CHAPTER 7

Invasion of a Stable Business by Radical Innovation

Whenever technological discontinuities occur, companies' fortunes change drastically.

Richard N. Foster, from *Innovation: The Attacker's Advantage*

On a recent stay in London my family and I were foiled in our attempt to find a carton of fresh milk in a small grocery store near our quarters. The refrigerated cabinets contained other perishables, but no milk. Observing our confusion, the storekeeper directed us to a section of ordinary unrefrigerated shelves where, to our surprise, the milk was stored in normal abundance along with a variety of nonperishable products. What made this possible was asceptic packaging, an innovation of Tetrapak, a Swedish firm, which developed the process of "flash sterilization" to eliminate the costly necessity of refrigeration and special handling for milk and fruit juices. This method of dealing with food preservation has been a success with the food industry and with consumers where refrigeration is limited. Asceptic packaging has been slow to enter the large U.S. market with its abundant refrigerated distribution and home refrigerators, but has grown rapidly in areas where refrigeration is less plentiful. Indeed, U.S. packagers of milk have adopted extra sterilization to preserve its shelf life in partial adoption of Tetrapak's idea. To date the U.S. market has seen only speciality and convenience items such as coffee cream and small cartons of fruit juice in asceptic form.

Earlier chapters mentioned how waves of innovation—or discontinuities—have swept through typing, lighting, and plate glass-making. This chapter examines that process in detail, focusing on the early history of an industry for which asceptic packaging may very well represent the next wave of transforming innovation.

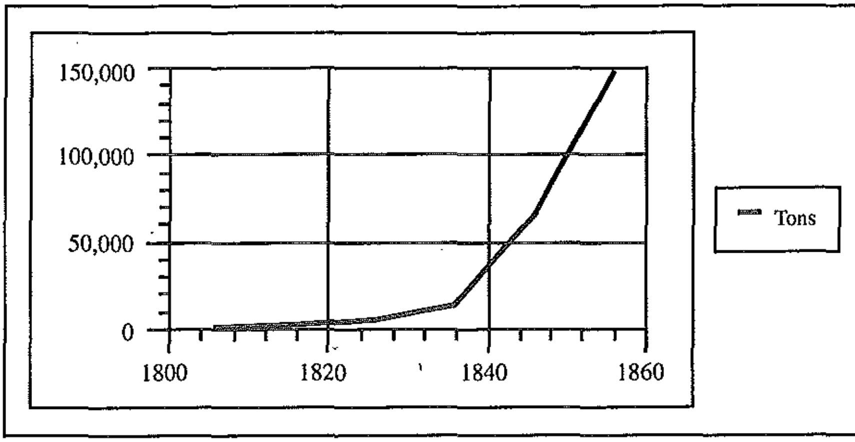
AMERICA'S ICE INDUSTRY

Contemporaries called him the "Ice King," and in 1833 Frederic Tudor of Boston was ready to take his greatest gamble ever. In the spring of that year he had 200 tons of ice cut from a local pond and hauled to the wharf in neighboring Charlestown. There the cold cargo was carefully packed aboard the ship *Tuscany,* with generous amounts of sawdust between each layer and all around, for a 180-day voyage to India. The long months under sail were almost entirely through tropical waters: down past the West Indies, then across the equator off the west coast of Africa, around the Cape of Good Hope into the Indian Ocean, and across the equator once again en route to Calcutta. At the end of the journey, *Tuscany* still had 100 tons of ice to sell. This venture lost money but opened a new market that would soon contribute profits to Tudor's far-flung ice empire.

Tudor could well afford this initial loss. Since his first shipment of ice from Charlestown, Massachusetts to Martinique in the West Indies in 1806, he had built the harvested ice business into a major industry, and the best days were yet to come (see Figure 7-1). By 1856, his company was shipping 146,000 tons per year in 363 separate cargos to such U.S. ports as Philadelphia, Charleston, Savannah, New Orleans, and San Francisco, and to the Caribbean islands, Havana, Rio de Janeiro, Madras, Bombay, and Hong Kong. A comparable amount of ice was marketed locally, where it was now an indispensable commodity for the brewing and fishing industries as well as for meat processors, dairyfarmers, restaurants, and hospitals. The ice business was a young enterprise on which many economic activities had come to depend and through which great fortunes were made. Most remarkable was the fact that Tudor and those like him succeeded in turning something once considered totally worthless into a financial bonanza.

It was the resourcefulness of Tudor, and other Bostonians who became his competitors, that prompted historian Daniel Boor-

FIGURE 7–1. **Tudor Ice Company, Quantity of Ice Shipments, 1806–1856**



Source: Based on data in Henry Hall, *The Ice Industry of the United States with a Brief Sketch of Its History and Estimates of Production,* U.S. Department of the Interior, Census Division, Tenth Census, 1880, v. 22 (Washington, D.C.: U.S. Government Printing Office, 1888, reprinted by the Early American Industries Association), p. 3.

stin's remark that "Using the sea, New England versatility made the very menaces of the landscape [granite and ice] into articles of commerce."[1]

This chapter and the next continue our exploration of the relationships between innovation and its impact on competitive success. Here we investigate the case of the American ice-harvesting industry and its subsequent decline in the face of machine-made ice. Far from being an arcane historical curiosity, this case provides a look at a familiar process technology over its full life cycle. This long-term perspective helps us to see how a competing technology emerged, from what source, and how the dominant technology responded when challenged.

