Temperature Control in Electronics INTELEC® 2008

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Abstract - **Zomeworks has manufactured thousands of passively cooled outdoor battery cabinets. Heat is radiated from the plenum lid of the cabinet to the night sky which cools water that then accepts heat gain during the day from the batteries and the environment**

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Electronics can be cooled in the same way but usually the heat load is too great to be dissipated by radiation and convection from the lid alone. In the past few years we have done extensive work on cooling higher fluxes, several watts per square foot of cabinet floor, by using various vertical radiators with inner water storage. Vertical PVC pipes, flattened above their exit from the cabinet proved good radiators, as did round pipes with central floats. In both cases the part of the pipe inside held the water cooled at night. Good performance was achieved but we worried about the lifetime of the exposed PVC pipes.

Our next experiments were with 3' x 4' external vertical steel plenums plumbed to 20 gallon tanks inside the cabinets. This has proven to be a satisfactory cooling method for fluxes of up to 20 Watts per plate when the temperature inside the cabinet is allowed to approach the daytime high temperature. The performance is determined by:

1. The resistance of the outside radiators to heat loss to the ambient air and the cold sky.

2. The circulation of heat transfer fluid – usually plain water thermo-siphoning from inner tanks to the outer plenums, and

3. The resistance the heat encounters in moving from the equipment to the water tanks in the enclosure. Here, radiation, having the equipment "see" the tanks, proves important, as well as free convection of air about tanks and electronics.

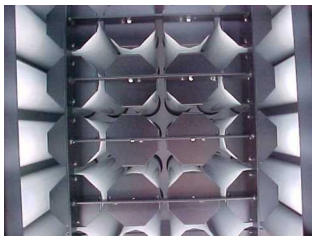
Circulating fans within the cabinet can greatly reduce temperature rise between inside air and tanks. Our tests continue, using plastic mat radiators. As fluxes increase, but roof area remains constant, convection plays a greater and greater role in heat loss.

Prototype Quill Cool Cell with Flattened Radiators above the Lid

PASSIVE COOLING OF ELECTRONIC CABINETS AND SHELTERS

High Flux Cool Cell - Zomeworks High Flux Cool Cell® Temperature Regulating Enclosures (US Pat. No: 6357512B1, 5609200, 5316872, 5513696) were first used to cool batteries. The enclosure is well insulated. An internal water reservoir is connected to a hollow plenum radiator lid on top of the enclosure. Night radiation chills the water in the tank below at night. There is no circulation during the day as the lid warms. The cabinet stays cool during the day. Batteries on float charge don't dissipate much heat and the lid of the cabinet, radiating to the sky is able to keep batteries below the average night and day temperatures. Even in the hot southwestern USA deserts battery Cool Cells rarely rise above 30°C.

Quill Cell Cool Cell Enclosure for US Navy In California's Desert.



View Looking Up at the Quills from Inside the Cabinet

We are now cooling electronic equipment. The electronics produce more heat than the batteries, but are able to tolerate higher temperatures. Our usual requirement is to keep the electronic equipment below 40°C or 45°C.

Rated by the footprint, the battery boxes have only about a Watt per square foot (10 watts per square meter) of inner heat production.

Cool Cells for electronics can have five or ten times as much heat per cabinet floor area. To get rid of these greater fluxes we sometimes make the upper walls of the cabinet a plenum with water circulating by convection to tanks below. Walls are not as good as roofs at radiating heat because half of their view is the warm earth while the lid sees only the cold sky.

After we exhausted the lid and the walls as radiators, we changed our tactics and now make rows of vertical cooling plenums above the enclosure. These dissipate heat principally by convection. The plates are 6" apart. The inside plates don't radiate as effectively. They do not see sky or earth, only their neighbor. A rule of thumb is this cuts the heat dissipation in half. The end plenums run much cooler than the center plenums.

Typically plain tap water is used in the Cool Cell, whether for batteries or electronics. Plain water, because it has maximum density at 4°C (39°F) shuts off the cooling cycle at about 8°C which suits most applications. Occasionally we'll use a light solution of anti-freeze when there is high heat dissipation by the equipment, a low upper temperature limit and the likelihood that the enclosure would overheat if the radiators froze and convection stopped.

All components are freeze tolerant. Quilted 14 gauge steel plenums flex on freezing, but do not rupture. Rubber heater hose easily withstands freeze / thaw cycles and the inside tanks are low density polyethylene which can also freeze.

Our high flux cooling system is modular, consisting of one 20 gallon tank, one 3' x 4' vertical plenum radiator and the interconnecting hoses. They are installed on the lid of the enclosure on 6" centers and are suspended above the electronic equipment. A typical system is 3 to 12 modules, depending on the heat load. Each tank is 38" x 30" x 4" thick. The plenum radiators are connected at the top to a common tank for easy filling.

