Cooling Device For Non-Refrigerated Coolers Powered By Solar Energy

Department of Mechanical Engineering

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Mission Statement

To first create an easy to use prototype of a cooling device that incorporates the use of solar energy, and that will be installed and used in existing non-refrigerated coolers, which are typically used for outdoor recreational activities.

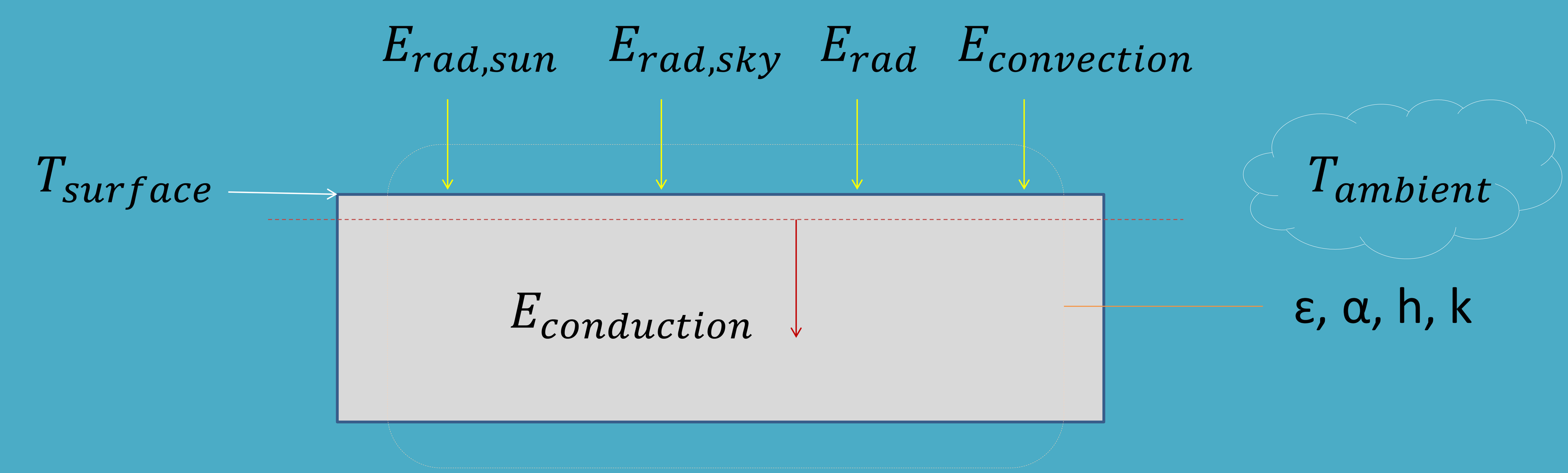
Design Objectives

1.) The cooling device will be able to cool a cooler of dimensions (22" x 15" x 17"), and the cooler can still be used without device attached.

2.) Cooling device will be in a separate, portable box, attached to the cooler by an air duct, in which the cool air will be transported by gravity into the cooler.

3.) The material used for the box will be wood and will be adaptable to sunlight, strong winds, and light rain. The design allows the material to be of day to day use, so it will be possible to make the box more durable.

Heat Transfer Analysis



Energy balance of an infinitesimally thin control volume at the surface,

$$E_{rad,sun} + E_{rad,sky} = E_{rad} + E_{convection} + E_{conduction}$$

The energy from irradiance from the sun plus sky is equal to the energy lost by radiation from the body to the environment, plus the energy lost by convection to the environment, plus the energy that is conducted through the cooler. The equation below solves for heat transfer by conduction to determine how much heat needs to be removed within the cooler.

$$E_{conduction} = \mathbf{q} = \cos(\theta)\alpha G_{sun} + \varepsilon\sigma T^4{}_{sky} - \varepsilon\sigma\, T^4{}_{surface} - h(T_{surface} - T_{ambient}) = \frac{k}{L}(T_{surface} - T_{inside})$$

$$q = \left(\frac{0.0350}{0.0375}\right) \times (346 - 283) = 58.8\ \frac{W}{m^2}$$

Since there will be conduction on 5 sides of the cooler, disregarding the bottom surface, the area is needed to determine the energy removed. The dimensions of the cooler are L = 22'', W = 15'', H = 17''.

