

Ice Melting Time in a Patient Shipment Container

By Charles Platt, Aschwin de Wolf, and Jay Wasserlauf

Suspended Animation, Inc, April 2005

Abstract

We compared the time taken for ice to melt inside a "Ziegler box" mortuary shipping container in three experiments, using generic two-inch large-cell styrofoam insulation, half-inch foil-clad foam board, and no insulation, respectively. We conclude that half-inch foil-clad foam board is necessary and adequate for shipment of a cryonics patient in as little as 43 kilos (95 lbs) of water ice in an external environment of approximately 25 degrees Celsius (77 degrees Fahrenheit) or below, although additional ice may be necessary if a patient is unusually warm or heavy.

Introduction

Cryonics standby protocol developed by Michael Darwin, Jerry Leaf, and others during the 1980s requires the patient to be packed in water ice prior to air shipment. Anecdotal evidence suggests that a minimum of 45 kilograms (100 lbs) of water ice is necessary during a transport lasting up to 24 hours, and Darwin has advocated using additional ice in conjunction with fiberglass insulation around the patient shipment container. In a personal communication Darwin has also stated that experiments were performed to measure the time taken for ice to melt. Since no written record of these experiments can be found, and since "hardware superstores" such as Home Depot have begun selling synthetic foam insulation since the original work by Darwin and Leaf, the authors of this report decided to perform some simple tests to find out how long ice would take to melt using thick insulation, thin insulation, and no insulation, in a temperature-controlled environment.

Equipment

From a Florida mortuary we obtained a shipping container measuring approximately 30 cm x 50 cm x 190 cm (12 in x 20 in x 75 in) fabricated from heavy galvanized steel. The lid of the container was fitted with a rubber gasket and could be fixed in place via sheet-metal screws around the perimeter.

We placed the shipping container on two wooden blocks about 4 cm (1.5 in) in height inside a wooden box measuring 61 cm x 91 cm x 244 cm (24 in x 36 in x 96 in) fabricated from 3/8-inch plywood. This plywood box was separated from a concrete floor by two more wooden blocks about 4 cm (1.5 in) in height.

Two hair dryers were secured with cable ties in diagonally opposite corners of the plywood box, directing their flow of air along the long dimension of the box to create active air circulation. The hair dryers were set on "low," drawing approximately 800 watts each. They were switched by an Aube model TH101D thermostat, which claims an accuracy of +/- 0.5 degrees Celsius when used with fan-powered heaters. The thermostat was put in Manual mode at its highest target setting, 27 degrees Celsius, to maintain a relatively stable environment.

To measure "box temperature" one type-T thermocouple probe was secured with duct tape inside the plywood box, near the thermostat, in such a way that it was protected from direct air currents from the hair dryers. The thermocouple wire ran out of the plywood box, through a half-inch hole, to a Cole-Parmer DualogR which had been set to record temperature in increments of 0.1 degrees Celsius at intervals of 5 minutes.

A simulated patient was carved from a solid styrofoam block approximately the dimensions of a person weighing about 90 kilos (200 lbs). We used styrofoam because its heat capacity is negligible compared with other variables in the experiment. The simulated patient was placed inside a lightweight, 3-mil vinyl body bag of the type used by mortuaries. This bag was then placed inside a heavyweight, 20-mil body bag of the kind used in forensic work, and the two bags containing the patient were placed in the shipping container. This double-bagging procedure is part of standard Suspended Animation protocol.

Experiment 1

A sheet of two-inch-thick styrofoam was obtained from a Home Depot store. The styrofoam was unmarked with any brand name and did not have an R-rating. It was generic large-cell styrofoam.

The patient shipping container was removed from the plywood box, and slabs of the styrofoam were cut to fit the faces of the container as precisely as possible. After applying duct tape externally along all the joints between styrofoam segments, the container in its cladding was replaced in the plywood box.

43.5 kilos (96 lbs) of ice was obtained in 8-lb bags from a local convenience store

and was emptied into two ice chests. The ice was rebagged in one-gallon Zip-Loc bags, each of which was approximately half filled. The Zip-Loc bags were placed in contact with the simulated patient, filling almost all the space available inside the lightweight body bag.

Midway during the process of loading ice, a second thermocouple probe was placed against the "head" of the simulated patient, under two bags of ice. Its wire was run through a hole in one body bag, out of the second body bag at the end of the zipper, and out of the shipping container, through the same hole in the plywood box as the box-temperature probe. The wire was plugged into the same DualLogR as was being used to record temperatures from the first probe.

