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An indirect heating solution to reduce CO_2 emission and improve efficiency of gas distribution networks

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ABSTRACT

The gas industry relies on indirect heating to prevent gas from freezing when it is transferred from high-pressure networks to lower pressure distribution systems. The main challenge in preheating natural gas is designing an indirect heating system capable of consistently maintaining a target temperature, despite large load diversity. The most common form of heating technology has traditionally been water bath heaters and boiler houses. In this paper, a novel technology is introduced, and its performance compared to existing installations. The Immersion Tube Thermosyphon Heater was developed specifically to address high load diversity; it combines a high-efficiency immersion burner with a sub-atmospheric two-phase loop thermosyphon. The use of low-temperature steam provides a flexible and precise solution for temperature control easily adapted to variable gas flows. The Immersion Tube Thermosyphon achieved an average thermal efficiency of 90%, considerably higher than the 46% efficient water bath, allowing an estimated annual saving of 7,660 tonnes CO_2 for 1-megawatt gross heat capacity operating with a 50% load factor.

1. Introduction

1.1. Natural gas transportation

Natural gas is transported at high pressures to reduce required pipeline sizes. For delivery to end users, it undergoes expansion and a subsequent temperature drop as a result of the Joule–Thompson effect. To avoid reaching temperatures below freezing post-expansion, the gas is preheated to an appropriate temperature, which depends on the problem's boundary conditions. The main challenge of this task is maintaining the target station outlet temperature for varying gas flows, as shown in Fig. 1.

1.2. Existing indirect heating technology used in preheating

The most common indirect heating technology used on gas distribution networks worldwide is the Water Bath Heater (WBH). Its design is principally based on a fire-tube combined with a natural gas process coil, whereby a heated water/glycol bath is used to indirectly transfer heat to a process coil, as illustrated in Fig. 2.

This simple configuration of a WBH minimises maintenance costs and has been an attractive choice for the gas industry for several decades. The primary drawbacks of WBHs are their low efficiency and lack of precision temperature control due to large system inertia, which can result in imbalances between energy required and energy delivered. Fig. 3 illustrates a three-day temperature and flow profile from a Pressure Reduction Site (PRS/City Gate Station) located in the United Kingdom, whereby a 1.2 MW water bath heater is used to maintain a 2 °C set-point.

As shown, as gas flows undergo transient variations to meet peak morning and evening demand, the WBH is unable to recover in sufficient time to sustain a stable gas temperature after pressure reduction. A common solution to avoid temperatures dropping below safe operating limits for pressure regulation equipment is to increase the station outlet temperature set point. However, higher set points are not desirable as they result in a higher proportion of fuel use, contributing to overheating of natural gas flows beyond that which is beneficial for maintaining safe operating temperatures.

Water bath heaters form part of critical infrastructure installed on gas networks. However, they limit network flexibility in terms of acceptable load diversity due to poor responsiveness and increased carbon intensity from low thermal efficiency. In contrast, thermosyphons were shown to have inherent heat transfer properties that are beneficial to application in preheating, offering potential to overcome limitations of WBHs, particularly where load diversity is high.

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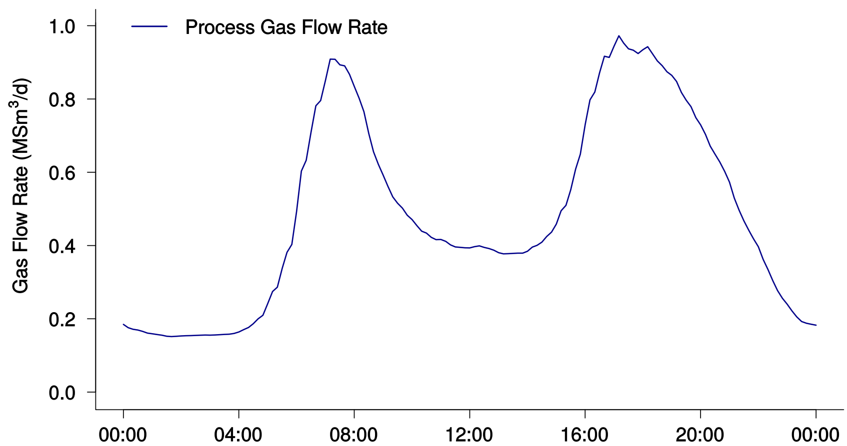

Fig. 1. Gas flow fluctuation for a pressure reducing station (PRS) located in the UK over a 24 h period.

