



Low-grade waste heat recovery for simultaneous chilled and hot water generation

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ABSTRACT

An investigation of heat recovery from industrial processes with large exhaust gas flow rates, but at very low temperatures, was conducted. Heat recovered from a gas stream at 120 °C was supplied to an absorption cycle to simultaneously generate chilled water and hot water to be used for space conditioning and/or process heating. With the steep increase in energy costs faced by industry, it may be possible to use previously unviable techniques. At nominal conditions, 2.26 MW of heat recovered from the waste heat stream yields a chilled hydronic fluid stream at 7 °C with a cooling capacity of 1.28 MW. Simultaneously, a second hydronic fluid stream can be heated from 43 °C to 54 °C for a heating capacity of 3.57 MW. Based on the cost of electricity to generate this cooling without the waste heat recovery system, and the cost of natural gas for heating, savings of \$186/hr of operation may be realized. When extrapolated to annual operation with a 75% capacity factor, savings of up to \$1.2 million can be achieved. The system requires large components to enable heat exchange over very small temperature differences, with the largest component being the waste heat driven desorber. Minor increases in heat source temperature result in substantial reductions in heat exchanger size.

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1. Introduction

This study investigates the feasibility of utilizing waste heat from industrial processes for the purpose of generating chilled water and hot water to be used for space conditioning and/or process heating applications. Numerous industrial plants in the USA and worldwide release large volumes of hot exhaust gases, with representative flow rates from single plants at a site with several plants being as high as 800 Nm³/sec. Such exhaust gases are typically mixtures of process gases at temperatures as high as 960 °C, but diluted with ambient air at a representative nine-to-one ratio. At such dilution rates, the exhaust stream is available at a nominal temperature of 120 °C. It is clear that this waste heat stream is a very low grade heat source, bordering on the limits of feasibility for utilization in an absorption cycle. Although it is noted that the waste stream may have a heat content of up to 80 MW, this would require cooling the 120 °C stream to such a low temperature (~37 °C) that it would not serve as a heat source along much of this temperature profile from 120 °C to 37 °C.

The objective of the present study, therefore, is to evaluate whether sources of such low grade heat can in fact be recovered in a beneficial manner. In view of the substantial projected worldwide increase in industrial production over the next 15 years, coupled

with the steep increase in energy costs currently being faced by industry, previously unviable techniques might be used now to advantage. In addition, the current concerns about global climate change and the environment are constantly leading to increasingly stringent requirements about emissions as well as source energy utilization efficiencies. This background serves as a favorable setting for the investigation of the feasibility of heat recovery through an absorption system.

2. Operational envelope

Industrial operations of the same global corporation often operate over a wide range of capacities and are also sited in diverse locations with ambient temperatures ranging from –30 °C to 35 °C. This wide range of ambient conditions and waste heat capacities leads to the selection of ammonia–water as the working fluid instead of Lithium Bromide–Water, which is more commonly used in large tonnage commercial chillers. Furthermore, the low grade heat source dictates the use of a simple single-effect cycle. Multiple-effect cycles yield higher coefficients of performance (COPs) [1–7]; however, they require higher temperature heat sources. There is also a “half-effect” cycle [8] for specialized low grade applications, but the additional complexity and capital investment of that cycle might preclude its use. Based on these considerations, a single-effect ammonia–water cycle is investigated here to accomplish the following:

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