"2U Rack Mountable Vapor Compression Cooling System for High Power Electronics"

Glenn Deming, Ronald Wysk, and Kang P. Lee, PhD, Aspen Systems, Inc.

Vapor compression refrigeration has long been used to cool telecommunications equipment and some high performance computers. On the whole however, its usage has been confined to high-value, relatively large, and stationary applications. The advantages of vapor compression cooling (VCC) systems are fairly well known. They can provide heat sinks at below ambient temperatures[1], remove large amounts of heat using relatively low power, and can protect electronic components from overheating. Additionally, at low temperature, reliability improves and microprocessors run at faster speeds. Historically though, VCC systems have had difficulty fitting within the space limitations of a small electronics chassis[2]. The challenge has been to create a small but powerful enough system for electronics systems.

A major obstacle to building small VCC systems was the absence of commercially available and affordable miniature refrigeration compressors in the fractional-kilowatt range that would fit within a small space. Recently, such a compressor has been developed and become available[3] that is only 5.6 cm in diameter, 7.6 cm high, and weighs only 630 g. A photograph of the mini-compressor is shown in Figure 1. The compressor is a rotary design with a rolling piston driven by a sensorless brushless DC motor running at 24 V DC.

Figure 1. Miniature Refrigeration Compressor

The use of this compressor was recently evaluated in an application that had been using a rather large thermoelectric cooler (TEC) in a mobile satellite antenna electronics case for the U.S. Army. The TEC unit positioned on top of the case weighed 25 kg necessitating a separate transport case for moving and had insufficient cooling capacity in many operating conditions. Utilizing the miniature compressor, a compact VCC Electronics Cooling Unit (ECU) system that can slide into a standard 48 cm wide and 2U high electronics rack was developed as shown in Figure 2. The specifications for the 2U Rack mounted ECU is shown in Table 1. The replacement 2U rack-mounted ECU was to deliver 500W (J/s) of cooling and 800W (J/s) of heating to satisfy the requirements in all

operating conditions. Figure 3 shows the same antenna electronics case with the new VCC system mounted inside.

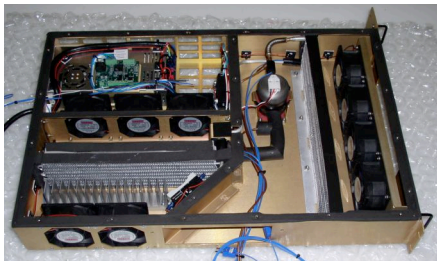

Figure 2. 2U Rack Mountable VCC Refrigeration System incorporating new miniature compressor

Figure 3. Mobile Satellite Antenna Electronics Case with the Rack Mounted Cooling System inside

The ECU was designed as a sealed forced air system, where the outside airstream for the condensor was isolated from the recirculating inside air to cool the electronics components. The vapor compression cooling system layout is shown in Figure 4. In addition to the miniature refrigeration compressor, it consists of the following custom and off-the-shelf components: evaporator heat exchanger, condenser heat exchanger, power supply, relays, fans, heater, and mounting board.

Parameter	**Specification**
Space Volume	8.8 cm x 45 cm x 61 cm
Weight	11 kg max.
Cooling Load	500 watts
Heating	800 watts
Ambient	-30ºC to +60ºC
Power Available	120 VAC, 60 Hz
Internal Air Temperature Range	0ºC to +50ºC
Maintenance	Easy Access for Cleaning
Sealing	No Leakage Into Electronics Compartment

Table 1 Design Specification for ECU[3]

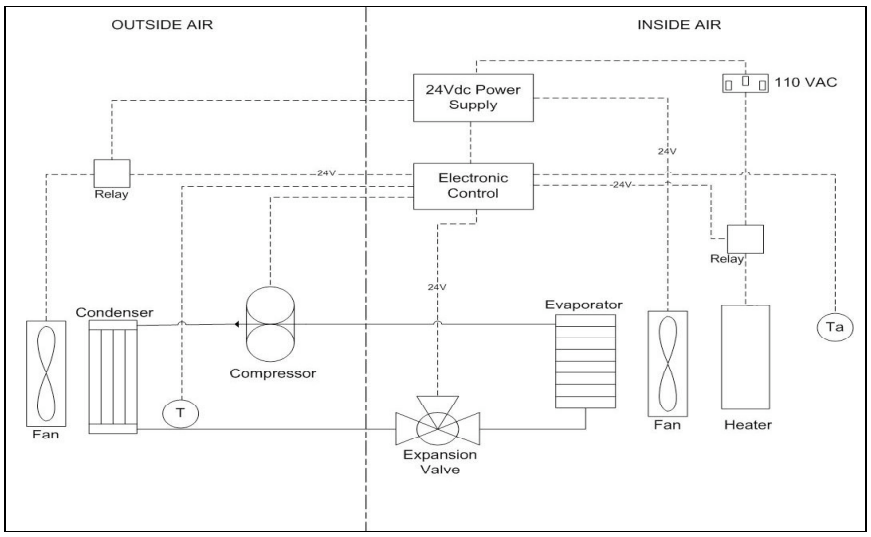

Figure 4 Layout of Refrigeration Components for ECU

Due to space limitations, the design also employed other high performance components including custom designed evaporator and condenser heat exchangers. In order to keep the condenser's heat transfer surfaces clean from airborne particulates, an air filter was included in the sealed air system. The satellite communications unit was intended for use in outdoor environments with wide ranging ambient temperatures, severe dust, driving rain and other severe and stringent conditions required for military operation.