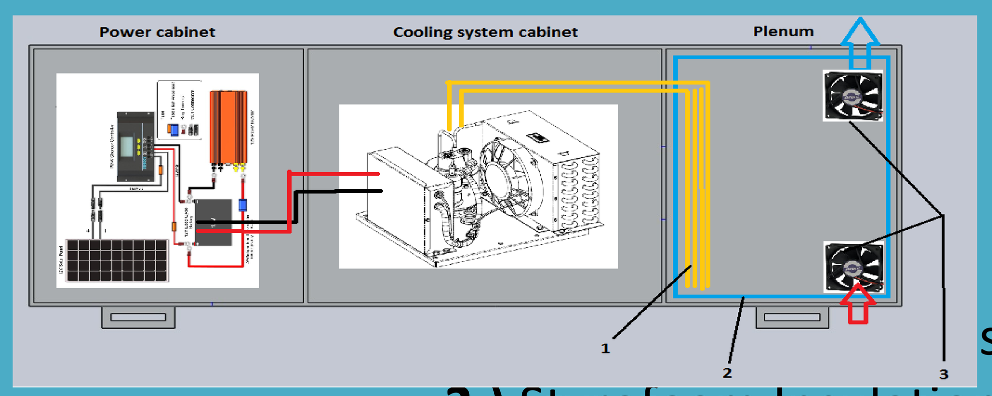
$$A_{total} = A_{top} + 2\ A_{side\ 1/2} + 2\ A_{side\ 3/4} = 1.024\ m^2$$

$$E_{removed} = q \times A_{total} = 60.4\ W$$

The amount of energy that needs to be removed is about 60 W and the overall estimate of energy that needs to be removed due to substances within the cooler, should be around 300 W at minimum. This energy may vary so at maximum, *500 W* was determined to be the amount of energy removed from cooler.

Prototype Design

Schematic



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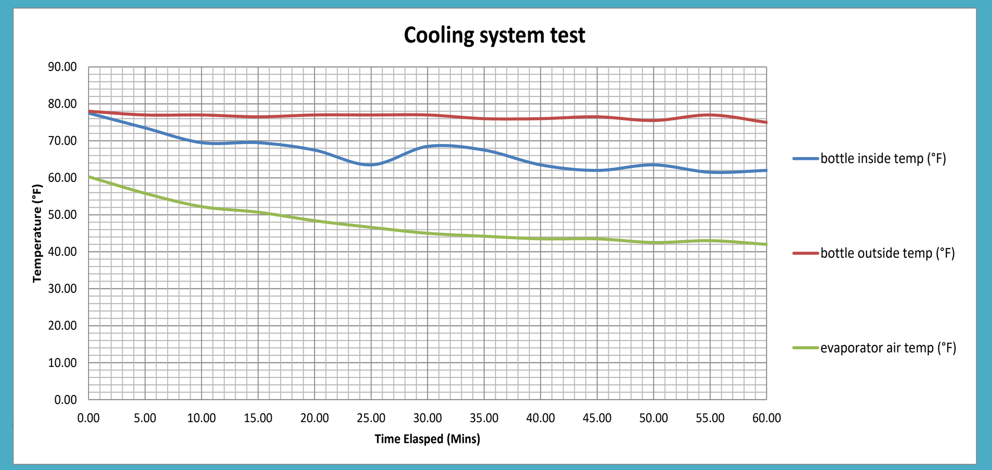
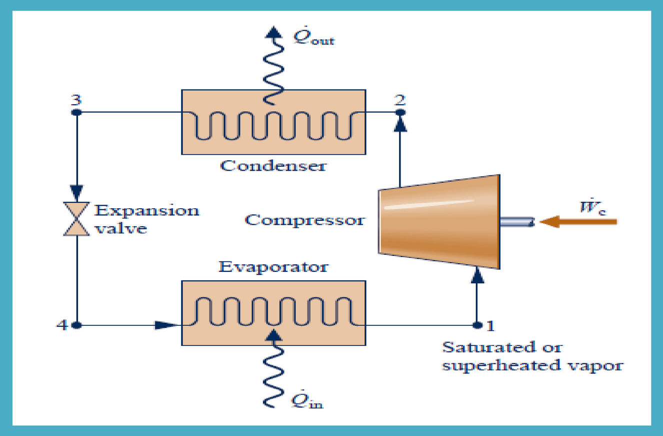
2.) Styrofoam Insulation

