REFRIGERATED RAIL CAR UNIT PLAN

Compelling Question	**How would your life be different without the refrigerated rail car?**		
Standards and Practices	*C3 Historical Thinking Standards* – D2.His.1.9-12. Evaluate how historical events and developments were shaped by unique circumstances of time and place as well as broader historical contexts. *C3 Historical Thinking Standards* – D2.His.2.9-12. Analyze change and continuity in historical eras. *Common Core Content Standards* – CCSS.ELA-LITERACY.WHST.9-10.1.B Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner, that anticipates the audience's knowledge level and concerns. *AP World History Learning Objectives – ENV-2* Explain how environmental factors, disease, and technology affected patterns of human migration and settlement over time. *AP World History Learning Objectives – ENV-4* Explain how environmental factors have shaped the development of diverse technologies, industrialization, transportation methods, and exchange and communication networks. *AP World History Learning Objectives – ENV-5* Explain the extent to which the development of diverse technologies, industrialization, transportation methods, and exchange and communication networks have affected the environment over time. *AP World History Learning Objectives – ECON-1* Explain how technology shaped economic production and globalization over time. *AP World History Learning Objectives – ECON-7* Explain how local, regional, and global economic systems and exchange networks have influenced and impacted each other over time.		
Staging the Question	How are perishable foods transported from producers to consumers?		
Supporting Question 1	**Supporting Question 2**	**Supporting Question 3**	**Supporting Question 4**
What were the motivations for and early attempts at refrigeration?	How was mobile refrigeration accomplished?	How did refrigerated rail cars impact agriculture and eating habits?	How has refrigerated transport impacted modern society and what is the future of this technology?

Formative Performance Task	**Formative Performance Task**	**Formative Performance Task**	**Formative Performance Task**
Create a timeline of refrigeration from medieval times to the late 19th century.	Build a functional model of an ice car and test how long it will keep an ice cube from melting.	Create a map illustrating the changes in the American food supply chain that were caused by the introduction of refrigerated rail cars.	Make a list of everything in your life that requires refrigeration, and write a diary entry describing a day in your life without those things.
Featured Sources	**Featured Sources**	**Featured Sources**	**Featured Sources**
1A. “To Thomas Jefferson from Thomas Moore, with Jefferson’s Note, 21 June 1802,” *Founders Online,* National Archives, last modified June 29, 2017, http://founders.archives.gov/documents/Jefferson/01-37-02-0526. [Original source: *The Papers of Thomas Jefferson*, vol. 37, *4 March–30 June 1802*, ed. Barbara B. Oberg. Princeton: Princeton University Press, 2010, pp. 650–651.] 1B. "Ice House." Thomas Jefferson's Monticello. Accessed September 29, 2017. https://www.monticello.org/site/house-and-gardens/ice-house. 1C. "New Forest Heritage." New Forest Explorers Guide. Accessed September 27, 2017.	2A. Danes-Wingett, Linda. "The Ice Car Cometh: A History of the Railroad Refrigerator Car." *The San Joaquin Historian*, New Series, X, no. 4 (Winter 1996): 1-3. 2017. Accessed September 30, 2017. http://www.sanjoaquinhistory.org/documents/HistorianNS10-4.pdf. 2B. "Tiffany Refrigerator Car Company." Builders of Wooden Railway Cars. April 11, 2006. Accessed December 19, 2017. http://www.midcontinent.org/rollingstock/builders/tiffany.htm. 2C. Goodspeed, Thomas W., D.D., LL.D. *Gustavus Franklin Swift, 1839-1903*. Vol. 1. University of Chicago Biographical Sketches. Chicago, IL: University of Chicago, 1922. Accessed November 18, 2017. http://libsysdigi.library.illinois.edu/oca/Books2009-	3A. Weld, L. D. H., Ph.D. "Private Freight Cars and American Railways." *Studies in History, Economics, and Public Law*31, no. 1, Columbia University Press (1908). 3B. Weld, L. D. H., Ph.D. "Private Freight Cars and American Railways." *Studies in History, Economics, and Public Law*31, no. 1, Columbia University Press (1908). 3C. "Refrigerator Cars." *Scientific American*66, no. 1698supp (1908): 44. doi:10.1038/scientificamerican07181908-44bsupp. 3D. Hinds, Russell H. "A Performance Test of Refrigerated Rail Cars Transporting Frozen Food." Washington, D.C. : U.S. Dept. of Agriculture, Agricultural Marketing Service, Marketing Research Division, 1957. Hathi Trust Digital Library. Accessed November 18,	4A. "The future of staying cool: New project could completely change the refrigeration industry." Phys.org - News and Articles on Science and Technology. December 17, 2013. Accessed September 30, 2017. https://phys.org/news/2013-12-future-cool-refrigeration-industry.html. 4B. "Engineers develop the refrigerator of the future." Phys.org - News and Articles on Science and Technology. February 2, 2016. Accessed September 30, 2017. https://phys.org/news/2016-02-refrigerator-future.html. 4C. Mayer, Marina. "How America Depends on Rail." Refrigerated Frozen Food RSS. November 7, 2014. Accessed November 18, 2017. https://www.refrigeratedfrozenfood.com/articles/88

http://www.newforestexplorersguide.co.uk/heritage/history-in-the-landscape/ice-houses.html. 1D. "Ice Houses in the UK: Then and Now." The Ice Co. March 29, 2016. Accessed September 30, 2017. http://www.theiceco.co.uk/blog/ice-houses-in-the-uk-then-and-now/. 1E. Mitenbuler, Reid. "The Stubborn American Who Brought Ice to the World." The Atlantic. February 05, 2013. Accessed September 30, 2017. https://www.theatlantic.com/national/archive/2013/02/the-stubborn-american-who-brought-ice-to-the-world/272828/. 1F. Ruddick, J. A. b. 1862. (1907) . *The use of ice on the farm.* Ottawa: Dept. of Agriculture. https://babel.hathitrust.org/cgi/pt?id=aeu.ark:/13960/t3st96810;view=1up;seq=11 1G. Anderson, Oscar E. Refrigeration in America: a history of a new technology and its impact. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.	06/gustavusfranklin00good/gustavusfranklin00good.pdf. 2D. Thevenot, R. & Fidler, J.C. & International Institute of Refrigeration. *A history of refrigeration throughout the world*. Paris, International Institute of Refrigeration, 1979. 2E. Anderson, Oscar E. *Refrigeration in America: a history of a new technology and its impact*. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953. 2F. Highsmith, Carol M. "One of many displays tracing the history of refrigeration at the Cedar Falls Ice House, a historic structure in Cedar Falls, Iowa." The Library of Congress. Accessed September 30, 2017. https://www.loc.gov/item/2016630448/. 2G. Blank, Fred. "Treasures at the MOT - March 2008." St. Louis Chapter National Railway Historical Society. Accessed September 30, 2017. http://www.stlouisnrhs.org/MOT_Treasure/treasures_200803.htm.	2017. https://babel.hathitrust.org/cgi/pt?id=uva.x030493218;view=1up;seq=24. 3E. "From Ice Blocks to Satellite Technology, Perishable Foods Transportation Has Come a Long Way." Union Pacific: Building America. May 2, 2006. Accessed November 18, 2017. https://www.uprr.com/newsinfo/releases/service/2006/0502_reefers.shtml. 3F. ABCO Transportation advertisement, https://www.shipabco.com/history-refrigerated-trucking/ 3G. Anderson, Oscar E. *Refrigeration in America: a history of a new technology and its impact*. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.	696-how-america-depends-on-rail.

Summative Performance Task	**Argument**	Some economists believe that "supply creates demand." To what extent was this true for the businesses connected with refrigeration? Write a thesis essay that directly addresses this question using specific claims and relevant evidence from historical sources to support your claims while acknowledging competing views.
	Extension	Research the ways that working-class Americans got along before refrigeration was commonplace. In what ways were their lives different?
Taking Informed Action	**UNDERSTAND:** Research the current environmental impact of the refrigerate d transport industry. **ASSESS:** Weigh the environmental impact of refrigerated transport industry against its contributions to society. **ACTION:** Write a letter to one of your elected representatives arguing for or against the continuation of refrigerated transport. Include, as part of your argument, the viability of alternatives, like local food sourcing. Use the evidence from your research to support your position.	

TO THE TEACHER

All *REACH* Instructional Units are intended to be “classroom-ready.” Each unit begins with a *Unit Plan* in the form of a *C3 Inquiry Design Model*. The *Unit Plan* includes learning objectives, content standards, formative and summative tasks, links to primary and secondary resources, and a warm-up activity.

Units are organized around a *Compelling Question* designed to inspire curiosity and promote discussion among students. To that end, we have also included a brief student introduction to the topic entitled, *Staging the Question*. Once students have been introduced to the topic, any number of *Formative Performance Tasks* may be completed using the included *Document Excerpts* (teachers may elect instead to utilize full-text documents linked within the *Featured Sources* section). *Document Excerpts* are print-ready in single-sheet format and keyed to the citations in the *Featured Sources* section of the *Unit Plan*. Teachers should select the *Formative Performance Tasks* and accompanying *Sources* that best suit their own instructional needs – content requirements, performance goals, student readiness, and time constraints. Upon the completion of each unit, students should be adequately prepared to complete the *Summative Performance Task* and *Taking Informed Action* sections of the *Unit Plan*.

To further assist the teacher, we have included a more thorough *Background Information* section. This document is intended to serve as professional reading prior to implementing the unit. Teachers may also wish to read the full-length primary and secondary sources from which the shorter excerpts were taken.

STAGING THE QUESTION

Refrigerated rail cars ("reefers") were neither the first mobile delivery system using ice, nor was the long-haul transport of food the inspiration for the development of reefers. The first use of harvested ice was for private or consumer use.

Preserving Food

For millennia, householders stored food in dug out pits beneath their homes or in sacks on riverbanks, though these methods did not protect the food from mold, insects or other predators. The alternative techniques for preserving foods were smoking, canning, pickling, or salting. However, these methods changed the character of the foods, and was not as good a solution as eating a varied diet of fresh foods.

As populations around the world grew and people migrated across geographical boundaries, the acquisition and storage of fresh foods became a major objective. Access to foods previously unavailable in certain regions or climates meant that more people could have a more varied, healthier diet. Simultaneously, merchants saw potential profit in selling meat, fish, dairy, fruits, and vegetables to distant regions of their own countries as well as to foreign markets. The food trade expanded during the Industrial Revolution, when merchants and cargo companies were already profiting from shipping a variety of manufactured products around the world. The challenge was preventing spoilage of produce during transport to market or in maintaining effective temperatures in storehouses, and this, and the desire of consumers to have ice on hand in warmer months led to the ice trade.

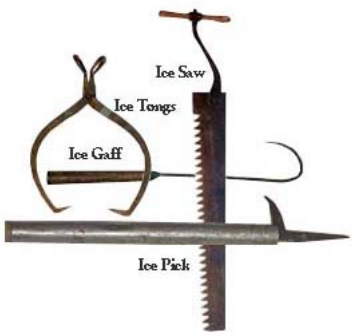
Ice Houses

Thomas Jefferson's ice house at Monticello (roof under reconstruction in the 1950s)

In areas where rivers and lakes froze over in winter to a depth of several inches or more, ice could be harvested in large blocks and stored in bunkers called ice houses. These structures pre-date the refrigerator rail car by at least 300 years. The first ice houses were built underground to prevent quick melting, and additives such as sawdust were used to maintain the temperature. Heavy-walled brick, stone, or wooden sheds were built over the entrances to protect the ice and keep the sun out. Before 1700, ice harvesting and delivery were already a major activity, though mainly to serve the wealthy. For example, an ice house at the Boboli Gardens in Florence Italy was built in the mid-1500s. in 1637, King Charles I of England granted Sir William Berkeley (1605-1677) a patent "to gather, make and take snow and ice and keep the same in such pits, caves and cool places as he should think fit," effectively giving Berkeley (later the first governor of the Virginia colony) a monopoly on the sale of snow and ice for cooling food in England. (Berkeley, 16; 270-271.) Berkeley's patent was renewed by Charles II in 1665. In America, George Washington was directly involved in building the ice house on his property in Mount Vernon, New York, and Thomas Jefferson was inspired to have an ice house built on his estate (Monticello) after studying plans for them in Italy and Virginia the late 1700s. The 1803 ice house was the second one he had built. In England, Moseley Park near Birmingham, was built around the end of the eighteenth century or early nineteenth century. Archaeologists working at the Beaulieu site of the Beaulieu Palace House, a residence of the English Lord Montague built around 1872, discovered an ice house on the property using a Light Detection and Ranging (LIDAR), a system of pulsed laser beams to detect variable distances.

