FFS REFINERS

AN INTERESTING CASE STUDY OF COMBUSTION TUBE FAILURE

BACKGROUND

The ducting failure in an enameling oven occurred after a change in fuel. The furnace is an indirectly fired baking kiln with no forced hot air circulation. The heat is supplied by 5 burners, firing into combustion tubes of ~600□ x ~2000 long reducing down to ~250□, turning 180^{O} and existing via a stack. The materials of construction were 4,5mm thick 310 stainless steel.

The oven relies on radiance and convection heat transfer from the combustion tubes to heat the air as there is no forced circulation in the oven.

The system ran successfully for about 8 months on LO10 before the tubes were replaced. The burners were set by FFS during commissioning.

New tubes were then installed which lasted only ~37 days. The new tubes had a slightly greater wall thickness. The burner nozzles were also changed to larger units and the pressure increased to increase the heat input to improve productivity

A significant amount of dust was recovered from the inside of the ducting, which the customer mistakenly took for fuel ash.

FUEL CHARACTERISTICS

Paraffin has a very low radiance flame. It thus takes longer for the heat to transfer from the flame into the ducting and a short duct or low residence time application results in heat loss up the stack. Paraffin has a sulphur content of <0,1%

LO10 has a more radiant flame than paraffin and thus will transfer the heat from the flame into the ducting more quickly. In a short duct or low furnace residence time application, this will improve the efficiency by reducing the stack outlet temperature. LO10 has a sulphur content of <0,5%.

STEEL CHARACTERISTICS

The materials of construction were specified as 310 stainless steel, which has excellent thermal properties.

Thermal stresses induced from over-heating and cooling result in the localised buckling that can be seen on the ducting.

Temperatures in excess of 1200^{O}C will cause the steel to expand and creep unevenly and then shrink unevenly causing further distortion.

310 Stainless steel, with its 26% chrome and 20% nickel, is a highly heat-resistant material and well suited to the application. The upper temperature limits[1] are given as **1150^{O}C** in an oxidising environment without sulphur and **1100^{O}C** in the presence of high sulphur (100mg/m^{3}) for continuous operation, or **1025^{O}C** and **975^{O}C** respectively for intermittent operation. The combustion gas will be oxidising when there is excess oxygen (>5%). If the oxygen in the combustion gas is low (<1%) we have a reducing environment and the corrosion rate can be up to 50% lower. The higher the temperature, the faster the corrosion rate. An increase in temperature from 1000ToC to 1100^{O}C will result in an increased corrosion rate of approximately 125%. The corrosion rates on a continuous application at 1000^{O}C and 1100^{O}C are expected to be in the region of 0,5 mm/year to 1,15 mm/year[1]. The rate of loss of material to oxidation is also dependent on the number of heating and cooling cycles. The standard American Metals corrosion rate test of 3000 cycles heating to 1000^{O}C, holding for 15 minutes and then cooling with forced air for 5 minutes, shows an expected loss in the region of 1,8 mm/year on this material.

Although the outside of the duct is in contact with air (oxidising environment) the skin temperature would be very much less than the inside steel skin temperature and thus the main corrosion would occur on the inside.

INSPECTION

An inspection of the flue ducting showed severe distortion (buckling), discoloration and heavy scaling. A duct was seen to have an extensive circumferential crack. An amount of particulate matter was removed from the ducting. This material was magnetic and identified as ferrous/ferric oxide[3] being a product of oxidation of the steel. The material was sent to the laboratory to determine the amount of carbon present at the request of the customer to confirm that it is not un-burnt fuel.

The combustion tube was observed in operation to be orange-yellow in colour, which would indicate a temperature in the region of 1300^{O}C – 1500^{O}C[3].

The furnace temperature is measured and was recorded at 860^{O}C at the time of the inspection. There are no temperature probes on the combustion tube or on the stack outlet.

CONCLUSION

1. It would appear that the operating temperature of the stainless steel ducting had been in excess of the recommended limits of 1000^{O}C – 1100^{O}C [2]. This resulted in extensive distortion taking place and accelerated the oxidation rate of the steel, which greatly reduces the life of the steel.
2. Due to the higher radiance flame of LO10 over that of paraffin, the LO10 is likely to be more efficient at transferring heat and will heat the tube to a higher temperature. Thus less fuel should be required to achieve the same heat transfer as that of paraffin. This should be evident in a lower stack outlet temperature. This has also been confirmed by the customer's observation of a 20% reduction in fuel consumption at the same production rate.
3. Temperature probes on the combustion tubes are required to ensure that the maximum acceptable temperature is not exceeded. This would have prevented the damage from the higher radiance fuel and from the increased heat input from changing to larger nozzle size.
4. The burners should be set with optimal oxygen content to ensure that the flue gas is not unnecessarily oxidising. This can be achieved with the use of a combustion gas analyser to set the burners to achieve optimal oxygen (<1-2%0, CO_2 (maximum) and CO (<10 ppm) content. This will have the added benefit of improving fuel efficiency, which will save money, and reducing harmful flue gas emissions.
5. Excessive cycling of the burner operation and rapid heating and cooling will significantly reduce the life of the steel. Burner nozzles should be optimally sized to limit excessive cycling.
6. Although LO10 has a slightly higher sulphur content than paraffin, it is still considered a low sulphur fuel and will not significantly increase the corrosion rate of the steel.
7. FFS Refiners' LO10 is eminently suited for this application but should not be used to over-heat the combustion tubes in order to increase the production rate.

