THE PERFORMANCE OF THERMOELECTRIC HEATING AND COOLING SYSTEMS FOR BATTERY ENCLOSURES

By Thomas A. Oravetz
Champion Products Inc., 489 Evergreen Road, Strafford, MO 65757

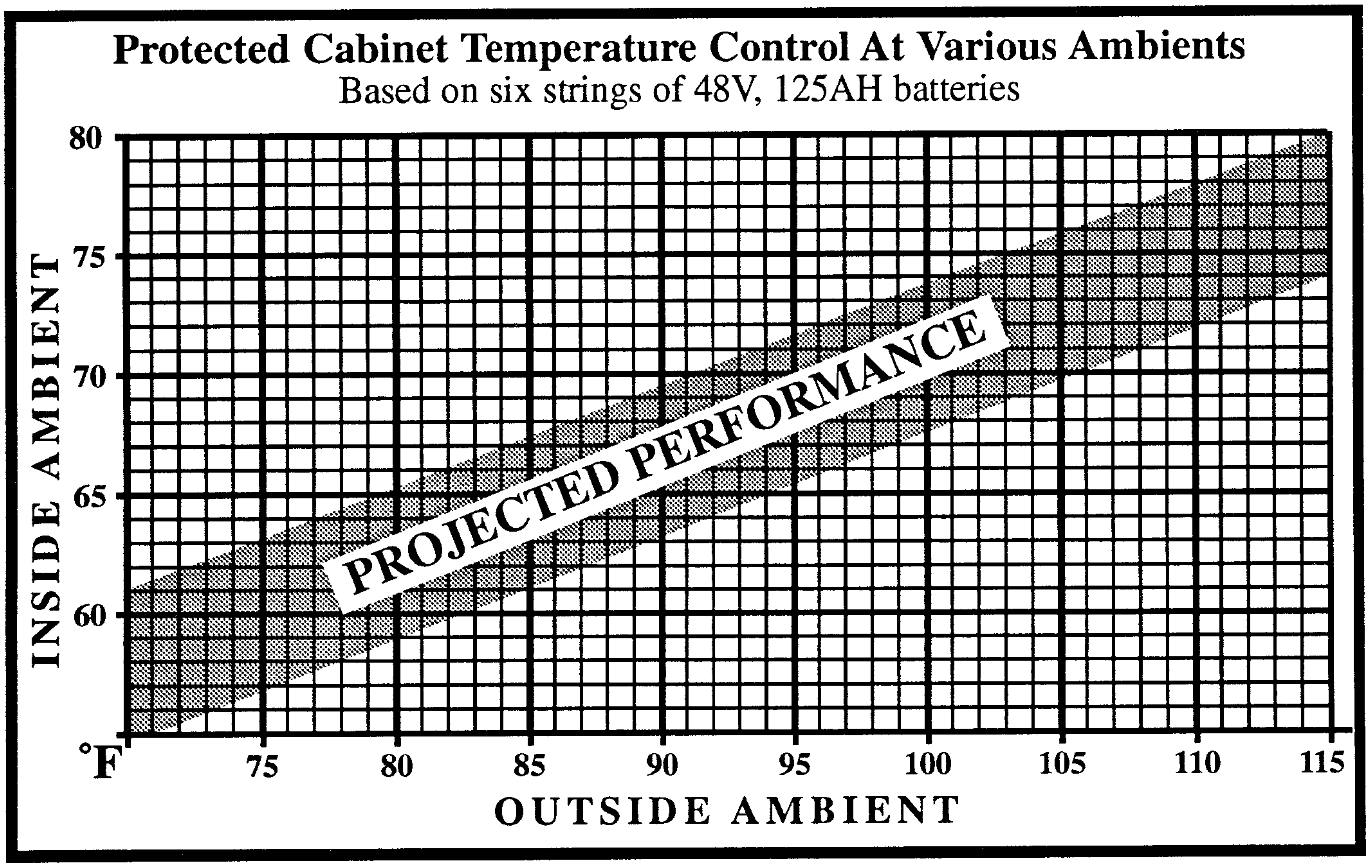
Among other limiting factors, heat experienced by the battery has a direct effect on it's life. As always, heat is either the catalyst or cause of failure. Until the past year, the means to control and regulate the environmental temperature of a battery enclosure and ensure the reliability and life of standby battery power has included air conditioning, underground vaults, fans, passive systems, simple convection, and benign neglect.