3.) Fans (Future)

Testing



Vapor Compression Cycle



1.) Most commonly used process for refrigeration.

2.) Simple cycle; Compressor, Evaporator, Condenser, Expansion Valve.

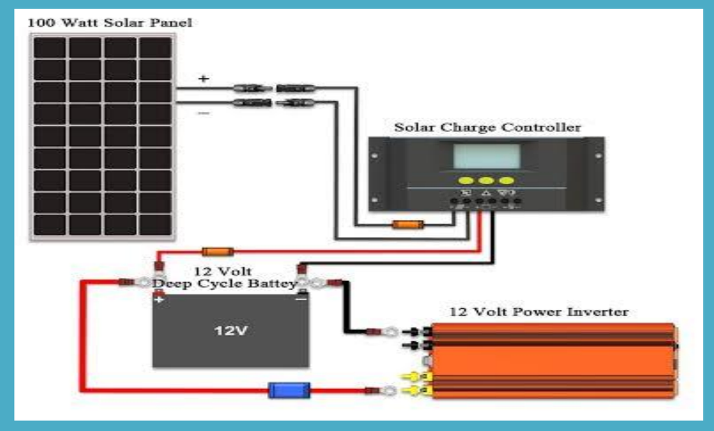
$$W_{ave,electrical} = 65\ W$$

Actual COP of current fridge using desired cooling needed…

$$COP_R = \frac{Q}{W_{avg}} = \frac{500\ W}{65\ W}$$

$$COP_R = 7.69$$

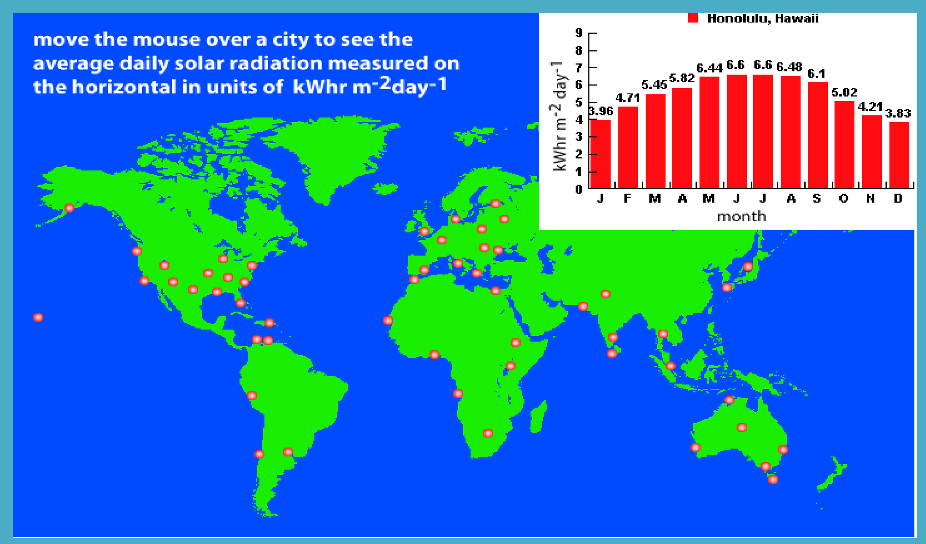
Power System Diagram

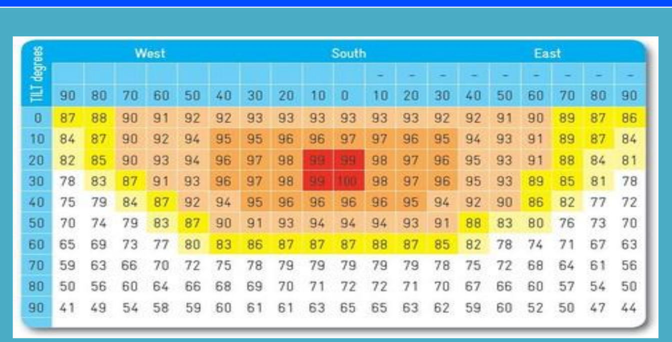


1.) Solar panel was able to produce a maximum of 6 Amps @ 18 Volts, which produces 108 Watts when laid flat. On average, 5.2-5.6 Amps was produced to get 93.6-100.8 Watts of energy.

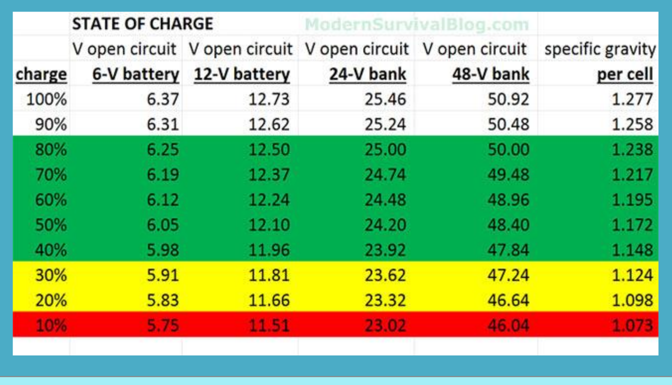
2.) The Inverter converts 12 Volt Direct Current into 120 Volt Alternating Current. The Solar charge controller will limit the electrical energy received from the solar panel, into the battery. The battery will then store the energy, which can be used for back up energy when there is no sunlight.

Solar Power Charts





TILT degrees	West									South									East
											-	-	-	-	-	-	-	-	-
	90	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80	90
0	87	88	90	91	92	92	93	93	93	93	93	93	92	92	91	90	89	87	86
10	84	87	90	92	94	95	95	96	96	97	97	96	95	94	93	91	89	87	84
20	82	85	90	93	94	96	97	98	99	99	98	97	96	95	93	91	88	84	81