We also observe here how one generation of technology applied to a commonplace requirement (cooling) gave way to others. Thus refrigeration using harvested ice was rendered obsolete by machine-made ice—an innovation based on a radically different technology—which in turn was superseded by electromechanical refrigeration.

THE SECOND ICE AGE IN NEW ENGLAND

Farmers had for years cut and chopped ice for storage in their own underground ice wells. No less a progressive agrarian than George Washington built a "dry well" ice house at Mount Vernon in the fall of 1784, using a design described to him by Robert Morris, then U.S. Superintendent of Finance. Washington's original underground facility, which provided no drainage, had been a failure, but Morris's design worked very well, and thereafter Washington spent many days each January supervising the cutting and hauling of ice from the Potomac to his new, improved ice house. Farmers in northern states made a community event of ice harvesting; as in barn raising, the men and boys cut, loaded, and transported ice to each farmer's ice house in turn, while the women and girls cooked up a big communal meal and provided warm clothing for any who fell into the frigid water. It was heavy work—cutting and chopping chunks of ice, hauling them out by hand, and loading and unloading them from farm wagons and sleighs. It remained for Frederic Tudor to turn this winter ritual into a commercial venture, to create a uniform and marketable "product" in place of assorted chunks of ice, and to support innovation of the processes that would make it highly profitable.

Successful innovators often have able collaborators. George Eastman had chemist Henry Reichenbach; Edison had mechanic Charles Batchelor; Henry Ford relied on the engineering management know-how of Charles Sorenson. Frederic Tudor was no exception. Tudor benefited greatly in knowing a young Harvard graduate named Nathaniel Jarvis Wyeth, who had taken over the management of his family's hotel on the shores of Fresh Pond in Cambridge, Massachusetts in the early 1820s. Like other establishments serving food during the summer, Wyeth's hotel put in a load of ice each winter. But unlike other operators, Wyeth developed methods and equipment to make ice harvesting more efficient and the final product more uniform for ease of storing.

In 1825, Wyeth designed and applied for a patent on an "ice plow"—a cutting device that harnessed the muscle power of horses to the task of etching uniformly shaped blocks that could then be cut from the pond and more efficiently transported and stacked in barn-like ice houses. That same year, he became exclusive supplier to Frederic Tudor, and before long ice from Fresh Pond was finding its way down the Atlantic seaboard and around the world in Tudor

Company ships with names like *Ice King, Iceland,* and *Iceberg.* Wyeth's invention of the ice plow was followed by more than 50 specially designed saws, snow scrappers, and other assorted tools, each of which enhanced and systematized the process of ice harvesting.[2] These process innovations are said to have cut the price of delivered ice by one-third.

Crews using Wyeth's methods foraged broadly among Boston area ponds and even invaded the solitude of Concord's Walden Pond, where the reclusive Henry David Thoreau observed the harvest and offered this description in the pages of *Walden*:

> . . . a hundred Irishmen, with Yankee overseers, came from Cambridge every day to get out the ice. They divided it into cakes by methods too well known to require description, and these, being sledded to the shore, were rapidly hauled off on to an ice platform, and raised by grappling irons and block and tackle, worked by horses, on to a stack, as surely as so many barrels of flour, and there placed evenly side by side, and row upon row, as if they formed the solid base of an obelisk designed to pierce the clouds. They told me that in a good day they could get out a thousand tons, which was the yield of about one acre.

By the time *Tuscany* returned from India in 1834, the Tudor Ice Company enjoyed a virtual monopoly in the Boston area; it had exclusive arrangements with both the British and Dutch governments for supplying the West Indies and had a similar understanding with Spanish colonial authorities in Cuba. Storage facilities were sited in Charleston, South Carolina and Savannah, Georgia as well as at Kingston, Jamaica, and Havana, Cuba. Preventing ice from becoming an instant puddle in the scorching climates of these cities was no simple task, and Tudor himself supervised construction and experiments with dockside ice houses, the first being set up in Havana in 1816. This facility was a square, double-shell building prefabricated in Boston and sent down to Havana by ship. The sides measured 25 feet on the outside, and 19 feet on the inside, and the structure was designed to hold 150 tons.[3] We must assume that the space between the two sets of walls was filled with wood shavings or some other form of insulating material. Tudor conducted a number of empirical studies on the "decay" rate of ice at this facility, measuring the amount of run-off using different forms and methods of insulation. His best recorded decay rate for the

Havana ice house was 56 pounds of water per hour. His own ice elevator on Fresh Pond boasted of being able to store ice for upward of three years. Improved methods permitted Tudor to bring down the price of his product and expand its distribution. In Charleston, South Carolina, for example, per-ton prices dropped from $166 in 1817 to $25 in 1834.

Tudor's growing success was not lost on his Boston neighbors, and several entered the business. One of these rivals, a Mr. Hittinger of Gage, Hittinger and Company, sought to develop a British market with a cargo of Fresh Pond ice sent in 1842. Hittinger knew that the tradition-bound British would not use ice unless they were shown how, so he hired a number of Boston bartenders and took them to London on a ship scheduled to arrive before the ice. When the cargo of "cold comfort" arrived, Hittinger and his bartenders were already set up in an opulent and brightly illuminated hall and there "initated the English into the mysteries of juleps, cocktails" and "Boston notions" of various types.[4] Before long, fashionable Britons were hooked on New England ice.

