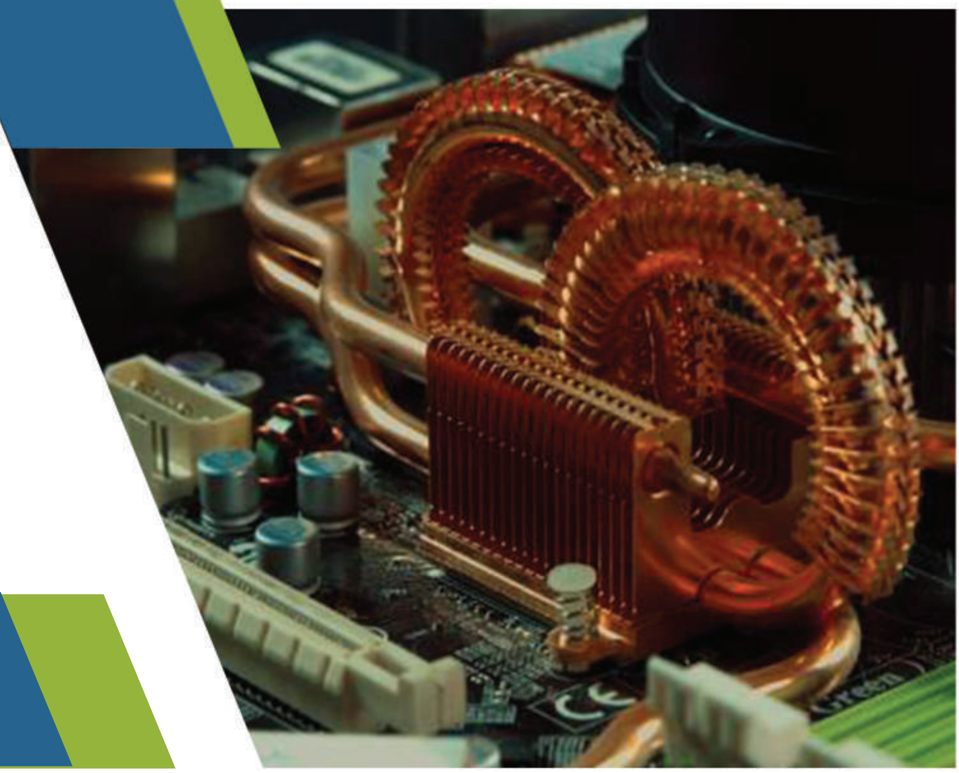
COMPARING TECHNOLOGIES FOR ELECTRONICS COOLING

FIGURE 1 - Aspens Miniature Compressor Enables Small Environmental Control Units



INTRODUCTION

Vapor Compression vs. Thermoelectric Cooling Technology

All electronics devices require some form of cooling to prevent overheating and failure. When electronics are kept inside an air conditioned office building, a simple fan blowing over the electronics is sufficient to prevent overheating. When electronics are used in a mobile or remote location they are put into an enclosure for protection from rain and dirt. Electronics operated inside these enclosures do require a cooling system to assure that the enclosure does not overheat, causing shutdown or permanent damage. When the ambient temperature is high, an active cooling system with capability to operate below ambient temperature is often required to assure the inside “case” temperature is low enough.

Prior to 2008 the only systems small enough for electronics enclosure cooling were based on thermoelectric technology. Unfortunately, thermoelectric systems consume 4 to 6 times more power than equivalent vapor compression systems, making them very costly to operate. In addition, the thermoelectric modules are made from delicate semiconductor materials and require large and heavy structures for safe packaging. As a result the only cooling systems available for electronics enclosure cooling were large, heavy, and inefficient thermoelectric units.

In 2008, Aspen Systems developed and put into production the miniature refrigeration compressor, shown in Figure 1 that is 10 times smaller and lighter than equivalent capacity compressors. For the first time, small refrigeration compressors suitable for electronics enclosure applications were developed and available. The world’s first truly miniature vapor compression system, shown in Figure 2 was developed and put into production by Aspen Systems using this advanced miniature compressor. This system, branded ECU-Chill®, is sold into a wide range of military electronics cooling applications. Over 1500 of these systems have been shipped to The US Department of Defense for use in hostile, dirty, austere environments. For the first time the benefits of efficient, reliable, lightweight, and small vapor compression technology is being used to protect mission critical computing and communications systems.

