THERMOELECTRIC HEAT SINK, MODELING AND OPTIMIZATION

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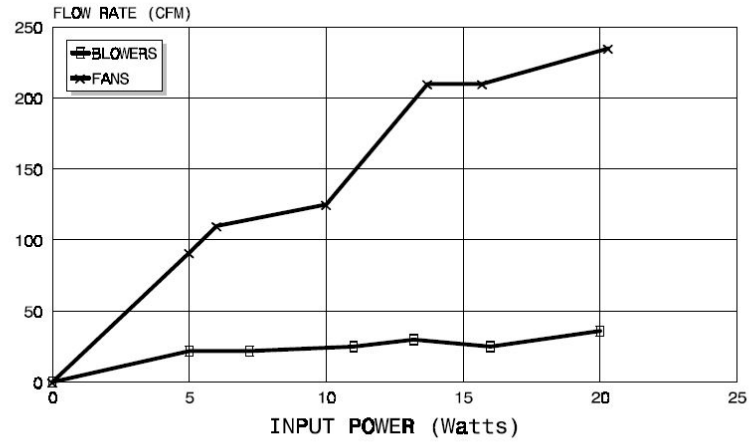
Proper design and optimization of a thermoelectric (TE) heat sink has been a topic of some neglect in the design of the TE cooling systems. Collectively, TE material researchers have spent tens of millions of dollars to advance the performance level of TE materials only to have it dashed away by ineffective heat sink design. The combination of detailed thermal modeling and high-speed personal computers makes it no less effort to fully optimize a heat sink design then to just derive one that "works." Of course, derivation of a thermal model employing accurate calculations for fluid dynamics and heat transfer can be a significant investment of time and effort but, once completed, the pay-off can yield big dividends. The process of model development begins with examination of classical fluid dynamic theory but should be validated and verified by experiment. The model used by TE Technology, Inc. was developed over a period of over 30 years using feed-back test data from literally thousands of exchangers and exchanger configurations. Empirical corrections were applied to adjust the classical theory to better match "realworld" test results. As such, the details of this model are proprietary. However, the use and application of this model and the methods employed to optimize are the subject of this paper.

SYSTEM DESCRIPTION

Throughout this paper, the term, heat sink, shall refer to a metal (usually aluminum) exchanger with a fluid flowing through it. Aircooled heat sinks can consist of a finned area with either flat, louvered, wavy, perforated, "breathing effect," slotted or pin-type fins. These exchangers are usually combined with a centrifugal blower or tubeaxial-type fan as the air mover. The air direction can be vertical, parallel or radial. Although the method demonstration presented in this paper involves a simple flat fin exchanger together with a tubeaxial fan and centrifugal blower, the principles and methodology are generically the same as with other configurations, including liquid-cooled heat sinks. Of course, liquid cooled heat sinks can involve simpler tube-type configurations because of the higher heat transfer characteristics of water or other liquids. Properly applied, the methods described in this paper provide the means for optimizing the heat sink design and cold or hot extenders as described by Lau., et al (1). The result can maximize the effectiveness of the TE modules resulting in reducing size, weight, power-consumption and cost of the entire thermoelectric product, as described by Ritzer.

AIR MOVER (Coolong Fan) CHARACTERISTICS

FIGURE 1. Free-flow rate comparison between fans and blowers of the same power consumption.



After the general size of the heat exchanger has been scoped, selection of the potential air movers should be the first step in the design optimization process. This is because geometry and configuration of the air mover is fixed, once selected. Whereas, the mating finned exchanger is flexible and can be modified to accommodate the air mover characteristics. FIGURE 1. Free-flow rate comparison between fans and blowers of the same power consumption. FIGURE 2. Stall pressure head comparison between fans and blowers of the same power consumption.Figures 1 and 2 illustrate the typical maximum characteristics of tubeaxial fans versus centrifugal blowers as a function of the power required to drive them. Each point on the charts are different models of fans and blowers. These are specific data taken from a single manufacturers, but they represent the typical trends of all fans and blowers. That is, fans typically increase quite rapidly

