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NAVIGATING THE CHALLENGES: OPTIMIZING FIRED HEATERS WITH AIR PREHEATERS

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1. ABSTRACT

Incorporating air preheaters (APHs) into refinery heaters boosts furnace efficiency but introduces notable challenges such as the need for additional space, the risk of corrosion and leakage due to flue gas acid dew points, changes in adiabatic flame temperature, higher NOx emissions, and modifications in radiant section heat flux which can impact the operation run length. Through a case study, we highlight these issues and emphasize the importance of adopting a comprehensive approach to modernizing refinery heaters, balancing efficiency gains with the mitigation of potential challenges.

2. INTRODUCTION

In thermal management and energy recovery contexts, equipment like fired heaters plays a pivotal role in converting fuel into heat through combustion. In 2023, 123 crude oil refineries were active in the United States, collectively processing an average of 17.7 million barrels of crude oil daily. This operation translates to approximately 2,500 fired heaters in action within these refineries, with larger facilities potentially managing between 20 to 40 heaters each. These critical components have a service life ranging from 20 to 50 years, highlighting their durability and importance in industrial applications. Our prior research has explored monitoring the performance of fired heaters and estimating fouling and slagging in the convection and radiant sections of the fired heater [1]. Integrating air preheaters (APHs) into fired heaters offers promising improvements in operational efficiency and fuel consumption. Implementing APH systems in refinery fired heaters presents challenges that can affect their performance, longevity, and safety, as well as impact the environment. This paper examines these obstacles.

Corrosion in APH units, often triggered by fuel composition affecting the acid dew point of the flue gas, can cause material wear and leaks, leading to decreased efficiency in heat transfer, constraints to the combustion air supply, and potentially system shutdown. Addressing these challenges necessitates thoughtful design choices, particularly in material selection and engineering solutions, to prevent such issues. Moreover, installing an APH influences the fired heater operation, including radiant heat flux and adiabatic flame temperature. The heat flux directly affects tube wall temperature, influencing coking rates and operational longevity. Additionally, alterations in adiabatic flame temperature contribute to increased thermal NOx emissions [2]. For the full benefits of APH installation to be realized, these negative impacts must be quantified and understood. This discussion includes an example that further clarifies these points, emphasizing the importance of comprehensive evaluation and adaptation in refinery operations.

3. CASE STUDY

Table 1 details the operational conditions of an existing fired heater (without an APH) of a crude preheat train, serving as the base case for our analysis. We will explore the effects of adding an APH to this scenario. A commercial

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fired heater performance monitoring, prediction and optimization tool from HTRI, Xfh Ultra was used to evaluate the fired heater operation [3].

Table 1 Example fired heater operational data

Operational parameter	Value
Process stream capacity	220,000 bbl/day
Furnace duty	38.3 MW
Fuel type	Refinery Gas and Fuel Oil No. 1
Radiant section: Firebox type	Cabin
- Radiant section heat transfer area	496.6 m^2
- Process stream duty	21.35 MW
Convection section	
- Heat transfer area	3417.3 m^2
- Process stream duty	10.98 MW
Combustion air temperature and pressure	25 °C /1.01325 bara

4. RESULTS

Table 2 summarizes the fired heater performance with and without an APH. While APH installation (case 2) has increased the furnace efficiency by 10%, resulting in a reduction in carbon emission by 15%, the increased adiabatic flame temperature and peak heat flux adversely affected performance. Thermal NOx emission is impacted by the adiabatic flame temperature [4], and in this example, an increase in a factor of 1.3 is observed. The increase in peak heat flux can result in in-tube coking [5], and a separate evaluation of the impact on the process stream composition is necessary. While heat recovery benefits efficiency, controlling flue gas temperature is crucial to avoiding acid dew point corrosion.

Table 2 Example comparison of fired heater performance with and without APH

Parameters	Case 1: Without APH	Case 2: With APH (no airside bypass)	Case 3: With APH (40% airside bypass)
Draft type	Natural draft	Balanced draft	Balanced draft
Flue gas outlet temperature, °C	327.3	111.3	195.1
Adiabatic flame temperature, K	2202	2356	2297.1
Relative NOx emission	1	1.3	1.27
Peak heat flux, kW/m^2	78.58	81.6	80.44
Overall fuel efficiency, %	84.9	94.8	90.88
Total CO_2 emitted, te/day	152.1	128.7	137.5

Figure 1(a) shows that in Case 2, the coldest metal temperature in the APH falls below the acid dew point. To ensure safety, Figure 1(a) suggests bypassing the APH by at least 40%, leading to a new operational mode, Case 3, detailed in Table 2. This approach balances maintaining the APH integrity with enhancing efficiency (Figure 1(b)) and reducing CO_2 emissions.

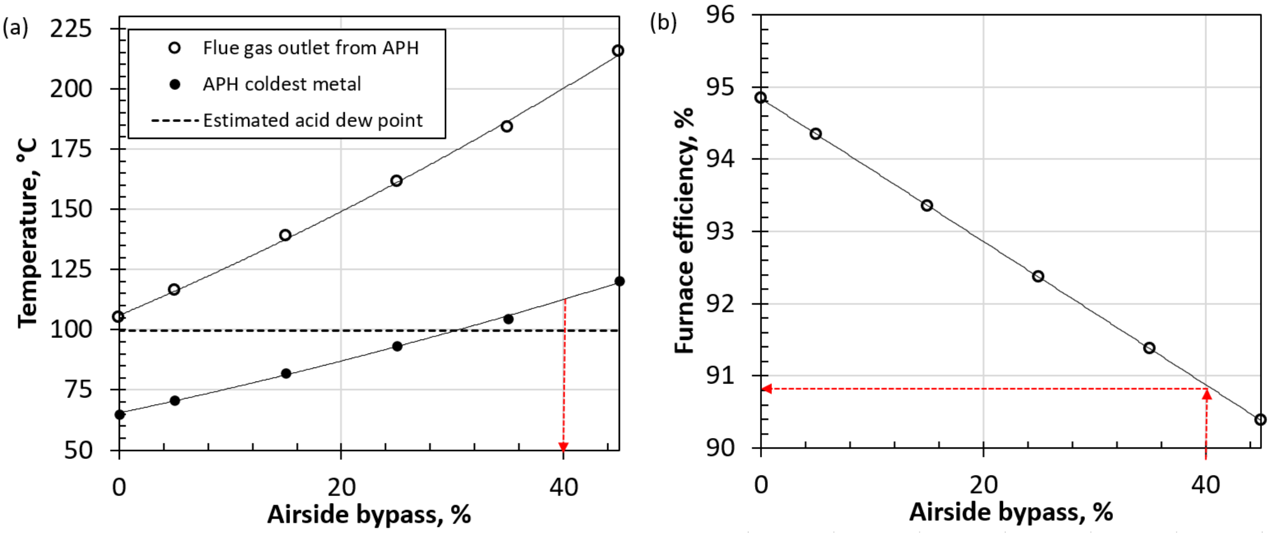

Fig. 1 Relationship between airside bypass and (a) APH temperature and (b) efficiency

5. CONCLUSIONS

Despite the evident efficiency improvements and carbon emission reductions, the introduction of APHs presents significant challenges, including risks of corrosion and leakage, increased NOx emissions, and altered heat flux impacting run length. This analysis emphasizes that upgrading refinery heaters requires a holistic approach, in which benefits are carefully weighed against potential downsides to ensure sustainable and efficient operations.

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