When all the ice had been loaded the lid of the shipping container was screwed into place, and the last remaining slab of styrofoam was taped down so that the container was now insulated on its top, bottom, and sides, with duct tape covering all edge-to-edge joints.

The lid of the plywood box was set in place, and initial readings from the DualLogR showed a box temperature of about 26.5 Celsius. The head-temperature probe gave a reading of about -5 Celsius, gradually dropping to -10 Celsius as the system reached equilibrium.

As the air around the shipping container inside the plywood box cooled slightly, the thermostat activated the hair dryers in a duty cycle approximating 25% on and 75% off. The experiment was allowed to continue unattended, with periodic inspection to note the box temperature. When the box temperature climbed above 10 degrees Celsius, data logging was terminated, the thermostat was unplugged, and the equipment was dismantled.

Readings from the DualLogR were uploaded via a Cole-Parmer 91100-85 Infra-Red Adapter, connected via serial cable to a desktop computer running HyperTerminal software (bundled with Windows xp). Box temperature readings were examined and were found to remain consistently within a range of 24 to 25.5 degrees Celsius. Patient temperature readings were edited using WordPad text editing software. An initial data point was chosen as the first patient temperature between 0 and 0.5 degrees Celsius. Preceding temperatures were discarded. Subsequent temperatures were retained at 60-minute intervals following the initial data point. Intervening 5-minute temperature readings were discarded, since short-term variations were too small to be of interest. Readings after the patient temperature reached 10 degrees Celsius were discarded.

The remaining patient temperature readings were rendered graphically in Adobe Illustrator version 8.0, using the Graph Tool built into that software.

Experiment 2

This experiment proceeded identically to Experiment 1, except that instead of generic large-cell styrofoam we purchased half-inch Rmax R-Matte Plus-3 foil-clad foam board, with a stated R value of 3.2. In an attempt to emulate a standby team working with poor tools under time pressure, we cut six pieces of this foam board to create a large, loose-fitting, poorly made box that allowed an air space of 10 to 15 cm around the shipping container. Gaps between sections of the foam board were patched with duct tape.

Experiment 3

This experiment proceeded identically to Experiment 1, except that no insulation of any type was placed around the shipping container.

Results

Graphed data suggests that most of the ice in Experiment 3 (using no insulation) melted within 24 hours. The box temperature in Experiment 1 (2-inch generic insulation) remained close to 0 degrees Celsius until shortly after 48 hours. Box temperature in Experiment 2 (half-inch foil-clad foam board) remained close to 0 degrees Celsius for more than 60 hours.

In a real case, a human patient would contain significant heat which should be expected to melt the ice faster. In a case where a standby team has been unable to cool the patient significantly prior to shipment, conceivably the body temperature could be as high as 35 degrees Celsius, although this is unlikely since some air cooling will occur during transfer of a patient to a mortuary where the procedure of packing for shipment is usually performed.

In cases where a standby team obtains vascular access and chills the patient with blood washout solution, body temperature may be as low as 5 degrees Celsius. Overall we believe that a body temperature ranging from 10 degrees to 25 degrees is probable.

To determine how much ice will be melted by the heat inherent in the patient, we assume that the latent heat of fusion of a human body is approximately the same as that of pure water (i.e. 80 calories per gram). The weight of melted ice will be derived by multiplying the patient mass by the patient temperature and dividing by 80. This calculation will be simplified if we assume that the patient mass may be around 80 kilograms (176 lbs). In this scenario a patient at 10 degrees Celsius will

melt 10 kilos of ice, a patient at 15 degrees Celsius will melt 15 kilos, and so on. The nomogram in Figure 2 provides a quick way to calculate the approximate weight of ice that is likely to be melted by patients of varying weights and temperatures.

The melting of ice over time, in our experiments described above, is likely to be an approximately linear function. In other words, loosely speaking, we can expect that half as much ice will melt in half the time. If we can be sure that a transport will take no more than 30 hours, we can feel comfortable using no more than 43 kilograms of ice even when a patient weighing 80 kilograms (176 lbs) has an initial temperature as high as 20 degrees Celsius (68 degrees Fahrenheit). This patient will melt half of the available ice, so long as we use half-inch foam board insulation.

Conclusion

The necessity for insulation around a patient shipment container has been confirmed beyond doubt. Half-inch foam insulation is significantly effective, even when applied hastily with poor attention to detail. Such insulation is available from “hardware superstores” all over the United States. Alternatively a standby team could bring the insulation in pre-cut panels that can be transported inside a single Pelican container and could be assembled on-site using duct tape. Suspended Animation intends to create this “insulation kit” for use in future cases.