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Over 1000 of these systems have been in use on SOCOM MRAPS for over 2 years. The reliability and effectiveness of this system is demonstrated by its over 90,000 hour MTBF, and maintenance free design.

Figure 2 ECU-Chill 550 Refrigeration Based Cabinet Cooler

TRANSIT CASE COOLING OPTIONS

Vapor compression refrigeration and thermoelectric cooling are the only two technology options available to achieve below ambient cooling for transit case and other electronic enclosures. Given the success of the ECU-Chill product in field operations, it is useful for system integrators to understand the performance differences between these technologies in support of developing their optimum cooling solution.

In order to fairly assess the size, weight, cooling capacity, efficiency, and relative cost of the two technologies, Aspen conducted thermal evaluation tests of the ECU-Chill and a competing TE Cooler similarly rated. ECU-Chill 550, shown in Figure 2, is a compact, ruggedized vapor compression air conditioner rated to reject 550W (1875Btu) of heat from transit case electronics. A competing TE Cooler similarly rated and ruggedized for military service was selected for comparison. The TE Cooler is rated to reject 1500 Btu (440W) of transit case electronic heat; a TE Cooler of identical rating was not commercially available. Aspen's evaluation methodology was to examine each product under the same environmental conditions, using the same transit case mounting and thermal chamber. A series of performance data was generated using a common electric heat source to determine the cooling capacity and power use at various ambient and internal transit case temperatures. The results of these tests are presented below in terms of comparing the SWAP-C characteristics as rated, and the economic impact of using the higher efficiency ECU-Chill product. For the latter analysis Aspen assumed a military mobile communication system mission scenario requiring 6kW of electronics cooling.

BASELINE PERFORMANCE COMPARISON

The initial evaluation compared the fundamental size, weight, and power characteristic of each cooler at rated conditions. The internal thermal load was varied until the internal temperature could be maintained and the actual thermal capacity and power consumption measured. The data in Table 1 show ECU-Chill 550 is physically smaller and lighter than the TE Cooler, providing a 694 Watts of cooling capacity versus 303 Watts for the TE Cooler. Similarly ECU-Chill consumed considerably less power to cool the thermal load, 373 Watts versus 721 Watts, respectively. These data underscore the significant advantage inherent in vapor compression technology over thermoelectric.

Table 1 Baseline Size, Weight, Capacity, and Power Comparison

Characteristic	ECU-Chill (Rated 550W)	TE Cooler (Rated for 440W)
Volume	9"h x18.5"w x 6.7"d	18.3"h x 10.0"w x 7.1"d
Weight (lbs)	20	50
Cooling Capacity (Watts)	694	303
Power (Watts)	373	721

To fairly evaluate the implication of these characteristics and select an optimal cooling solution one must normalize the characteristics for the desired amount of cooling capacity needed in the application. Therefore as an example, we normalized the characteristic for each 100W of cooling capacity and to demonstrate the economics, evaluated them in a 6kW, multi transit-case, mission scenario. Figure 3 shows the results of this normalized comparison. Vapor compression systems are 3 times smaller, over 4 times more efficient, and 5 times lighter than thermoelectric coolers.

