

Cooler Research: An evaluation of Drained versus Un-Drained coolers loaded with ice.

Introduction

Coolers or “ice chests” are commonly used to store food and beverages when electricity is not available. Refrigerated storage helps prevent sickness due to foodborne microorganisms. The National Park Service “2016 Commercial Operating Requirement” states that commercial operators must keep “potentially hazardous” food at or below 45F (7.2C). (Ref 1). Canned food does not need refrigeration, although there is considerable interest in cooling canned, fermented beverages prior to consumption (Ref 2).

There are numerous opinions on the best method of ice management. We have compared two identical side by side coolers in a series experiments designed to measure the performance of different cooler/ice strategies. Over 150 week long experiments have been completed over the last seven years. This first publication in the series details the comparative performance of a sealed undrained cooler to one which is continuously drained as the ice melts.

Methods and Materials

All experiments were conducted in a custom 512 cubic foot insulated thermal chamber. Room temperature was controlled with a 6 kW electric heater and a PID heater controller. Three fans were arranged to provide uniform air temperature at the cooler locations. Room temperature was continuously monitored and maintained at 107.2F (41.8C) with a standard deviation of 0.09F (0.05C) over a typical five day run.

Two identical Yeti 125 coolers were purchased new and used in each run – a control and a test. Each cooler was placed on a polymer cart. In order to minimize any effects from differences in the seals, the hinges were removed and the tops fastened down with NRS straps.

For the Drain experiments, a drain tube was passed into one cooler through a small hole drilled in the drain plug. The tube drained into a container on the floor.

Six small, fast response Platinum resistance temperature sensors were mounted in a vertical insert in each cooler and spaced every 2 inches from 2 inches from the bottom to 2.5 inches from the top. Chamber temperature uniformity was monitored throughout the test run by thermal data loggers.

24.0 kilograms of ice were used in each cooler, 47% of the manufacturers stated capacity of 113 pounds. The ice was made from tap water and frozen in plastic tubs in an upright freezer with a -4 F (-20 C) internal temperature. The ice was removed from the tubs before loading the coolers. The Drained and Un-Drained runs used six 4.0 kg blocks of ice in each cooler.

Experiments were initiated by removing the ice from a freezer, loading it immediately into coolers and closing the coolers. Each cooler lid was held down using two NRS-9 tie-down straps around the lid and cooler. The cooler was not opened during the duration of the study. The fans were started and the room was closed. The room heater control and temperature collection were started. Room temperature reached set point in ~18 minutes and had fully stabilized by ~33 minutes.

Results

The results for each cooler are described below and the data presented in graphs. The temperature at the six sensors in the cooler is plotted vs the hours since closing the cooler. For both coolers there is an initial period (Phase1) of ~10 hours when the freezer temperature ice is warming up. The legend in the lower right identifies the vertical position of each sensor in the cooler: (Top, High, Mid-High, Mid-Low, Low, Bottom). A red dotted horizontal lines shows the Park Service upper limits for Commercial Operators. A horizontal blue line shows the freezing point of water.

Un-Drained Cooler: The results for the temperature sensors in the Un-Drained cooler are plotted in Fig 1.

The temperature at the bottom sensor of the Un-Drained cooler stays below the Commercial Operators Limit of 45 F for 92 hours (3 days, 20 hours). The temperature at the low sensor stays below 45 F for 85.6 hours and the temperature at the mid-low for 65 hours.

The temperature at the top three sensors is never below the Park Service limit after Phase 1 when the freezer temperature ice is warming.

Drained Cooler: The results for the temperature sensors in the Drained cooler are plotted in Fig 2.

The temperature at the bottom sensor of the drained cooler stays below the Commercial Operators Limit of 45F for 32.5 hours (1 day, 8 hours). The temperature at the low sensor stays below 45F for 26.2 hours and the temperature at the mid-low is only below 45 F during Phase 1 when the freezer temperature ice is warming.

The temperature at the top four sensors is never below the Park Service limit after the Phase 1.

