Center for Ocean Engineering
Naval Construction & Engineering Program
Department of Mechanical Engineering

Massachusetts Institute of Technology
77-massachusetts Avenue, Building 5-317
Cambridge, Massachusetts 02139–4307

Cooling System Design Tool for Rapid Development and Analysis of Chilled Water Systems aboard U.S. Navy Surface Ships

Amiel B. Sanfiorenzo

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Abstract

Over the last several decades, there has been a dramatic increase in the complexity and power requirements of radars and other combat systems equipment aboard naval combatants and this trend is expected to continue for the foreseeable future. This increase in the power demand has a direct effect on the amount of heat which has to be removed by the cooling systems, with future combatants expected to require 5-10 times the cooling capacity currently installed on naval combatants (McGillan, Perotti, McCunney, & McGovern). In the past, the cooling system could be designed and integrated into the ship towards the later stages of the ship design process; however, this is no longer possible. The growing complexity and size of the cooling systems needed require preliminary design and integration in the early-stages of the ship design process. To design and integrate cooling systems several tools are available to the naval architect, but vary in complexity and usefulness depending on the design stage considered.

The focus of this thesis is on the early-stage design of cooling systems aboard U.S. Navy surface ships utilizing the principles of naval architecture and mechanical engineering concepts. The intent was to study the heat transfer process within the chilled water system and the auxiliary seawater system and develop a Cooling System Design Tool (CSDT) based on the thermodynamic laws that govern heat transfer as well as the hydrodynamic principles that govern fluid flow, specifically the incorporation of flow network analysis (FNA). The key purposes of the CSDT are to provide rapid visualization and analysis of the cooling system to test overall feasibility and performance of the system.

The framework of the model was built using Matlab in conjunction with Excel. The program interacts with the user primarily through the command window, guiding the user through the design process. Some visualization is provided as the design progresses, allowing the user to quickly determine and correct errors in the design. The CSDT also displays important results of various analyses that can be performed on the data, including a weight summary, a static temperature distribution, and a temperature distribution that captures transients in space and time. The program interaction, chilled water plots and analyses output enables the user with the ability to quickly visualize, develop and analyze cooling systems aboard naval vessels.

Thesis Supervisor: Chryssostomos Chryssostomidis
Title: Professor of Mechanical and Ocean Engineering