SEAWATER DESALINATION BY FLUE-GAS HUMIDIFICATION-DEHUMIDIFICATION

By

Mostafa Hussein Ahmed El-Nahas

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Chemical Engineering

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Title of Thesis:

Seawater desalination by flue-gas humidification-dehumidification

Key Words:
Desalination; seawater; humidification; dehumidification

Summary:
Three alternative schemes has been proposed for a seawater desalination process by humidification-dehumidification that utilizes the waste heat of the flue gases produced from electric power stations that operate by fuel oil or natural gas. The process includes preheating of seawater or air, humidification of a flue-gas or an air stream by direct contact with seawater, dehumidification of the same stream by cooling in a surface condenser, and a desulphurization step for the flue gases produced from only fuel oil. The model included derived correlations for some of the seawater physical properties, and a study on the characteristics of the flue gases. The schemes were compared with respect to the total cost of the produced fresh water. The cost includes the fixed costs of all the used equipment based on the cost index of 2015 and their operating costs based on the current cost of electricity.

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Mostafa El-Nahas

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Abstract

The objective of the work is to utilize waste heat from power stations' flue gases in desalination of seawater by humidification-dehumidification. The effect of temperature and seawater concentration on vapor pressure, specific heat, density, viscosity, and thermal conductivity of seawater are first correlated on the basis of various published data. Some of these correlations will be used later in the proposed model. Two power station fuels namely fuel oil and natural gas are considered. The two fuels differ in composition, calorific value, and usage of percent excess air requirements. In order to achieve the same electric power production, the composition (moisture content and specific heat) and amount of flue gases ensuing from combustion of the above two fuels will be different. This study will also be included in the proposed model.

Three alternative humidification-dehumidification desalination schemes are generated and compared with respect to the anticipated cost of produced water. Cost is calculated on the basis of energy balance and design equations for each scheme. The schemes include: preheating of either seawater or air using hot flue gas, humidification of an air or flue gas stream by direct contact with seawater, and dehumidification of the same stream by indirect cooling in a condenser. In case of fuel oil combustion, desulphurization of the flue gas by seawater is also included. The cost of produced fresh water from each scheme includes the fixed cost of heat exchangers, condensers, humidifiers, packing, pumps and fans based on the cost index of 2015, and the operating cost is based on the current electricity cost. In all the schemes, the results will show that the total cost of the produced water is much less in the case of using flue gases ensuing from natural gas fueled power stations. This happens because the flue gases in this case have a very high humidity ratio which will result in the condensation of a significant amount of water on cooling. As a result, the total amount of fresh water produced is greater than in the case of fuel oil flue gases. The results will also show that regardless of the source of the used flue gases, the second scheme will always yield the highest amount of fresh water with the lowest cost, therefore it is the recommended scheme to be used. The only problem of this scheme is that using the flue gas directly in the humidification-dehumidification process might cause the fresh water to have traces of SO_2. This problem can be solved by the alkalization of the produced water to remove any traces of SO_2.