Ice in excess of 43 kilograms should be used in cases where:

- a) The patient is exceptionally heavy, or
- b) Body temperature is unusually high, or
- c) Insulation for the shipping container is unavailable, or
- d) An exceptionally long transport time is expected.

A nomogram is supplied for calculating additional ice to compensate for excessive melting in cases a) and b) above.

Temperature measured adjacent to left side of head of dummy styrofoam patient inside Ziegler box containing 43 kilos of water ice. Dummy patient was enclosed in one 3-mil lightweight body bag plus one 20-mil heavyweight body bag. Ambient temperature around Ziegler box was maintained between 24 and 25.5 degrees Celsius. Data sets were synchronized to begin with the first reading between 0 and 0.5 Celsius (earlier values discarded).

Experiments by Platt, Wasserlauf, and de Wolf
Suspended Animation, March/April 2005
Preliminary tabulation.

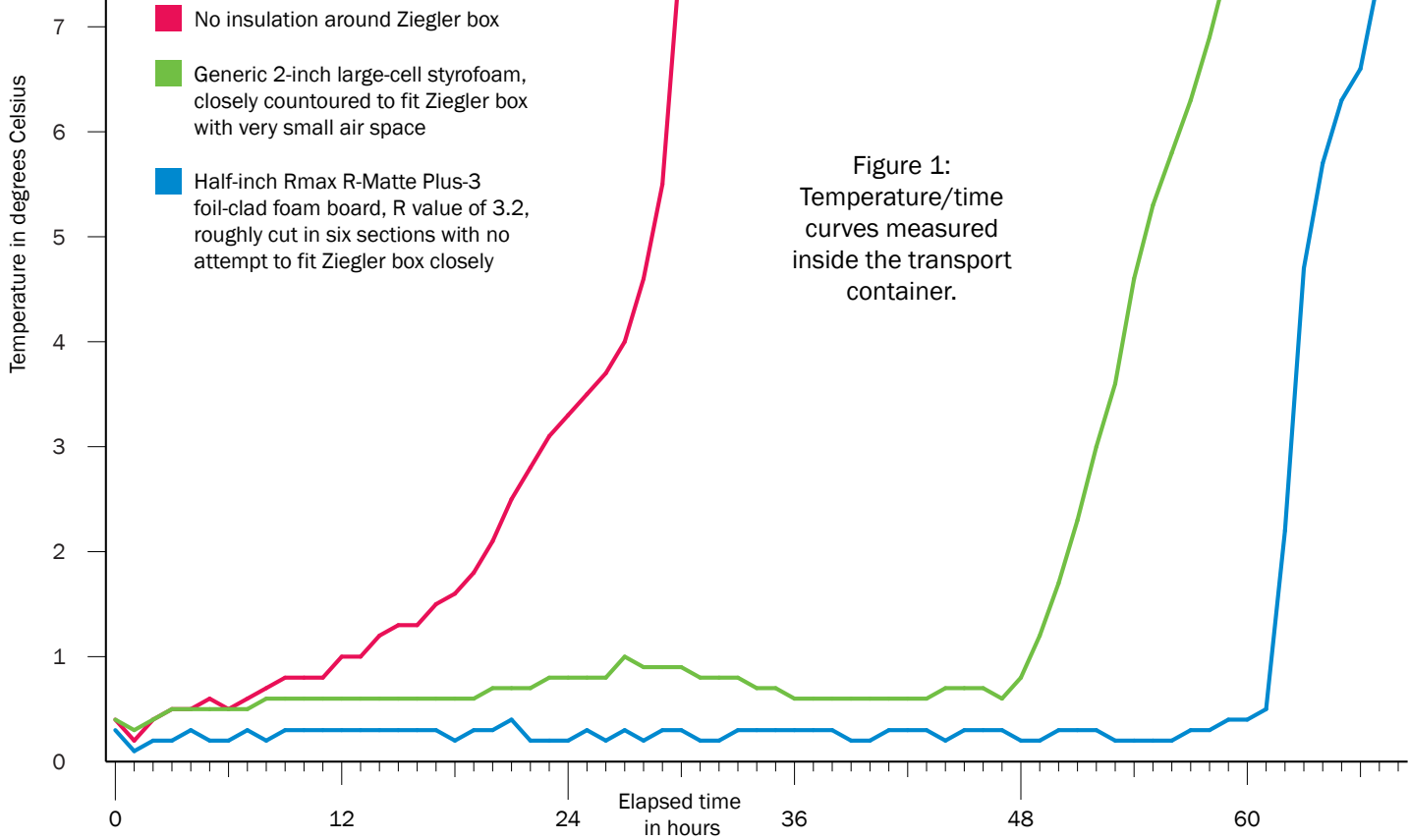


Figure 1:
Temperature/time
curves measured
inside the transport
container.

