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Sandia Cooler

Air-cooled heat exchangers are used to reject excess heat from a concentrated source to the surrounding atmosphere for a variety of mechanical and electrical systems. Advancements in heat exchanger design have been very limited in recent years for most product applications.

In support of heat exchanger advancement, Sandia developed the Sandia Cooler

IPO

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

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BACKGROUND

Heat exchangers may be used in HVAC systems, power plants, and mechanical devices and systems that require heat transfer. Examples include various electromechanical systems, and electronics applications such as conventional computing systems. In a typical computing system that includes a central processing unit (CPU), one or more memory devices, and other circuitry, cooling of the CPU in particular is an important design consideration.[1] Air-cooled heat exchangers are used in a wide variety of applications, particularly where water is unavailable. They provide a simpler solution than water-cooled systems consisting of more comprising pumps, piping, and a central chiller or cooling towers—all of which increase the operating cost and maintenance of the system.[2]

The operating principle of an air-cooled heat exchanger is straightforward. Waste heat is transmitted to finned surfaces (typically aluminum or copper), and as ambient air passes over the fins, the waste heat is rejected to the atmosphere. While this is a fundamentally simple concept, maintaining optimum air-cooled heat exchanger performance takes diligence as the exchanger surface will deteriorate over time due to accumulation of particulate matter and other airborne contaminates.[3]

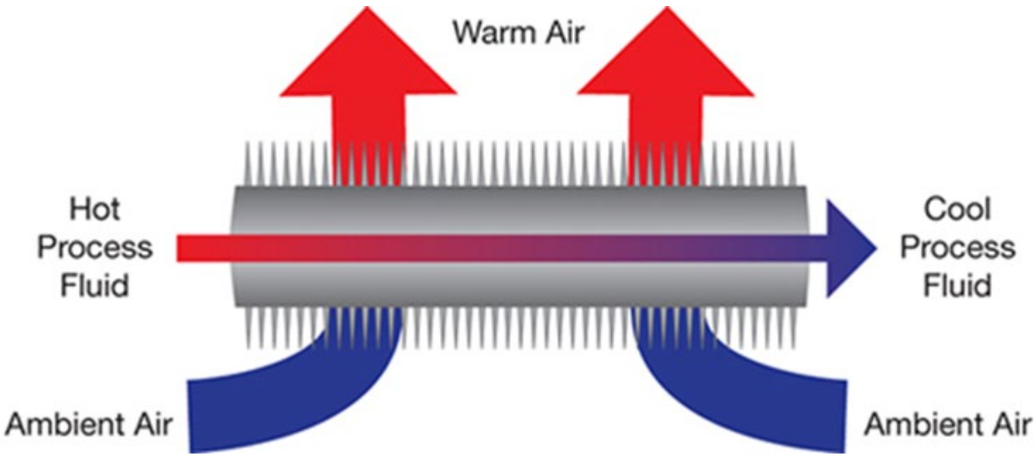

Figure 1: Air-cooled heat exchanger basics

The sizes of these units vary widely, from the very small (e.g., a car or truck radiator) to the very large (e.g., an A-frame vacuum steam condenser). Due to the variety of size, researchers can take several approaches to the optimization of existing air-cooled heat exchangers, one of which lead to the development of the Sandia Cooler.

TECHNOLOGY DEVELOPMENT

In 2008, researchers at Sandia National Laboratories developed the Sandia Cooler, a new technology for air-cooled heat exchangers, addressing major obstacles that exist in traditional CPU coolers.

In traditional CPU coolers, there is a heat transfer bottleneck, a layer of motionless air that adheres to and envelops all surfaces of the heat exchanger fins. This bottleneck largely determines the thermal resistance of the heat exchanger and is the primary physical limitation to the heat exchanger's performance. Another obstacle is posed by the inevitable deterioration of the heat exchanger surface over time by particulate matter and other airborne contaminates. This deterioration is especially important in applications where little or no preventative maintenance is typically practiced. The third major obstacle concerns inadequate airflow to the heat exchanger resulting from restrictions on fan noise. Small and medium-sized fans have relatively poor mechanical efficiency as unproductive expenditure of mechanical work on the surrounding air results in high noise levels.[5]