Once the British trade was in full swing, a pecking order in the snob appeal of American ices emerged—just as we witness today with various bottled waters. The product of the Wenham Lake Ice Company (near Beverly, Massachusetts) came to be cherished above all others for its clarity and supposed purity. According to claims of the time, a newspaper could be read through a block of Wenham ice two feet thick. (The British lords and ladies most likely did not realize the extent to which teams of horses strained on the surface of pristine Wenham Lake, doing what horses do in abundance. Ice companies, in fact, had a job category for young boys whose sole duty was to pick up after these horses. How thorough they were is anyone's guess.) No London dinner party was thought to be complete without Wenham Lake ice. This British bonanza ended within just four or five years when Norwegians invaded the market with much lower-priced ice, most of it drawn from Lake Oppengaard, which the Norwegians spuriously renamed "Wenham Lake" and sold under that name.

By the late 1870s, a decade before the high-water mark of the natural ice business, there were no fewer than 14 firms in the Boston area cutting almost 700,000 tons of ice each year. Maine and New Hampshire also had thriving ice companies. It was the perfect occupation for New England in that it drew on a number of abundant local resources: cold winters; many freshwater ponds; farmers, immigrants, fishermen, and mariners in search of winter occupation; mountains of sawdust (for insulation) that was otherwise a nuisance to the logging industry; and a maritime infrastructure for shipping. Process innovation continued to make the product more uniform and lowered the cost of production. For example, many winters were not sufficiently cold in New England to produce thick ice. So, once a few inches of ice were formed, icemen would pump a thin layer of water onto it; this would freeze easily overnight. This process would be repeated each day, building the thickness inch by inch, until the entire sheet was thick enough for harvesting.

Northern-tier states from New York to Wisconsin also developed regional ice industries during this period to serve the growing meat-processing and dairy industries and to accommodate the growing urban populations of the heartland. And while these landlocked ice producers lacked the means to reach overseas markets, they did have access to good railroads, which made long-distance transportation to cities like Chicago, St. Louis, and hundreds of others—large and small—efficient and inexpensive. Railcars were loaded directly at lakeside during the harvest season and from ice elevators during the remainder of the year.

The ice business was a large and important part of the U.S. economy of the 1870s and expanded as householders became regular consumers of harvested ice. City dwellers had begun purchasing "ice boxes" in growing numbers after 1850, and these soon became a modern necessity. By the turn of the century, household consumers accounted for half of the total domestic ice market. The future looked rosy. As the Ice King himself had told the Boston Board of Trade back in 1857, "The ice trade was born here in Boston, and has been growing and extending itself with no successful competitor for more than half a century, and there is reason to think it is yet in its infancy."[5]

Though no one recognized it at the time, the 1880s were to be the zenith of the harvested ice industry. The market for refrigeration was to continue expanding with the growing nation, but a radical innovation based on a totally different technology had already invaded the periphery of the industry. Though generally unnoticed at the time, the new technology was destined to eventually dominate the market for ice and refrigeration.

THE INVASION OF MACHINE-MADE ICE

As industry and households became more dependent on ice for food preservation, iced drinks, confectioneries, and medical applications, its cost and supply reliability became more serious issues.

Because of the industry's seasonal nature and dependence on the weather, the price of harvested ice fluctuated greatly, especially during the summer, according to one's distance from the sources of production. Summer prices in the north were typically in the range of \$6–\$8/ton delivered. Even in years when warm winters resulted in poor harvests, supplies of ice were not seriously disrupted because of the producers' efficient ice houses, which could carry ice through several years. In southern port cities, however, transportation costs and losses due to melting pushed summer prices to the \$20–\$30/ton range. When yellow fever epidemics created abnormally high demand, or when poor northern harvests reduced supply, the price of ice soared to \$60–\$75/ton.[6] Inland southern cities had to pay even more, often as much as \$125/ton. As a result, southern markets offered the greatest receptivity to innovations affecting the supply and price of ice.

This situation bears a striking resemblance to the experience of the United States with regard to petroleum during the 1970s. In both cases the resource was found in abundance where it was needed least. The oil producers of the Middle East had most of the oil and very little domestic need for it; New Englanders lived in a natural ice box for half the year and enjoyed temperate weather for most of the remainder. At the same time, the users of the resource who needed it the most were far away and had to pay premium prices for it. It is no surprise that all the innovations in creating substitutes and efficiencies for petroleum (synfuels, solar power, and conservation) are occurring in countries faced with uncertain supplies and high prices. Likewise, the radical innovations to challenge the ice industry of New England, and the first large-scale adoptions of them, occurred in the steamy regions of the South. Brewers and meat packers in the rural South were among the earliest experimenters with mechanical methods of producing ice. They represented the market niches where high prices for substitutes could be tolerated.