Now, a solid state 'heat pump' system using thermoelectric principles is available. The system is equipped with a programmable microprocessor having four 'trigger points' for on and off control of both heating and cooling. It operates on 120v at 3 amps or less. That, and a wide non-powered passive range of 50° to 75°, results in very low operating costs. Additionally, as is required of any battery enclosure, a safe means of venting hydrogen gas is provided. A picture of a typical battery enclosure equipped with the system is shown in Appendix A. A representative single line sketch of an effective thermoelectric module can be referred to in Appendix B. The sophistication of combining these three simple elements into a system is what proved to be patentable.

Projected Temperature Control of the System

The projected temperature control of the system is illustrated in Figure 1 below. The system consists of a standard module rated at 190 watts, mounted on a standard cabinet capable of holding a maximum of six (6) strings of 125AH batteries. A simulated battery heat load of 25 to 40 watts was placed in the cabinet. Excess capacity of approximately 25% was designed into the system to ensure that acceptable (less than 77°) temperature levels are maintained under even adverse and exceptional microclimates. The graph is based on multiple tests at ambients ranging from 80° to 115°. Each test was performed at constant temperatures for at least 24 hours. Performance under test conditions was considered satisfactory.

Figure 1.



FLORIDA PERFORMANCE

Florida test site performance is described in Figure 2 below. A thermally protected cabinet was installed adjacent to a standard 'unprotected' cabinet. The standby batteries were removed from the 'unprotected' cabinet and placed on float in the thermally protected cabinet. The microprocessor control was programmed to bring cooling on at 70°. Ambient and both internal cabinet temperatures were recorded simultaneously. Figure 2 represents the maximum temperatures of each.

The unprotected cabinet averaged a maximum of 106.4° with a temperature fluctuation of 22.7° at an ambient average of 93.5°. The thermally protected cabinet averaged a maximum of 70.6° and a temperature fluctuation of only 9.4°. Both the maximum temperature and total temperature fluctuation were effectively controlled.

Figure 2.

