuel may change this situation and increase the rate of corrosion.

Refractory calculations were also carried out based upon the current materials and their respective thicknesses currently installed in the heater. Our calculations confirm that the refractory and thicknesses installed are suitable for safe operation, in accordance with API 560.

Recommendations:

- **Clean the glass observation doors on the radiant section:** The benefits of such actions are clear, the flame shape and stability inside the heater will be clearly visible. The tubes and tube supports will also be viewable for inspection during operation.

- **Tube thickness checks to be carried out at the next available shut down:** These checks will provide assured confidence that the tube wall thickness is sufficient for safe operation. Particular attention should be focussed around the upper convection tubes whereby corrosion due to flue gas condensation is most likely.

- **Consideration of changing the A312 TP 304 SS upper convection tubes to the more resistant Incolloy 600 material:** This recommendation should be seriously considered if evidence is found of tube corrosion due to flue gas condensation on the tubes.

- **General inspection of tube supports:** This should be done at the next available shut down