Attempts to produce ice by mechanical or chemical means were made as early as the mid-1700s, but only out of scientific curiosity. Evaporation of water in a vacuum was used successfully to make ice in a laboratory in 1755. The use of sulfuric acid to absorb water vapor and enhance this process was attempted in 1810 and improved in 1824. In 1834, a New Englander named Jacob Perkins, then living in London, received a British patent for a mechanism that produced ice by vaporizing a volatile liquid and then condensing that vapor in a continuous and closed cycle. Perkins's was the first practical ice-making innovation, and its principles form the basis for refrigeration to this day, incorporating as it does a compressor, a condenser, an expansion valve, and an evaporator.[7]

In hot, humid Apalachicola, Florida Dr. John Gorrie began experimenting in 1838 with the use of ice to cool hospital rooms where he treated victims of malaria. The price and unreliable supply of northern ice led Gorrie to design and build an ice-making machine based, apparently without foreknowledge, on the same general principles followed earlier by Perkins. Gorrie received a U.S. patent in 1851. Gorrie attempted to form a commercial venture in New Orleans to develop and exploit his patent, but this initiative ended with Gorrie's death in 1855.

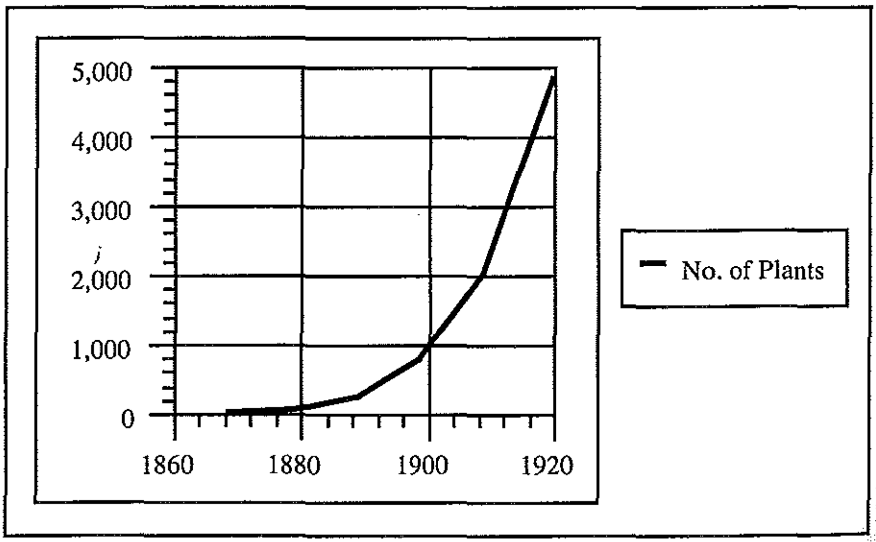
A number of French, German, English, and American inventors experimented with new designs, using either ammonia, ether, naptha, or some other vapor. Historical sources differ as to just when the first successful commercial applications of ice-making machinery were made, and as to their capacity. Jones mentions 1862 as the year in which a machine of French design was brought into San Antonio through Mexico—thus skirting the Union blockage of shipping to and from the Confederate states. In 1868, New Orleans got its first ice-making plant, which began selling manufactured ice for around $35 per ton, substantially less than the price of natural ice. Another commercial-scale operation began in Waco, Texas in 1869.[8] In an 1886 industry study sponsored by the U.S. government, Henry Hall described the rocky road faced by the innovators:

> There are now about forty different styles of ice machines in operation in different parts of the world. Nearly a hundred have been patented at Washington. Not over half a dozen, however, are in this country considered of much practical value at the present time. . . . In order to carry on a successful business in artificial ice-making the product must be manufactured at a cost of not to exceed $2 or $3 a ton. The chief cause of the numerous disastrous

> failures so far has been that the product costs anywhere from $20 to $250 a ton. One aim of inventors in this country is to make ice at from 75 cents to $1 per ton. Many times during the last ten years the announcement has been made that the result has been accomplished. It is doubtful if, in practice, any ice-maker in America has yet been able to produce ice so cheaply; but the cost has, nevertheless, been reduced at length to a point where the making of ice is commercially practicable, and it is now carried on as a regular industry in a large number of southern cities in competition with the importation of natural ice from the north.[9]

From less than a handful of plants in the 1860s, the number had grown to 30 in the southern states and 5 in California by 1879. The largest of these, the Louisiana Ice Company in New Orleans, had a daily capacity of 118 tons.[10] A decade later, in 1889, 222 ice-manufacturing plants were in operation, still mostly in the south, but now also in middle states like Ohio, Illinois, and Indiana. In the decades that followed, the number of ice plants skyrocketed (see Figure 7-2). Improvements to compressors and other aspects of ice-making equipment increased rapidly, and a number of firms,

FIGURE 7–2. **Ice Making Plants in the United States, 1869–1920**



Source: U.S. Bureau of the Census, cited in Cummings, *The American Ice Harvests*, p. 11, and Jones, *America's Ice Men*, p. 159.

including several makers of steam engines, entered the field. New England ice was finding itself effectively driven out of southern markets.

Even as the new technology bit off larger chunks of the industry, the ice merchants of the north pushed ahead with their own improvements and still greater production. Steam-powered circular saws were applied to the job of cutting blocks from rivers and ponds; mechanical conveyors were installed to provide continuous hauling of ice cakes from ponds to ice houses, or directly onto specially designed railroad cars. On the Hudson River, 100 specially designed barges were introduced to transport ice more efficiently from their source to inland river ports farther south. The Knickerbocker Ice Company—the leading manufacturer of ice-harvesting equipment and one-ton "ice wagons" for urban distribution—introduced steam-powered conveyors to lift ice from boats and barges and move it efficiently into the many ice elevators the company owned and operated.[11] Many producers milled their ice blocks into more uniform sizes with incised edges to keep them from freezing together and to make storage more efficient. Thus, even as the door was closing on their industry, the northern ice men continued to make incremental improvements to both their product and the processes by which it was harvested, stored, and delivered. These improvements resulted in greater volume and lower unit costs.