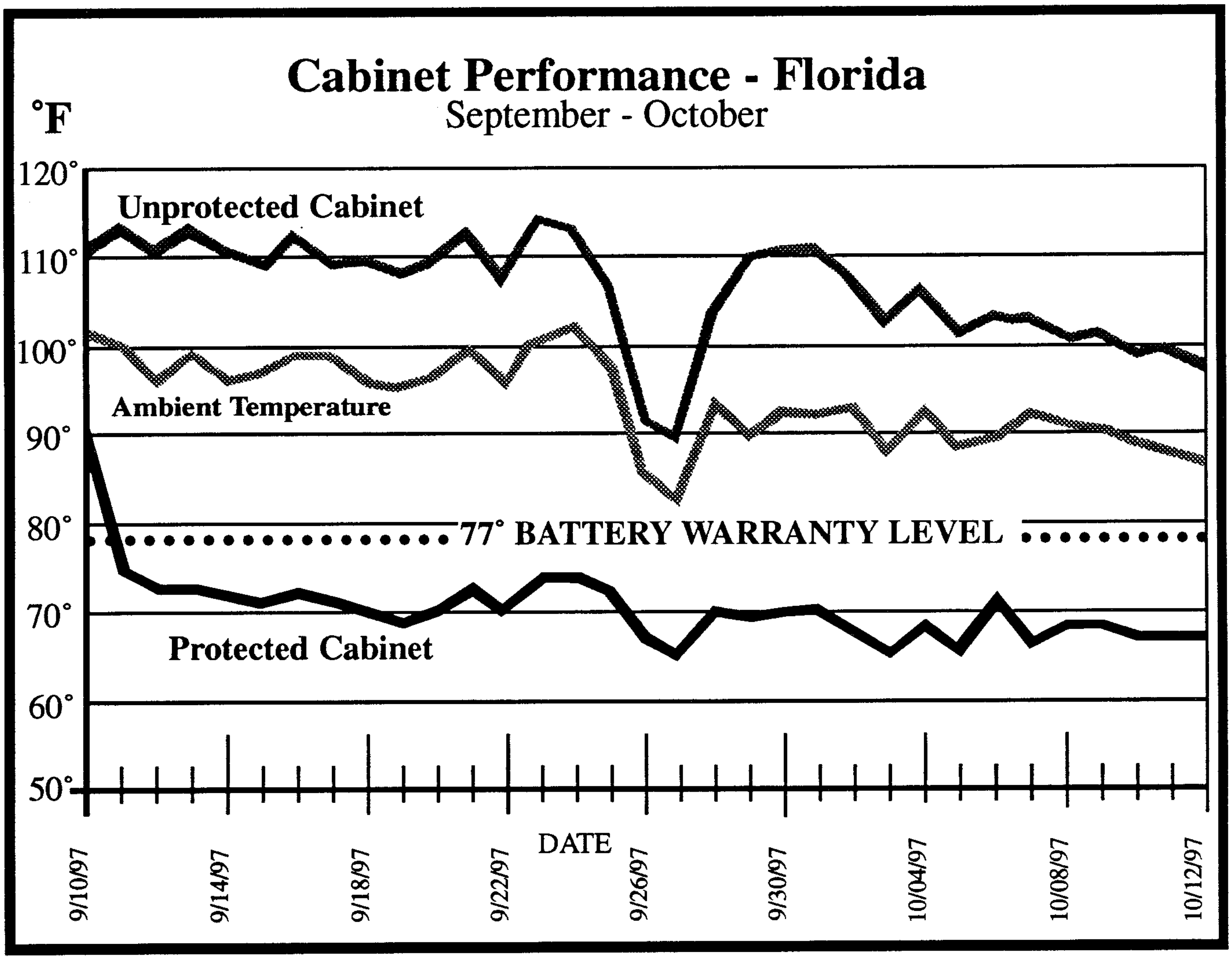
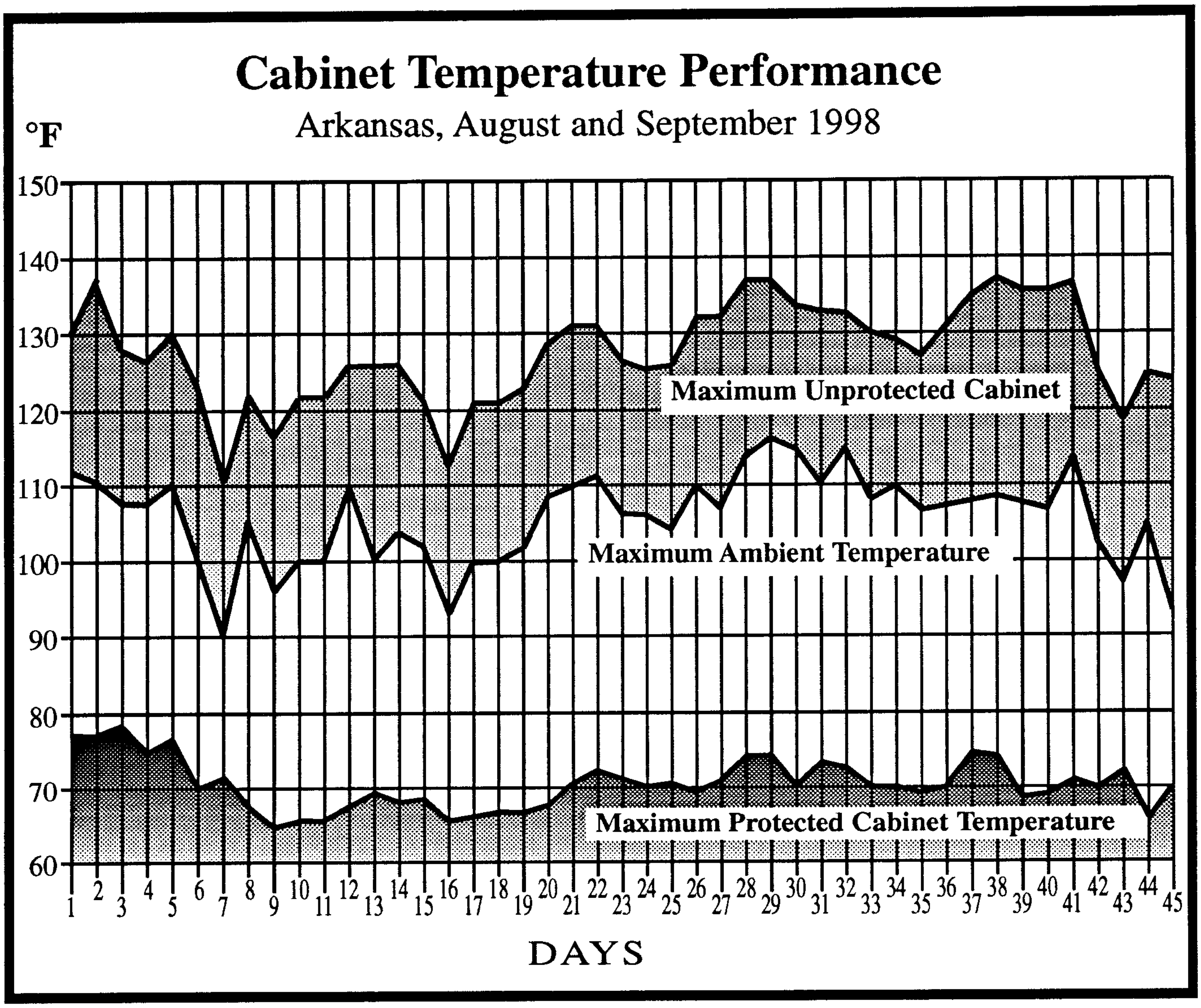