Indoor Refrigeration
Although Jefferson had an icehouse at Monticello, in 1804 he purchased a small refrigerator designed by Thomas Moore who thought its advantage was its portability.
In 1824, Mary Randolph (1762-1828) published *The Virginia Housewife*, in which she described and illustrated her idea for an indoor refrigerator , noting that it would be "more convenient than an icehouse." The idea for consumer refrigerators was circulating by the early 1800s, when harvested ice could be delivered to shops, hotels, and homes for a subscription fee.

Natural Ice Harvesting
The first use of harvested ice for which we have any evidence was approximately the first millennium BCE in China. In the regions around the Mediterranean Sea, including Greece, Italy, and North Africa, the wealthy had ice and snow harvested from nearby mountains to chill their drinks and food. During this period, people in numerous regions around the world were using an evaporation method to make ice-Ice and Refrigeration-1904-Page 4 overnight in shallow clay pans of water covered with straw.



The practice of cutting ice from frozen bodies of water (rivers, lakes, streams) and using it to store food, seeds and other perishable necessities in human-built huts was well established during c 1300-1850, a period of climate change referred to as the "Little Ice Age." Over time, a number of tools were developed to facilitate extraction and loading and to standardize the slabs of ice for stacking and transport or storage. Harvested blocks of ice were carried by cart over roads to the estates of the wealthy or to businesses, to be stored in ice houses for use during the summer months. Wagons were also used to move harvested ice to docks for shipping to other ports around the world.

The Ice Trade
The harvest of natural ice was such a common practice in the 1800s that Henry David Thoreau described his personal observation of it in his book, *Walden*:

To speak literally, 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. – "The Pond in Winter," p 333

Historic Location Marker: Frederic Tudor Ice Company in Fresh Pond, Concord Ave. and Moulton St., Cambridge, Ma.

Frederic Tudor, the "Ice King"

In the 1800s, ice was being transported by cargo ships from the Northeastern United States, the Great Lakes region, and from Norway to distant locales in the southern United States, the Caribbean, India, Europe, Asia, and Australia. Among the first to commercialize long distance ice delivery was Frederic Tudor (1783-1864), dubbed the "Ice King," who began shipping ice to Cuba and other islands in 1806. Tudor's business suffered temporarily, during the Napoleonic Wars, when the American shipping was halted with the Embargo Act, and again during the War of 1812. In 1833, he partnered with Samuel Austin and William Rogers to export almost one hundred tons of harvested ice from the U.S. to Calcutta, India, where, after a four month journey, it was well received. Tudor was shipping natural ice to Sydney Australia by 1839. According to the Founders archives, when Tudor died in 1864, his company had depots around the world including in Brazil, Cuba, India, Jamaica, and Singapore as well as Boston and New Orleans and Tudor Ice Company was worth over a million dollars. Even after refrigerator rail cars were introduced, refrigerated cargo ships continued to play an important role in the ice and food trade.

Other sources of Ice Trade

It has been estimated that at the end of the nineteenth century, a million tons of ice were exported from Norway annually, mainly to Germany and England.

A number of people made their living from harvesting and selling ice for the fishing industry. For example, in England, J. Marr a fish and ice merchant during the late 1800s, acquired ice from the glaciers of Norway or from British fields flooded specifically to make and harvest ice. The Fylde Ice and Cold Storage Company was founded in 1908 to manufacture ice for fishermen. Fylde built its first large cold storage facility to serve fish merchants in 1927. In 1987, inspired by the American party ice business, they began producing and selling bagged ice to consumers. Today the business that became The Ice Company in 2010 is the largest ice supplier in Europe.

By the mid-1800s a number of people had separately transferred the existing method of using harvested ice to keep food fresh in individual homes and warehouses, to carriages or trucks. The problem was that placing foodstuffs on ice could damage the food itself through "freezer burn" or because the ice melted before the fresh food could get to its destination. A number of individuals came up with the idea of building double-walled carts and shoveling large quantities of harvested ice into the space between them.

In the mid-1800s, U.S. ranchers regularly shipped live cattle ("on the hoof") from the West to meat processing plants in other parts of the country. With the advent of ice rail cars, dressed (butchered and packaged) meat could be shipped to market in the East and South.

“Reefers”

The development of the steam engine to pump water out of coal mines in the eighteenth century presented not only the opportunity to use engines to manufacture a variety of products, but to move goods and people across long distances by rail. With the expansion of the steam railroad after the 1830s, food merchants considered the advantages of transporting their goods over established rail lines, rather than in open or covered wagons. The first cars were cooled by packing insulation material such as sawdust, felt, or animal hair in the space between the inner and outer walls of the car. Ice was packed with the food, in ice chests on the floor of the car or in bunkers above the car. Salt was sometimes added to the ice to slow the rate at which the temperature of the cooling agent rose, especially in warm weather. In 1842, the *American Railroad Journal* reported new insulated freight cars in use by the Massachusetts-based Western Railroad. (Danes-Wingett, 1) The compartment that resulted from false walls built several inches inside the outer car wall was packed with a combination of ice plus 4” of powdered charcoal, which was cheaper than ice itself.

National expansion of the railroads coincided with the development of the meat packing industry in the United States. In the years before the Civil War in America, attempts were made to add perishable train cars to the young railroad system, but these were generally unsuccessful, either due to a lack of ventilation or a lack of a stable refrigerant. After the end of the American Civil War, a number of people filed patents for the design of improved ice box cars or for particular methods of cooling their contents, or improvements to the original ideas. For example, J. B. Sutherland’s *Improved Refrigerator Car*. U.S. Patent 71,423, issued 26 November, 1867 described the use of two ice chests, one at either end of the car, each holding approximately eight hundred pounds of ice, and space between inner and outer walls to hold insulating material such as felt, hair, or sawdust, and pipes running along the roof of the car to hang fresh meat, so that the cold air, recirculated through the car, would keep it fresh. The design by David William Davis described in US Patent 272,124, 13 February, 1883 for the owner of a meat packing company, George Hammond, was also meant to improve air circulation.

Early resistance

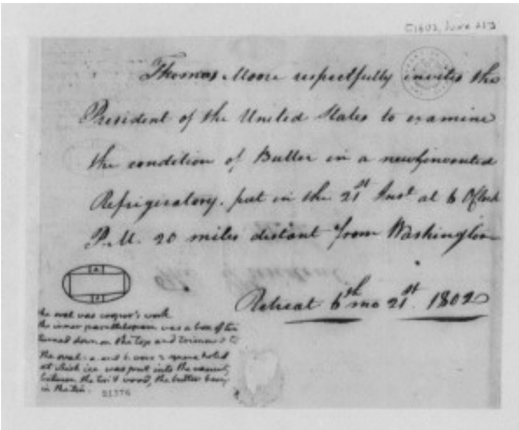
Despite the logic of shipping dressed meat and fresh produce both across country and from ships bearing produce from international ports, rail lines initially resisted adopting refrigerator rail cars. The specialized cars were more costly: a regular box car could be purchased for eight hundred dollars in the 1880s, while a refrigerator car cost one third more: about twelve hundred dollars. Furthermore, railroad operators already had inventories of cattle cars used to ship live animals, and had already invested in ancillary facilities such as stock yards and feed; the expense of the extra cars, without a guarantee of safe delivery of perishables was not an incentive. This had to do with the cars themselves: the addition of false walls for insulation and ice bunkers reduced the capacity of the cars, so more cars were needed for larger, more profitable shipments. Furthermore, the cars were more complicated and labor-intensive to use than regular box cars. Finally, reefer cars were usually one way carriers –that is, they might return to the original point empty. Consequently, railroads charged higher fees for running refrigerator cars on a rail line. One response from meat packers was to develop their own rail fleets. For example, by the 1880s, Adolphus Busch, Philip Armour, and Gustavus Swift all owned their own fleets of refrigerator rail cars.

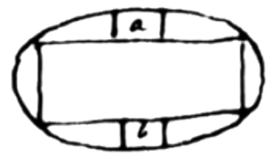
By the 1880s, the shipment of produce was a major money-making activity for the railroads. In addition to citrus and other fruits and vegetables shipped from the South, bananas were being shipped from South America to Chicago via New Orleans on the Illinois Central Railroad. (Welsh, 48) (http://www.american-rails.com/reefers.html) As with other products, the reefer cars were owned by the companies that shipped the goods. For example, Tropicana owned a fleet of bright orange reefers emblazoned with its logo that transported orange juice from Florida to the Northeastern United States.

By the 1960s 28 million tons of food were carried across the country in insulated cars driven by diesel-electric power. These electro-mechanical refrigeration systems could keep food frozen, not just chilled, and the business of ice suppliers dwindled. (Welsh, 58) During the second half of the twentieth century as cooled tractor-trailer, ship, and air transport increased, the number of reefer cars used to carry perishable goods declined. Consequently, individual cars were integrated into freight trains that transported a variety of goods, rather than in reefer fleets. (Welsh 61)

PRINT DOCUMENTS

Document 1A


Thomas Moore respectfully invites the President of the United States to examine the condition of Butter in a newinvented Refrigeratory, put in the 21st Inst at 6 OClock P.M. 20 miles distant from Washington
Retreat 6th mo 21st 1802



[Diagram and note by Thomas Jefferson, "TJ"]

The oval was cooper's work the inner parallelogram was a box of tin turned down on the top and trimmed to the oval: a. and b. were 2 square holes at which ice was put into the vacuity between the tin & wood, the butter being in the tin.

(Transcript below)

Retreat 6th. mo 21st. 1802

Thomas Moore respectfully invites the President of the United States to examine the condition of Butter in a newly invented Refrigiratory, put in the 21st Inst. at 6 OClock P.M. 20 miles distant from Washington—

RC (DLC); addressed: "The President U.S."; with diagram and note by TJ at foot of text; endorsed by TJ: "Cooler for butter."

Thomas Moore (1760–1822) was a cabinetmaker in Loudoun County, Virginia, before moving to Brookeville, in Montgomery County, Maryland, north of Washington. There he farmed, and, like his brother-in-law, Isaac Briggs, was part of a Quaker community. Moore made a study of agriculture, and Briggs, earlier in 1802, probably sent TJ Moore's pamphlet, The Great Error of American Agriculture Exposed. Moore sent a copy of that work to James Madison, hoping to promote sales of the publication to defray the printing costs. With Briggs and another brother-in-law, Moore established the Triadelphia cotton mills in Montgomery County in 1809. Working as an engineer beginning in 1805, he oversaw construction projects that included the James River and Kanawha Canal and a causeway near Washington. In 1806, TJ appointed Moore one of three commissioners to begin work on the Cumberland Road (later called the National Road). As the chief engineer for the Virginia Board of Public Works, Moore in 1820 reported on the feasibility of a canal along the Potomac River to Cumberland, Maryland, that became the first segment of the Chesapeake and Ohio Canal.

Refrigiratory: Moore soon decided that "the most appropriate term" for his invention was "refrigerator." The oval tub of the device was made of cedar, with a hinged lid, insulated on the outside with rabbit fur and coarse woolen cloth. The tin chamber held 22 one-pound pieces of butter. Although Moore designed the prototype as a means of transporting butter to market, he anticipated modifications to the design that would make refrigerators for home use and for butchers, purveyors of fresh provisions, and carrying fish to market. After he received a patent for his "Refrigerator for domestic uses" in January 1803, he sought to implement a licensing system for rights to make and use refrigerators according to his specifications. He offered to allow free use of the technology for anyone carrying modest amounts of

SOURCE: "To Thomas Jefferson from Thomas Moore, with Jefferson's Note, 21 June 1802," Founders Online, National Archives, last modified June 29, 2017, http://founders.archives.gov/documents/Jefferson/01-37-02-0526. [Original source: The Papers of Thomas Jefferson, vol. 37, 4 March–30 June 1802, ed. Barbara B. Oberg. Princeton: Princeton University Press, 2010, pp. 650–651.]

butter to market. Moore presented himself as a practical farmer with only a "small stock of philosophical knowledge," but his description of his invention discussed scientific principles concerning the conduction of heat and melting of ice. He calculated that the mean temperature inside a refrigerator of his design would be about 48° Fahrenheit. Because his device required the use of ice, Moore also recommended improvements in the design and insulation of icehouses.

SOURCE: "To Thomas Jefferson from Thomas Moore, with Jefferson's Note, 21 June 1802," *Founders Online,* National Archives, last modified June 29, 2017, http://founders.archives.gov/documents/Jefferson/01-37-02-0526. [Original source: *The Papers of Thomas Jefferson*, vol. 37, *4 March–30 June 1802*, ed. Barbara B. Oberg. Princeton: Princeton University Press, 2010, pp. 650–651.]

