Therminol 3 Pyrolysis furnaces NOx reduction strategy

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1. EXECUTIVE SUMMARY

The Eastman Newport Therminol plant currently has 5 furnaces, 3 of which are currently not in compliance with the environmental permit due to elevated NOx levels of ~220 mg/Nm^3, ~350 mg/Nm^3 and ~350 mg/Nm^3 respectively versus the emission limit value of 200 mg/Nm^3.

A number of techniques and technologies have been considered and/or trialled to bring the furnaces into compliance, including excess air adjustments, reducing air preheating, water or steam injection, and changing the burners design. Reduced air preheating was shown to bring the furnaces into compliance, but at considerable additional annual costs with respect to increased energy usage, increased CO_2 emissions and loss of production, thus this has not been installed at this time.

A new low NOx burner design has been chosen to provide the best long-term cost-effective, efficient and compliant operation, albeit at a high up-front Capital cost.

One of the three furnaces is currently being upgraded with the new burner design with installation and commissioning during the 2nd quarter 2020. Once proven in operation the remaining two furnaces will then be upgraded with the new burner design with installation and commissioning in the 3rd quarter 2021.

2. BACKGROUND

The Eastman Newport Therminol plant currently has 5 furnaces; the TH2 pyrolysis furnace, the East and the West TH3 pyrolysis furnaces, the biphenyl furnace and the santowax furnace. The TH2 pyrolysis furnace is part of the old plant dating back to the 1960s, whereas the other four furnaces are part of the new plant that was started up in 2016.

After startup and once stable operation was reached on the East and West TH3 pyrolysis furnaces in 2017 it was found that the NOx emissions were not in compliance with the environmental permit.

Although initially expected to be decommissioned, the Business decided to continue operation of the TH2 pyrolysis furnace, but this requires the furnace to be upgraded to meet current standards.

This report assesses the ways in which current NOx emissions from the two TH3 pyrolysis furnaces can be reduced to comply with the ELV (emission limit value, 200 mg/Nm^3) in the environmental permit. A Capital project is already in progress to make necessary upgrades to the TH2 pyrolysis furnace, which includes compliant burners.

The TH3 pyrolysis furnaces are currently emitting NOx at a concentration of ~350 mg/Nm^3. The TH2 pyrolysis furnace is currently emitting NOx at a concentration of ~220 mg/Nm^3.[*]

[*] Note that all NOx values are at a 3% oxygen reference.

3. WORK TO DATE ASSESSING TH3 NOX EMISSION REDUCTION

The US Environmental Protection Agency's report *Nitrogen Oxides (NOx), why and how they are controlled* (EPA 456/F-99-006R) was consulted to help determine the range of furnace combustion NOx limiting technologies that could be available to bring the TH3 pyrolysis furnaces into compliance (see appendix 5.1 for a table of technologies).

The most pertinent methods for use at Newport were then listed for further consideration, with the most likely considered to be:

- Less excess air
- Reduced air preheat
- Water or steam injection
- Low NOx burners
- Flue gas recirculation

Other methods listed for potential consideration if the above were not successful were:

- Selective Catalytic Reduction
- Selective Non-Catalytic Reduction
- Absorbent material

The next sub-sections detail the methods that have currently been given the most attention.

3.1 *Less excess air*

The existing burners on the TH3 pyrolysis furnaces are [redacted] burners [redacted]. Between the two TH3 pyrolysis furnaces there are [redacted] burners.

[redacted]

TH3 pyrolysis furnaces' burners

NOx emissions on the two smaller TH3 furnaces (biphenyl and santowax) were both non-compliant initially, but optimisation of excess air brought them into compliance. However, the design of these furnaces is such that [redacted] flame impingement is not an issue.

Low excess air was trialled on the East and West pyrolysis furnaces but had no significant effect on NOx reduction – the minimum obtained was ~284 mg/Nm^3. The excess air was reduced [redacted] but flame impingement of the coil is an issue at this level. Normal operation is at [redacted] excess air.

Additional excess air was also trialled, but [redacted] excess air was the maximum that could be achieved with the existing fans. This again had minimal effect on NOx reduction. An excess air of around 40% is expected to be required to drop the flame temperature significantly (<1 700°C), although the cooler temperature effect on NOx reduction would be expected to be offset by additional oxygen availability.

3.2 Reduced air preheating

A reduction in flame temperature will lead to a reduction in NOx generation. Currently the combustion air is preheated before entering the TH3 pyrolysis furnaces, so a trial was undertaken on one of the furnaces to determine the benefit and detriment of reduced preheating.