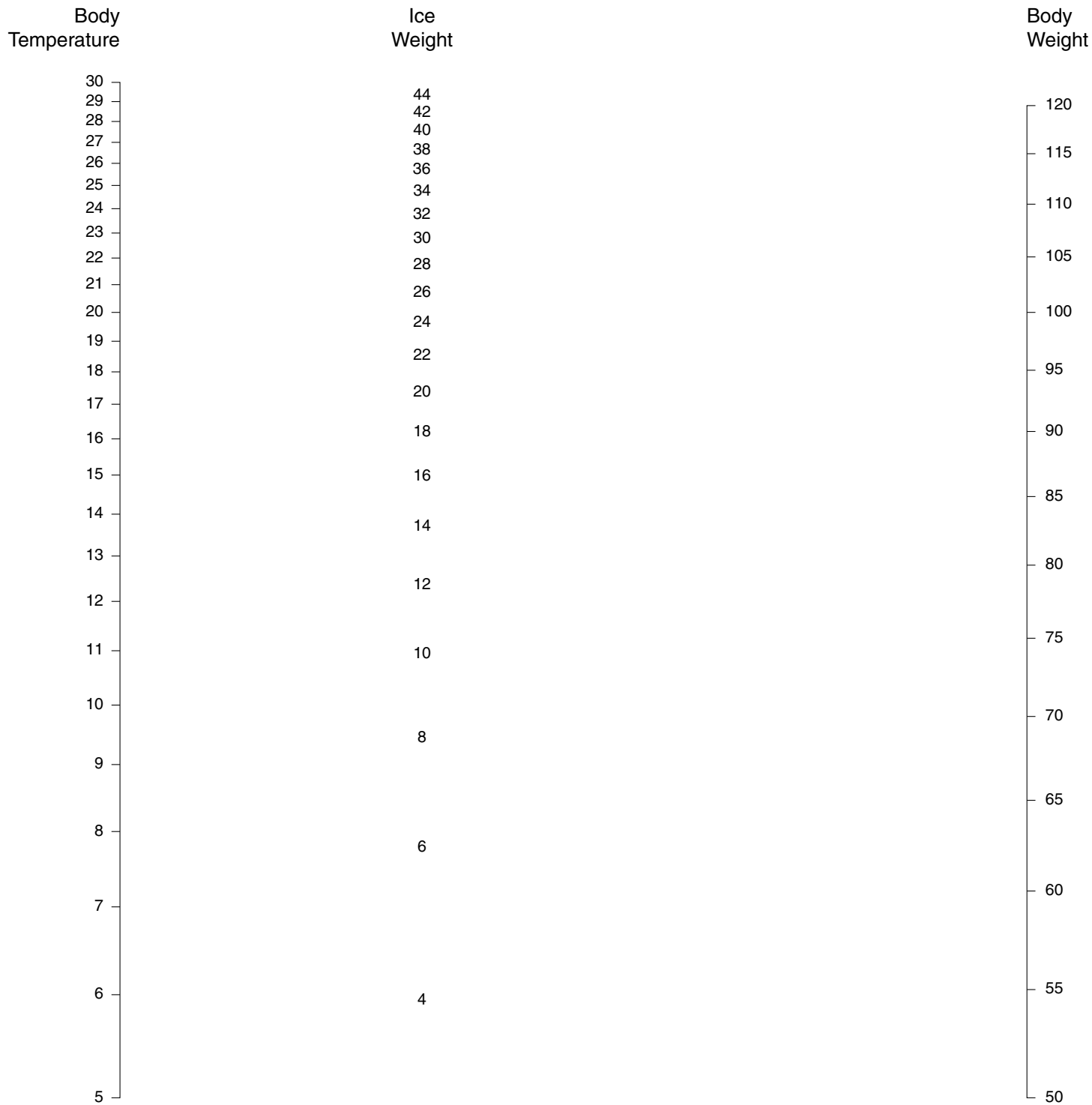


Figure 2: Nomogram to determine the weight of ice that will be melted, from a known body weight and temperature. Place a straight edge between body weight (on the right-hand scale) and body temperature (on the left-hand scale). The quantity of ice will be shown by the center scale. Weights are in kilograms, temperature is in degrees Celsius.