One of the main benefits of conservation is that it is the simplest, fastest and least costly means to reduce energy consumption. Sustainability begins with using current technology more effectively with little upfront or ongoing cost. In an investigation for the European Commission Directorate-General for Energy, it was estimated that potential savings in industrial energy efficiency represented 20-23 per cent of total energy consumption.

In the UK, process heat represents the largest share of industrial energy use, accounting for up to 66 per cent of industrial energy consumption in 2016. Therefore, heat holds among the highest opportunities for conservation potential, as it can be optimised with a range of techniques to reduce losses and ensure efficient use.

Stefan Romocki and Sébastien Le Fouest explain how ProHeat Systems is optimising gas temperature control as a strategy for energy conservation on gas distribution networks.
This article will review opportunities for improving temperature control of indirect heaters used in preheating applications on gas distribution networks.

As gas is transferred from high pressure transmission networks to lower pressure distribution systems, its temperature drops due to the thermodynamic principle known as the Joule-Thompson effect. Safe operation of distribution networks is ensured by preheating process gas, such that its temperature is above freezing following the reduction in pressure. Indirect heaters used for natural gas preheating form part of critical network infrastructure and their reliability is required to ensure safe delivery of gas to end users.

The first UK preheating assets installed in the 1970s were water bath heaters (WBHs). These were conceived during an era of energy abundance, and featured a characteristically simple design selected for its high reliability and long asset life.

Innovation driven by the growing importance of energy conservation resulted in the gas industry’s adoption of modular condensing boiler houses (BHs), which achieve higher thermal efficiency by reducing combustion losses and extracting heat from exhaust gases. There are over 400 WBHs and 500 BHs currently in use on UK gas networks.

The existing consensus around water-based (single-phase) indirect heaters was established as they represent a cost-efficient means of heating natural gas. However, there remains an unanswered question concerning what portion of the heat supplied to gas may be considered useful, in other words heat that contributes to maintaining an ideal outlet gas temperature to prevent freezing.

This doubt arises from the inherent inability of conventional indirect heating technology to maintain a steady outlet temperature, particularly when embedded in a dynamic system such as a gas network, where gas flows and station operating pressures see large inter-hour swings, creating significant load diversity.

As part of a strategic pipeline heat study performed by ProHeat and SGN, the overheating loss was evaluated across multiple pressure reduction stations (PRSs). Problems associated with poor temperature control can be divided into two categories: underheating and overheating, respectively referring to the fluctuation of station outlet temperature below and above ideal safe operating temperature.

Currently, the most practical solution for gas networks to avoid underheating is to increase the target setpoints on heating systems. A higher setpoint provides a larger energy buffer within the system, but also leads to a greater proportion of energy being used ineffectively, contributing to over-delivery of heat beyond what is required. Thus, low temperature events caused by rapid increases in loads are often mitigated at the expense of energy conservation.

Preheat losses account for heat not delivered to gas, escaping to the environment either through flue-gases or from hot surfaces. As shown, the BH’s improved thermal efficiency results in a significant reduction in heating losses. Nevertheless, overheating losses for both cases represent 16.7 per cent and 20.8 per cent of the heater’s fuel consumption.

Improving temperature control has the benefit of reducing overheating losses, whilst also ensuring network resilience with reduced underheating. Temperature control can be improved with a range of techniques that do not require asset improvement. Perhaps the most obvious improvement involves upgrading the control system itself. Preheating
The UK has made significant commitments towards greenhouse gas reductions, aiming to reduce carbon emissions by 57 per cent by 2030, based on 1990 levels. Infrastructure is currently controlled by heuristically-tuned PID (proportional, integrating, differentiating) control structures. Over the past 70 years, these have been commonly adopted for industrial control use for their reliability, simplicity and affordability. However, actuator constraints (and the inability to have a memory or understand predictable patterns) limit performance, resulting in frequent deviations from an ideal process control value.

Machine learning, neural networks and memory enabled control systems are active fields of research as building blocks for artificial intelligence. Their industrial application allows preventative control by mimicking the human brain’s reasoning process to recognise patterns that would be considered prohibitively subtle to analyse with manpower or previous computational methods. For process heat, they can significantly improve temperature control, as illustrated.

Although large inter-day and inter-hour flow changes are displayed, the largest peaks (like those circled in grey, representing morning and evening gas demand) are expected to occur daily. Their magnitude and occurrence can be predicted accurately using very large datasets of past gas flow fluctuations and, in turn, this information may be used to perform smart control of a preheating unit by firing the heater prior to an increase in morning gas flow, for instance. The limitations of memory-enabled control are characterised by fluctuations, such as those highlighted in red, which do not happen on a daily basis and thus cannot be predicted. The magnitude of this discrepancy, however, is negligible and will not cause considerable losses when handled by traditional methods of controlling gas temperatures.

Another limitation to accurate control of conventional indirect heating processes are physical process constraints. When a temperature sensor identifies a value below a chosen operating setpoint, the controller sends a signal informing the heater to run. However, the mass of heat transfer fluid contained in the heater adds substantial inertia, lengthening the time for heat to reach the process gas and ultimately contributing to response lag and poor control. Additionally, since the heater and controller are separated by a length of pipe, thermal transport delays determined by gas flows can range from a few minutes to more than an hour.

Dual-phase technology, such as the Immersion Tube Thermosyphon Heater (ITTH) developed by ProHeat Systems (depicted), relies on energy released during a change of phase, rather than the difference in temperature between a warm heating media and a cooler process gas flow. Thermal lag is greatly reduced in the dual-phase system as steam carries up to 25 times more energy per unit of mass compared to traditional single-phase technology. This largely resolves the issue of system inertia by reducing the mass of heat transfer fluid required, and provides the basis for much more responsive and adaptive control.

The UK has made significant commitments towards greenhouse gas reductions, aiming to reduce carbon emissions by 57 per cent by 2030, based on 1990 levels. There are a number of opportunities to improve indirect heater performance on gas networks. The most promising relates to modernising control systems to maximise the effective use of energy consumed. The adoption of memory-enabled control has the potential to optimise set-point performance, eliminate low temperature callouts and reduce carbon emissions associated with pre-heat by as much as 15 per cent. The introduction of dual-phase thermosyphons offers another example of an innovative solution to a complex problem, and represents an exciting opportunity for a new generation of fast responding preheat technologies that easily adapt to changing heat demand whilst maintaining precise temperature control.

ProHeat Systems is a British design and professional engineering consultancy specialising in energy conservation for critical infrastructure. For more information, visit www.proheatsystems.com