The ice harvesters had developed an entire "system" for production, storage, and distribution that was remarkably efficient. Despite the rapid spread of machine-made ice throughout the south, the 1886 ice harvest was the biggest ever—25 million tons, suggesting how the demise of a technology can be obscured by a growing market.

It was, as we now know, a losing battle, because the technology for manufacturing ice was improving by orders of magnitude while incremental improvements to ice harvesting yielded smaller and smaller gains. Experimentation with vapor compression machines was continuing, and a number of refrigerants were tried, including methyl, ether, oil, and ammonia. The use of ammonia as a refrigerant was an important step forward for, in addition to its thermodynamic advantage over other refrigerants, the pressures it required were easy to produce and the machines that used it could thus be made smaller. David Boyle patented the first ammonia compression machine in 1872 and many improved versions quickly followed. The ammonia compression machine represented an enabling technology, one that opened the door to other important advances.

One problem with early machine-made ice was its cloudiness owing to included air. This gave natural ice a distinct quality advantage insofar as certain users were concerned. It was soon discovered that distilled water, when frozen, was nearly transparent, and this led to a variety of designs using condensed steam from the vaporization stage of ice-making equipment as the water to be frozen in the final product. Other operators found ways to cut down on the amount of refrigerant leakage from pumps and joints—a common problem when using high-pressure gases.

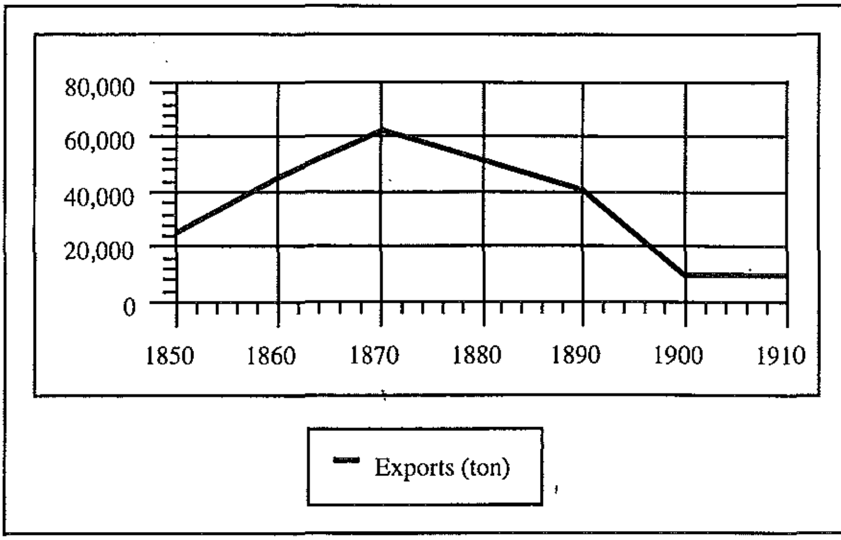
From the workshops of inventors and individual mechanics, companies were formed to produce ice-making equipment, and some became large enterprises. A number of major improvements to the equipment were introduced by users, such as a New York City brewery that developed a system of oil sealing for its compressors to prevent ammonia leakage. After 1890, electricity began to be substituted for steam as a source of power. The first trade journal, *Ice and Refrigeration,* made its appearance in 1891. Improved efficiency, automation, and ease of use characterized the process of producing ice.

THE END OF THE HARVESTED ICE ERA

Despite efforts to lower costs and improve their product, the ice harvesters steadily lost markets to plant-made ice. A few gave in and acquired ice-making equipment of their own; most went down with the ship. As industrial historian Richard Cummings described it, "Some ice distributors found it cheaper to abandon natural ponds and set up plants. Others sought to cut harvesting cost by time saving devices. . . . But, since plant ice processes were being constantly improved, natural ice harvesters were in a losing fight."[12] Massachusetts, the last bastion of the ice empire, itself had seven mechanical ice plants by 1909.

As the mechanical ice-making technology spread abroad, the export market for ice plummeted (Figure 7-3). The *coup de grace* came after World War I, when old-fashioned ice boxes, the local—and last—sizable market for harvested ice, began to give way to electric refrigerators.

FIGURE 7–3. **U.S. Ice Exports, 1850–1910**



Source: U.S. Census Bureau, cited in Cummings, *The American Ice Harvests.*

By the mid-1920s, the natural ice industry was gone for good, except in a few outlying areas. Ice elevators stood vacant and over the years fell into ruins. Today, along the shores of Fresh Pond and Wenham Lake no visible signs remain of the great ice houses of the nineteenth century or of the vast and prosperous industry they represented.

In later years, even the new ice-making plants would become outmoded, replaced by a new wave of innovation: electromechanical refrigeration. Blocks of ice—from any source—became less important as refrigerated rail cars, ships, storage lockers, and electric home refrigerators satisfied the basic requirement for cooling more conveniently and at lower cost.

As a footnote we might consider the emergence of several small companies with a high-price, unique product: glacial ice. In the 1980s, several Alaskan entrepreneurs began bagging ice from glaciers and selling it as a premium product for use in mixed drinks in the lower 48 states. As with Wenham Lake ice in England over a century before, it wasn't a party without the perfect ice, in this case ice with its own prehistoric effervescence!

