

Table of Contents

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Table of contents.

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For Laura Anne and Roemer

UNDER THE SNOW

3

A TEXTBOOK PLACE FOR BEARS

13

RIDING THE BOOM. EXTENSION

56

HEIRS OF GENERAL PRACTICE

75

OPEN MAN

176

ICE POND

192

MINIHYDRO

203

NORTH OF THE C.P. LINE

249

ICE POND

Summer, 1981

At Princeton University, off and on since winter, I have observed the physicist Theodore B. Taylor standing like a mountaineer on the summit of what appears to be a five-hundred-ton Sno-Kone. Taylor now calls himself a "nuclear dropout." His has been, at any rate, a semicircular career, beginning at Los Alamos Scientific Laboratory, where, as an imaginative youth in his twenties, he not only miniaturized the atomic bomb but also designed the largest-yield fission bomb that had ever been exploded anywhere. In his thirties, he moved on to General Atomic, in La Jolla, to lead a project called Orion, his purpose being to construct a spaceship sixteen stories high and as voluminous as a college dormitory, in which he personally meant to take off from a Nevada basin and set a course for Pluto, with intermediate stops on Ganymede, Rhea, and Dione—ice-covered satellites of Jupiter and Saturn. The spaceship Orion, with its wide flat base, would resemble the nose of a bullet, the head of a rocket, the ogival hat of a bishop. It would travel at a hundred thousand miles an hour and be driven by two thousand fission bombs. Taylor's colleague

Ice Pond : 193

Freeman Dyson meant to go along, too, extending spectacularly a leave of absence from the Institute for Advanced Study, in Princeton. The project was developing splendidly when the nuclear treaty of 1963 banned explosions in space and the atmosphere. Taylor quelled his dreams, and turned to a sombre subject. Long worried about the possibility of clandestine manufacture of nuclear bombs by individuals or small groups of terrorists, he spent his forties enhancing the protection of weapons-grade uranium and plutonium where it exists in private industries throughout the world. And now, in his fifties—and with the exception of his service as a member of the President's Commission on the Accident at Three Mile Island—he has gone flat-out full-time in pursuit of sources of energy that avoid the use of fission and of fossil fuel, one example of which is the globe of ice he has caused to be made in Princeton. "This isn't Ganymede," he informs me, scuffing big crystals under his feet. "But it's almost as exciting."

Taylor's hair is salt-and-peppery now but still stands in a thick youthful wave above his dark eyebrows and luminous brown eyes. He is tall, and he remains slim. What he has set out to do is to air-condition large buildings or whole suburban neighborhoods using less than ten per cent of the electricity required to cool them by conventional means, thereby saving more than ninety per cent of the oil that might be used to make the electricity. This way and that, he wants to take the "E" out of OPEC. The ice concept is simple. He grins and calls it "simple-minded—putting old and new ideas together in a technology appropriate to our time." You scoop out a depression in the ground, he explains—say, fifteen feet deep and sixty feet across—and line it with plastic. In winter, you fill it with a ball of ice. In summer, you suck ice water from the bottom and pump it

indoors to an exchanger that looks something like an automobile radiator and cools air that is flowing through ducts. The water, having picked up some heat from the building, is about forty-five degrees as it goes back outside, where it emerges through shower heads and rains on the porous ice. Percolating to the bottom, the water is cooled as it descends, back to thirty-two degrees. Taylor calls this an ice pond. A modest number of ice ponds could cool, for example, the District of Columbia, saving the energy equivalent of one and a half million barrels of oil each summer.

The initial problem was how to make the ice. Taylor first brooded about this some years ago when he was researching the theoretical possibilities of constructing greenhouses that would aggregately cover tens of millions of acres and solve the pollution problems of modern agriculture. The greenhouses had to be cooled. He thought of making ice in winter and using it in summer. For various regions, he calculated how much ice you would have to make in order to have something left on Labor Day. How much with insulation? How much without insulation? The volumes were small enough to be appealing. How to make the ice? If you were to create a pond of water and merely let it freeze, all you would get, of course, would be a veneer that would break up with the arrival of spring. Ice could be compiled by freezing layer upon layer, but in most places in the United States six or eight feet would be the maximum thickness attainable in an average winter, and that would not be enough. Eventually, he thought of artificial snow. Ski trails were covered with it not only in Vermont and New Hampshire but also in New Jersey and Pennsylvania, and even in North Carolina, Georgia, and Alabama. To make ice, Taylor imagined, one might increase the amount of water moving through a ski-resort snow

machine. The product would be slush. In a pondlike receptacle, water would drain away from the slush. It could be pumped out and put back through the machine. What remained in the end would be a ball of ice.

Taylor had meanwhile become a part-time professor at Princeton, and on one of his frequent visits to the university from his home in Maryland he showed his paper ice ponds to colleagues at the university's Center for Energy and Environmental Studies. The Center spent a couple of years seeking funds from the federal government for an ice-pond experiment, but the government was not interested. In 1979, the Prudential Insurance Company of America asked the university to help design a pair of office buildings—to be built just outside Princeton—that would be energy-efficient and innovative in as many ways as possible. Robert Socolow, a physicist who is the Center's director, brought Taylor into the Prudential project, and Taylor soon had funds for his snow machine, his submersible pumps, his hole in the ground.