Document 1B

To keep ice for the plantation, Thomas Jefferson constructed an ice house. In the winter of 1802-1803 the summer's harvest of wheat was safely stored in barrels and barns. Monticello overseer Gabriel Lilly had to wait for freezing temperatures before he could harvest his next crop: ice from the Rivanna River. Every available neighborhood wagon was assembled to bring ice from the river to the newly constructed ice house on the mountaintop. Jefferson, monitoring the operation from Washington, recorded it took “wagon loads of ice to fill it," and cost $70 for the hire of wagons and food and drink for the drivers.

This was not Jefferson's first ice house. He had had one built and filled at the President's House the year before. Until then he did without ice in the country and bought a weekly supply in the city.
In Philadelphia in 1792, he actually subscribed to a summer ice service. The vaulted cellar of James Oeller's Chestnut Street hotel provided a daily supply of ice for a shilling a day. A Wiltshire clothier stopped at Oeller's for a refreshing round of punch, and thought fit to record that it was "brought to us with a lump of ice in each glass." He was not the last Englishman to marvel at the American ice-cube habit.

Jefferson had taken notes on ice houses in Italy and Virginia before he undertook construction of his own. He placed it on the coldest side of the house, under the North Terrace. His drawings show a cylinder sixteen feet below ground level and six feet above it, with openings at the top "left only 9 inches square that a person may not get in at them."

That specification indicates that more than ice was in the ice house. "Dishes of butter, cold dressed provisions, salads, etc." were kept in Oeller's ice cellar and Monticello's may have been used in a similar way. The preservation of butter and fresh meat was Jefferson's main concern. It would be "a real calamity" if the ice house were not filled, he wrote his overseer in 1809, "as it would require double the quantity of fresh meat in summer had we not ice to keep it."

Then there were the less critical uses for the ice crop, such as the making of ice cream or chilling of wine. Jefferson liked to tell of his efforts to elicit expressions of astonishment from the Indian delegations that visited him at the President's House. He succeeded only once-when wine bottles in ice-filled coolers were placed on the table in July.

After viewing the Italian ice house, Jefferson had recorded that "snow gives the most delicate flavor to creams; but ice is the most powerful congealer, and lasts longest." We know that in 1815 the ice lasted until October 15.

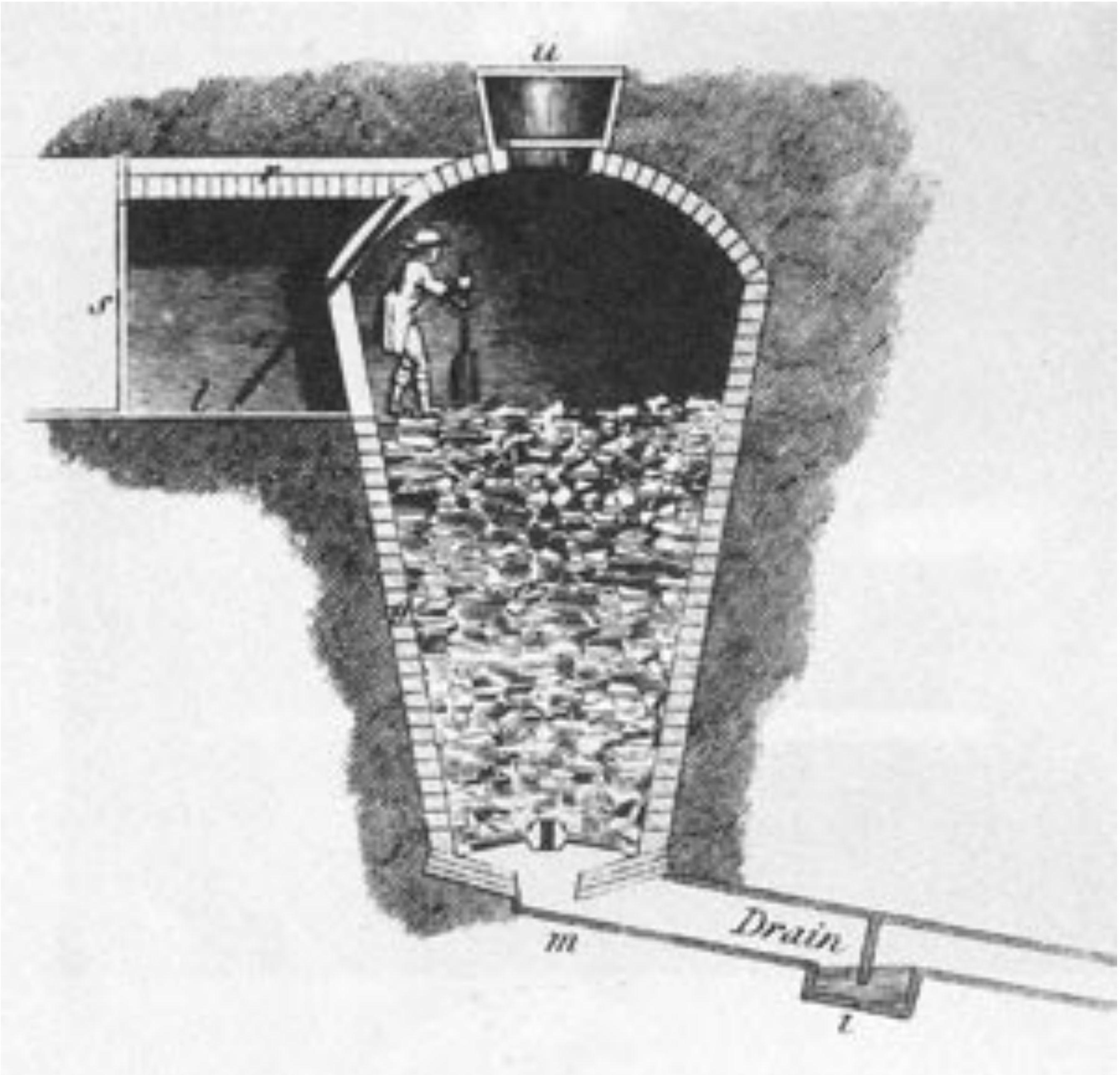
The ice house roof under reconstruction in the 1950s.

SOURCE: "Ice House." Thomas Jefferson's Monticello. Accessed September 29, 2017. https://www.monticello.org/site/house-and-gardens/ice-house.

The day before Christmas in 1813 Jefferson wrote: "Filled the ice house with snow." As ice house at the river took over the primary role and the mountaintop cellar now became the "snow house"-and Monticello may be here today because of it. In the spring of 1819, the North Pavilion caught fire. As Jefferson reported to a friend, "our snow house enabled us so far to cover with snow the adjacent terras which connected it with the main building as to prevent it's affecting that."

SOURCE: "Ice House." Thomas Jefferson's Monticello. Accessed September 29, 2017. https://www.monticello.org/site/house-and-gardens/ice-house.

Document 1C



An Ice House shown in the 1819 Cyclopaedia or Universal Dictionary of Arts, Science and Literature (s - doorway, l - air trap, r - entrance passage, u - aperture through which ice may be put in)

SOURCE: "New Forest Heritage." New Forest Explorers Guide. Accessed September 27, 2017. http://www.newforestexplorersguide.co.uk/heritage/history-in-the-landscape/ice-houses.html.

Document 1D

Ice houses are underground chambers that you could look at as being a pantry, cold room, or sort of fridge that was used to keep food cold many centuries ago. These weren't for everybody though. It was the upper class who would have these to store and preserve food and drink, which would be kept next to ice blocks to keep it chilled and fresh for longer.

Ice houses are typically well hidden under a mound of soil and start with an oval opening, of which will lead to a tunnel, taking you to an underground compound.

The idea of having an underground compound meant that throughout the mini ice age (1600 – 1800), the temperature would remain low, helping the ice to stay as a block for longer. Eventually the ice block would slowly melt away, but could last for up to 18 months!

The ice blocks used to keep it cold were imported from abroad or cut from frozen lakes and ponds in the winter.

Ice Houses tell a great story of how our cultural heritage has changed and although fridges and freezers were once alien, the concept actually evolved many years ago!

When warmer winters came in the 1800's it meant that ice houses could not continue in the way they had always operated. But the concept led to the introduction of commercial refrigeration and ice manufacturing.

Although The Ice Co, at the time known as J Marr, was a fishing merchant in the late 1800's, by 1908 Joseph Marr had shares at The Fylde Ice and Cold Storage Company where they manufactured ice for fish merchants and crushed ice for trawlers. By 1927, the rise in demand for cold storage from fish merchants led to the build of their first cold store (essentially a very, very big, more modern ice house).

SOURCE: "Ice Houses in the UK: Then and Now." The Ice Co. March 29, 2016. Accessed September 30, 2017. http://www.theiceco.co.uk/blog/ice-houses-in-the-uk-then-and-now/.

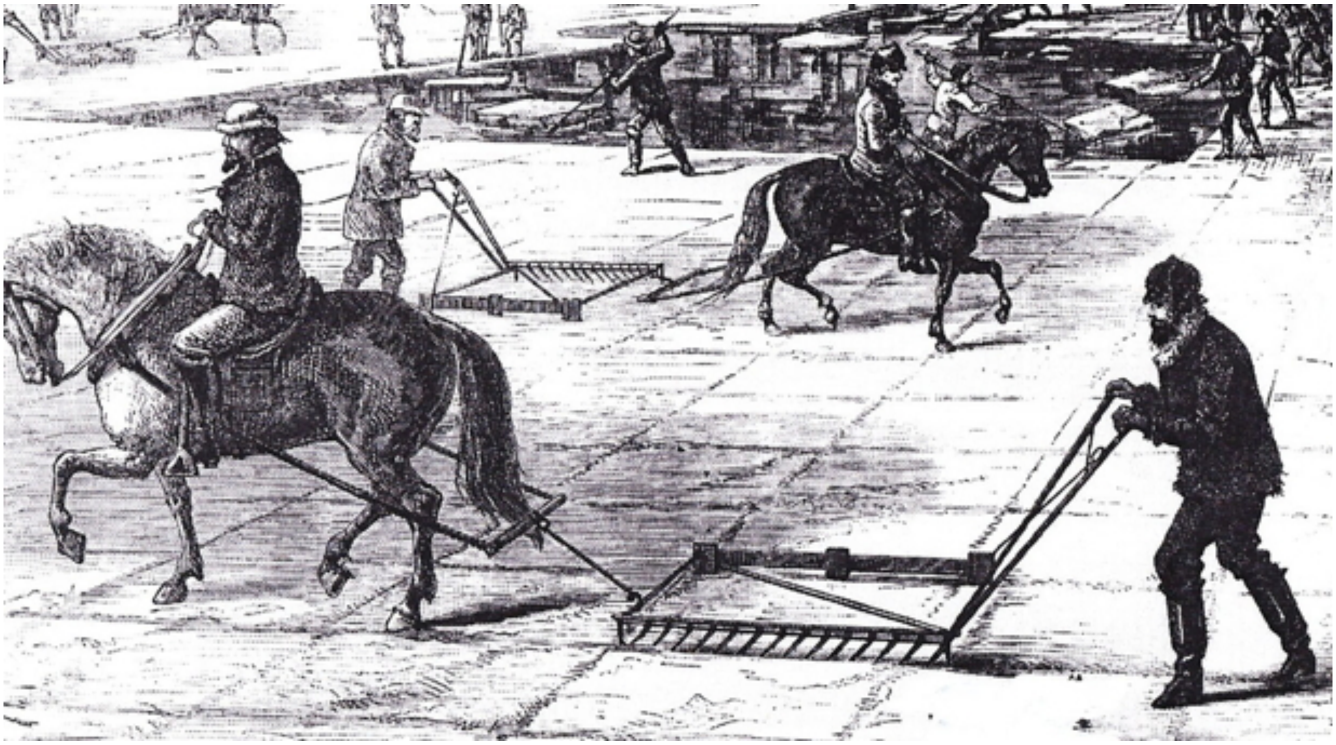
Now almost 90 years on and six generations further into the Marr family, The Ice Co is Europe's largest manufacturer of ice and The Ice Co Storage and Logistics is the growing temperature controlled storage and logistics arm of the business – an extraordinary and exciting development from the original ice houses.

Ice houses are now being discovered across the country in good and bad conditions, 10 have been found in the New Forest alone. Although some look like they have hardly changed, some have unfortunately been filled with rubbish and soil.