Figure 3.



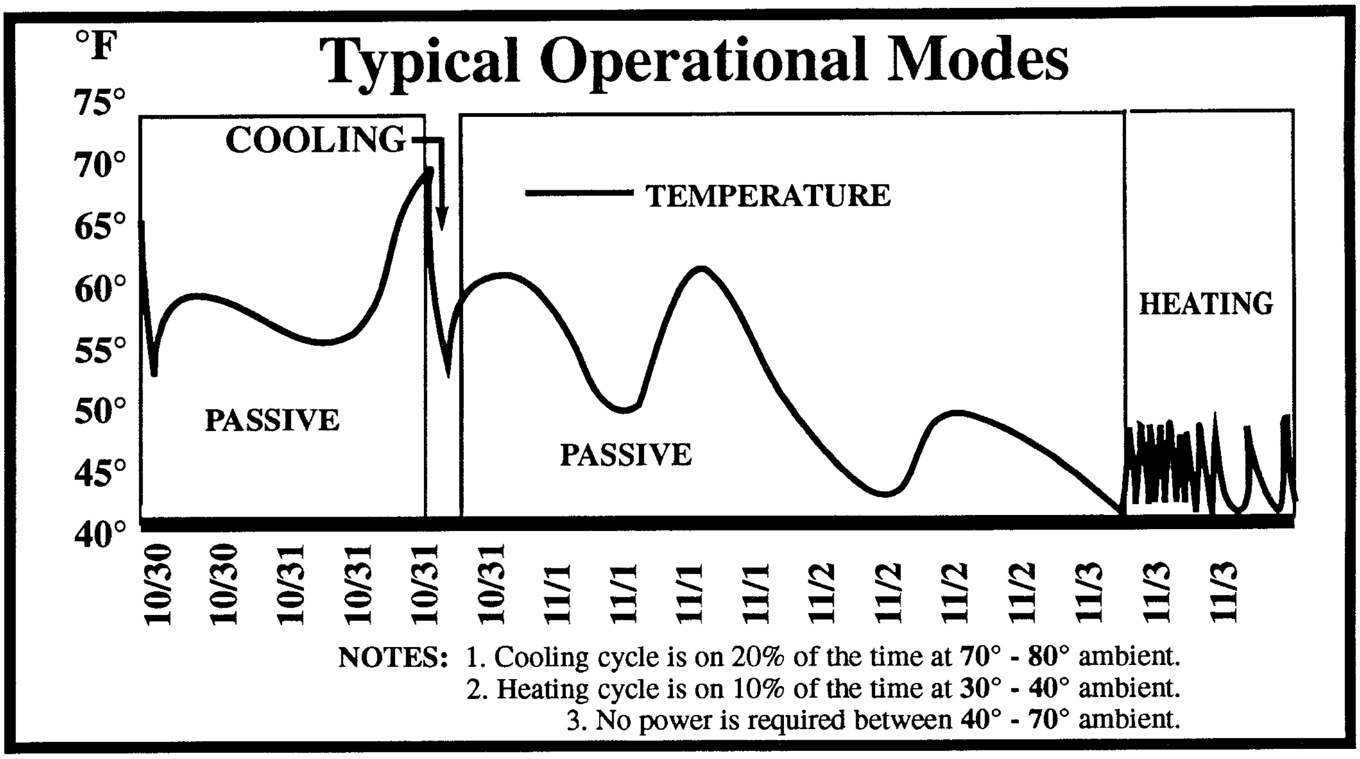
ARKANSAS TEST PERFORMANCE

Arkansas performance at ambient temperatures exceeding 110° is described in Figure 3 above. As in the Florida test, the thermally protected enclosure was adjacent to the unprotected cabinet. The batteries were removed to the protected cabinet. The default settings of the controls were the same as in the Florida tests. At maximum ambients of 114°, the unprotected cabinet reached 137°, while the thermally protected cabinet reached only 75°. It is evident that another advantage of the system is its increased efficiency at temperatures approaching 100°.

