Final Report FNE 93-6

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DEVELOPMENT AND EVALUATION OF AN ALTERNATIVE ICE HOUSE REFRIGERATION SYSTEM

My name is Charlie Chase. I am a full time farmer. My main crop is Christmas trees. I have 30 acres of Christmas trees, but I also have greenhouses, a tree nursery, an apple orchard, and a sugar house for maple syrup production. During February and March, I collect maple sap and boil it on weekends. Sometimes, the stored sap will almost freeze solid in my tanks. This occurrence made me wonder if the ice would keep the sap cold for a longer period of time if kept in an insulated building. If so, my need for cold storage during the nursery season could benefit as well. There never seems to be enough time to get everything planted before everything starts to bud out. With great imagination, I have come up with an idea.

Having grown up in Rhode Island, I have seen many ponds and buildings that were once used for making and storing ice. Historically, the process of using ice for refrigeration is well known to have been a major industry in New England a hundred years ago. Since the arrival of modern refrigeration technology, the making and storage of natural ice is but a fond memory. However, modern refrigeration has not been perfect. The effect that it has had on our atmosphere calls for a search for alternative methods of cold storage. I say that it is time to resurrect the old ice house, with a modern twist.

My idea is to make ice inside of an insulated building during Winter. Labor is the most expensive part of most ventures, so less handling of the ice would be more efficient. The biggest obstacle would be knowing how much water to expose to the sub-freezing temperature and for what duration of time. To maximally cool the exposed area, a fan with an automatically opening vent would be placed at the opposite end of the building and would be running at all times when the temperature is below 32 degrees Fahrenheit (°F).

Being a full time farmer, I am dirt poor and did not begin construction of the building until after Christmas. It was not fun banging nails in the ten degrees above zero temperatures of January, 1994. I wasn't quite finished building the ice house when water was first pumped onto the new floor at 2 p.m. on February 9, 1994. This first year is experimental and serves only as a model as to what could happen.

Some people may criticize my experiment by saying that this Winter of "94" was not a normal winter because of the extremely cold temperatures in January, 1994. It could be said that Rhode Island is "the tropics" of New England and does not really get cold compared to Vermont. Rhode Island has had winters during which there was no snow and the ground did not freeze. This only strengthens my theory that this idea has broader applications and could be utilized in states further south, because I started in February and missed the coldest part of winter.

An ice house can be any size; and the larger the better. Because we cannot predict the weather, an ice house should be large enough to make more ice than might be needed so that enough ice can be produced even during a mild winter. The building should be insulated following the guidelines for cold storage published by the Northeast Agricultural Engineering Services: "Refrigeration and Controlled Atmosphere Storage for Horticultural Crops". I used R-20, R-30, and R-40 insulation factors for the floor, walls, and ceiling, respectively. Extruded polystyrene insulation panels were used in the floor for the ability to resist water and to hold the R-factor if crushed under the weight of the ice. Loose cellulose insulation was used in the walls and ceiling for its ability to fill all voids and the fact that more insulation could be added to it after settling. Additionally, loose cellulose insulation has the environmentally beneficial quality of being made from recycled newspapers. The walls were constructed to be 10 inches thick in order to produce an R-factor of thirty. First the floor was installed; next the ceiling was installed; and finally, a non-supporting interior wall was installed. The loose fill insulation was blown into the walls from the ceiling. The interior wall was only tacked into place so that when expansion of the ice pushes the walls out, it will simply squish the loose fill insulation and not interfere with the structural integrity of the building.

Before the first drop of water could hit the floor, a plastic liner was laid on the floor, folded up along the walls with another sheet overlapping to the height of the wall. A temporary partition was placed between the ice room and the cold storage room. The partition was needed only to support the plastic and extended only to half of the height of the room so as not to interfere with the air flowing to the fan. The partition was not insulated and could be removed in the Spring to give easy access to the ice.

Originally, I was going to use mist nozzles from my propagation greenhouse to spray a fine mist of water from the ceiling to the floor, but I soon encountered a problem with the nozzles freezing. Heating cables could have solved the problem, but I did not want any heaters inside of the ice house. It kind of defeats the purpose, don't you think? Instead, I used the method of flooding, which works best and is the easiest.

The flooding method works as follows. When the temperature drops below 30 °F, a thermostat opens the vent and turns on the fan, the 24 hour timer, and the heating cable going to a submersible pump in a nearby pond. These things stay on all of the time that the outside temperature is below freezing. The 24 hour timer turns on a 60 minute timer that turns on the pump for 5 minutes, which is the amount of time required to flood the ice room floor 1/2 inch deep.