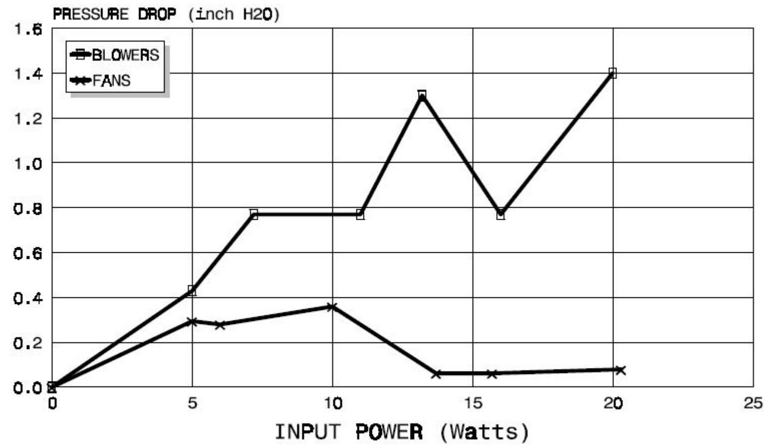
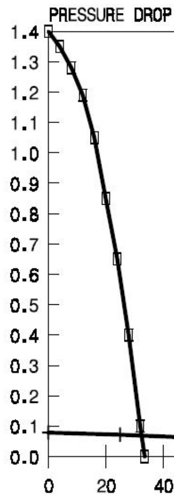
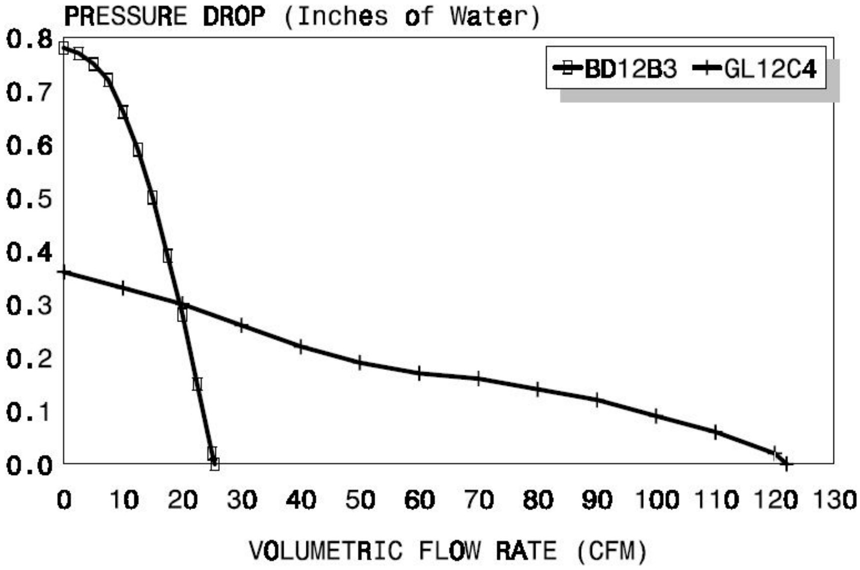
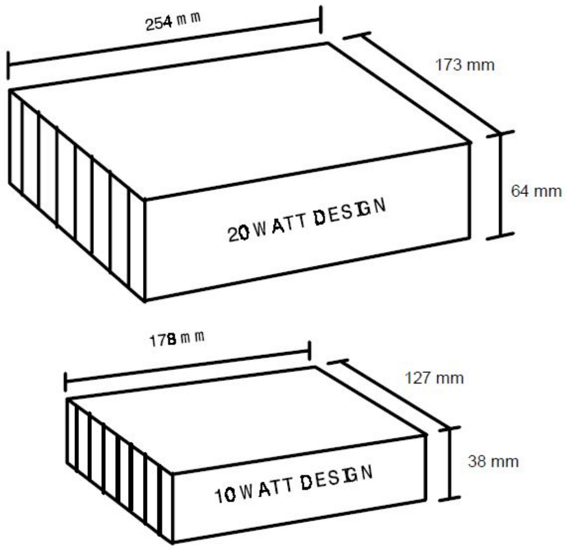