A trial was undertaken where the air preheater had no combustion gases flowing through it and thus air at ambient temperature (instead of being preheated to [redacted]) was entering the burners. The reduction in air temperature into the burners led to reduced flame temperatures in the furnace which led to reduced NOx generation.

Removal of air preheating from the East and West pyrolysis furnaces would lead to NOx emissions of ~160 mg/Nm^3, approximately a 50% reduction.

The impact of no air preheating for the same rate of production was determined to be:

- an additional energy and CO_2 emissions cost of [redacted] per annum
    - [redacted] energy
    - [redacted] in additional carbon tax from CO_2 emissions
- additional CO_2 emissions of [redacted] tonnes per annum
- [redacted] reduction in the maximum potential rate of production
- Reduced resilience to out-of-service burners

Reduced air preheating has not been installed at this time due to the additional energy cost, the CO_2 emissions that would result, and the loss of production it would cause.

3.3 Water/steam injection

This method causes a reduction in combustion temperature by the stoichiometry of the mixture being changed and dilution of calories generated by combustion.

A first pass evaluation of steam and water flowrate requirements in order to reduce flame temperatures to [redacted] was undertaken using Aspentech Hysys process simulation software. This indicated that flowrates of [redacted] kg/h water or [redacted] kg/h steam were required to reduce flame temperatures to [redacted]. As with reduced air preheating above, downsides with respect to additional energy cost, increased CO_2 emissions and loss of production would be expected. As a result of this and considering the additional difficulties with modifying a furnace so as to allow a trial to take place, this method has not been taken any further forward at this time.

3.4 Low NOx burners

The companies that tendered for the TH3 pyrolysis furnaces' back in 2013 were not able to offer any specifically low NOx burners that would fit within the furnace design. The furnace design was constrained by having to be the same as that for the TH2 pyrolysis furnace. Unfortunately, it was only after it was determined that the TH3 pyrolysis furnaces had a NOx issue in 2017 that we learnt of burners that were similar to the TH2 [redacted] type burners that could be fitted into our furnaces, such as [redacted] type burners, which were also specifically low NOx.

[redacted]

[redacted] type burner

Although coming with a high up-front Capital cost, suitable low NOx burners make most sense for long-term cost-effective, efficient and compliant operation, and thus have been chosen as the most appropriate method to bring the TH3 pyrolysis furnaces into compliance. The TH2 pyrolysis furnace is currently being upgraded to meet current standards, upgrades which include low NOx [redacted] type burners.

4. TH3 NOX REDUCTION STRATEGY

The TH3 pyrolysis furnaces NOx reduction strategy is to prove a new low NOx burner design on the TH2 furnace, and then upgrade the TH3 pyrolysis furnaces with them once they have been proven in operation.

4.1 TH2 pyrolysis furnace upgrade

The TH2 pyrolysis furnace currently has [redacted] type burners.

[redacted]

[redacted] type burner

The TH2 pyrolysis burners exceed the NOx limit with a concentration of ~220 mg/Nm^3. Although at a lower NOx emission than the TH3 pyrolysis furnaces, the TH2 furnace is being upgraded first since its burner management system is obsolete and thus from a safety perspective is being upgraded first. Due to our experiences with the TH3 pyrolysis furnaces' burners, there is a desire to prove the new burner design in operation before upgrading the TH3 furnaces. The [redacted] project to upgrade the TH2 pyrolysis furnace includes a new coil, renewed refractory, burner assemblies, and a new burner management system. The upgraded burner assemblies constitute about [redacted] of this cost.

The new burners have recently been tested under conditions as close as possible to those that they will experience in actual operation (see appendix 5.2 & appendix 5.3 for Eastman's appraisal report and vendor's test report), and the results of this test indicate that the burners should be compliant.

The TH2 project has had Capital release, has placed all the major orders, and is currently in the final stages of detailed design with the new burners due to be installed and commissioned during 2nd quarter 2020.

4.2 TH3 pyrolysis furnaces upgrade

Once the [redacted] burners have been proven in operation on TH2 (expected to be after a few months of operation), a Capital project will be progressed to upgrade some or all of the TH3 pyrolysis furnaces' burners. Capital proposal form (CPF) number THE1910 has been approved and is on the site Capital plan for installation and commissioning in the 3rd quarter 2021. The current estimate for this project to upgrade both TH3 pyrolysis furnaces is [redacted]

Dependant on the NOx reduction seen in practice on TH2, it is currently envisaged that the TH3 pyrolysis furnaces will be upgraded in a stage-wise approach. There are [redacted] burners, [redacted] The current intention is to change out enough [redacted] on each furnace to meet the compliance limit for NOx. The remaining [redacted] will then be changed out with the new burner design as and when they need replacing due to 'wear and tear'.