PATTERNS IN THE EMERGENCE OF RADICAL INNOVATIONS

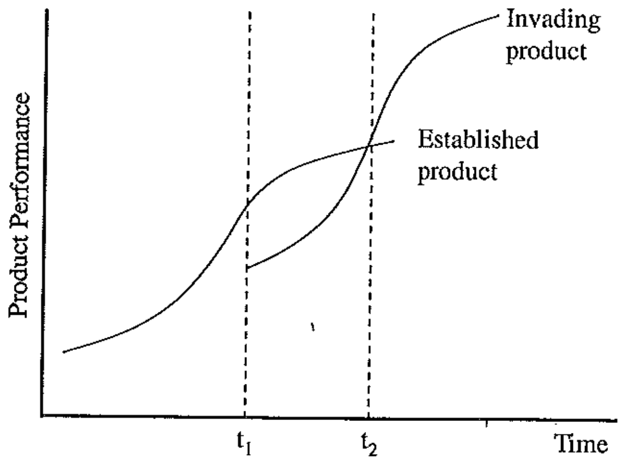
This long tale about the ice industry is not told here merely as a quaint story, but as an example of how a radical technological innovation can emerge and successfully invade—and eventually overwhelm—the established technology in almost any circumstance. It is a recurring phenomenon in industries past and present, and the same struggle between new and old can be seen today in duels between plywood and strandboard, copper wire and optical fiber, supercomputers and massively parallel computers.

There is a general pattern to the invasion process of this story, other industries previously discussed, and still others encountered beyond the covers of this book. One could generalize that in any product market there are periods of continuity, when the rate of innovation is incremental and infrequent, and periods of discontinuity when major product or process changes occur. Radical changes create new businesses and transform or destroy existing ones, just as mechanical ice-making destroyed the New England ice-harvesting industry.

An invading technology has the potential for delivering dramatically better product performance or lower production costs, or both. Figure 7-4 shows that the performance of a particular product improves rapidly during the period when many alternative design approaches are being tried. With the appearance of a dominant design, however, product performance accelerates. After major advances have been made, a period of more incremental and infrequent change sets in, as indicated by a leveling off of the product performance curve.

At the time an invading technology first appears (t_1), the established technology generally offers better performance or cost than does the challenger, which is still unperfected. The typewriter case provided an excellent example of this in its latest wave of innovation, when the first word processors appeared. These were crude devices by contemporary standards and difficult to master. And Apple Computer's first personal computer, like Mark Twain's Remington, produced only uppercase letters. No self-respecting typist would have given up an IBM Selectric for one of those toys! The new technology may be viewed objectively as crude, leading to the belief that it will find only limited application. The performance superiority of the established technology may prevail for

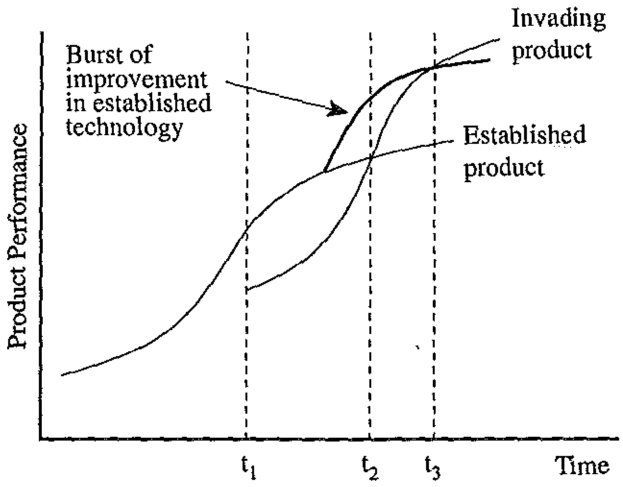
FIGURE 7–4. **Performance of an Established and an Invading Product Contrasted along One Performance Dimension**



quite some time, as was the case for harvested ice relative to machine-made ice in most locations for the last quarter of the nineteenth century, but if the new technology has real merit, it typically enters a period of rapid improvement—just as the established technology enters a stage of slow innovative improvements. Eventually, the newcomer improves its performance characteristics to the point where they match those of the established technology (t_2) and rockets past it, still in the midst of a period of rapid improvement.

Of course, the established players do not always sit back and watch their markets disappear. Most fight back. The gas companies came back against the Edison lamp, as we saw in Chapter 3, with the Welsbach mantle, which increased the efficiency of gas lighting by five times. There was nothing incremental about that. Purveyors of established technologies often respond to an invasion of their product market with redoubled creative effort that may lead to substantial product improvement based on the same product architecture. Figure 7-5 describes this behavior. Here, the established product enjoys a brief period of performance improvement (the dotted line), but by time t_3 the relentless pace of improvement in the new product technology allows the challenger to equal, and then surpass, the established product. Continued investment in

FIGURE 7–5. **Performance of an Established and an Invading Product. Burst of Improvement in Established Product.**



older technologies invariably leads to performance improvement, but this generally becomes marginal over time. The new technology, on the other hand, often has so much more potential for better performance that it is usually just a matter of time before that potential is realized and the new surpasses the old.

In cases where cost was the dimension of performance that determined the outcome, Figures 7-4 and 7-5 could easily be inverted to describe declining cost curves for the established technology and its challenger.