(Foot Note: subsequent to this report the materials of construction were tested and found to have been incorrectly supplied as 304L stainless steel, instead of the specified 310, which does not have the same high temperature properties)

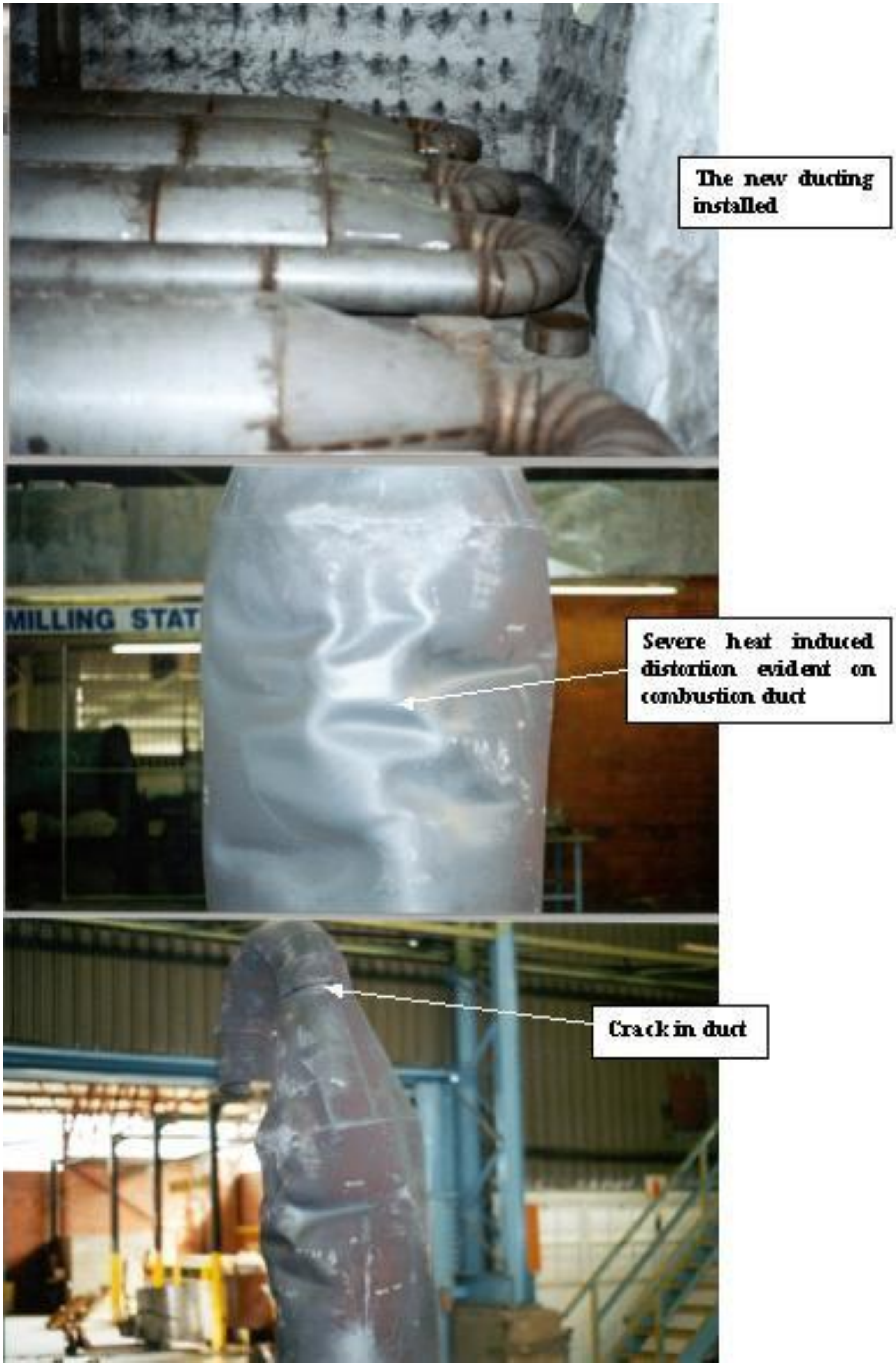
<u>REFERENCES</u>:

1. Metals Handbook, American Society for Metals Vol-1 Properties and Selections of Metals.

2. Koot Viljoen, Head Metallurgist at Columbus Steel – personal communication.

3. Ian Burns, Metallurgist at Umgeni Iron Works – personal communication.

Don Hunter Pr.Eng


The new ducting installed
MILLING STAT
Severe heat induced distortion evident on combustion duct
Crack in duct