For ease of draining, the tanks below are interconnected with a common drain. Fluid flow through the radiators is powered by convection. Two hoses pass from the two lower corners of the radiators to the upper corners of the tanks. We use symmetry because we discovered if we connected the top of the tank to the top of the plenum and bottom to bottom, as one would expect, the system would occasionally flow backwards, very slowly, which effectively shuts off all cooling. Backflow is a puzzling phenomenon. It rarely occurs, but even once is too often. Symmetrical plumbing makes backflow impossible.

Trailer Mounted High Flux Cool Cell for Joshua Tree National Park Interior Showing Tanks, Radiators and Equipment Space

Mobile Air Quality Monitoring System for Joshua Tree National Park
Seven Radiating Tanks

260 Watt High Flux Cool Cell Enclosure Test for ARAMCO Pipeline in Saudi Arabia. It Has 10 Radiators and 10 Tanks. These Have Been In The Field In Saudi Arabia For Three Years.

Each modular system as described can handle 20 watts of heat and not exceed the daily high temperature if the diurnal temperature difference is at least 20°F.

If the electronic equipment could be coupled directly to the water, the equipment could be kept 5 to 10F cooler than the air inside. Heat transfer by water is at least 50 times as effective as air. We have the cool water ready to go to work

Electronics and water don't mix. Many engineers don't like the idea of having water in the same cabinet as their electronics, much less plumbing it through heat sinks. Electronic parts thus suffer heat in private, insulated by air, unable to touch the water that could effectively cool them.

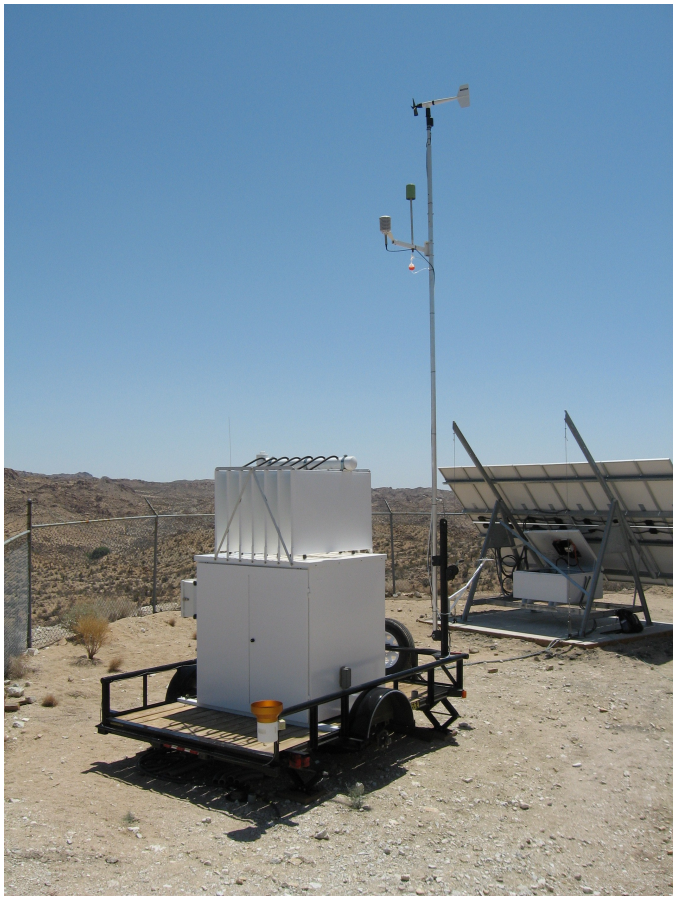
From our tests we use a rule of thumb: For the cooling modules described to avoid inside temperatures rising above the daily high temperature, do not load more than 20 Watts per tank and plenum module. This assumes a daily outdoor temperature difference of at least 20°F between highs and lows, and that the cabinets are kept pure white.

High Flux Cool Cell, Mono Lake, California

The High Flux Cool Cell in the Joshua Tree National Park has been in use for almost three years. This cool cell contains seven, twenty gallon internal tanks, which are connected to seven external radiator fins. Two electronic devices are stored in the bottom equipment space of the cool cell which produces a 150 Watt load 24 hours a day seven days a week. An additional 150 Watts is produced every day for a period of one hour.

This site at the Joshua Tree National Park is monitored by the National Park Service Air Resources Division. For the past three years, temperature data has been collected from the High Flux Cool Cell as well as the surrounding ambient temperature. The ambient temperature was recorded with a thermocouple placed on a mast, located about ten meters above the ground. Usual temperature readings are recorded at ground level which would indicate higher high temperatures and lower low temperatures.