Innovations from Outsiders

In the cases we have examined thus far, innovations have not come from the industry leaders as much as from outsiders. Thinking back to our typewriter story, Christopher Sholes was a civil servant working in the obscurity of a Milwaukee office; he had no standing in the printing or document-processing establishment of his day. Yet his innovation set the pattern for processing documents for several generations. When the next wave of innovation hit that industry—electrics—it was not one of the giants of the typewriter business that pioneered its development or growth. It was the outsider, IBM. Still later, when computer technology moved into the document-processing business, the innovating came from unknown hardware companies such as Wang, Apple, Tandy, and dozens of software firms. IBM would eventually acquire its share of the hardware business, but as a follower, not as a technical leader.

In the lighting industry we observed how the great leap forward into incandescent electric lamps was not led by anyone with standing in that business but by Thomas Edison, whose accomplishments to date had been in totally unrelated fields: telegraphy and recorded sound. Those with the biggest stake in home and commercial lighting at the time, the gas illumination companies, were totally out of the picture. Years later it would be a market bit player—Sylvania—that would make the greatest innovations in the next wave of lighting technology: fluorescent lamps.

The case of mechanical manufacturing of ice again conforms with our pattern of innovation by outsiders. The great fortunes in ice had all been made by northerners, primarily in the Boston area. They created the product and controlled distribution; the Knickerbocker Company, not a producer itself, was nevertheless a major player in process equipment, distribution equipment, and ice elevators. Despite the great stakes of Knickerbocker and the ice barons in this business, the radical innovation came from outsiders. (One is tempted to say that *because* of their great investments in the established forms of the business, they were impeded from making the industry-altering innovations.) We have already discussed the economic logic of this phenomenon, and we can speculate that if the merchants of Calcutta and Hong Kong—the farthest borders of the ice empire—had been handier with Western science and technology, it might have been they who created the first important innovations in ice manufacturing.

Industry outsiders have little to lose in pursuing radical innovations. They have no infrastructure of existing technology to defend or maintain and, as is made clear through the case of ice innovators in the southern United States, they have every economic incentive to overturn the existing order.

Industry insiders, on the other hand, have abundant reasons to be slow to mobilize in developing radical innovations. Economically, they have huge investments in the current technology; emotionally, they and their fortunes are heavily bound up in the status quo; and from a practical point of view, their managerial attention is encumbered by the system they have—just maintaining and marginally improving their existing systems is a full-time occupation. Owners and managers of dominant firms who are deliberate in their pursuit of radical innovation are remarkable and few.

Reluctance to Adopt the New Technology

A critical pattern in the dynamics of technological innovation—and one that should give every business strategist a great deal of discomfort—is the disturbing regularity with which industrial leaders follow their core technologies into obsolescence and obscurity. Firms that ride an innovation to the heights of industrial leadership more often than not fail to shift to newer technologies. Few attempt the leap from the fading technology to the rising challenger; even fewer do it successfully. No one has addressed this gloomy phenomenon or articulated its dimensions more fully than Richard Foster. Foster cites a long list of products in the container and packaging business with market positions that have been overturned by innovative competitors: glass bottles by steel cans; steel cans by aluminum cans; glass bottles by plastic bottles; plastic-coated milk cartons by plastic jugs; and so forth. In each case, he notes that market leadership passed from one set of firms to another. Today's leaders, in these cases, were never leaders in the next product generation:

> I don't know of any comprehensive statistics that would stand up to academic scrutiny, but my feeling is that leadership changes hands in about seven out of ten cases when discontinuities strike. A change in technology may not be the number-one corporate killer, but it certainly is among the leading causes of corporate ill-health.[13]

It is easy to understand how established firms can ignore a radical innovation when it first appears. For one thing, in the early stages it is far from clear that the radical innovation will have much impact. Like biological mutations, radical innovations crop up sporadically, but very few have the qualities that lead to long-term survival. The problems that plagued the early mechanical ice-making technology were sufficiently large that industry analyst Henry Hall, writing in the early 1880s, just when the technology was about to take off, failed to see any major role for manufactured ice outside the South. In the nineteenth-century lighting industry, the "gas men," as Edison called them, certainly recognized trouble when the first incandescent lighting systems were being introduced. But one wonders if this would have been the case if an unknown technologist—and not the acclaimed Edison—were its guiding spirit. In the early days of the photographic industry, as the next chapter will make clear, the low quality of the celluloid roll film innovated by Eastman failed to convince many that it could be perfected to the standards of first-rate photography—even to the standards of that time.

Established firms also carry the burden of large investments in people, equipment, plant, materials, and knowledge, all of which are closely linked to the established technology. It takes a rare kind of leadership to shift resources away from areas where one currently enjoys success to an area that is new and unproven.

Finally, there is the very human problem of managers resting on their laurels—or in this case, on the technologies that have made them successful. Few, if any of us, are blameless in this. These managers bind up their thinking and planning too closely with their own technology and not closely enough with customer needs. When this happens, managers can satisfy changing customer needs only by making improvements or enhancements to their own technology, even though a different technology may address the customer's needs much more successfully. In the case of the ice industry, the northern producers responded to the technological threat by increasing the efficiency of their existing processes of production and distribution; there is no indication that any northern ice producers adopted plant-ice technology, at least until the end of the harvested ice era. None built ice plants in the South to serve their existing customers. None experimented with what today seems like a reasonable adaptation: sending harvested ice south in refrigerated ships (to reduce melting), and returning to the populous, urban northeast with southern agricultural produce in those same refrigerated holds (though this was suggested at the time).