Fig 1.

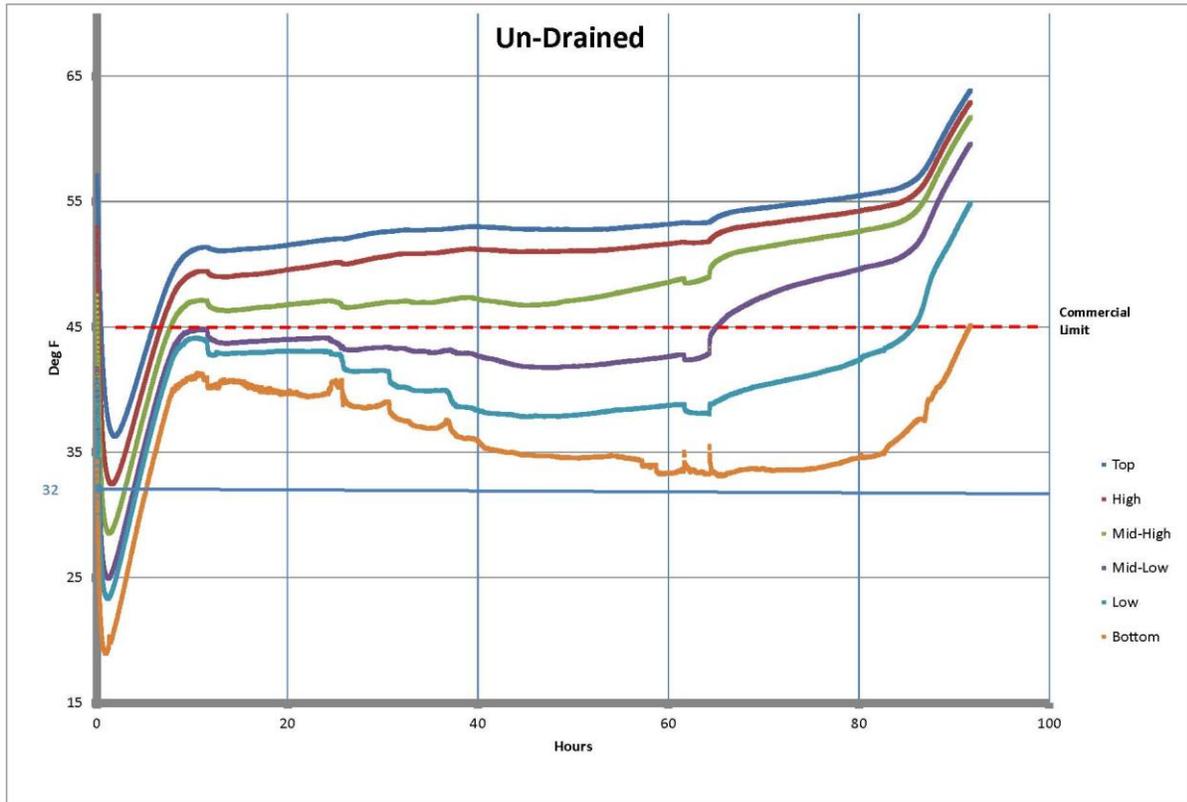
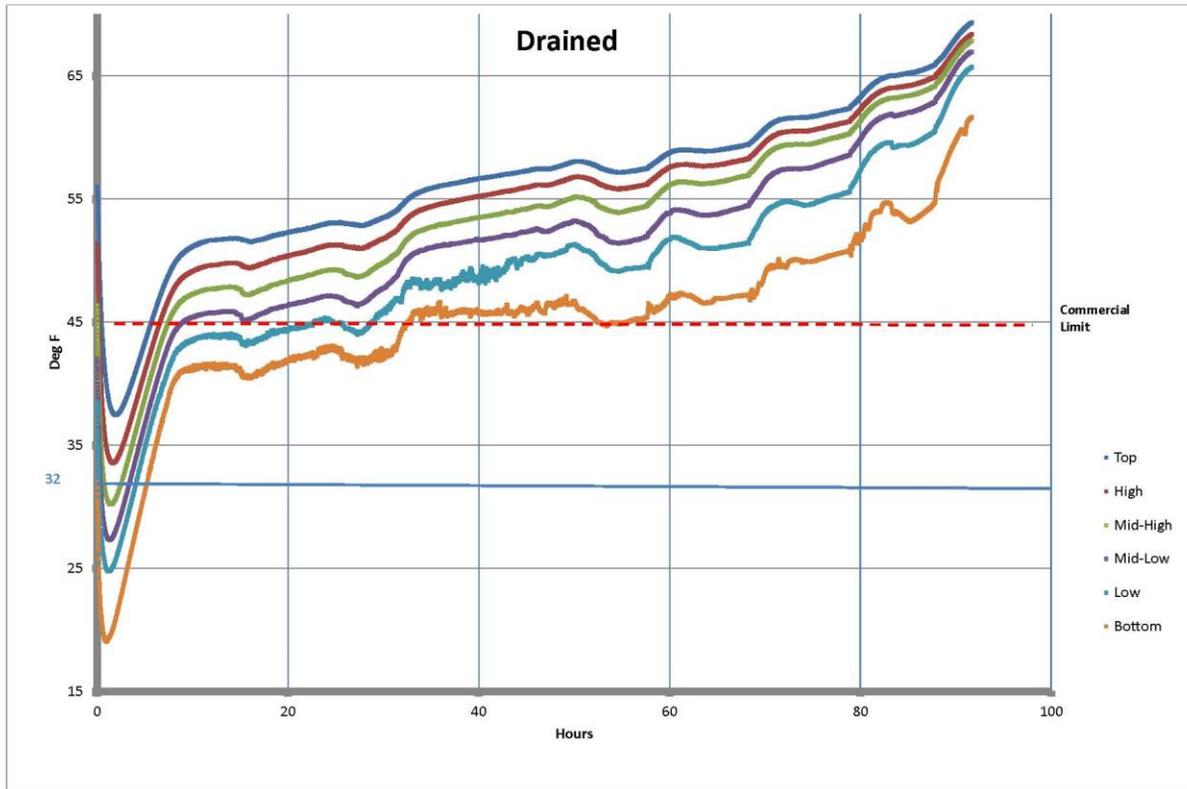