SOURCE: "Ice Houses in the UK: Then and Now." The Ice Co. March 29, 2016. Accessed September 30, 2017. http://www.theiceco.co.uk/blog/ice-houses-in-the-uk-then-and-now/.

Document 1E

…We can thank technology for the trickle down of many luxuries, but the transformation of ice from luxury to necessity largely occurred before the widespread availability of refrigeration. One man in particular, the Boston businessman Frederic "The Ice King" Tudor, engineered the change during the first half of the 1800s. Known for his pigheadedness as much as his marketing savvy, he revolutionized both the ice trade and the way we live.



Tudor's workers divide a pond into a chessboard pattern and cut ice into two-foot square blocks.

Tudor wasn't the first to notice the value of ice, of course. The ancient Greeks, Romans, Persians, and Chinese all harvested and stored ice during winter to chill their food and drinks in summer. But with few exceptions, ice was reserved for the rich, and the ancient markets were relatively regional. Tudor's ice trade stood apart because of its sheer ambition: He believed that cutting ice from Massachusetts lakes and shipping it across the world to the tropics would make him "inevitably and unavoidably rich."

Most potential investors saw nothing inevitable or unavoidable about Tudor's vision. Instead, with their flinty New England gazes, they saw what historian Daniel Boorstin described as Tudor's "flamboyant, defiant, energetic, and sometimes reckless spirit." Yes, the market for ice was growing in the U.S., but wouldn't it just melt during a long voyage to the tropics? Their understanding of the science was accurate, and much of the ice Tudor shipped to Martinique and Cuba from 1806-1810 melted into large financial losses.

During each successive trip, however, Tudor learned to minimize melting by packing the ice tighter and insulating it with sawdust instead of straw. He made his first profits by 1810, only to be swindled by a business partner and land in debtor's prison. After Tudor was released, he secured a loan enabling him to continue with his obsession, but significant profits were still another 15 years away.

SOURCE: Mitenbuler, Reid. "The Stubborn American Who Brought Ice to the World." The Atlantic. February 05, 2013. Accessed September 30, 2017. https://www.theatlantic.com/national/archive/2013/02/the-stubborn-american-who-brought-ice-to-the-world/272828/.

Tudor first sold his ice to scientists and physicians in the tropics who saw its potential for preserving food and for medical uses. He later expanded the market to cafes and wealthy private households for chilling drinks. Like a drug dealer, Tudor at first gave away his ice for free, then charged once people were hooked. After people tried their drinks cold, they could "never be presented with them warm again," Tudor wrote.

Tudor's increasing success led to the hiring of a new foreman named Nathaniel Wyeth to help meet growing demand. At that point, ice was laboriously cut by hand with saws. Wyeth developed a horse-drawn ice plough and a system where frozen bodies of water could be divided into chessboard patterns and cut into ice blocks about two feet square. This mass-produced ice was easier to transport and store, reducing Tudor's costs by two-thirds and enabling him to sell to a greater portion of the public.

Tudor's most ambitious plan came in 1833, when he set out to deliver ice to Calcutta, a voyage of 14,000 miles that involved crossing the equator twice. Tudor and his investors wondered if the ice would even sell. But his extraordinary profits answered that question. Until that time, residents had been importing slush from the mountains for the few weeks during the year when it was available. The prospect of a steady supply of Tudor's clear, solid blocks prompted English residents in the city to throw parties serving claret and beer chilled with his New England ice. The *India Gazette* thanked him for making "this luxury accessible, by its abundance and cheapness."

By that point, Tudor's success had drawn competition to the ice trade. Henry David Thoureau chronicled the growing industry near his Walden outpost, describing one stack of ice as "an obelisk designed to pierce the clouds." The ice symbolized an increasingly complicated world breaking from its preindustrial past, and a luxurious counterpoint to his experiment in simplicity. Besides, Thoreau didn't appreciate having his peace disrupted. He couldn't help but marvel, however, that "the pure Walden water is mingled with the sacred water of the Ganges."

By that time, Thoreau's fellow Americans were developing a taste for ice cream and iced drinks, German immigrants brewed lager beer year-round, and fisherman stayed at sea longer with their catches packed in ice. Across the ocean, the British Royal Navy, in pursuit of empire, was using imported ice to cool its gun turrets.

The ability to preserve perishables with ice also meant that food could be sold in the distant markets of America's fast-growing cities. Ice was becoming integral to daily life, and newspapers followed the ice trade closely. Unseasonably warm winters prompted warnings of "ice famines," and ice harvesters would sail to the Arctic and make up the shortfall by chopping up icebergs.

The vast majority of the trade was still natural ice, even though people had known for centuries how to artificially cool things. The ancient saltpeter-cooling approach was eventually followed by techniques that included freezing mixtures of salts and mineral acids. But these other methods were expensive and didn't make ice as well as nature did. Even though the British had advanced artificial refrigeration, Queen Victoria still got her ice from Massachusetts.

Artificial ice was only used in places where natural ice was almost impossible to get. This included the American South after it was cut off from the northern ice trade during the Civil War. The Confederacy's hospitals needed ice, and the South convinced France to send it ice-making technology that utilized an ammonia-and-water absorption process. Artificial ice became more popular after the Civil War, when cities expanded and intruded on the places where natural ice was harvested. Pollution had been a threat to the natural ice trade far before artificial refrigeration came along, but now it started causing health scares. Nonetheless, natural ice dominated into the early 20th century, but artificial ice was substituted where it made sense.

SOURCE: Mitenbuler, Reid. "The Stubborn American Who Brought Ice to the World." The Atlantic. February 05, 2013. Accessed September 30, 2017. https://www.theatlantic.com/national/archive/2013/02/the-stubborn-american-who-brought-ice-to-the-world/272828/.

Document 1F

Every farmer in whose vicinity natural ice is available should store a sufficient quantity for use during the summer months. A supply of ice is worth all its costs, if properly applied on the preservation of milk, butter, meat, vegetables and other perishable articles. The dairy farmer especially will find in a supply of ice a great saving of labor and a positive safeguard in keeping his milk during hot weather. The crudest kind of building, which will keep out the sun and the rain, or the corner of a shed, will serve for the mere storage of ice if dry saw-dust or marsh hay is available in which to pack it for protection against the heat. All that is necessary to do is to provide for some drainage and cover the ice on all sides, top and bottom, with about 12 inches of saw-dust, or 24 inches of hay or cut straw, and protect the covering from the weather.

The Necessity of Cooling Milk

Patrons of cheese factories or creameries, who wish to keep Saturday evening's or even Sunday morning's milk until Monday morning during the hottest weather, will find a supply of ice indispensable, as well as useful on other nights of week, if the milk is to be delivered to the factory in proper condition. Proper condition implies not only that the milk must be sweet enough to be accepted, but that it shall not have passed the stage of 'ripeness' which permits of a first-class quality of product being made from it. Milk which is too 'old' or too far advanced towards the stage when it is known as 'sour' will make neither a fine quality of butter or cheese, nor a maximum amount of it. An enormous loss results to the patrons of factories every year in both directions. The amount of waste which occurs from the handling of overripe milk at cheese factories would be astonishing if it could be accurately measured or were more generally known. This waste may be prevented by a proper cooling of the milk at the farms. A supply of ice will facilitate the work and insure successful handling of the milk under any conditions imposed in practical dairying.

A supply of ice on the farm is very necessary for those engaged in a city milk trade. Immediate cooling after milking, to the lowest possible point, is the true secret of preserving milk. Those engaged in supplying milk for direct consumption cannot escape the responsibility which rests on them for exercising every precaution which will enable them to furnish such a necessary and universal article of diet, carrying the least possible danger to public health….

Ice Necessary for Long Keeping

Roughly speaking, 10 pounds of ice are equal in cooling power to 100 pounds of cold water….

But the most important advantage in the use of ice arises from the fact that by its use the temperature of the milk can be reduced to, and maintained at, a lower point than is possible with the use of water alone; and a low temperature is absolutely necessary for preserving milk for lengthy periods. The temperature should be reduced to 50 degrees and maintained at that temperature when milk is to be kept from Saturday night or Sunday morning till the following Monday morning.

SOURCE: Ruddick, J. A. b. 1862. (1907). ***The use of ice on the farm.*** **Ottawa: Dept. of Agriculture.**
https://babel.hathitrust.org/cgi/pt?id=aeu.ark:/13960/t3st96810;view=1up;seq=11

Document 1G

Ice was not used to a significant extent for refrigerating foods in the United States before 1830. Although there was an occasional icehouse, in general what little refrigeration was used in colonial days was provided by spring houses, wells, or cellars. In the early years of the nineteenth century for temporary storage of meats and milk some city-dwellers used “safes,” boxes with sides and ends of woven wire which permitted air but not insects to come in contact with the food, but the main means of preserving foods continued to be those used for centuries: salting, spicing, smoking, and drying.

One reason for the limited use of refrigeration before 1830 was that the need for it was little felt. Foods whose preservation required low temperatures – fresh meats, fish, milk, and fruits and vegetables of inferior keeping qualities – did not play as important a part as they do now, for American diet was based on foods not so perishable; it was dominated by bread and salted meats. This diet was largely the result of long-established habits, and although it was short on many of the foods we now value so highly, it was fairly adequate for people who led active lives in the open. The fare of the wealthy, of course, was more varied than that of the poor. Not only were foods that required coolness less used than at present, but refrigeration was not necessary for transporting them as it was to become, for no great distances separated grower from consumer.

Although refrigeration was not a principal method of food preservation before 1830, its use was by no means unknown. In the first decade of the nineteenth century Thomas Moore, a Maryland farmer, had a refrigerator of his own invention to carry butter to market and to keep it hard until sold. Early in the century fish packed in ice were carried in light carts from the New Jersey coast to supply the Philadelphia market, while after 1825 lots of ice-packed fish were occasionally shipped on the Erie Canal. Refrigeration, however, was not yet practical for general transporting of perishables. Shipment was much too slow when any considerable distance was involved, and packing the product to be preserved in the ice itself was not a method that could be applied to all types of foods. Farmers continued to carry their products to market during the night to receive the benefit of the comparatively low temperatures, and the coastwise trade in perishables was confined to the cool seasons of the year. There was little use of refrigeration in the market place. In northern cities a few butchers used ice for holding their fresh meat, and in southern ports some products were stored in the icehouses built by Yankee traders. But ice, in both the North and the South, was difficult and expensive to obtain before 1830, and in its absence most marketing was done in the early morning hours. Most butchers slaughtered for only a day’s fresh-meat trade, while dealers in fresh fish tried to keep their product alive until sale….

The increased consumption of fresh foods between 1830 and 1860 made preservation by low temperatures more necessary than it had been before….

SOURCE: Anderson, Oscar E. *Refrigeration in America: a history of a new technology and its impact*. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.

Document 2A

Experimentation with railroad refrigerator cars began around 1842. In that year The American Railroad Journal reported on a new type of insulated freight car in use by Western Railroad of Massachusetts. It used ice in summer with four inches of powdered charcoal between inner and outer walls to protect cargo. Plans to convert "the whole country into a garden for our great cities" were not visionary for the 1840's, yet follow-up or further experimentation with insulated railroad cars did not happen quickly.

A great variety of specialty cars appeared shortly after the Civil War, with none more interesting than the refrigerator car. Before the refrigerator car was invented, it was impossible to ship foodstuffs long distances. …it was not until 1867 that the first patent for a refrigerator car was issued.

I.B. Sutherland was granted the first patent for a refrigerator car on November 26, 1867. Joel Tiffany, a Chicago lawyer, obtained another patent in 1877. Tiffany recommended using air ducts within walls for air circulation and fans to circulate air but could not devise a dependable way to power them….

Railroads were initially reluctant to purchase refrigerator cars. Transporting refrigerated produce was an uncertain venture, and refrigerator cars were expensive, costing twice as much as a standard box car. Box cars carried revenue-producing loads on return trips, while most refrigerator cars returned empty. Shippers considered them a poor bargain for regular cargo since their interiors were smaller because of their insulated walls. They also had a reputation for being damp and musty.

Beef packers made the first demands for refrigerator cars. However, railroads were heavily invested in cattle cars, stock yards, feed lots, and related facilities; and, therefore, they were slow to invest more money in refrigerator cars. When they did, the railroads demanded twice the rate for hauling processed beef than for hauling live cattle shipments.

...Compared to stock cars and box cars, refrigerator cars were costly and complex: their double walls, insulation, tight fitting doors, ice bunkers, and drains drove the costs upward. In 1883, while a single box car cost approximately $800.00, a refrigerator car cost approximately $1,200.00.

Beef packers initially dominated most of the refrigerator car business, controlling ice plants, setting icing fees, and developing methods to obtain rebates and mileage rates from customers. Eventually, refrigerated transport expanded to include vegetables.