30	78	83	87	91	93	96	97	98	99	100	98	97	96	95	93	89	85	81	78
40	75	79	84	87	92	94	95	96	96	96	96	95	94	92	90	86	82	77	72
50	70	74	79	83	87	90	91	93	94	94	94	93	91	88	83	80	76	73	70
60	65	69	73	77	80	83	86	87	87	87	88	87	85	82	78	74	71	67	63
70	59	63	66	70	72	75	78	79	79	79	79	79	78	75	72	68	64	61	56
80	50	56	60	64	66	68	69	70	71	72	72	71	70	67	66	60	57	54	50
90	41	49	54	58	59	60	61	61	63	65	65	63	62	59	60	52	50	47	44



STATE OF CHARGE ModernSurvivalBlog.com

charge	V open circuit 6-V battery	V open circuit 12-V battery	V open circuit 24-V bank	V open circuit 48-V bank	specific gravity per cell
100%	6.37	12.73	25.46	50.92	1.277
90%	6.31	12.62	25.24	50.48	1.258
80%	6.25	12.50	25.00	50.00	1.238
70%	6.19	12.37	24.74	49.48	1.217
60%	6.12	12.24	24.48	48.96	1.195
50%	6.05	12.10	24.20	48.40	1.172
40%	5.98	11.96	23.92	47.84	1.148
30%	5.91	11.81	23.62	47.24	1.124
20%	5.83	11.66	23.32	46.64	1.098
10%	5.75	11.51	23.02	46.04	1.073

Future Improvements

1.) Material used for the box can be metal, plastic, or fiberglass. It will have to be weather resistant and fight corrosion from salt water.

2.) Minimize the size and weight of box so it can be easier to push around or take places.

3.) Get a new compressor/condensing unit that can incorporate more cooling for bigger coolers.

4.) Use of a fan within the plenum to create forced convection for faster transportation of cool air through duct.