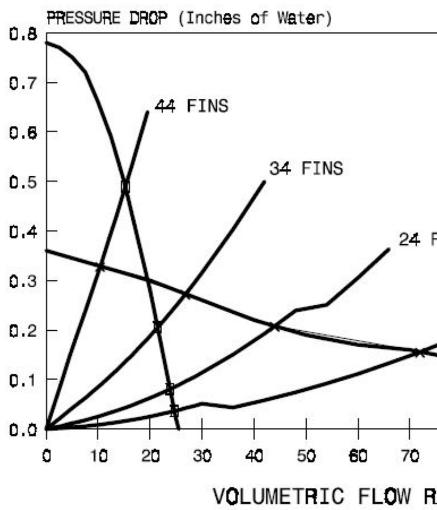
FIGURE 2. Stall pressure head comparison between fans and blowers of the same power consumption.





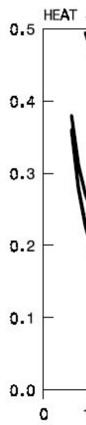


[illegible] the fin density (number



[illegible]

FIGURE



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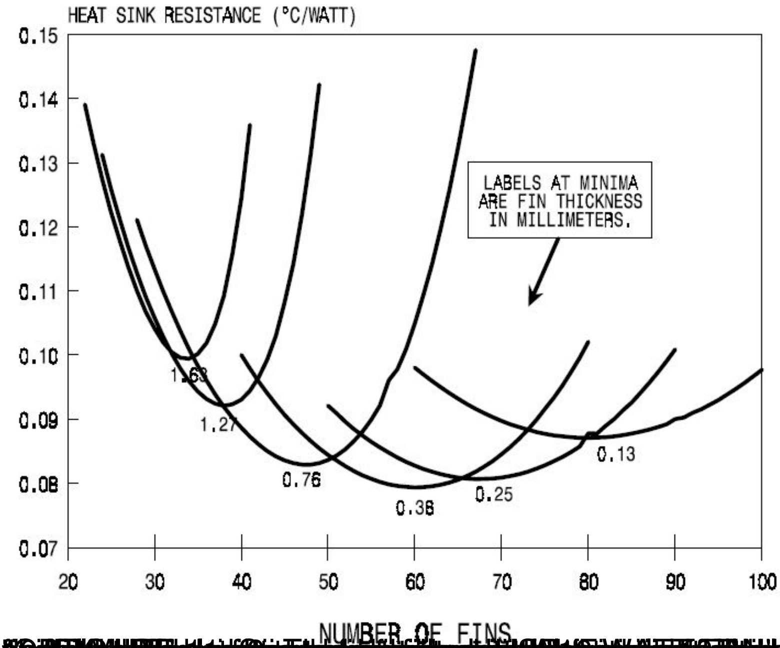
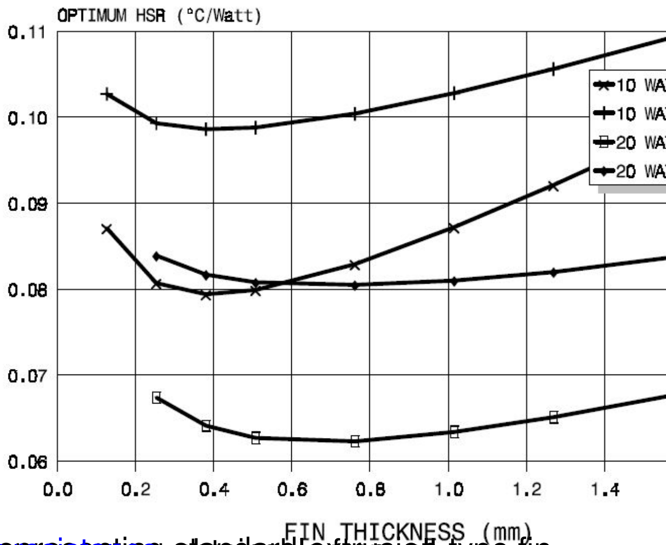