MICROPROCESSOR CONTROL

A programmable microprocessor control is contained in the sensor probe. The probe is attached to the module by a light gauge wire and is the only component of the heating and cooling system which intrudes into the battery compartment. The control uses proprietary software to program 4 settings for heating and cooling. On and off default settings for cooling are set at 75° and 65° respectively. On and off default settings for heating are set at 50° and 65° respectively. This reserves a temperature range of 50° to 75° as a passive temperature range requiring neither heating nor cooling. **Therefore this temperature range requires no power as shown in Figure 4.**

Figure 4.

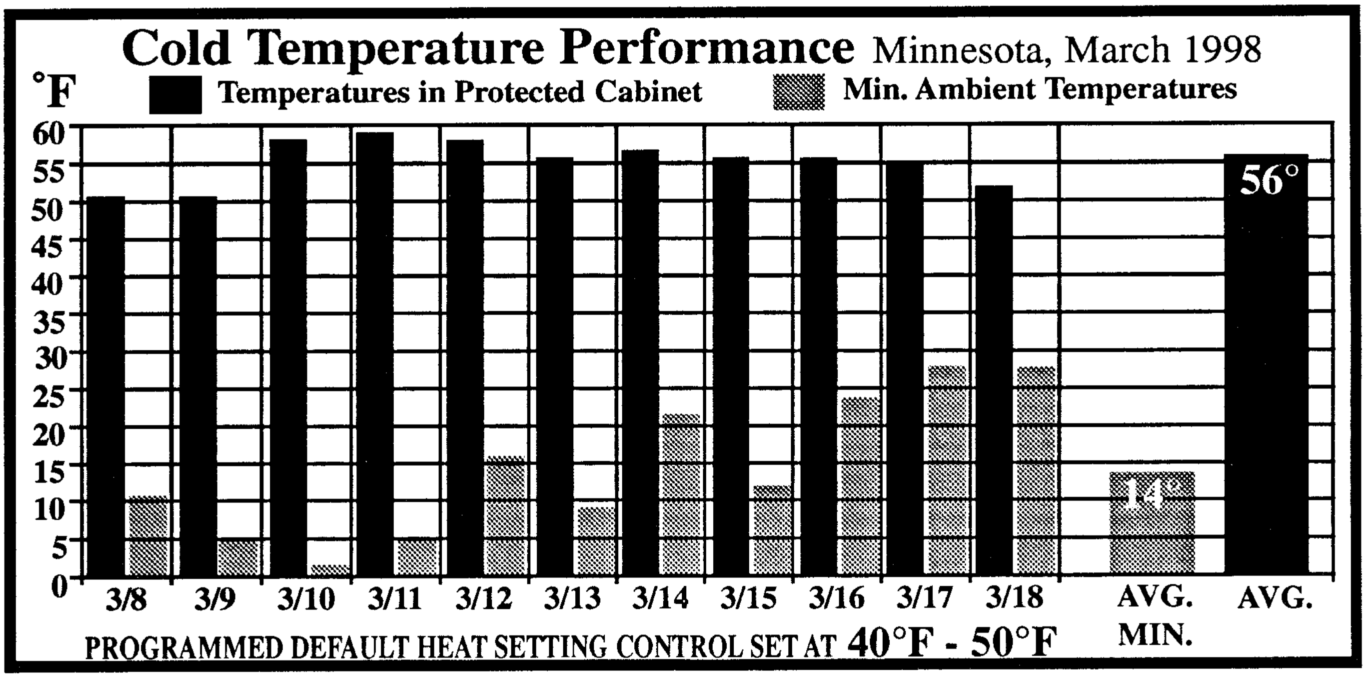


NOTES: 1. Cooling cycle is on 20% of the time at 70° - 80° ambient.
2. Heating cycle is on 10% of the time at 30° - 40° ambient.
3. No power is required between 40° - 70° ambient.

COLD WEATHER PERFORMANCE

A simple change in polarity changes the system from cooling to heating. Again the microprocessor control can be programmed to automatically heat upon temperature demand. In this case the default settings were set to bring heat on at 40° and off at 50°. With ambient averaging 14°, the cabinet was kept at an average of 56°. Heating proved to be even more efficient than cooling. See figure 5.