Railroad refrigerator cars traveled the nation's railways for approximately 100 years. During most of this time the majority of the cars were privately owned. Railroads considered themselves a common carrier and treated anything that could not be transported in a box car or hopper car as a special product. Shippers of specialty items were encouraged to provide their own equipment, and railroads would move them in the normal interchange of service. The burden of investment was placed on the shipper instead of the railroads, which were generally capital poor.

Nevertheless, after 1901, the railroads began an aggressive acquisition of refrigerator cars. The railroads were motivated by three reasons: they had witnessed consumers' demands for refrigerated and fresh products, they were certain consumers' demands were not temporary, and they finally believed they could receive a fair return on capital invested in railroad refrigerator cars.

SOURCE: Danes-Wingett, Linda. "The Ice Car Cometh: A History of the Railroad Refrigerator Car." The San Joaquin Historian, New Series, X, no. 4 (Winter 1996): 1-3. 2017. Accessed September 30, 2017. http://www.sanjoaquinhistory.org/documents/HistorianNS10-4.pdf.

Despite even these benefits, the attitude of the railroad industry toward refrigerated transportation was guarded. On one hand, it was attractive because it produced good revenue, with long hauls of 2,500 miles vs. one-tenth that for other merchandise shipments. However, seasonal food production meant expensive cars sat idle until the next harvest season.

The problem of idle cars was eliminated in two ways: a national refrigerator car pool was established by the United States Railroad Administration during World War I when it operated the major carriers. After the war, this car pool was continued by the railroad industry. Under this plan cars were distributed from place to place as different crops matured, ensuring their maximum use….

Trains loaded with fresh foods for America's consuming markets rolled eastward from vineyards, orchards, fields, and gardens in the western states, and the movement and distribution was indeed well organized. Cars were available when and where they were needed. Routing was exact, with produce sent to areas needing it, not to areas already glutted. In this way America's railroads and the railroads' refrigerator cars were a vital part of national health and well-being.

At one time, over 180,000 railroad refrigerator cars were involved in transport of America's produce. Money invested for the cars and fleet support Icing stations, repair shops, warehouses, and employees -- amounted to hundreds of millions of dollars.

By 1900, the railroad refrigerator car industry was in good condition. The shiny yellow refrigerator car -- decorated with colorful signs, lettering, and slogans -- was the most glamorous freight car in America. It had grown in size and measured 35 feet long, carrying 30 tons of goods.

However, by 1930, the number of railroad refrigerator cars in service peaked; thereafter, though the volume of reefer traffic grew, there was a decline in the size of the fleet. This was due to larger refrigerator cars and faster schedules, which meant growers were able to be more efficient and more productive.

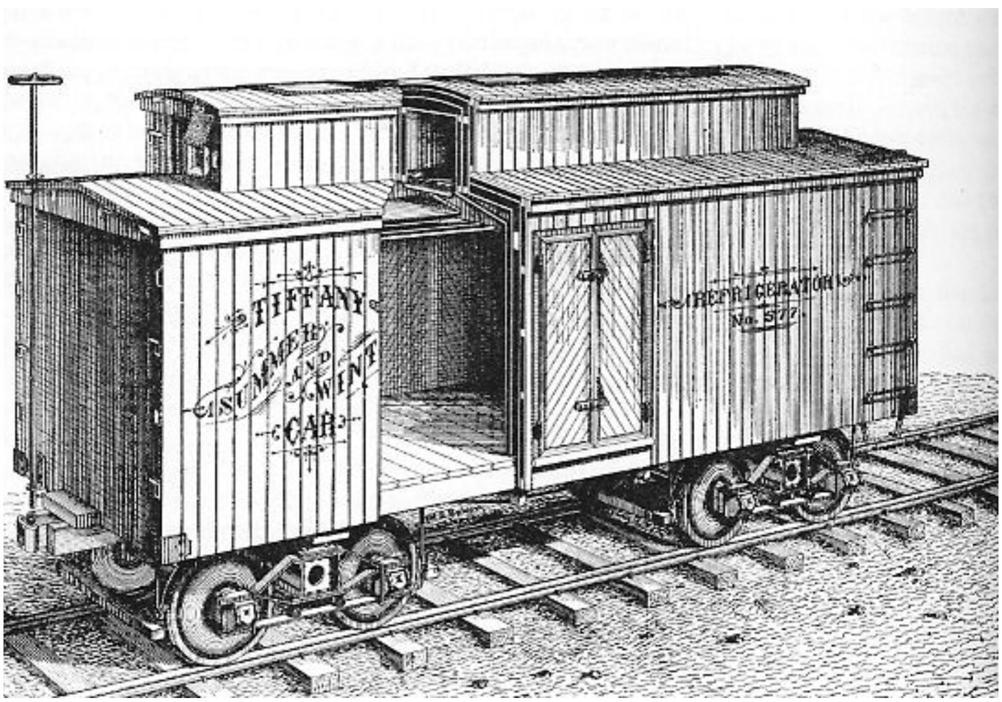
Throughout its history, the railroad industry experienced monopolies, takeovers, abuses and overcharging, antitrust action by the Federal government, and regulation by the Interstate Commerce Commission. During times of growth and change, ownership and control of refrigerator cars moved back and forth between private and railroad-controlled domination. By 1965, 85% of all the private refrigerator cars were railroad controlled. By that time, however, highway refrigerator trucks were competing with railroads and undercutting rail operations.

Between 1922 and 1960, the number of railroad-owned refrigerator cars dropped from 63,000 to 25,000. Railroads were experiencing competition for transportation of goods. By the early 1950's, trucks were carrying major portions of America's eggs, poultry, milk, fruits, and vegetables. By 1960's, work on the nation's Interstate Highway System was sufficiently complete to link America by highways. At the same time, Detroit was producing larger transport vehicles designed for heavier long-haul truck shipments on inter-state highways.

SOURCE: Danes-Wingett, Linda. "The Ice Car Cometh: A History of the Railroad Refrigerator Car." ***The San Joaquin Historian*****, New Series, X, no. 4 (Winter 1996): 1-3. 2017. Accessed September 30, 2017. http://www.sanjoaquinhistory.org/documents/HistorianNS10-4.pdf.**

Tiffany is often credited with being a pioneer in the design of refrigerated railroad cars, but though his patent [Pat. No. 193,357 (24 July 1877)] describes an insulated and ice-cooled car in great detail, all that is claimed for protection by the patent is “A refrigerated-car having its sides and top provided with an external jacket, forming horizontal air-passages extending the entire length of the car, said passages having openings at each end, provided with stoppers for converting the passages into dead-air chambers, in combination with dead-air or packed chambers constructed within and surrounding the body of the car... ” In other words, Tiffany did not patent the idea of a refrigerated car; only a means of circulating a variable amount of air to cool the already-insulated chamber within. Insulation was provided in ways already recognized: dead air spaces created by thin boards and felt paper, and then stuffed with hair or sawdust.

Tiffany’s earliest design—illustrated below—had an “ice tank” in something like a clerestory above the carlines of the roof. The car was cooled by a combination of contact with the bottom of this galvanized iron “ice chamber” and of air passed through pipes or flues under the ice within the ice container and then through enclosed spaces in the insulated walls of the car, and thence into the inner chamber. The force to move “dry, sweet, clean, cool air” through these pipes or flues into the car and “warm, foul air” out was provided by “wind-sails” [air scoops] either on top of, or built into the end of, the clerestory (the opening like a window in the illustration below).



This engraving of Tiffany’s original “Summer and Winter Car” appeared in the Railroad Gazette just before Tiffany received his refrigerator car patent. Though not part of the patent’s claims for protection, the external “ice tank” in its clerestory is very prominently featured.

Within 18 months after the patent was issued, there were 95 Tiffany cars in service in the United States and 7 more in Europe.

By this time the distinctive clerestory had been abandoned, replaced by a shallow, full-length ice bunker mounted directly under the carlines of the roof. This overhead ice bunker would remain one of the hallmarks of the Tiffany car throughout the life of the company and was one of the features that made it

SOURCE: "Tiffany Refrigerator Car Company." Builders of Wooden Railway Cars. April 11, 2006. Accessed December 19, 2017. http://www.midcontinent.org/rollingstock/builders/tiffany.htm.

so successful. These v-shaped bunkers sloped gently toward the ends of the car, where a tank collected the melt-water. A drip-pan mounted slightly below the bunker caught any condensation and carried it too to the collection tank.

The merit of the overhead bunker was proven by the comparatively small amount of ice needed. Tiffany claimed that on a trip between Chicago and Boston during the hottest part of the summer Tiffany cars used just ½ the ice needed by end-bunker cars. Indeed, this makes sense, as putting the ice at the highest (and hottest) point of the car provides for natural circulation of air, as the warmer air rises from the floor and the cooled air descends naturally to the floor. Cars with end-bunkers do not have this natural circulation, and thus either require some sort of artificial circulation or else cool the car's contents much better at the ends, adjacent to the bunkers than in the middle. Icing of the Tiffany cars was accomplished through several hatches mounted flush in the car roof…

It is interesting that the overhead bunker became so identified with the Tiffany cars, as they were not the first to use the idea, nor were they the last. The first appears to be a car built by the Sacramento Shops of the Central Pacific Railroad in 1870 that had 10 ice bunkers suspended from the ceiling of the car at intervals by iron rods. This car successfully carried fruit from California to New York, and there were plans to build more like it.

Despite resistance to the idea, overhead bunkers were part of Charles P. Jackson's patented car of 1880, and were central to an 1883 patent issued to Theodore N. Ely, John W. Cloud and Edward B. Wall, three important mechanical officials of the Pennsylvania Railroad. Yet neither of these efforts was successful. With few exceptions, we don't know who built Tiffany cars, as we have been able to find nothing about a Tiffany plant or works of any kind. It would appear that the Tiffany organization was a management concern built on the financial and management expertise of Charles F. Pierce, having cars built by others which it leased to the railroads, and licensing the patent(s) to those that wanted to build for themselves. In May 1879, Tiffany had 10 cars built with iron tube underframes by the National Tube Works of Boston. The wooden bodies were built to Tiffany's design, while the iron tube underframes were built to the design of Bernard J. LaMothe, developed almost 20 years earlier. There is nothing to indicated the success or failure of these cars, but neither is there anything to suggest their duplication.

By 1880, Tiffany reportedly had 400 cars in service. By the summer of 1883 there were 1,000 Tiffany cars in service. And less than four years later (1887) there were 3,000 in service. They were running on the Erie, the Grant Trunk, the Milwaukee Road, the North Western, and the Union Pacific. In 1886 the Santa Fe Railroad had 10 cars built for it according to the Tiffany patent by Missouri Car & Foundry. The National Despatch Refrigerator Line, a private car line founded by the Grand Trunk, Vermont Central, Rutland and Boston & Lowell railroads in 1869, was a loyal patron of the Tiffany Refrigerator Car Company. In February 1880, it had 100 Tiffany cars in service and another 100 on order. By the fall of 1881, it had 300 Tiffany cars carrying dressed beef between Chicago and Boston. National Despatch and its associated lines ran Tiffany cars until the late 1890s, but the Tiffany design appears to have gone out of favor by then, as it is no longer illustrated in the 1898 edition of the Car Builders Dictionary.

SOURCE: "Tiffany Refrigerator Car Company." Builders of Wooden Railway Cars. April 11, 2006. Accessed December 19, 2017. http://www.midcontinent.org/rollingstock/builders/tiffany.htm.

Document 2C

In its beginnings the new business was preparing dressed beef and sending it to eastern markets. The economy of sending dressed beef instead of live cattle was enormous. It did not have to be fed and watered on the way. A steer in the shape of dressed beef weighed more than 40 per cent less than when alive. But obstacles in the way of making the new business successful were well-nigh insurmountable. The railroads were opposed to it because it reduced freight bills nearly one half. The eastern stockyards were hostile because it threatened their business. The eastern butchers fought against it for the same reason. Every sort of misrepresentation was employed to prejudice the eastern public against Chicago dressed beef. It could, at that time, 1877, be sent only in the winter, and even during the winter the eastern consumer would have none of it. Mr. Swift, through his agents on the Atlantic Coast, set to work to break down this prejudice and build up an eastern market for western beef. And meantime, in the opening of the winter of 1877, he began to make shipments. He took the greatest personal pains with the cars in which they were made. As Charles Winans tells the story:

He rigged up a car after his own ideas. He superintended the loading of it himself. He even took an active part in hanging the quarters of beef by ropes from the 2X4 timbers he had arranged. The car was sealed up and started on its journey eastward Barnes was waiting for it when it came. It was with grave doubts and misgivings that he opened it. But when, at last, he did open it and the quarters of beef stood revealed as fresh and sweet and in better condition for food than when they left Chicago, then Barnes knew that western dressed beef had got to the east to stay there. He knew that the task of uprooting the prejudices that were so strongly planted was no easy one. But he set about it with the true New England energy and persistence, and he kept at it until it was a fact accomplished.