HEAT SINK RESISTANCE (°C/WATT)
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
20
30
40
50
60
70
80
90
100
LABELS AT MINIMA ARE FIN THICKNESS IN MILLIMETERS.
1.63
1.27
0.76
0.38
0.25
0.13
NUMBER OF FINS

[illegible]


OPTIMUM HSR (°C/Watt)
0.11
0.10
0.09
0.08
0.07
0.06
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
FIN THICKNESS (mm)

[illegible]

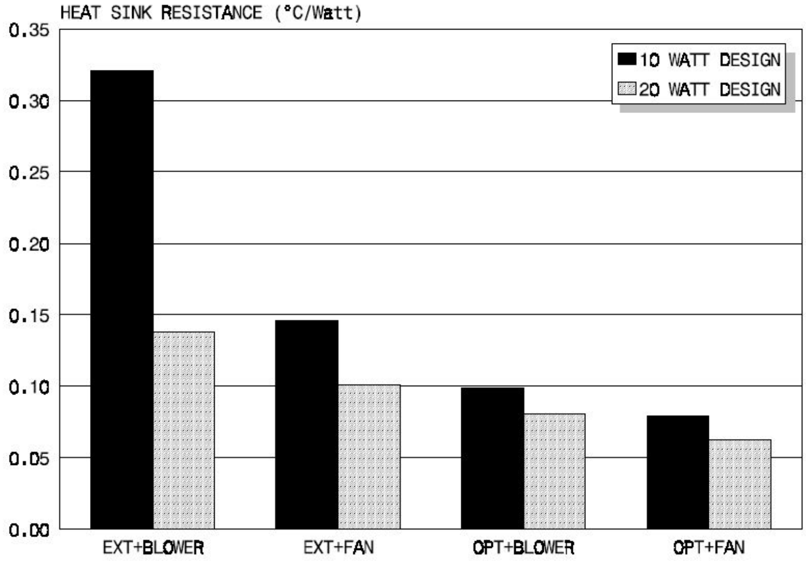
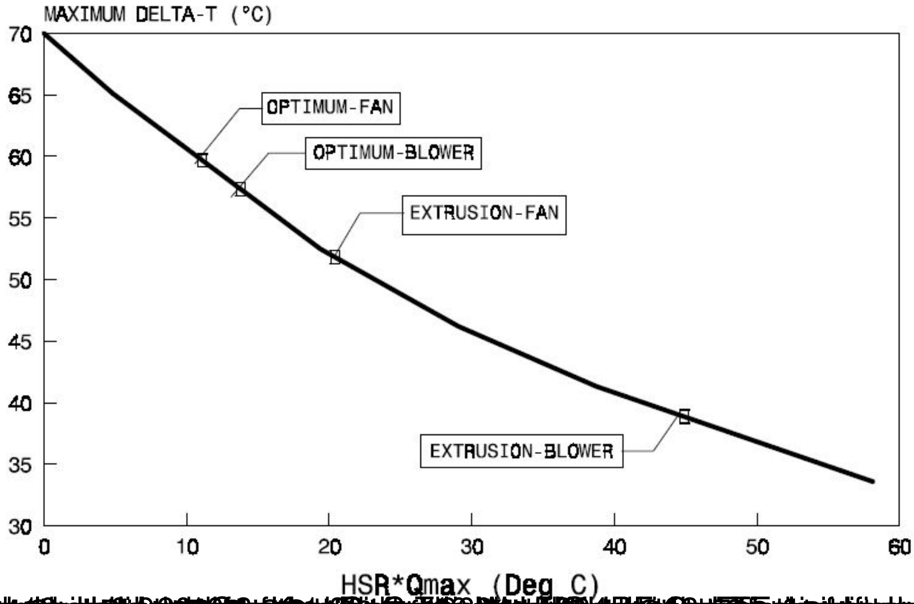


FIGURE 12. Comparison of the best heat sink resistance obtainable from all systems studied.

[illegible]



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