Figure 5. Cold Temperature Performance



OPERATIONAL COSTS

Operating costs are dependent upon three factors, current draw, power cost and duty cycle. The current draw at 120v is 3 amps maximum. Power costs can vary from area to area. For comparison at a meaningful level, $0.08 per kWh was used. Figure 6 below is a conservative estimate of costs for various regions of the country. Duty cycles of 95% maximum for cooling and 80% maximum were used. However actual performance has shown that duty cycles of 50% to 55% are more realistic. Therefore, actual annual costs are less than shown in the table.

Figure 6.

ESTIMATED ANNUAL ENERGY COST AT 8¢ PER KILOWATT HOUR

	WINTER DEC-FEB		SPRING MAR-MAY		SUMMER JUN-AUG		FALL SEP-NOV		TOTAL ANNUAL COST BY REGION
	MODE	MODE	MODE	MODE	MODE	MODE	MODE	MODE	
NORTHERN REGION	%	HRS	%	HRS	%	HRS	%	HRS	
HEATING MODE	80%	345.6	40%	172.8	0%	0	40%	172.8	
PASSIVE MODE	20%	0	50%	0	30%	0	50%	0	
COOLING MODE	0%	0	10%	129.6	70%	907.2	10%	129.6	
TOTAL HOURS		345.6		302.4		007.2		302.4	
TOTAL COST		$9.95		$8.71		$26.13		$8.71	$ 53.50
CENTRAL REGION									
HEATING MODE	60%	259.2	10%	43.2	0%	0	10%	43.2	
PASSIVE MODE	40%	0	80%	0	10%	0	80%	0	
COOLING MODE	0%	0	10%	129.6	90%	1166.4	10%	129.6	
TOTAL HOURS		259.2		172.8		1166.4		172.8	
TOTAL COST		$7.46		$4.98		$33.59		$4.98	$ 51.01
SOUTHERN REGION									
HEATING MODE	20%	86.4	10%	43.2	0%	0	10%	43.2	
PASSIVE MODE	70%	0	20%	0	5%	0	20%	0	
COOLING MODE	10%	129.6	70%	907.2	95%	1231.2	70%	907.2	
TOTAL HOURS		216		950.4		1231.2		950.4	
TOTAL COST		$6.22		$27.37		$35.46		$27.37	$ 96.42

POWER REQUIREMENTS: 3 AMPS @ 120 VAC
WATTAGE: 360 WATTS

ASSUMPTIONS

POWER COST: **8 CENTS PER KILOWATT HOUR**
OPERATING COST: 2.9 CENTS PER HOUR
SEASONAL HOURS: 2160 HRS

DUTY CYCLES

HEATING MODE:20% WITH OUTSIDE AMBIENT OF 30-40 DEGREES F
PASSIVE MODE:10% WITH OUTSIDE AMBIENT OF 40-70 DEGREES F
COOLING MODE:60% WITH OUTSIDE AMBIENT OF 70-80 DEGREES F

BASED ON PROTECTING 4 STRINGS OF 48V-125AH BATTERIES.

OBSERVED ADVANTAGES

Visible operational status
Temperature control for 24 hrs. per day
Programmable on and off defaults
Heats and cools automatically
Exact temperature control
Integral high and low temperature alarms
Solid state, 10 to 30 year life components
Non intrusive
Dust, dirt, shade,clouds and humidity have no effect
Smaller footprint
Equal or less capital cost
Passive hydrogen vent
Maintenance free
Non skilled 15 minute replacement