The success achieved was such that Mr. Swift became more and more determined that the eastern market must be supplied the whole year round, spring, summer, and autumn, as well as winter.

This was to be the work of the refrigerator car, upon which his mind had been fixed from the beginning. The devising of that car dated back more than ten years. It had not been entirely successful. From year to year it had been improved but was still far from the perfection it has since attained. Other packers were studying it with interest, but perhaps Mr. Swift's mind comprehended its vast potentialities a little sooner than did the minds of other men. But if the difficulties in the way of introducing Chicago dressed beef into the eastern market in the winter had been great, those confronting its introduction in the summer by means of the refrigerator cars were immensely greater.

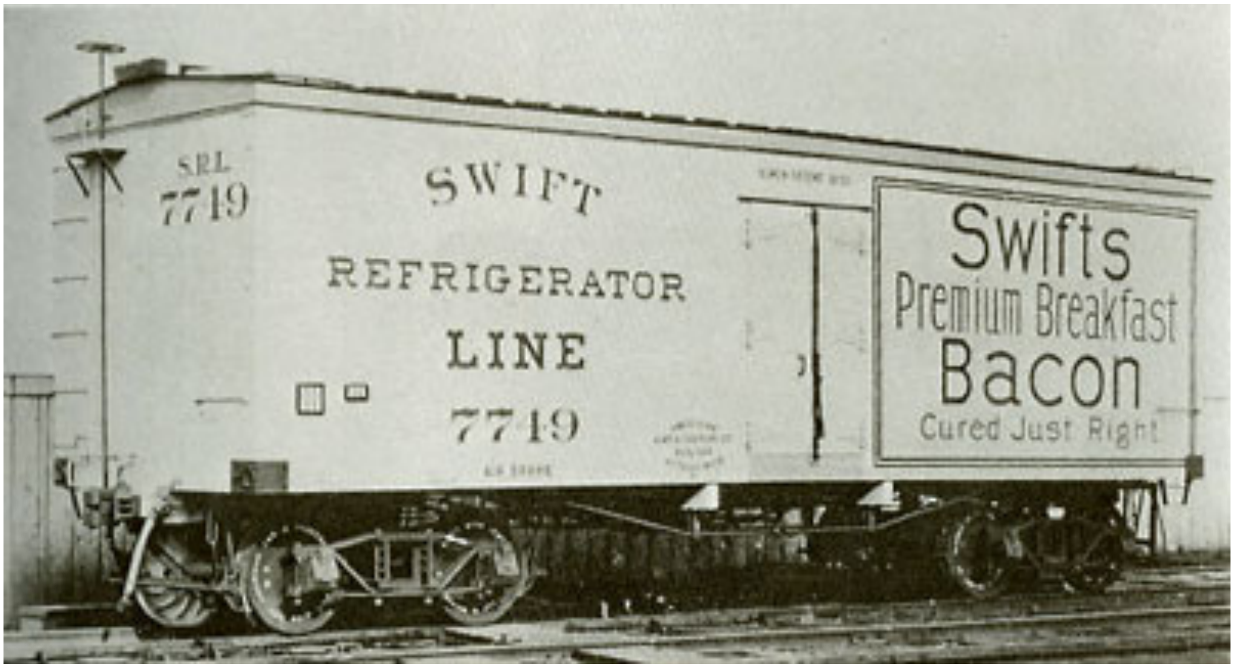
He went to the Grand Trunk Railway, which, owing to its longer line to the East, had little live-stock business, and proposed that the road should unite with him in building up a business in shipping dressed beef providing refrigerator cars that would carry the product the year round. He would furnish the business if they would provide the cars. The road welcomed the proposal to accept the new business, but they would not build refrigerator cars. "Will you haul the cars, if I build them myself?" said Mr. Swift. The management answering "yes," he arranged for the building of ten of the best refrigerator cars then made and put them into immediate use.

This was the origin of his private car lines. During the twenty-five years that followed, that is during Mr. Swift's lifetime, these ten cars grew into thousands.... Few things in industrial and commercial history have wrought such a revolution in business methods and expansion as the refrigerator car.

SOURCE: Goodspeed, Thomas W., D.D., LL.D. Gustavus Franklin Swift, 1839-1903. Vol. 1. University of Chicago Biographical Sketches. Chicago, IL: University of Chicago, 1922. Accessed November 18, 2017. [http://libsysdigi.library.illinois.edu/oca/Books2009- 06/gustavusfranklin00good gustavusfranklin00good.pdf](http://libsysdigi.library.illinois.edu/oca/Books2009-06/gustavusfranklin00good/gustavusfranklin00good.pdf).

In 1905 Charles E. Russell, in Everybody's Magazine, told the story of Mr. Swift's relation to the first successful use of the refrigerator car. His articles were written in a far from friendly spirit, and this makes all the more interesting the following enforced tribute to Mr. Swift:

A man named Tiffany had lately invented and was trying to introduce a refrigerator car. Mr. Swift studied this scheme and gradually unfolded in his mind a plan having the prospect of enormous profits—or enormous disaster. When his plan was matured he offered it to certain railroad companies. It was merely that the railroads should operate the refrigerator cars summer and winter, and that he should furnish them with fresh dressed meats for the Eastern market. This proposal the railroads promptly rejected.



https://www.creativezest.com/Refrigerated-Rail-Cars_a/261.htm

Thus thrown upon his own resources Mr. Swift determined to make the desperate cast alone. Commercial history has few instances of a courage more genuine. The risk involved was great. The project was wholly new: not only demand and supply had to be created, but all the vast and intricate machinery of marketing. Failure meant utter ruin. Mr. Swift accepted the hazard. He built refrigerator cars under the Tiffany and other patents and began to ship out dressed meats, winter and summer.

The trade regarded the innovation as little less than insanity. Mr. Swift's immediate downfall was generally prophesied on all sides, and truly only a giant in will and resources could have triumphed, so beset. He must needs demonstrate that the refrigerator car would do its work, that the meat would be perfectly preserved and then he must overcome the deep-seated prejudices of the people, combat the opposition of local butchers, establish markets and distribute products. All this he did. People in the East found that Chicago dressed beef was better and cheaper than theirs, the business slowly spread, branch houses were established in every Eastern city and the Swift establishment began to thrive. By 1880 the experiment was an indubitable success.

As soon as it was discovered that Mr. Swift was right a great revolution swept over the meat and cattle industries, and eventually over the whole business of supplying the public with perishable food products. The other packing houses at the stockyards went into the dressed-meat trade, refrigerator cars ran in every direction, shipments of cattle on the hoof declined, the great economy of the new process brought saving to the customer and profit to the producer, and the new order began to work vast and unforeseen changes in the life and customs of the nation.

Mr. Russell goes on to declare "Gustavus F. Swift the chief founder and almost the creator of the refrigerator car as a factor in modern conditions" and "really the most remarkable figure" in the packing industry of Chicago. It is certain that the man who made the refrigerator car the factor it has become in business was a benefactor of mankind, for in the conditions of our modern life he feeds the world, carrying to every part of it perishable foods of every other part.

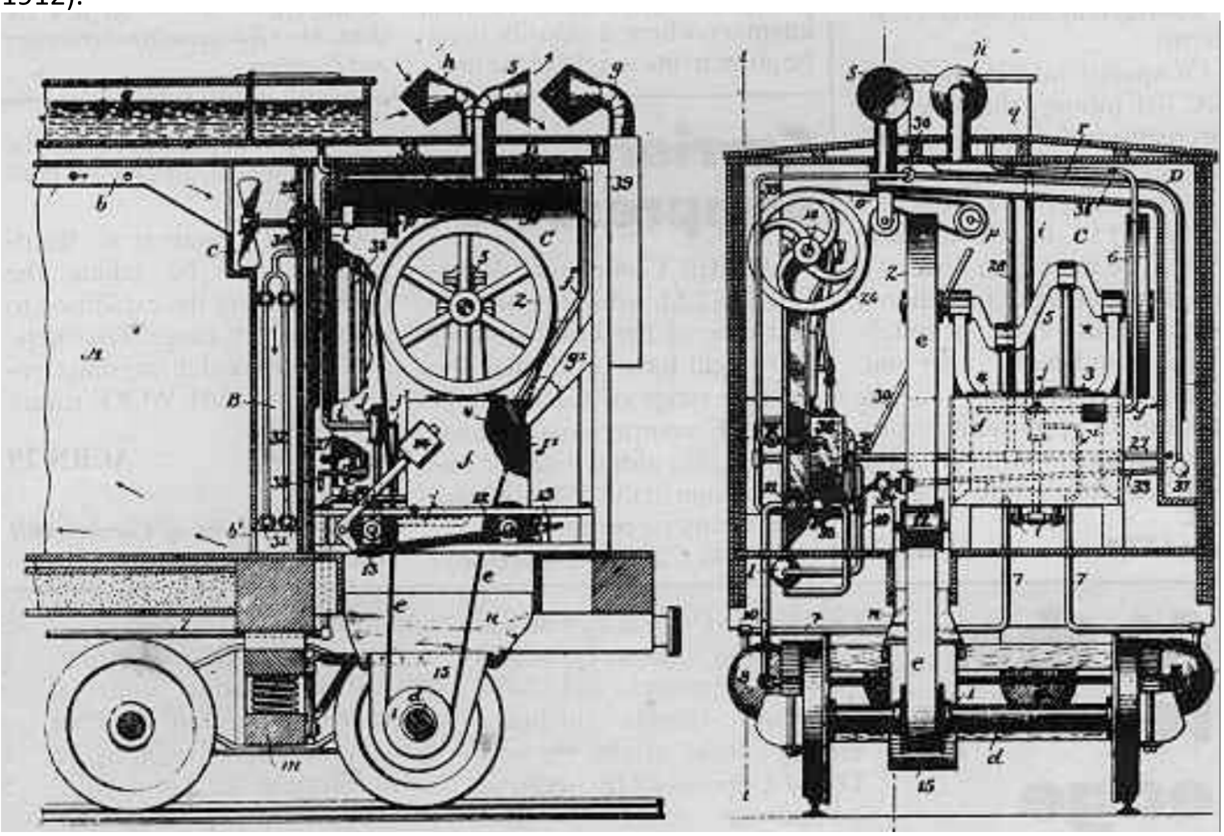
SOURCE: Goodspeed, Thomas W., D.D., LL.D. *Gustavus Franklin Swift, 1839-1903*. Vol. 1. University of Chicago Biographical Sketches. Chicago, IL: University of Chicago, 1922. Accessed November 18, 2017. http://libsysdigi.library.illinois.edu/oca/Books2009-06/gustavusfranklin00good/gustavusfranklin00good.pdf.

Document 2D

By the eve of the first world war, refrigerated rail transport had already developed to an extraordinary extent, almost unbelievable, in the United States. The count of thermally insulated wagons, most of which were cooled by ice, was 100,000 in 1913.

There are records in the United States of some “refrigerated” rail transport, more or less successful, from 1842. There were game, fish, butter, poultry, etc., shipped in wagons haphazardly insulated with sawdust, and holding containers of natural ice. But the true refrigerated wagons date from the patents and productions of J.B. Sutherland (1867) and D.W. Davis (1868) at Detroit. The former placed an ice bunker at each end; Davis produced successively two models, one with four cylindrical containers (diameter 40 cm) holding ice and salt, and then in 1870, a wagon with lateral ice bunkers, loaded from the roof. In 1877, J. Tiffany made a wagon with an overhead ice bunker.

The very first American iced wagons were made for the carriage of meat and dairy produce. Wagons for fruit immediately followed…. The total of refrigerated wagons was already some 50,000 in 1900 (on this date, less than [one] quarter of them belonged to the railway companies; three quarters belonged to industry or to private traders). About 1890 the American refrigerated wagon was 10 m long, had a carrying capacity of 20 t and a dead weight of 21 to 24 t. At the beginning of the 20th century, the length was increased, the load increased to 30 t, the interior capacity to 50 m^3, and the wagon was lighter in weight (17 t). Fairly soon, differentiation took place, with a “beef type” for meat and a wagon with fans for fruit and vegetables. From 1908 to 1916, the American Department of Agriculture thoroughly studied how these wagons could be improved (especially in experiments carried out by Mary Pennington from 1912).