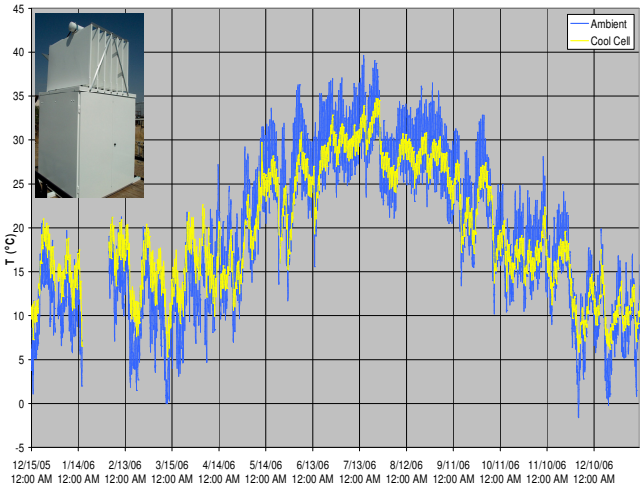
Trailer Mounted High Flux Cool Cell for Joshua Tree National Park
Interior Showing Tanks, Radiators and Electronic Equipment



Trailer Mounted High Flux Cool Cell for Joshua Tree National Park
Showing Trailer and Mast with Temperature Sensors

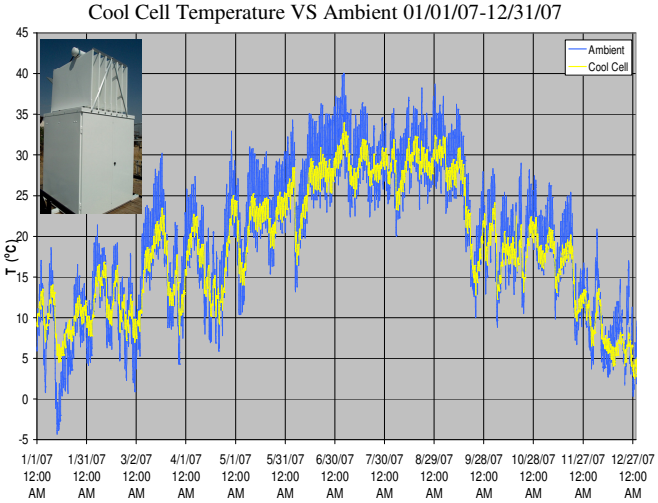
The data recorded by the National Park Service Air Resources Division was sent to Zomeworks and plotted. The results of the data show the temperature of the cool cell staying above the ambient temperature in the colder months and below the ambient temperature in the warmer months.

Joshua Tree National Park
Cool Cell Temperature VS Ambient 12/15/05-12/31/06
System Consists of 7 x 20gal Water Tanks and 7 Radiators
Loading Consists of 150W 24hr/day
with additional 150W - 1 hr/day (@10am)



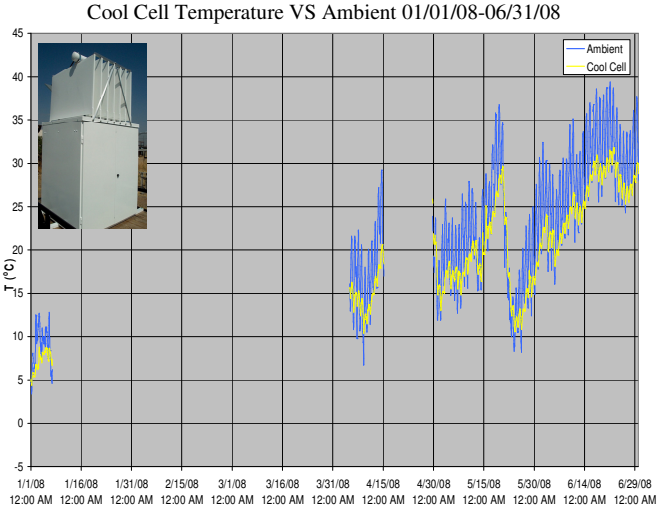
Trailer Mounted High Flux Cool Cell for Joshua Tree National Park
2006 Cool Cell Temperature VS Ambient

Cool Cell Temperature VS Ambient 01/01/07-12/31/07



Trailer Mounted High Flux Cool Cell for Joshua Tree National Park
2007 Cool Cell Temperature VS Ambient

Cool Cell Temperature VS Ambient 01/01/08-06/31/08



Trailer Mounted High Flux Cool Cell for Joshua Tree National Park
2008 Cool Cell Temperature VS Ambient