5. APPENDICES

5.1 Furnace Combustion NOx Limiting Technologies (EPA)

Technique	Description	Advantages	Disadvantages	Impacts	Applicability
Less Excess Air (LEA)	Reduces oxygen availability	Easy modification	Low NOx reduction	High CO Flame length Flame stability	All fuels
Off Stoichiometric a. Burners Out of Service (BOOS) b. Over Fire Air (OFA)	Staged combustion	Low cost No capital cost for BOOS	a. Higher air flow for CO b. High capital cost	Flame length Fan capacity Header pressure	All fuels Multiple burners for BOOS
Low NOx Burner (LNB)	Internal staged combustion	Low operating cost Compatible FGR	Moderately high capital cost	Flame length Fan capacity Turndown stability	All fuels
Flue Gas Recirculation (FGR)	<30% flue gas recirculated with air, decreasing temperature	High NOx reduction potential for low nitrogen fuels	Moderately high capital cost and operating cost Affects heat transfer and system pressures	Fan capacity Furnace pressure Burner pressure drop Turndown stability	All fuels Low nitrogen fuels
Water/Steam Injection	Reduces flame temperature	Moderate capital cost NOx reduction similar to FGR	Efficiency penalty Fan power higher	Flame stability Efficiency penalty	All fuels Low nitrogen fuels
Reduced Air Preheat	Air not preheated, reduces flame temperature	High NOx reduction potential	Significant efficiency loss (1% per 40°F)	Fan capacity Efficiency penalty	All fuels Low nitrogen fuels

Selective Catalytic reduction (SCR) (add-on technology)	Catalyst located in the air flow, promotes reaction between ammonia and NOx	High NOx removal	Very high capital cost High operating cost Catalyst siting Increased pressure drop Possible water wash required	Space requirements Ammonia slip Hazardous waste Disposal	All fuels
Selective Non-Catalytic Reduction (SNCR) (add-on technology) a. Urea b. Ammonia	Inject reagent to react with NOx	a. Low capital cost Moderate NOx removal Non-toxic chemical b. Low operating cost Moderate NOx removal	a. Temperature dependent NOx reduction less at lower loads b. Moderately high capital cost Ammonia storage, handling, injection system	a. Furnace geometry Temperature profile b. Furnace geometry Temperature profile	All fuels
Fuel Reburning	Inject fuel to react with NOx	Moderate cost Moderate NOx removal	Extends residence time	Furnace temperature profile	All fuels (pulverized solid)
Combustion Optimization	Change efficiency of primary combustion	Minimal cost	Extends residence time	Furnace temperature profile	Gas Liquid fuels
Catalytic Combustion	Catalyst causes combustion to be at low temperature	Lowest possible NOx	Very high capital cost High operating cost Catalyst siting	Space requirements Disposal	Gas Liquid fuels

Non-Thermal Plasma	Reducing agent ionized or oxidant created in flow	Moderate cost Easy siting High NOx removal	Fouling possible Ozone emission possible	Uses electrical power	All fuels
Inject Oxidant	Chemical oxidant injected in flow	Moderate cost	Nitric acid removal	Add-on	All fuels
Oxygen instead of Air	Uses oxygen to oxidize fuel	Moderate to high cost Intense combustion	Eliminates prompt NOx Furnace alteration	Equipment to handle oxygen	All fuels
Ultra-Low Nitrogen Fuel	Uses low-nitrogen fuel	Eliminates fuel NOx No capital cost	Slight rise in operating cost	Minimal change	All ultra-low nitrogen fuels
Use Sorbents (add-on technology) in: a. Combustion b. Duct to Baghouse c. Duct to Electrostatic Precipitator	Use a chemical to absorb NOx or an adsorber to hold it	Can control other pollutants as well as NOx Moderate operating cost	Cost of handling sorbent Space for the sorbent storage and handling	Add-on	All fuels
Air Staging	Admit air in separated stages	Reduce peak combustion temperature	Extend combustion to a longer residence time at lower temperature	Adds ducts and dampers to control air Furnace modification	All fuels
Fuel Staging	Admit fuel in separated stages	Reduce peak combustion temperature	Extend combustion to a longer residence time at lower temperature	Adds fuel injectors to other locations Furnace modification	All fuels

5.2 TH2 Pyro burners Eastman's appraisal report

Following appendix redacted (Confidential)

5.3 TH2 Pyro burners vendor's test report

Following appendix redacted (Confidential)