At Los Alamos, when Taylor got together on paper the components of a novel bomb he turned over his numbers and his ideas to other people, who actually made the device. Had such a job been his to do, there would have been no bombs at all. His mind is replete with technology but innocent of technique. He cannot competently change a tire. He has difficulty opening doors. The university hired Don Kirkpatrick, a consulting solar engineer, to assemble and operate appropriate hardware, while unskilled laborers such as Taylor and Freeman Dyson would spread insulating materials over the ice or just stand by to comment.

"The first rule of technology is that no one can tell in

advance whether a piece of technology is any good," Dyson said one day. "It will hang on things that are unforeseeable. In groping around, one wants to try things out that are quick and cheap and find out what doesn't work. The Department of Energy has many programs and projects—solar-energy towers and other grandiose schemes—with a common characteristic: no one can tell whether they're any good or not, and they're so big it will take at least five years and probably ten to find out. This ice pond is something you can do cheaply and quickly, and see whether it works."

A prototype pond was tried in the summer of 1980. It was dug beside a decrepit university storage building, leaky with respect to air and water, that had cinder-block walls and a flat roof. Size of an average house, there were twenty-four hundred square feet of space inside. Summer temperatures in the nineties are commonplace in New Jersey, and in musty rooms under that flat roof temperatures before the ice pond were sometimes close to a hundred and thirty. The 1980 pond was square—seventy-five feet across and fifteen feet deep. It contained a thousand tons of ice for a while, but more than half of that melted before insulation was applied: six inches of dry straw between sheets of polyethylene, weighed down with bald tires. Even so, the old building was filled most of the time from June to September with crisp October air. Something under seven tons of ice would melt away on a hot day. Nonetheless, at the end of summer a hundred tons remained. "It's a nice alternative to fossil fuels," Robert Socolow commented. "It has worked too well to be forgotten."

The concept having been successfully tested, the next imperative was to refine the art—technically, economically, and aesthetically. "The point is to make it elegant this time," said Freeman Dyson, and, from its hexagonal con-

crete skirt to its pure-white reflective cover, "elegant" is the word for the 1981 pond. Concealing the ice is a tentlike Dacron-covered free-span steel structure with six ogival sides—a cryodesic dome—which seems to emerge from the earth like the nose of a bullet, the head of a rocket, the hat of a bishop. Lift a flap and step inside. Look up at the summit of a white tower under insulation. Five hundred tons of ice—fifty-eight feet across the middle—rise to a conical peak, under layers of polyethylene foam, sewn into fabric like enormous quilts. It is as if the tip of the Finsteraarhorn had been wrapped by Christo.

Taylor, up on the foam, completes his inspection of the ice within, whose crystals are jagged when they first fall from the snow machine, and later, like glacier ice, recrystallize more than once into spheres of increasing diameter until the ultimate substance is very hard and resembles a conglomerate of stream gravel. The U.S. Army's Cold Regions Research and Engineering Laboratory has cored it with instruments of the type used on glaciers in Alaska. Suspended from a girder high above Taylor's head and pointing at the summit of the ice is something that appears to be a small naval cannon with a big daisy stuck in its muzzle. This is SMI SnowStream 320, the machine that made the ice. In its days of winter operation, particles plumed away from it like clouds of falling smoke. Unlike many such machines, it does not require compressed air but depends solely on its daisy-petalled propeller blades of varying length for maximum effectiveness in disassembling water. "We are harvesting the cold of winter for use in the summer," Taylor says. "This is natural solar refrigeration, powered by the wind. Wind brings cold air to us, freezes the falling water, and takes the heat away. We are rolling with nature—trying to make use of nature instead of fighting it.

That machine cost seven thousand dollars. It can make about eight thousand tons of ice in an average winter here in Princeton—for thirty-five dollars a hundred tons. A hundred tons is enough to air-condition almost any house, spring to fall. In the course of a winter, that machine could make ten thousand tons of ice in Boston, seven thousand in Washington, D.C., fifteen thousand in Chicago, thirty thousand in Casper, Wyoming, fifty thousand in Minneapolis, and, if anybody cares, a hundred thousand tons of ice in Fairbanks. The lower the temperature, the more water you can move through the machine. We don't want dry snow, of course. Snow is too fluffy. We want slop. We want wet sherbet. At twenty degrees Fahrenheit, we can move fifty gallons a minute through the machine. The electricity that drives the snow machine amounts to a very small fraction of the electricity that is saved by the cooling capacity of the ice. In summer, electrical pumps circulate the ice water from the bottom of the pond for a few tenths of a cent a ton. The cost of moving air in ducts through the building is the same as in a conventional system and is negligible in comparison with the electrical cost of cooling air. We're substituting ice water made with winter winds for the cold fluid in a refrigerated-air-conditioner, using less than a tenth as much electrical energy as a conventional air-conditioning system. Our goal is to make the over-all cost lower than the cost of a conventional system and use less than one-tenth of the energy. We're just about there."