More recently, when rising fuel prices in the 1970s created customer demand for smaller, more efficient automobiles, U.S. automakers responded (with minor exceptions) by offering slightly smaller versions of their existing, inefficient line of cars. Only after many years of market failure did the notion of developing small cars from the bottom up result in managerial action.

MEETING THE CHALLENGE OF DISCONTINUOUS CHANGE

Established leaders face two hurdles in their contest with invading innovation. First, they need to develop an awareness of their own vulnerability—a slow and difficult process for any firm that has experienced substantial success. In 1980–1981, General Motors experienced horrific problems with its newly introduced "J" platform cars. The J cars were overweight and underpowered; they resisted starting in cold weather and caused tremendous problems on the assembly line because of poor body-panel alignments. The causes of these quality-related problems were investigated by a special focus group and presented to top management, which refused to believe what it heard. In 1982, another study was commissioned and pursued by the firm's newly established corporate quality and assurance department, this time to assess the quality methods of a number of highly respected American industrial firms. When presented with the results of the study, top management again refused, at least initially, to accept the notion that GM quality practices were not in a class with those firms. Full recognition of its quality problems would only take hold among GM leadership over time. Meanwhile, it was losing pieces of its market to foreign and domestic competitors.[14] Recognition of an external threat is the first requirement for effective action.

The second hurdle is to make the organizational adjustments that facilitate successful competition with an invading technology. The organizational problem for most established firms is that they and their technology are often stuck in the specific phase of development, while the challenger and its innovations are still in the fluid phase. The challenger brings a new and perfectable product with better performance (or performance potential), organizational flexibility, and entrepreneurial spirit; the challenger is unencumbered by human and physical assets geared to highly specific production. The established firm, on the other hand, is more bureaucratic, enjoys economies of scale (but in the wrong product), has tremendous investments in inflexible systems, and is managed by nonentrepreneurs. Thus we agree with Foster's estimate: the contest between the slow, muscle-bound champion and the nimble challenger will go to the challenger 70 percent of the time.

Foster believes that "the attacking and defending ought to be done by separate organizations."[15] This contention has intuitive appeal and can be supported by evidence from a number of industries. When IBM determined that it should take the personal computer market seriously, it did not attempt to develop its product offering from within the sprawling camp of IBM. It set up a separate unit in Boca Raton, Florida—far from its Armonk, New York, headquarters—to tackle the job. Ford Motor Company followed a similar path in its creation of "Team Taurus," a multidisciplinary development team headed by the late Lewis Veraldi and vested with extraordinary decision-making powers.[16] Team Taurus launched the most successful new American automobile model in the past ten years. General Motors went even further in setting up the Saturn company to be its champion in the contest with the best of Japan's small car makers; Saturn would design, build, and market its own products, free of GM doctrine on sourcing parts and labor. Saturn would have many of the earmarks of what our model describes as a "fluid phase" organization.

Meeting the challenge of technological discontinuities is one part of the broader issue of corporate renewal, which is addressed in Chapter 10.

Notes

1. Daniel J. Boorstin, *The Americans: The National Experience* (New York: Random House, 1965), p. 10.
2. Joseph C. Jones, Jr., *America's Ice Men: An Illustrative History of the United States Natural Ice Industry, 1665–1925* (Humble, Tex.: Jobeco Books, 1984), p. 20.
3. Philip Chadwich Foster Smith, *Crystal Blocks of Yankee Coldness: Development of the Massachusetts Ice Trade from Frederic Tudor to Wenham Lake* (Salem, Mass.: Essex Institute Historical Collections, vol. XCVII, 1961), p. 203.
4. A.P. Putnam, "Wenham Lake and the Ice Trade," in John C. Phillips, ed., *Wenham Great Pond* (Salem, Mass.: Peabody Museum, 1938), p. 36.
5. Henry Hall, *The Ice Industry of the United States with a Brief Sketch of Its History and Estimates of Production,* U.S. Department of the Interior, Census Division, Tenth Census, 1880, v. 22 (Washington, D.C.: U.S. Government Printing Office, 1888, reprinted by the Early American Industries Association), p. 3.
6. Oscar Edward Anderson, Jr., *Refrigeration in America: A History of a New Technology and Its Impact* (Princeton: Princeton University Press, 1953), p. 43.
7. Jones, *America's Ice Men,* p. 150.
8. Ibid., pp. 151–152.
9. Hall, *The Ice Industry,* p. 20.

10. Anderson, *Ice and Refrigeration,* pp. 86–87.
11. Hall, *The Ice Industry,* p. 17.
12. Richard O. Cummings, *The American Ice Harvests: A Historical Study in Technology, 1800–1918* (Berkeley, Calif.: University of California Press, 1949), p. 48.
13. Richard N. Foster, *Innovation: The Attacker's Advantage* (New York: Summit Books, 1986), p. 116.
14. See Gregory Watson, *Strategic Benchmarking* (New York: John Wiley, 1993), pp. 129–148.
15. Foster, *Innovation,* p. 210.
16. Presentation by Lewis Veraldi to Management of Technology students at MIT in 1987.