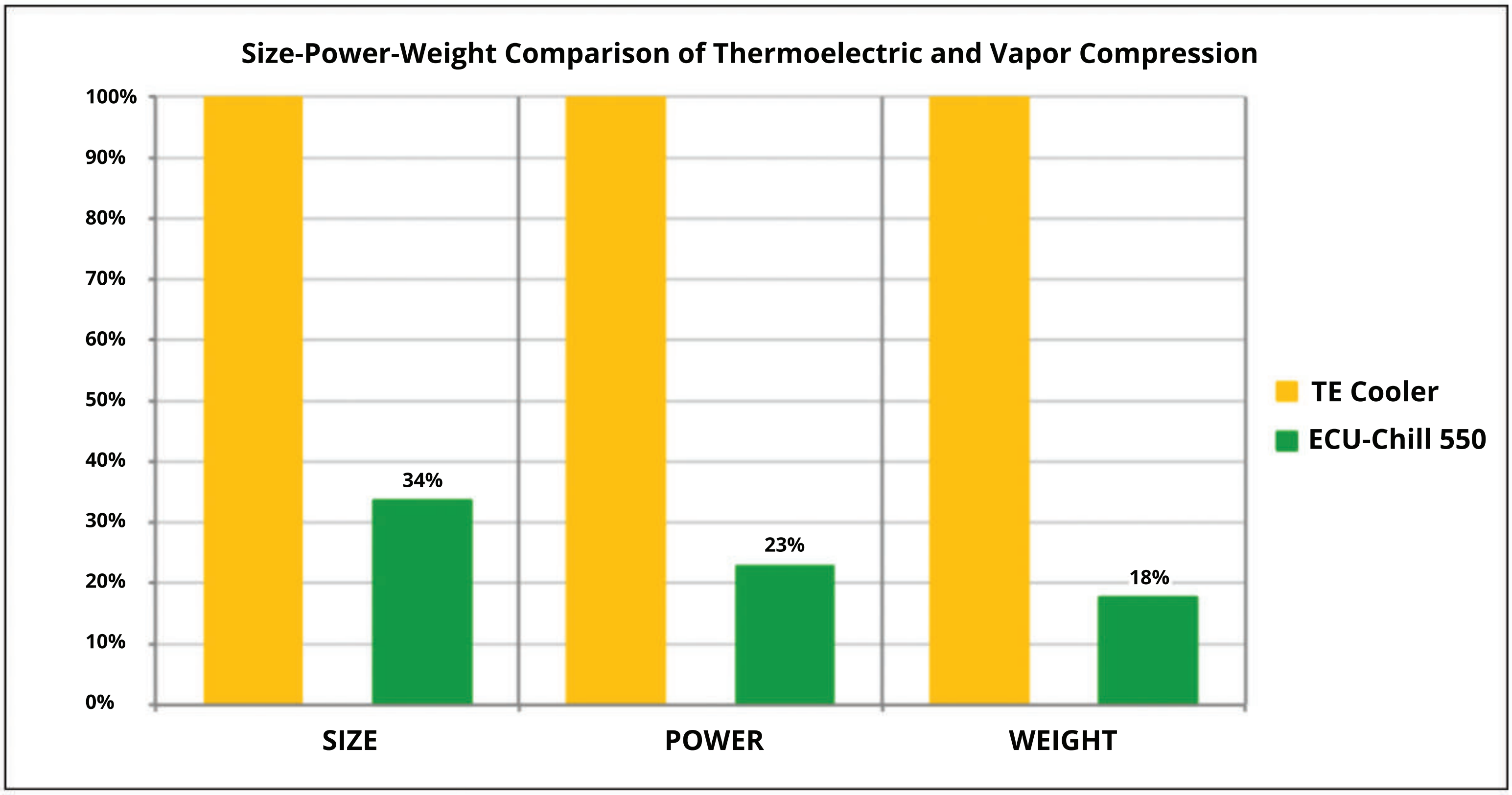

Figure 3 Vapor Compression cooling is 3 times lighter, 4 times more efficient, and 5 times lighter than thermoelectric

LIFE CYCLE COST ADVANTAGE

Perhaps the greatest misunderstanding regarding the two technologies is the great disadvantage in operating cost for TE Coolers. The technology is inherently inefficient by a factor of six. System integrators may consider the need for the larger power requirement, however few have been as concerned with the cost of fuel to operate the system over its life. To assess the functional implementation of the two technologies in a system that meets the requirements of a simulated military mission we assumed a field command post mission requiring 6 kilowatts of cooling for its electronics.

The scenario represented in Table 2, necessitates more than twice the number of TE Cooling units to meet mission requirements. They are considerably larger in weight, volume and power needs, but the initial cost is considered a disadvantage for ECU-Chill. However, when one considers the need for more TE Coolers and the increased cost of power to operate these units over the mission duration, the significant advantage of ECU-Chill is readily evident. Figure 8 presents these costs over a 1000 hour mission. While ECU-Chill has a capital cost disadvantage of $6,083 in normalized capital cost its operating cost saves an estimated $187,000 in a thousand hours. This estimate is based on an in-theater delivered fuel cost reported by the U.S. Army Mobile Electric Power Program Office of $14.33 per gallon.

Table 2 Field Command Post with 6KW Cooling Requirement

	TE Cooler (440 W)	ECU-Chill 550
Cooling Required (W)	6,000	6,000
Purchase Cost ($)	64,000	70,083
Number of units	20	9
Total Weight (lbs)	1,000	180
Total Volume (in^3)	28,940	10,035
Power Draw (W)	14,286	3,228
Total Cost at 1000 hr	$313,751	$126,509

While mission fuel costs may vary the advantage of ECU-Chill remains. At the estimated cost of fuel in this scenario the six-thousand dollar capital cost disadvantage is erased in merely 32 hours of field operation.