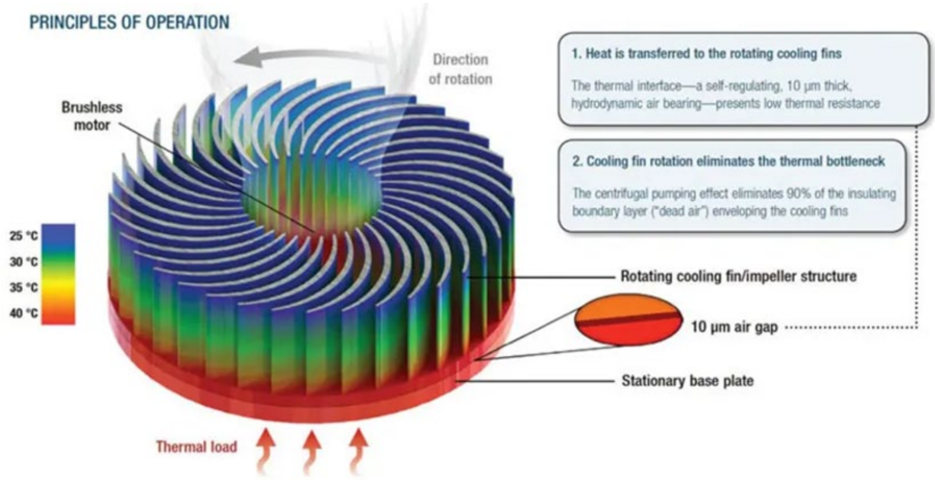

Figure 2: Sandia Cooler principles of operation

The Sandia Cooler is able to overcome the bottleneck of dead air, therefore offering a device which is smaller, quieter, and immune to clogging by dust. The new design allows heat to be efficiently transferred from a stationary base plate to a rotating structure that combines the functionality of cooling fins with a centrifugal impeller. The dead air that would traditionally lead to a bottleneck is subjected to a powerful centrifugal pumping effect, reducing the boundary layer thickness.[6] Additionally, high-speed rotation completely eliminates the problem of heat exchanger deterioration due to particulate fouling. Generating relative motion between the cooling fins and ambient air by moving the fins through the air also provides a drastic improvement in aerodynamic efficiency over traditional "fan-on-finned-heatsink" architectures, translating to an extremely quiet operation.[7]

RETURN ON INVESTMENT

Sandia's Integrated Partnerships Organization (IPO) has successfully established several Strategic Partnership Agreements (SPP) and one Work For Others agreement, which utilize the Sandia Cooler.

CPU Cooling

LED Lighting

Strategic Partnership Agreements

Laboratory Directed Research and Development

Within tech transfer, Strategic Partnership Projects (SPP) Agreements facilitate the availability of Sandia's unique resources to private industry and individuals, state and local governments, colleges and universities, non-profit organizations, international organizations, foreign governments, and foreign companies to validate or improve technologies. Sandia has multiple SPP agreements utilizing Sandia's various radiation detection technologies.

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

LDRD

The Laboratory Directed Research and Development (LDRD) program invests in high-risk, potentially high-payoff activities that enable national security missions and advance the frontiers of science and engineering. The LDRD program provides the flexibility to anticipate and respond quickly to future mission needs and to explore potentially revolutionary advances in science and technology.

Over the past 20 years, a number of LDRD projects were conducted utilizing the Sandia Cooler.

TECHNOLOGY DEVELOPMENT

The Sandia Cooler offers possible applications across a variety of industries and technologies including laptops, high-performance gaming personal computers (PCs), home video game boxes, light-emitting diode (LED) lighting, large appliances, and more generally, any device compromising one or more forced-air exchangers.

Since the creation of the Sandia Cooler, the Sandia team has worked with Wakefield-Vette Inc. to convert this technology to a market-ready, cost-competitive, electronics thermal management product, which was fulfilled in 2019 at TRL-8. The team also worked to target an energy sector application with high-visibility that could effectively serve as an advertisement for the Sandia Cooler technology.

At the beginning of the partnership, the team determined that high-powered LED luminaires for use in factories, warehouses, big-box stores, high bays, etc. would be the best application space, as 50% of the electrical power provided to LEDs is immediately converted to heat. LED luminaries were also chosen because the technology will be more visible as opposed to being hidden in a PC or similar technology. Because the light emitting element of LEDs must be kept at a temperature of 80°C or below, these thermal management challenges decrease wall-plug efficiency and drastically lower the LED service lifetime. Wall-plug efficiency is important because high-bay luminaires have very high-power consumption, while long operating lifetime is important from the standpoint of bulb replacement costs including labor; an operating lifetime of 100,000 hours results in significant cost savings because servicing luminaires 30 to 60 feet off the ground is both expensive and inconvenient.[8]

To address these challenges, the team used what they refer to as "Type-II Sandia Cooler technology". The distinction between Type-I and Type-II Sandia Cooler technology is important to understand for this application. In a Type-I Sandia Cooler, the thermal load is attached to a heat spreading plate that resides in the stationary frame.

In a Type-II Sandia Cooler, the heat load is mounted directly to the rotating heat-sink-impeller. This has two advantages compared to a Type-I Sandia Cooler—it eliminates the thermal resistance of the air-gap region (hydrodynamic air bearing) and its tight mechanical/manufacturing tolerances.[9]

During the implementation of this technology, the objective of transmitting 1000 watts of electrical power from the stationary to the rotating frame with very high efficiency (99%) and at low cost was achieved. With the success of this project, the team is looking to deploy the LED luminaire at TRL-9. In order to reach this level, the team has proposed changes for implementation in the first mass-produced version of the high-bay luminaire. Proposed changes include consolidating power electronics, optimizing the rotary transformer, and eliminating mechanical fasteners and heatsink paste.[10]

Figure 3: A photo-realistic CAD rendering of the Sandia Cooler LED Luminaire product demo unit.

SOURCES

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The Case Study Review

The Sandia Cooler

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The Sandia Cooler offers applications across a variety of industries and technologies including:

- *Laptops*
- *High-performance gaming*
- *Personal computers*
- *Home video game boxes*
- *LED lighting*
- *Large appliances*
- *And more*

Return on Investment:

- *Laboratory Directed Research and Development*
- *Strategic Partnership Projects*
- *Licenses*

2009
Researchers publish "A Fundamentally New Approach to Air-Cooled Heat Exchangers"

2012
First patent issued for "Heat exchanger device and method for heat removal or transfer"

2015
Subsequent patents issued for "Heat exchanger device and method for heat removal or transfer"

2019
Installation of two TRL-8 demo unit luminaires in a wire rope fabrication factory in Niles, MI.