The Prudential's new buildings—a hundred and thirty thousand square feet each, by Princeton's School of Architecture and Skidmore, Owings & Merrill—will be started this summer on a site a mile away. They are low, discretionary structures, provident in use of resources, durable, sensible, actuarial—with windows shaded just enough for

summer but not too much for winter, with heat developing in a passive solar manner and brought in as well by heat pumps using water from the ground—and incorporating so many other features thrifty with energy that God will probably owe something to the insurance company after the account is totted up. An ice pond occupying less than half an acre can be expected to compound His debt.

A man who could devise atomic bombs and then plan to use them to drive himself to Pluto might be expected to expand his thinking if he were to create a little hill of ice. Taylor has lately been mulling the potentialities of abandoned rock quarries. You could fill an old rock quarry a quarter of a mile wide with several million tons of ice and then pile up more ice above ground as high as the Washington Monument. One of those could air-condition a hundred thousand homes. With all that volume, there would be no need for insulation. You would build pipelines at least ten feet in diameter and aim them at sweltering cities, where heat waves and crime waves would flatten in the water-cooled air. You could make ice reservoirs comparable in size to New York's water reservoirs and pipe ice water to the city from a hundred miles away. After the water had served as a coolant, it would be fed into the city's water supply.

"You could store grain at fifty degrees in India," Taylor goes on. "We're exploring that. The idea is to build an aqueduct to carry an ice slurry from the foothills of the Himalayas down to the Gangetic plain. With an insulated cover over the aqueduct, the amount of ice lost in, say, two hundred miles would be trivial—if the aqueduct is more than ten feet across. In place of electric refrigeration, dairies

could use ice ponds to cool milk. Most cheese factories could use at least fifty thousand tons of ice a year. If all the cheese factories in the United States were to do that, they alone would save, annually, about six million barrels of oil. When natural gas comes out of the earth, it often contains too much water vapor to be suitable for distribution. One way to get rid of most of the water is to cool the gas to forty degrees. If ice ponds were used to cool, say, half the natural gas that is produced in this country, they would save the equivalent of ten million barrels of oil each year. Massive construction projects, such as dams, use amazing amounts of electricity to cool concrete while it hardens, sometimes for as much as three years. Ice ponds could replace the electricity. Ice ponds could cool power plants more effectively than environmental water does, and therefore make the power plants more efficient. Ice would also get rid of the waste heat in a manner more acceptable than heating up a river. In places like North Dakota, you can make ice with one of these machines for a few cents a ton—and the coolant would be economically advantageous in all sorts of industrial processing.”

Taylor shivers a little, standing on the ice, and, to warm himself, he lights a cigarette. “You could also use snow machines to freeze seawater,” he continues. “As seawater freezes, impurities migrate away from it, and you are left with a concentrated brine rich in minerals, and with frozen water that is almost pure—containing so little salt you can’t taste it. As seawater comes out of the snow machine and the spray is freezing in the air, the brine separates from the pure frozen water as it falls. To use conventional refrigeration—to use an electric motor to run a compressor to circulate Freon to freeze seawater—is basically too costly. The cost

of freezing seawater with a ski-slope machine is less than a hundredth the cost of freezing seawater by the conventional system. There are sixty-six pounds of table salt in a ton of seawater, almost three pounds of magnesium, a couple of pounds of sulphur, nearly a pound of calcium, lesser amounts of potassium, bromine, boron, and so forth. Suppose you had a ship making ice from seawater with snow machines that had been enlarged and adapted for the purpose. You would produce a brine about ten times as concentrated with useful compounds as the original seawater. It would be a multifarious ore. Subsequent extraction of table salt, magnesium, fertilizers, and other useful material from the brine would make all these products cheaper than they would be if they were extracted from unconcentrated seawater by other methods. The table salt alone would pay for the ship. You could separate it out for a dollar a ton. A ship as large as a supertanker could operate most of the year, shuttling back and forth from the Arctic to the Antarctic. At latitudes like that, you can make twenty times as much ice as you can in Princeton.”

“What do you do with the ice?”

“Your options are to return it to the sea or to put it in a skirt and haul it as an iceberg to a place where they need fresh water. The Saudis and the French have been looking into harvesting icebergs in Antarctica and towing them to the Red Sea. Someone has described this as bringing the mountain to Muhammad. I would add that if you happen to live in a place like New York the mountain is right at your doorstep—all you have to do is make it. The cost of making fresh water for New York City with snow machines and seawater would be less than the cost of delivered water there now. Boston looks awfully good—twice as good as

Princeton. Boston could make fresh water, become a major producer of table salt and magnesium and sulphur, and air-condition itself—in one operation. All they have to do is make ice. It would renew Boston. More than a hundred years ago, people cut ice out of ponds there and shipped it around Cape Horn to San Francisco. When this country was getting going, one of Boston's main exports was ice."