Applied Thermal Engineering 48 (2012) 446–457

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Desalination using low grade heat in the process industry: Challenges and perspectives

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ARTICLE INFO

Article history:
Received 12 December 2011
Accepted 8 May 2012
Available online 23 May 2012

Keywords:
Low-grade heat
Process industry
Desalination
Heat pump
Multi-effect distillation
Humification-dehumidication

ABSTRACT

This paper examines the use of low grade heat from process industries for thermal desalination processes as this is relevant not only to current energy conservation schemes but also may play a role in increasing the capacity to satisfy future water demands. The study focuses on low grade heat sources from a paper mill located on a British coastal area which presents a large quantity of recoverable waste heat at low temperature (<100 °C). Two scenarios are considered: (i) low grade heat is used directly to feed the desalination process, (ii) low grade heat is upgraded using a heat pump coupled with a desalination system.

In the first scenario, a Humidification Dehumidification process was identified as a suitable technology due to its low operating temperature. In the second scenario, the low grade heat temperature was upgraded using a hybrid absorption heat pump and subsequently used to feed a Multiple Effect Distillation desalination system. These two cases were compared in terms of performances and economics. For both cases, a payback period of less than 10 years could be obtained for water price equal to £2 per tonnes of water. This is comparable to the price of home water supply. Environmental aspects were also discussed from the results of a full Lifecycle assessment. Low grade heat utilisation in both cases reduced the Global Warming Potential in comparison with fossil fuel powered systems, but toxicological impacts appeared higher in comparison to a system using natural gas.

1. Introduction

At the beginning of the 21st century, industrial energy use (particularly the metal and chemical sectors) represented 25% of the total energy use in the UK [1]. Despite industry having invested in energy efficiency technologies for more than thirty years, a considerable amount of this energy is still wasted via gas, liquid or solid discharge. However heat from streams of low thermal quality cannot be economically recoverable within the processes themselves and is currently rejected into the environment. This is referred to as Low Grade Heat (LGH) according to Ammar et al. [2].

The market potential for surplus heat available from industrial processes in the UK was estimated in 2006, by the Carbon Trust to be 40 TWh [3] and more recently by the Government Office of Climate Change as 18 TWh [4] and 10–20 TW h by McKenna [5]. It is worth mentioning that it is difficult to obtain accurate estimates on waste heat at a national scale (this data often being confidential), so most of the results presented in the above investigations are extrapolated from industrial CO_2 emissions, probably due to the relative ease of obtaining emissions data. For instance, McKenna [5] developed a procedure to determine the quantity of thermal energy released into the environment, based on CO2 emission and energy consumed by industries. According to [6], a large amount of LGH was available in process industry as water from cooling towers with a temperature between 35 °C and 55 °C. Flue gas or vapour sources from stacks were equally abundant with a larger temperature range of between 30 °C and 250 °C. The temperature range for LGH sources reported in [7] is in accordance with the widely accepted threshold temperature for LGH which is around 250 °C with75–85% of all process heat transfer applications operating below 200 °C [8].

LGH is available in large quantities but effective utilisation requires matching the sources with potential end-users in the surrounding of the plant. As industrial sites are often located in

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doi:10.1016/j.applthermaleng.2012.05.012