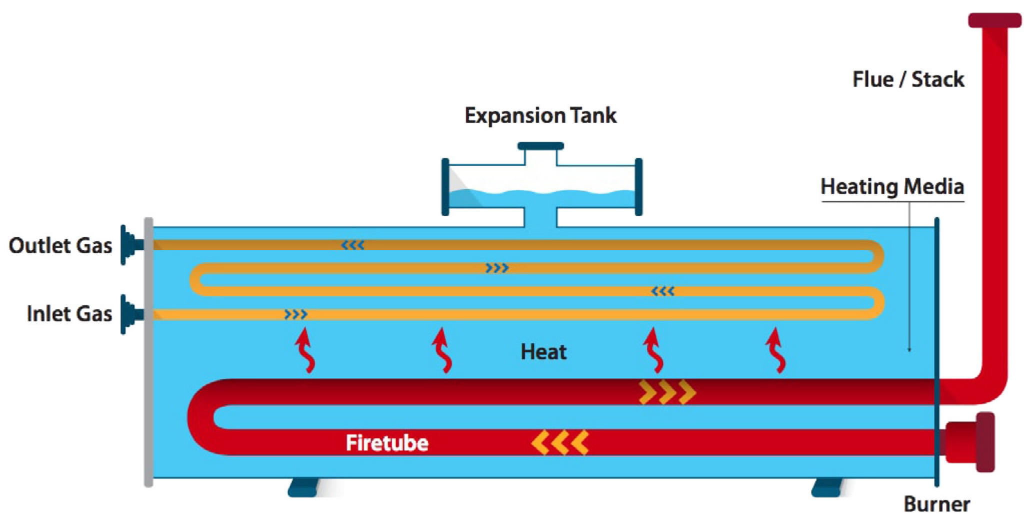

Fig. 2. Diagram of a typical water bath heater used for indirect heating of natural gas.

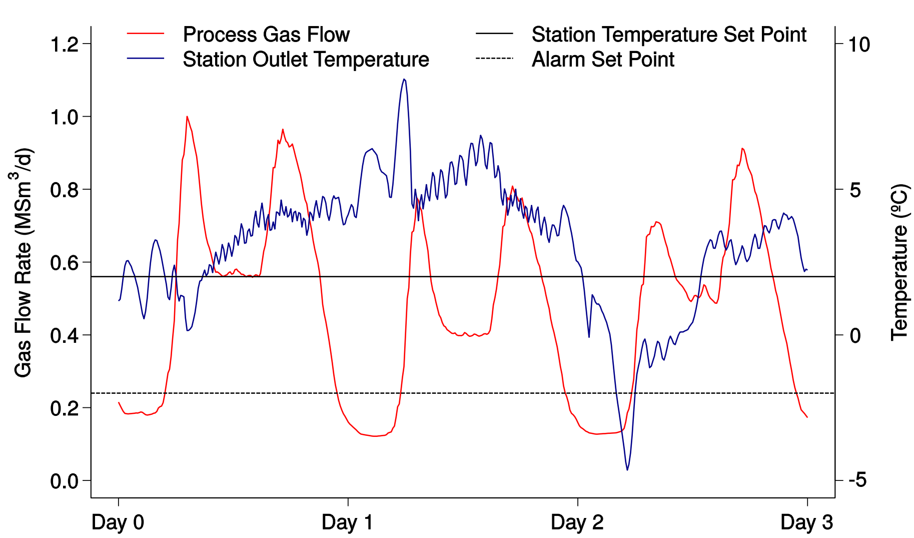

Fig. 3. 1.2 MW water bath heater PRS outlet temperature and gas flow rate over a three-day period.