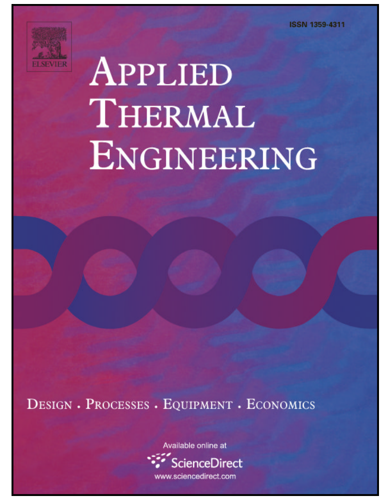
Accepted Manuscript



Method for evaluating the effect of inclination on the performance of large flattened-tube steam condensers with visualization of flow regimes

William A. Davies III, Yu Kang, Pega Hrnjak, Anthony M. Jacobi

PII: S1359-4311(17)34277-1
DOI: https://doi.org/10.1016/j.applthermaleng.2018.02.075
Reference: ATE 11857

To appear in: *Applied Thermal Engineering*

Received Date: 26 June 2017
Revised Date: 29 October 2017
Accepted Date: 20 February 2018

Please cite this article as: W.A. Davies III, Y. Kang, P. Hrnjak, A.M. Jacobi, Method for evaluating the effect of inclination on the performance of large flattened-tube steam condensers with visualization of flow regimes, *Applied Thermal Engineering* (2018), doi: https://doi.org/10.1016/j.applthermaleng.2018.02.075

Method for evaluating the effect of inclination on the performance of large flattened-tube steam condensers with visualization of flow regimes

William A. Davies III[1], Yu Kang[1], Pega Hrnjak[1,2]*, Anthony M. Jacobi[1]

[1]Air Conditioning and Refrigeration Center (ACRC), Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA
daviesi2@illinois.edu, yukang2@illinois.edu, pega@illinois.edu, a-jacobi@illinois.edu

[2]CTS – Creative Thermal Solution, Inc., Urbana, IL, USA

* Corresponding Author

Key words: air-cooled condenser, inclination, experimental facility, heat transfer, condensation, flattened tube

Abstract

An experimental study of convective steam condensation inside a large, inclined, flattened-tube air-cooled condenser for power plants is presented. This is the second of a four-part group of papers. The first part presents pressure drop and visualization results, while this study presents the experimental method along with heat transfer results. Follow-up papers present further heat transfer results and the effect of inclination.

The condenser in this study is steel with brazed aluminum fins. The condenser measures 10.72m in length, with a cross section of 214 mm x 18 mm. The condenser tube was cut in half lengthwise and covered with a polycarbonate viewing window in order to provide visualization access simultaneously with the heat transfer measurements. Inlet steam mass flux ranged from 6.2 – 9.5 kg m^{-2} s^{-1}, and condenser capacity varied from 25 – 31 kW. The angle of inclination was varied from horizontal to 75^{o} downward. The experiments were performed with a uniform fin-face velocity of crossflowing air at 2.2 m/s.

Condenser capacity was found to increase linearly with increasing downward inclination angle of the condenser, at a rate of 0.041% per degree of inclination below horizontal. This improvement was found to be the result of improved drainage and increased void fraction near the condenser outlet.

1. Introduction

Air-cooled condensers (ACCs) represent an alternative to wet cooling for thermal power plants. ACCs reduce water use in electricity generation, at the cost of decreased generation efficiency [1]. As electricity consumption increases while water resources remain finite, ACCs are becoming more prevalent, with installed capacity tripling between the years 2000 and 2004 [2]. Currently, thermoelectric power generation accounts for the largest proportion of freshwater withdrawals in the US, reaching 45% in 2010 [3]. Increasing ACC use to 25% by 2035 could reduce US water withdrawals by 10.7% [4]. However, using current technology, coal-fired plants using ACCs have a levelized cost of electricity about twice that of wet-cooled plants [5]. Therefore, this study aims to improve air-cooled power plant performance by investigating the steam-side behavior of forced-draught ACCs. Specifically, this study experimentally investigates the optimal inclination angle for condenser heat transfer performance.

The majority of current ACCs use flattened steel tubes with aluminum fins [2]. A large number of studies have been published investigating performance on the air side of these condensers (e.g. [6], [7], [8]), but not much research has been published investigating the steam-side performance. From a heat transfer perspective, the air side provides the dominant resistance over the majority of the condenser. However, as the air-side performance has improved, there is an opportunity for additional performance gains to be made by reducing the steam-side heat transfer resistance. ACCs utilize an A-frame design, with condenser tubes inclined around 60^{o} to the horizontal [9]. In this large, flattened-tube geometry, to the authors' knowledge there are no published experimental results for thermal performance at varied inclination, although some modeling studies have been published. Cheng *et al.* [10] analyzed the void fraction and heat transfer coefficient in the flattened ACC tube using a numerical model and conservation of mass arguments. They found an increase in void fraction as inclination angle increased, and an agreement with the correlations of Cavallini [11], Shah [12], and Chato