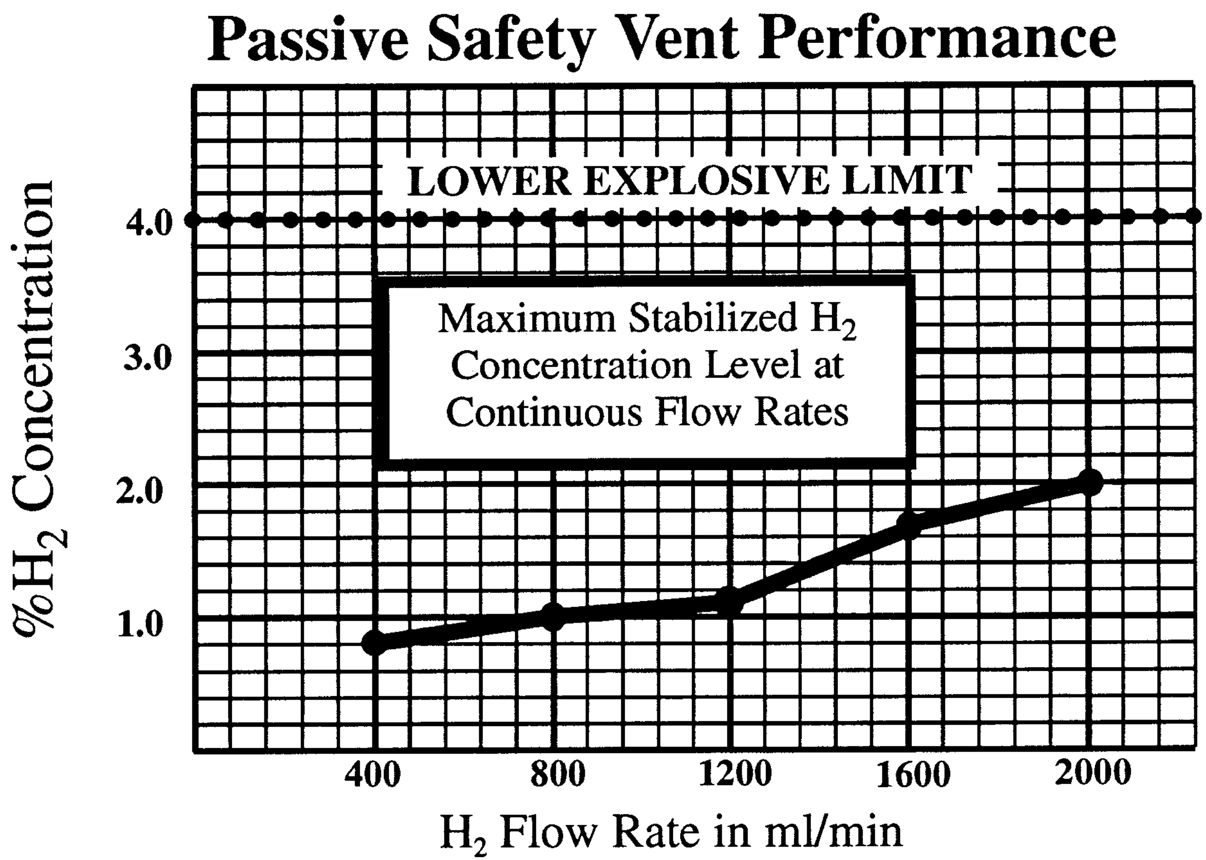
OBSERVED DISADVANTAGES

Requires 120v at 3 amps.
Annual operating costs of $25 to $96 annually

PASSIVE SAFETY VENT

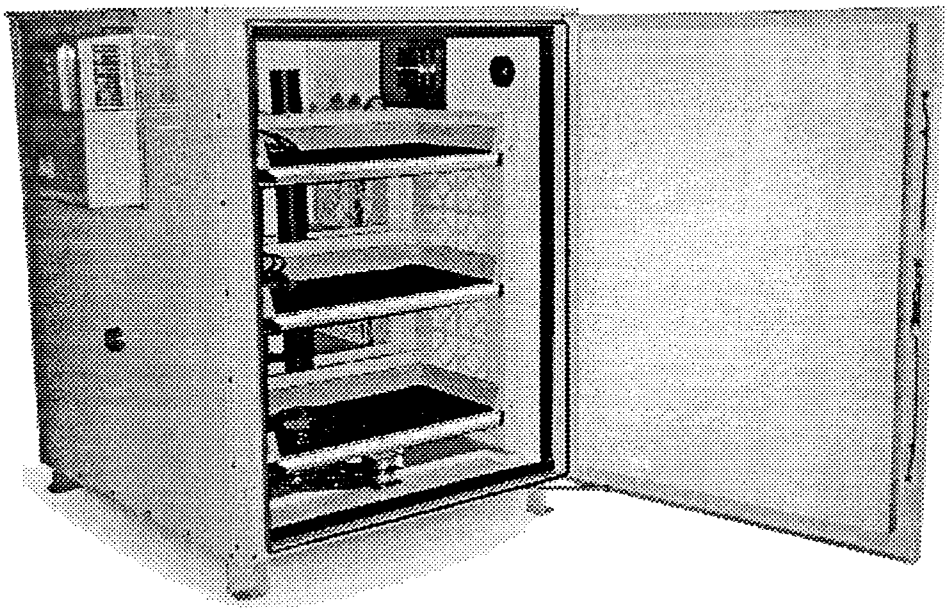
The hydrogen vent is passive and therefore is not susceptible to failure. The typical graph shown in figure 6 illustrates the hydrogen stabilization points at various flow rates, from 400 ml/min to 2000 ml/min for an enclosure large enough to hold four strings of 125 AH batteries. Typically, a vent effects temperature regulation inside the cabinet by only 1.5 to 2.0 degrees. See figure 7.