A battery of tests were performed under simulant conditions to evaluate the performance of the Antenna Electronics Case of the new unit. Figure 5 illustrates some of the thermal load measurements taken during these tests, which ranged from just over 100 watts to just under 500 watts. Although the data shows lower performance with the air filter in place as expected, the cooling system still provided adequate cooling to maintain the electronics case at safe temperatures.

A separate set of tests were also conducted in order to simulate the severe outdoor conditions of a desert environment. The testing subjected the electronics equipment case to an ambient temperature of 50ºC and 1,000 Watts per square meter (W/m^2) solar radiation, intended to represent the most stringent conditions on the earth's surface. Those tests performed for the Army demonstrated that the VC cooling system was able to maintain the electronic components within safe operating temperatures, even in the harshest conditions.

The vapor compression cooling unit designed for this project was substantially smaller and lighter than the legacy system, a thermoelectric cooler (TEC) that it replaced. As shown in Table 2, the cooling capacity of the VCC unit was higher than the TEC unit (500 vs. 350 W), and its COP was substantially higher (2.94 vs. 0.32). One of the key performance parameters in an electronics cooling application is the power density, or cooling capacity per unit volume or per unit weight. As shown in Table 2, the power density of the VCC unit on either a weight or volume basis is excellent.

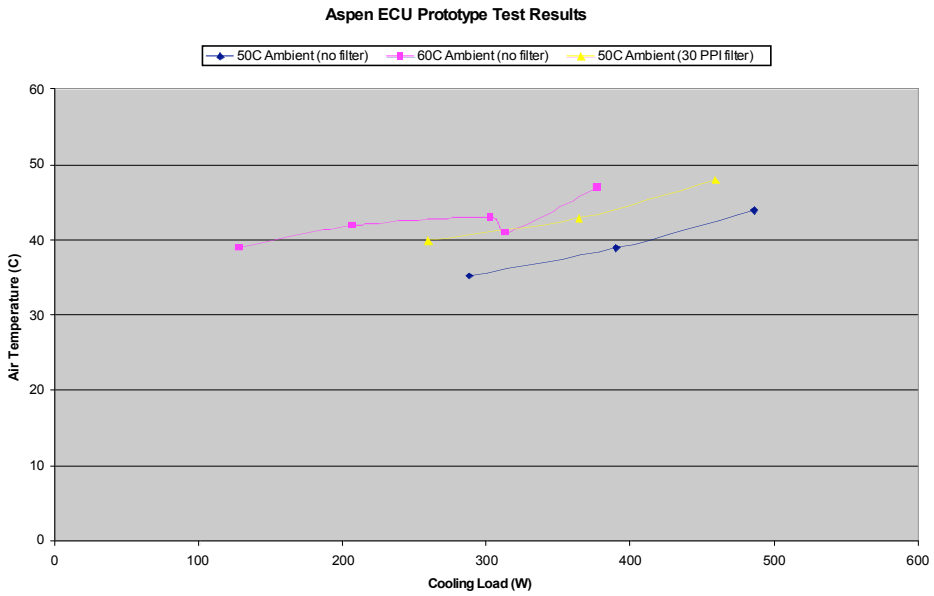

Figure 5 Cooling Load Versus Ambient Temperature[4]

ATTRIBUTE	CASE 1	CASE 2*
Technology	Thermoelectric	Vapor Compression
Weight, kg	26 kg + 9 kg Case	10 kg
Volume	Top 2U + External Case	Top 2U
Configuration	Top Through Mount	Rack Mount
Cooling Capacity, Watts @ 50ºC	350	500
Heating Capacity, Watts	800	800
Cooling Power Draw (Max), Watts	1,100	170
Heating Power Draw (Max), Watts	800	800
Air Temperature Control Precision, ºC	+/- 4.5 deg.	+/- 1.2 deg.
Coefficient of Performance (COP)	0.32	2.94

* Data shown includes VC Cooling Unit and separate Resistance Heating Unit

Table 2 Performance Comparison VC and TE Cooling in SatCom Transit Case

Refrigeration-based cooling is reliable and has been proven over many decades of use. It can lift high heat loads with a high COP. What has been demonstrated[5] here is a robust miniaturized refrigeration system, one with a unique size to fit a 2U rack with a cooling capacity of 500 watts. Although long term reliability has not yet been demonstrated, it can be concluded that a compact and rugged VC cooling system is able to protect microelectronics even under severe military environments.

References

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