Refrigerated rail wagon with cold air machine Patent No. 5773 1883
(from Train Refrigeration*, http://www.hevac-heritage.org/electronic_books/transport/3-trainrefrig.pdf)*

SOURCE: Thevenot, R. & Fidler, J.C. & International Institute of Refrigeration. A history of refrigeration throughout the world. Paris, International Institute of Refrigeration, 1979. http://www.hevac-heritage.org/electronic_books/transport/3-trainrefrig.pdf

Some American engineers studied the possibility of mechanical refrigeration of the wagons; a first patent was taken out in 1880. In 1888, there was a trial of a wagon with a methyl chloride compressor for transporting beef from Chicago to Florida. But it was not until after the second world war that mechanical refrigeration of wagons became really commercially significant. Until then, ice was practically the only cooling agent; the crossing of the American continent required reicing during the journey, and large reicing stations were built, which could recharge 18 wagons simultaneously.

SOURCE: Thevenot, R. & Fidler, J.C. & International Institute of Refrigeration. *A history of refrigeration throughout the world*. Paris, International Institute of Refrigeration, 1979. http://www.hevac-heritage.org/electronic_books/transport/3-trainrefrig.pdf

Attempts to contrive cars cooled by mechanical refrigeration dated from the eighteen-eighties. An experimental Chicago-to-Florida shipment of beef from Armour and Company was made in 1888 in a car cooled by chloride-of-ethyl-compression machinery. Several patents were issued over the years for units based on different principles, but although a few cars were built for demonstration purposes, none was adopted for regular service.

The reason for this, charged one early experimenter, C.C. Palmer, was the opposition of railroads and others who had heavy investments in ice plants, harvesting and storing facilities, icing stations, and existing cars. This charge contained elements of truth. But the fundamental reason for the reluctance of railroads and others to bring mechanical refrigeration into general use was the problem of economic feasibility. Cars were assigned to refrigerated shipments only part of the time. An example of the problem was the transportation of the citrus crop from southern California. Of the loads transported, not more than about one-third were refrigerated, for almost one-half of the fruit moved under ventilation alone, and a very high percentage of the westbound traffic required no ice in the bunkers. Under such conditions the installation of expensive machinery would have raised materially the cost of providing refrigerated service.

The refrigerator car was almost exclusively an American development. Few countries were faced with the long rail hauls and the climatic conditions that made it a necessity in the United States. In 1910 there were only about 1,085 such cars in continental Europe, while two years earlier there had been about 85,000 equipped with bunkers in the United States in addition to about 50,000 with insulation but no bunkers. In 1913 more than half of all refrigerator cars in Europe were in Russia, where the factors of distance and climate were most similar to those of North America.

Marine refrigerating machinery was developed in connection with the transoceanic meat trade. Charles Tellier, the versatile French inventor, attempted in 1868 to import meat from Uruguay to France in a ship refrigerated by an ammonia-compression system, but failed because of an accident to the machinery. In 1876 a French company experimented by sending meat to Buenos Aires in a steamship cooled by three Tellier methyl-ether units; in the following year the return voyage was made with a cargo of Argentine meat, part of which did not arrive in good condition. A Marseilles firm sponsored more successful voyages in 1877 and 1878, but these experiments, which failed to enlist the interest of the French public and the support of French capital, were not repeated….

Cold-air machines were favored by Henry and James Bell, J.J. Coleman, Andrew McIlwraith, and W.S. Davidson, the Britons who pioneered in the transportation to England of meat in mechanically refrigerated ships. Such equipment was in use by 1883 on vessels carrying meat from both American continents and from Australia and New Zealand. It predominated in marine refrigeration throughout the eighties.

But these machines had little potentiality. They were low in efficiency and expensive in their consumption of power. After 1890 they gradually were superseded by more efficient systems and came to be installed only in the relatively few situations where economy of power was of secondary importance.

Machines of the vapor-compression type began to displace cold-air units during the nineties. First carbon-dioxide sytems were introduced and then ammonia…. These vapor-compression systems were,

SOURCE: Anderson, Oscar E. Refrigeration in America: a history of a new technology and its impact. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.

of course, great improvements over the early units of their type first tried on shipboard in the seventies….

Great Britain, dependent on supplies of perishable foods from overseas for her very existence, led the world in the development and manufacture of refrigerating machinery for marine use. American contributions in the field were slight. As late as 1935 only ten per cent of all refrigerated cargo ships were equipped with machines built by manufacturers in the United States. One American firm, the United Fruit Company, based its extensive banana trade on marine refrigeration, but relied mainly in the period 1917 on ships and equipment of British design….

The refrigerator ship was a comparatively minor factor in the growth of the industry in the United States. It was not used to any significant extent for transporting perishables in domestic trade, but it did open foreign markets to some American fruit-growers. Apples and oranges were the fruits exported in large quantities. Though they did not require refrigeration during ocean transportation under all conditions, it was the refrigerator ship that made it possible for exports of green and ripe apples to increase from just over 135,000 barrels in 1891 to over 1,700,000 in 1917 and for exports of oranges to increase over sixteen times in value between 1900 and 1917. The refrigerator ship, of course, was a vital feature of the banana trade carried on by the United Fruit Company.

SOURCE: Anderson, Oscar E. *Refrigeration in America: a history of a new technology and its impact*. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.

Document 2F

Ice delivery truck, Cedar Falls, Iowa. The first ice harvest on the Cedar River began on January 10, 1922.

SOURCE: Highsmith, Carol M. "One of many displays tracing the history of refrigeration at the Cedar Falls Ice House, a historic structure in Cedar Falls, Iowa." The Library of Congress. Accessed September 30, 2017. https://www.loc.gov/item/2016630448/.

Document 2G

#3600 Anheuser-Busch "Beer Car" 1904

Produced in 1904 by the St. Louis Refrigerator Car Company [established 3 February 1878 by Adolphus Busch to facilitate wide-scale distribution of his product], this was one of the first Anheuser-Busch cars designed to transport draught beer. Although it incorporates a steel frame, it is wood-bodied and is insulated with horsehair, shredded paper, and wood shavings. Pre-cooled beer was loaded into the car, whose insulation kept the A-B products cool in warm weather and from freezing in winter. It is one of the oldest surviving examples of "billboard" advertising on railroad freight cars. Number 3600 was donated to MOT in April 1958. Records indicate #3600 transported 6,277,500 gallons of beer between the St. Louis brewery and Texas distribution points before it was removed from service.

SOURCE: Blank, Fred. "Treasures at the MOT - March 2008." St. Louis Chapter National Railway Historical Society. Accessed September 30, 2017. http://www.stlouisnrhs.org/MOT_Treasure/treasures_200803.htm.

The early history of refrigerator cars is somewhat obscure. There are no statistics to show the number owned by private companies over a series of years, and it is impossible to enumerate them exactly even at the present time. There are conflicting statements as to which was the first refrigerator car used, and attempts that have been made to write up this history have had to be based more on the recollection of men who were alive at the time when refrigeration in transit was first introduced, than on any definite and authentic records.

Probably the earliest attempts to refrigerate freight cars were made on the Michigan Central Railroad in the early sixties [1860s] for the carriage of fresh meat from Chicago to New York and Boston. Ordinary box cars were fitted with platforms at each end, about three feet from the floor, with metal catch-basins to carry away the melted ice, and heavy swing doors were suspended from the ceiling to hold the ice in place. These bins held from 2000 to 3000 pounds of block ice, and the ice could be placed in the car only when it was empty. A metal pipe carried the waste from the catch-basin through the bottom of the car. These were crude affairs, and can hardly be called refrigerator cars; but by carrying them on passenger trains as far as Suspension Bridge, NY, and there attaching them to fast freight trains, the railroads were able to land them in New York in about three days with the meat in good order. These attempts did not attract much attention, and were not successful enough to give any idea of the vast change that was soon to be brought about by the use of the more efficient refrigerator cars.

At about the same time, the Pennsylvania Railroad was also experimenting in refrigeration under the direction of W.W. Chandler, who was for years at the head of the Star Union Line, and who did more than any other man to further the early development of this kind of traffic. It was about 1857 that Mr. Chandler had thirty box cars refitted with double sides, roof, and floors, and the interstices packed with saw-dust, and thus hatched what the present officers of the company claim to have been the first refrigerator cars. These cars had a hole in the floor between the doors for the leakage of ice water, and a box of ice was put in the door after the car was loaded. Mr. Chandler called this the “ice box on wheels,” and it was used for the carriage of dairy products from the West. This car was soon improved by placing the ice in huge boxes hanging by iron straps in the ends of the car.

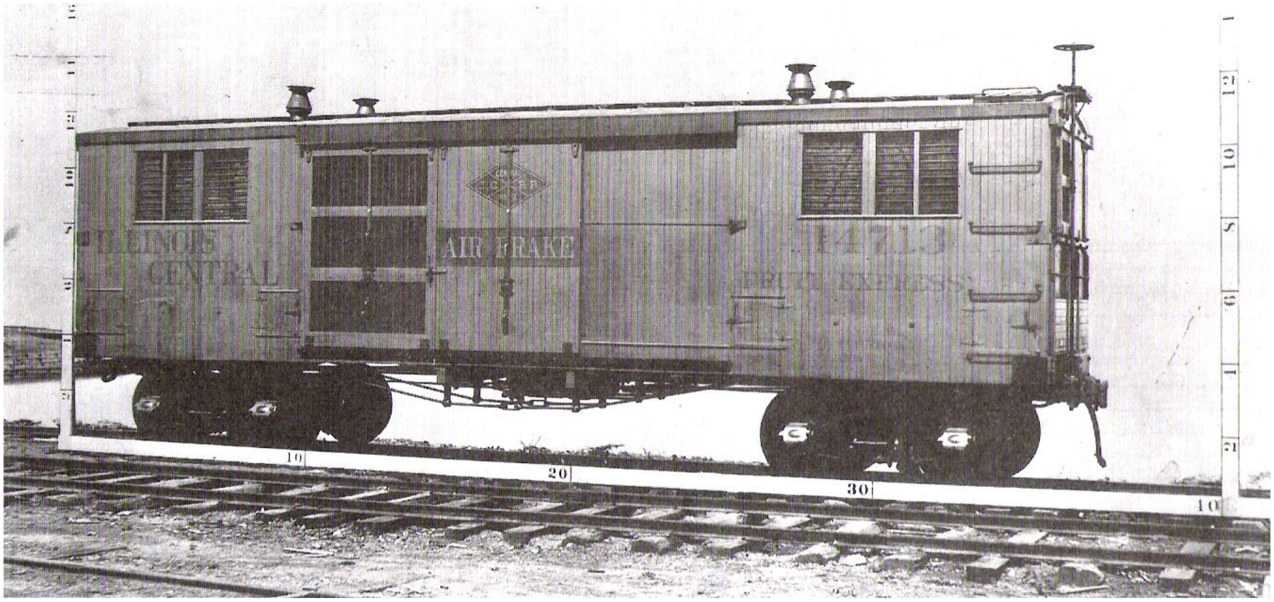
At about the same time that Chandler was instituting refrigeration in transit over the Pennsylvania, experiments were going on in Detroit in order to perfect a more efficient car. The first patent taken out for a refrigerator car was that of J.B. Sutherland, of Detroit, Michigan, under date of November 27, 1867…. A successful shipment of dressed beef from Chicago to Boston in September, 1869, in this car, may be said to be the real beginning of the dressed-beef industry….

The first attempts to refrigerate fruit in transit were probably those made in 1866 by Mr. Parker Earle, then residing in Cobden, Illinois. In that year he built twelve big refrigerator chests for shipping strawberries by express. Each chest held 200 quarts of berries and 100 pounds of ice. When taken good care of, the berries carried well, but on account of carelessness in handling, and excessive express rates, this method had to be abandoned…. In 1868 a Davis car was brought to Cobden, Ill., and loaded with strawberries. The car contained a vertical cylinder in each corner, about fifteen inches in diameter, and was iced from the top of the car, salt being mixed with the ice. The result of this experiment was that part of the berries were frozen, while the balance of the load was unequally cooled. The shippers suffered a loss, and did not feel encouraged to try it again….

SOURCE: Weld, L. D. H., Ph.D. "Private Freight Cars and American Railways." *Studies in History, Economics, and Public Law*31, no. 1, Columbia University Press (1908).

Mr. Earle, however, continued his experiments, and built a cooling house in his packing shed at Anna, Ill. By leaving his berries in this house for twenty-four hours to cool off, and then sending them to Chicago by express, he found that they arrived in much better condition than those which were sent as soon as picked….