Based on the weather forecast for specific expected low temperatures, I set the timer manually each day. By observing how fast the water froze at given Fahrenheit temperatures, I determined that the pump could cover the floor with water 1/2 inch deep as follows: in 3 hours for low temperatures of 25°F; in 2 hours for low temperatures of 20°F; and in 1 hour for low temperatures in the teens. When the weather forecast is incorrect such that it does not get as cold as the expected low temperature, there occurs a formation of a layer of ice, a layer of water, and then another layer of ice. When the weather forecast is incorrect such that it gets colder than expected, only a limited amount of ice forms when more could have been made. When the temperature rises above 32°F, the thermostat turns off everything. The vent closes, and the process is halted until the temperature drops below 30°F again.

My experimental results as of March 18, 1994 are that with an operating period of 37 days, a solid block of ice having dimensions of 12 feet by 12 feet by 18 inches (approximately 6 tons of ice) was formed. My first use of the cold storage took place in mid-March, 1994. The maple syrup season was uncommonly short, being approximately 21 days long in comparison to a normal season of 40 days. During a normal season, I produce approximately 60 gallons of syrup. This year I bottled 80 gallons. More sap flowed than I could manage. Rather than boiling for 24 hours straight, which tends to make me, shall we say, not a pleasant person to be around, I stored the extra sap in barrels kept on top of the ice in my ice house. With temperatures climbing into the "60's" and "70's" in late March, 1994, I could get a good night's sleep knowing that my sap would stay at a temperature of 34°F for the next couple of weeks. I was able to continue boiling sap for 3 weekends past the end of the maple syrup season.

In April, 1994, I purchased 30 thousand tree seedlings and expected to finish planting them before the end of the month. Due to labor problems and other circumstances, the planting was extended into late May, 1994. The entire length of the ice house was required to store all of the trees. Although the trees did not dry out because of the high humidity provided by the melting ice, the room temperature rose to 40°F and higher due to insulation of the ice by the trees. I cut blocks of ice and placed them on top of the trees to keep them cooler. As of the time of this report, less than 5% mortality of trees has been observed compared to the expected 10% to 20% expected mortality.

DEVELOPMENT OF AN ICE HOUSE REFRIGERATION SYTSEM
BY CHARLES R. CHASE

By May, 1994, all of the ice had melted. The reasons that the ice did not last into Summer, 1994 are many and are particular to the experimental procedures conducted during this season. The main reason that the ice melted is the leaking roof on the unfinished building. Rain and snow melted on the roof, wetting the insulation in the ceiling and walls, which caused the same effect as having no insulation at all. Another reason that the ice melted, which could be remedied just as easily, is the 4 mil??? plastic liner used to hold the water. As the water froze, the plastic liner formed many leaks that seeped into the walls and caused the insulation to become wet. Another reason that the ice melted is the frequent and prolonged opening of the ice house door that took place to inspect the ice; retrieve sap or nursery stock; and to show off the 6 ton block of ice to curiosity seekers or "tourists". A final reason that the ice melted is that a larger chunk of ice could have been created in the first place. Although an 18 inch thick piece of ice might be considered to be large, it is only 20% of the size that the room was expected to hold.

My building design does not have a permanent foundation. It was built on a gravel base with boards running the length of the building on the ground. The water created by the melting ice was supposed to drain towards the cold room. However, when you think of it, where would a 6 ton block of ice drain? Any place that it wants! Ha! Ha!

My experiment began with the recording of temperature for 24 hours per day from November 19, 1993 through April 9, 1994. The temperatures are documented at the end of this report. In that 140 day period, a total of 3,360 hours passed. Of that total time, 1,570 hours had temperatures below freezing, and the experiment had only 528 hours with temperatures below freezing. Calculating when to turn on the pump by the timer was tedious and not always efficient; a computer would do a better job. The thermostat that I used only turns things on at one temperature. Having ten thermostats set 2 degrees apart as well as a submersible pump for each would be too expensive. However, based on the recorded temperatures and the duration of the ice-making season during Winter of "94", it would have been possible to have made 20 tons of ice. In the arctic temperatures of Vermont, it may have been possible to make 100 tons of ice - anything is posssible! The applications are limitless as well. Just being able to store my maple sap until warmer weather when the tourists are more likely to visit makes this worthwhile for me. Many farms are basing their success on their ability to keep things cold as well as their ability to grow things. Some other potential applications include forcing bulbs year round, storing dormant plants or cut flowers, and storing spring and summer vegies. The list goes on and on!

ICE HOUSE TABLE: DURATION (HOURS) AT TEMPERATURES BELOW 32°F

BELOW FREEZING TEMPERATURE (°F)	DURATION AT TEMP. 11/19/93-2/9/94 (HOURS)	DURATION AT TEMP. 2/9/94-4/10/94 (HOURS)
30	66	100
28	136	100
26	106	48
24	86	56
22	56	26
20	66	60
18	90	22
16	38	20
14	76	10
12	66	22
10	84	24
8	32	28
6	52	8
4	22	2
2	28	2
0	16	0
-2	14	0
-4	8	0

***1 Total duration below 32°F = 1,570 hours**
(1042 hours + 528 hours)

***2 Total duration of experiment = 3,360 hours**
(140 days x 24 hours/day)