Figure 7.

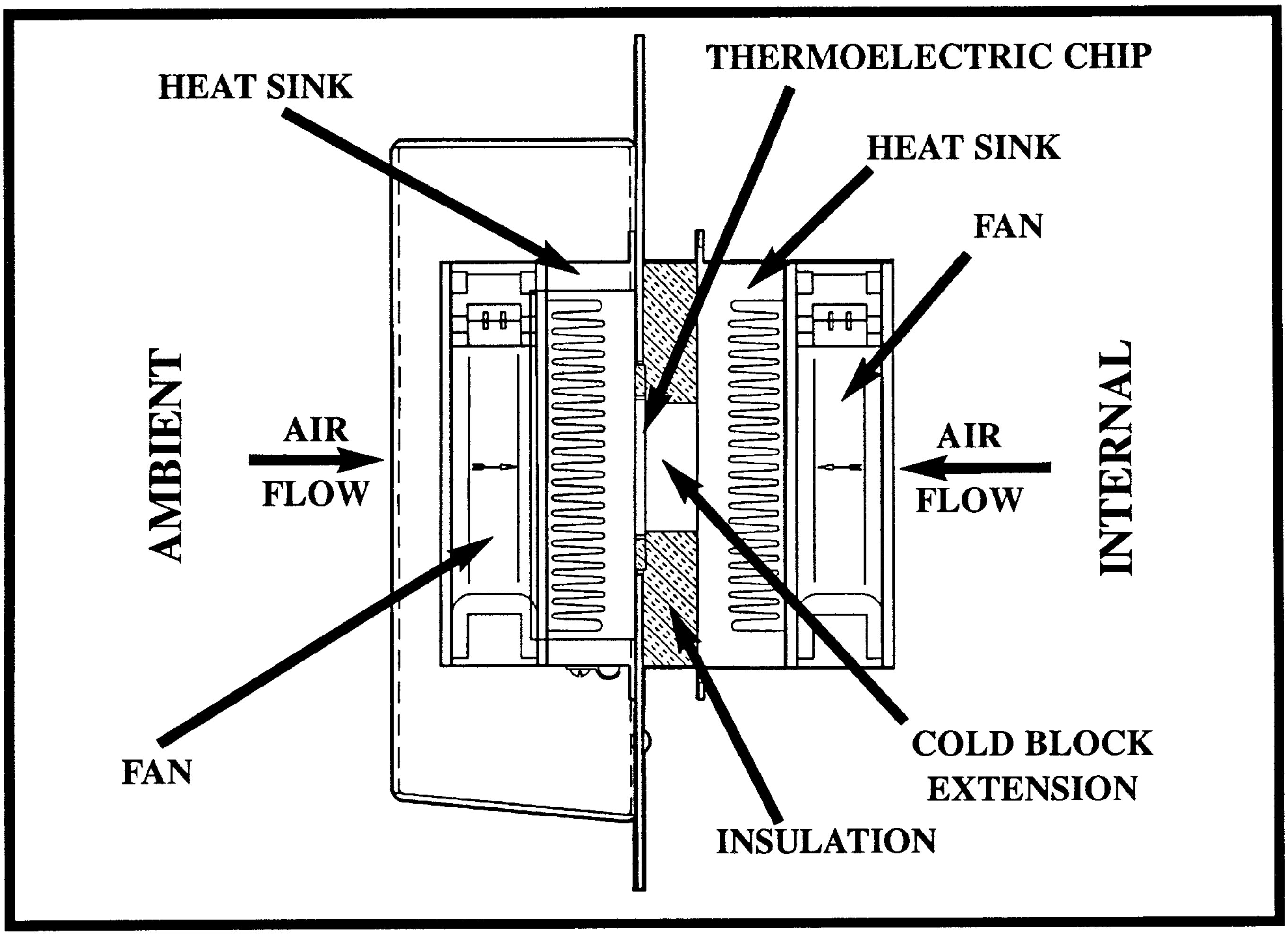


NOTES:
1. Normal gassing rate is 15cc/Hr/battery for 125 AH battery or 1 ml/min for a 48v string.
2. Tests used H_2 gas and an explosimeter calibrated for H_2.
3. Readings taken after 20 minutes stabilization.

APPENDIX "A"



APPENDIX "B"



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