Fig 2.



Discussion

The Table below summarizes the results.

Sensor Location	Hours below Commercial Limit	
	Un-Drained	Drained
Top	~10	~10
High	~10	~10
Mid-High	~10	~10
Mid-Low	65	9
Low	90	26
Bottom	92	32.5

Note: ~10 is the initial freezer ice warming period (Phase 1)

The water in the cooler is likely near 32F while ice is present in the cooler. Draining the cooler replaces this cold water with warm air, resulting in shortened ice time.

Two factors are responsible for this: The difference in the specific heats of water and air and the difference in their thermal conductivity.

Water has the unique characteristic of having a very high specific heat. The specific heat of a substance is the amount of heat required to raise the temperature of one gram by 1 degree. Water has a specific heat 4.1 times larger than dry air and 2 times higher than moist air. Keeping melted water in the cooler absorbs more of the infused heat with lower rise in temperature than an equivalent amount of air.

The thermal conductivity of water is 23.1 times higher than that of air. Water and ice exist in equilibrium at 32 F. The intimate contact of the water with the ice in the undrained cooler DOES cause the ice to melt faster than the ice in a drained cooler. But the temperature of the drained cooler is higher. The low thermal conductivity of the air does not transfer heat into the ice as quickly as does the water. Given the lower specific heat of the air, the heat not transferred into the ice goes into raising the temperature of the air in the cooler.

Conclusion

The results of this study show that draining water from a cooler significantly degrades cooling performance in a hot environment.

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References:

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Note: This is the first in a series of publications detailing ice management in coolers. The authors can be contacted at coolerresearch@gmail.com

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