Forced Convection Heat Sink Thermal Resistance Calculator

This calculator is based on W. M. Kays and A. L. London (of Stanford University) “Compact Heat Exchangers” research.

Basically, Kays and London were contracted through the U.S. Navy Bureau of Ships in 1945, in conjunction with the Bureau of Ships and Aeronautics, and the Atomic Energy Commission, to develop a method to calculate the performance of heat sinks (compact heat exchangers). Specifically, to develop a method of determining the thermal performance and pressure drop of heat sinks.

Kays and London fabricated 115 different heat sink geometries, with varying fin height vs. fin spacing ratios, and fin length vs. fin spacing hydraulic radius ratios.

For each of the 115 heat sink geometries, they varied the mass flow rate through the heat sink, and recorded the heat sink thermal resistance and pressure drop.

The key to any forced convection heat sink design is to know the thermal resistance and pressure drop, for a given mass flow rate, so that an appropriate air mover (fan or blower) can be selected. In other words, for any given fan or blower, and for any given heat sink geometric envelop, i.e. 100mm wide by 150mm long by 75mm high, there exists an optimum number of fins, fin width, and fin space, that results in the maximum heat transfer performance.

After 6 years of development, Kays and London were unable to develop a set of heat transfer and pressure drop equations for their work related to this matter. Instead, they developed a set of data and curves that an engineer could iteratively look up, until they reached a reasonably satisfactory solution.

This meant that an application engineer had to mathematically determining the Reynolds Number and Prandtl Number for a given heat sink geometry and mass flow rate, and then looking through a list of Kays and London’s 115 heat sinks, finding one of the 115 heat sink geometries that best matched the application engineers geometry, then by looking at Kays and London’s published curves, to determine the Stanton Number and Fanning friction value. If these values were outside the range for a given fan or blower, the applications engineer would change the fin geometry, and repeat the process.

This iterative method of is not only time consuming (taking days and sometimes weeks), it is less than accurate, if the application engineers fin geometries did not match one of the 115 Kays and London’s test geometries.

Daniel L. Thomas, solved this problem by taking the 115 sets of Stanton Number and Fanning friction data, over 2,000 data points (for the various mass flow rates), and writing an equation for the Stanton Number and Fanning friction as a function of the fin “height vs. space, and the fin “length vs. hydraulic diameter”.

After nearly 9 months of equation fit analysis, Thomas had developed Stanton Number and Fanning friction equations that are ~95% accurate (which can be verified by comparing against Kays and London "Compact Heat Exchangers" published data).

Thomas then developed a software program called SinkDes (sink design), which provides for the input of a PQ curve (pressure vs. flow curve) from a fan or blower, and when tied to optimization algorithms, the software can iteratively solve for any possible fin geometry, until it finds the best heat sink performance possible for that fan of blower. A less automated version of this program is located on our website at http://www.novelconceptsinc.com/calculators-forced-convection-heat-sink-thermal-resistance.cgi

For over 25 years, Thomas has been using these equations to solve some of most challenging heat sink problems, for many fortune 500 companies including:

3M
Agilent Technologies
Apple Computer
Applied Biosystems
Applied Materials
British Telecommunications (BT)
Cloud, LLC
Cutera
Cymer
Cytyc
Daylight Solutions
Delta Electronics Group
Device Semiconductor
Estari
Formation
IdeaLab
Intel
KDS Computers
Life Technologies
Meggitt Defense Systems
Nidec Corporation
Philips
Red Digital Cinema Camera Company
Sanera Systems
Sanyo Denki Corporation
Syracuse Research Corporation
Tampa Microwave