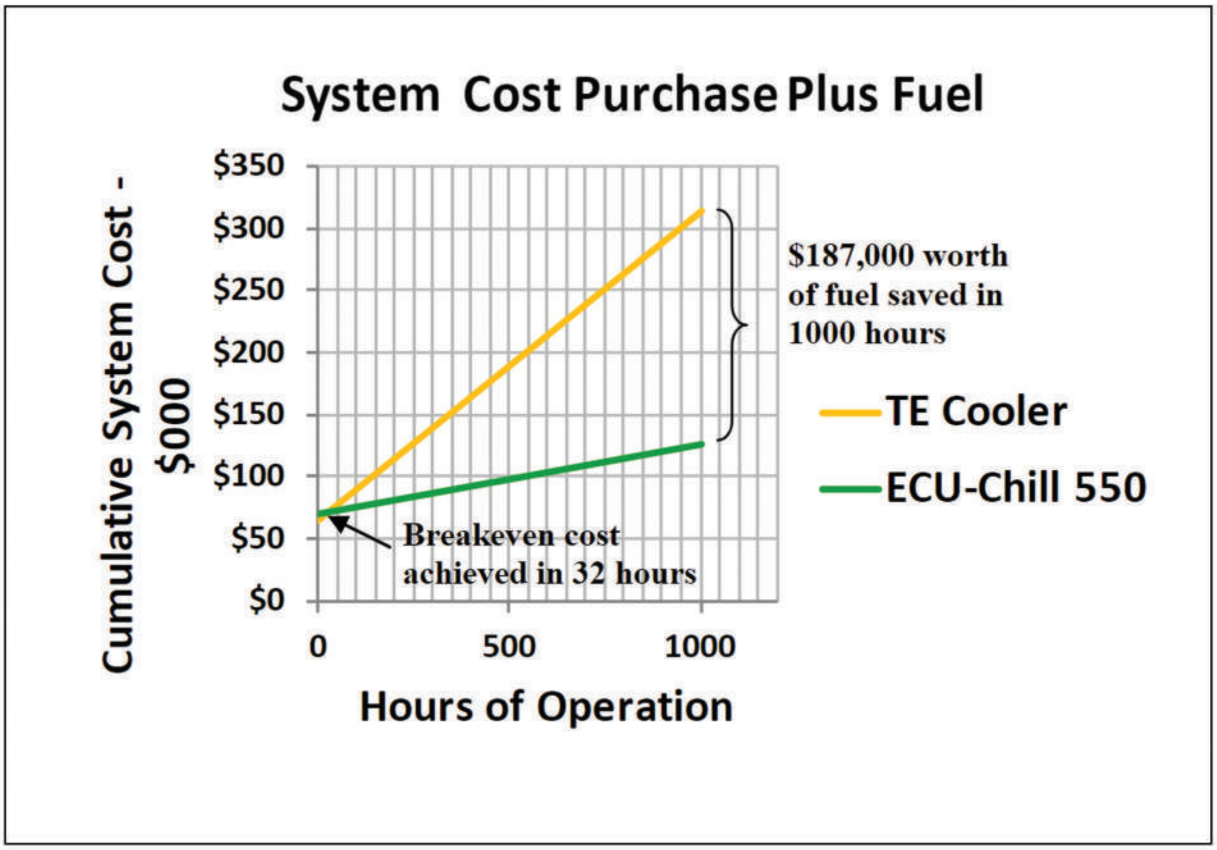

Figure 4 ECU-Chill provides significant energy cost savings in field operation.

CONCLUSIONS

Vapor compression technology has been shown to have significant advantages in size, weight, power consumption and cost. The technology described herein is the same as that used in our kitchens or room air conditioners. The difference is ECU-Chill is both miniaturized and ruggedized for the harsh military environment. ECU-Chill has proven its field operational capabilities with high reliability and durability, (it has a MTBF of over 90,000 hours). It uses environmentally friendly R134a refrigerant, and has no need of maintenance other than an occasional cleaning of the condenser coil when exposed to harsh environments. This paper describes the many reasons why vapor compression refrigeration is in use globally for cooling. It is inherently efficient and effective in providing below ambient temperature cooling. Thermoelectric coolers have a role in niche applications, just not for long-term bulk cooling. For cooling requirements above 100 watts, vapor compression refrigeration is a superior choice for SWAP+C sensitive programs.