What was needed was a car that would hold four or five tons of ice, so that the warm fruit could be cooled in the car, and then taken on a two or three day trip with safety. Mr. Earle soon had such a car built, -- one that was well insulated and with adequate ice capacity.



Illinois Central Railroad #14713, a ventilated fruit car dating from 1893. (Railroad and Locomotive Historical Society photo scanned from The American Railroad Freight Car p. 298)

The introduction of refrigerator cars was accomplished in the face of much skepticism and opposition on the part of both the growers and the traders. It was generally believed that when fruit had been on ice, it would decay rapidly after being taken off. This is true of fruit that is over-ripe before being placed on ice, though not true of fresh fruit if properly handled, but it took many demonstrations to induce growers to believe this. The use of refrigerator cars consequently increased but slowly at first, and it was not until some time later that even the experimental stage was passed. Mr. Armour, in his book, The Packers, The Private Car Lines, and The People, tells us that Mr. Hammond of Detroit was one of the pioneers in the use of the refrigerator car for the carrying of meat products, and that his first successful attempt was in 1871. In this car, the meat came in contact with ice, became discolored, and did not keep well after being removed. To obviate this difficulty, the meat was suspended from rafters and ceiling, but the motion of the cars in going around curves set the halves of meat swinging like pendulums, so that this motion was communicated to the cars. Some railroad wrecks were attributed to this cause, and the hostility of the railroads was aroused. Then came the partitioning-off of an ice bin at the end of the car, and later the true principle of refrigeration was discovered: that a current of air allowed to pass through an ice bunker in the upper corner of a car becomes chilled so that it is heavier than the air with which it comes in contact, and consequently sinks, circulates through the car, the warm air passing out through the ventilator. It was not until this system was adopted that refrigerator cars came into at all general use, and that refrigerator lines which could handle any extensive business were established….

SOURCE: Weld, L. D. H., Ph.D. "Private Freight Cars and American Railways." *Studies in History, Economics, and Public Law*31, no. 1, Columbia University Press (1908).

Document 3B

Of the various kinds of special-equipment cars, by far the most important is the refrigerator car. It has revolutionized the livestock and dressed-beef industries; it has made it possible to transport fruit and vegetables across the continent and across the ocean, and has therefore resulted in the development of certain sections of the country which would have otherwise remained poor on account of their distance from market….

As we have seen before, meat, in early times, was furnished by local slaughter-houses and the live animals were either shipped in the ordinary cattle cars of the railroads from the West to the Atlantic seaboard, or raised locally. There were extensive stockyards and slaughter-houses in all the principal cities of the East, and the carriage of live animals was an important item in the traffic of the trunk lines. During the seventies [1870s], as we have seen, dressed beef began to be shipped from Chicago to eastern markets in refrigerator cars.

It is easy to realize what great economies were made possible by this change. The weight of edible beef derived from a steer is only 50 to 57 per cent of the entire weight of the animal. In those early days, all the rest was absolute waste, and the slaughter-houses even paid sometimes to have it carted away. In other words, shipment of cattle meant the payment of freight on a steer weighing 1000 pounds in order to get about 550 pounds available for market. Furthermore, there was a deterioration in the value of cattle after carriage of 1000 to 2000 miles in cattle cars; many became sick and died enroute, there was always a considerable shrinkage in the weight of the animals, and the general quality of their meat was impaired. These economies were readily recognized and the shipment of dressed meats became general. As a result of this, the great packing centers of the Middle West began to spring up, and consequently the slaughtering of cattle in the East began to fall off. The following figures demonstrate this tendency:

Total Value of Meat Products from Slaughtering and Packing			
	1880	1890	1900
Boston	$7,096,777	$2,782,823	$1,392,010
New York	29,297,527	50,251,504	38,752,586
Chicago	85,324,371	203,606,402	256,527,949
Kansas City	965,000	39,927,192	73,787,771

At one time, Chicago was near the borders of the cattle-growing districts, and the short haul to that point soon made it by far the greatest livestock and packing center in the country. The cattle-raising country gradually extended farther and farther westward and the Chicago packers followed this westward movement by erecting plants at Kansas City, Omaha, St. Louis, St. Paul, St. Joseph, and even followed the industry to Texas, and built great plants at Fort Worth. This shifting of the meat-packing centers was made possible by the use of the refrigerator car.

The westward movement of the cattle-raising industry itself has likely been made possible by the refrigerator car. In the early days, when live cattle were shipped, the distance from west of the Missouri River to the Atlantic Coast was too great, and the expense of marketing the cattle too high, to make the raising of livestock profitable. With the introduction of refrigerator cars, the utilization of the vast grazing districts of the West was made possible. Thus, not only is the entire dressed-meat industry dependent on the refrigerator car for its existence, but also the raising of livestock has been extended, and many states have been developed and made wealthier through its use. As the Census of 1900 says: “The importance of artificial refrigeration to the meat trade would be hard to overestimate. The most important step in the development of American beef as an article of commerce, was the invention of the refrigerator car by William Davis of Detroit.”

Fully as important as the part that the refrigerator car has played in the development of the meat-packing industry, is its effect on agricultural development, in connection with both fruits and vegetables. It was not very long ago that fruit was raised only on a small scale, as it had to be consumed locally, and could not be transported for any considerable distance. Fruit could be had at any given place only at the time it ripened locally, and any that was brought by express or other means a little before or after the short season of three or four weeks was very expensive and considered a great luxury. As a result of refrigeration in transit, these conditions have all been changed; fruit is carried from the most remote sections of the country to the large cities throughout the year, and instead of being considered a luxury, it is looked on as a staple article of food…. Few people realize what an enormous business fruit growing has become under the impetus given it by refrigerator cars…. In 1899 the principal fruit-growing districts of the country shipped under refrigeration only 9,164 cars; in 1905 the same districts shipped 42,982 cars. This gives some idea of the rapid growth during the past few years.

California offers perhaps the best illustration of the development of fruit growing through the use of the refrigerator car. It is the greatest fruit-producing state in the country, it is situated at the greatest distance from the important markets, and it therefore depends particularly on transportation facilities…. The relations between the Harriman interests and the Santa Fe, recently made public, may possibly explain this friendliness to a certain extent. The movement of oranges and lemons from Califiornia for the last few years has been as follows:

Date	Carloads
1894-95	5,575
1895-96	6,915
1896-97	7,350
1897-98	15,400
1898-99	10,875
1899-00	18,400
1900-01	24,900
1901-02	19,180
1902-03	23,871
1903-04	29,299
1904-05	31,422
1905-06	27,610

SOURCE: Weld, L. D. H., Ph.D. "Private Freight Cars and American Railways." ***Studies in History, Economics, and Public Law*****31, no. 1, Columbia University Press (1908).**

Document 3C

A new refrigerator car, the design of two Liverpool experts, has been put upon the English market. The London Times, in describing it, says:

“Up to the present practically no improvement has been made in the ordinary iced box car for carrying perishable produce, a system which has decided limitations. The car now introduced accomplishes the cooling by means of a mechanical refrigeration plant, which consists of a small enclosed type ammonia compressor of special design mounted on one end of the car; an ammonia condenser designed for cooling by the air current produced by the motion of the car and placed on the roof; an expansion valve arranged to keep, automatically, a constant pressure in the evaporators within the car, and consequently a constant temperature therein, and ammonia evaporators placed in suitable positions inside the car arranged to provide a regular supply of cold to keep the car temperature constant during stoppages. The compressor is driven from one of the axles by chain gearing, a change speed gear and disengaging mechanism being interposed between the axle and compressor. The driving wheel placed on the axle may be arranged to allow the toothed part to swing in either direction, and thus keep in the same plane as the driven wheel on the intermediate shaft.

“The advantages claimed for this type of car over those now in use are that it is independent of any ice supply whatever; it is available at any point on the line and at all times; it obviates delays due to icing, and, in addition, the expense attaching to ice storage and filling; it effects a lower temperature than is possible with ice tanks; it can undertake any length of journey without renewals; and it is free from the risks due to careless or insufficient icing.”

SOURCE: "Refrigerator Cars." ***Scientific American*****66, no. 1698supp (1908): 44. doi:10.1038/scientificamerican07181908-44bsupp.**

Document 3D

Rapid expansion in the movement of packaged frozen foods by refrigerated cars over great distances has brought problems in protecting the quality of the commodity in transit. Research on the temperature tolerance of frozen foods has indicated the necessity for maintaining 0° F. or lower in-transit temperatures to maintain as closely as possible the inherent nutritive food qualities. The generally inadequate supply of the comparatively new mechanically refrigerated cars and the resulting use of many water-ice and salt cars in shipping frozen food have accentuated the problem of maintaining proper temperature.

This transportation refrigeration test was conducted to compare performances of two types of mechanically refrigerated rail cars and a standard water-ice and salt refrigerated car hauling frozen corn from Waseca, Minn., to Jersey City, N. J.… Car A was a 50-foot end-bunker water-ice refrigerator car with 6 inches of glass fiber insulation in the side walls, ceiling, and floor (fig. 1)….

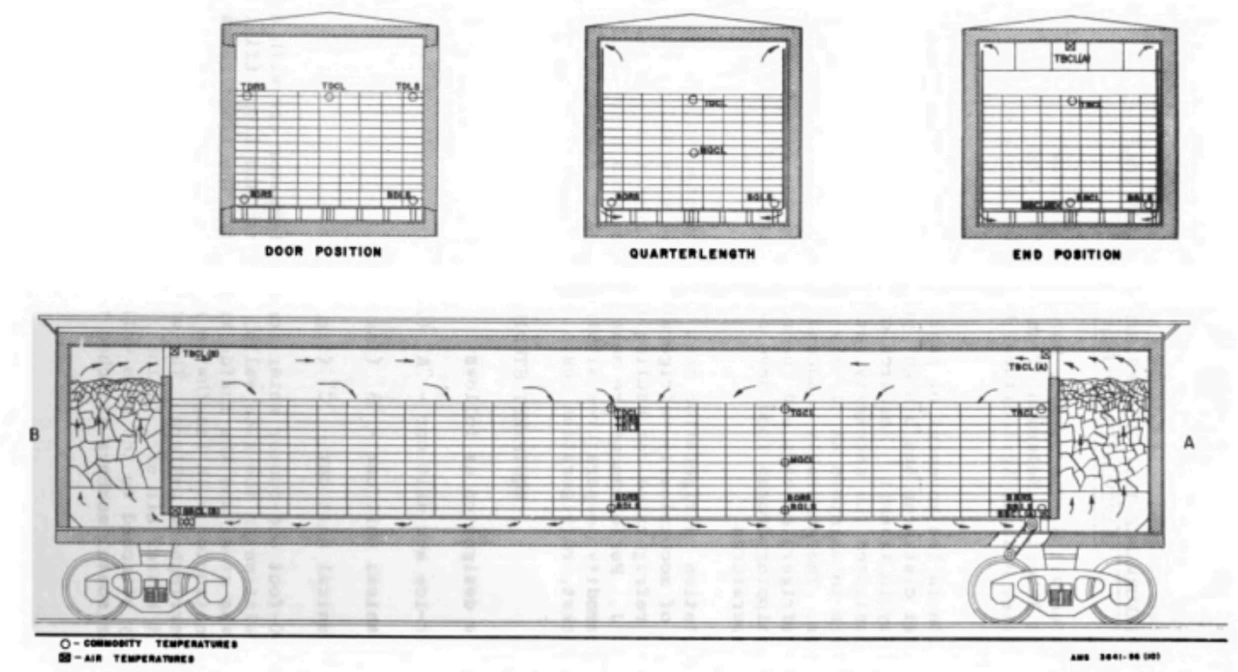


Figure 1.--Car A, a 50-foot water-ice refrigerated railroad car, loaded with packaged frozen corn. The locations of the electrical resistance and air temperature recording thermometers also are shown. For explanation of TDRS, TDCL, etc., see pages 7-8. A and B identify the ends of the car.

Mechanical car B was 50 feet long, with 6 inches of glass fiber insulation in the ceiling, walls, and floor (fig. 2)…. Each of the twin refrigeration units was powered by a 25 hp. 4-cycle gasoline-type engine burning diesel fuel. They had a combined rated capacity of 52,000 British thermal units [BTUs] per hour….

SOURCE: Hinds, Russell H. "A Performance Test of Refrigerated Rail Cars Transporting Frozen Food." Washington, D.C. : U.S. Dept. of Agriculture, Agricultural Marketing Service, Marketing Research Division, 1957. Hathi Trust Digital Library. Accessed November 18, 2017. https://babel.hathitrust.org/cgi/pt?id=uva.x030493218;view=1up;seq=24.

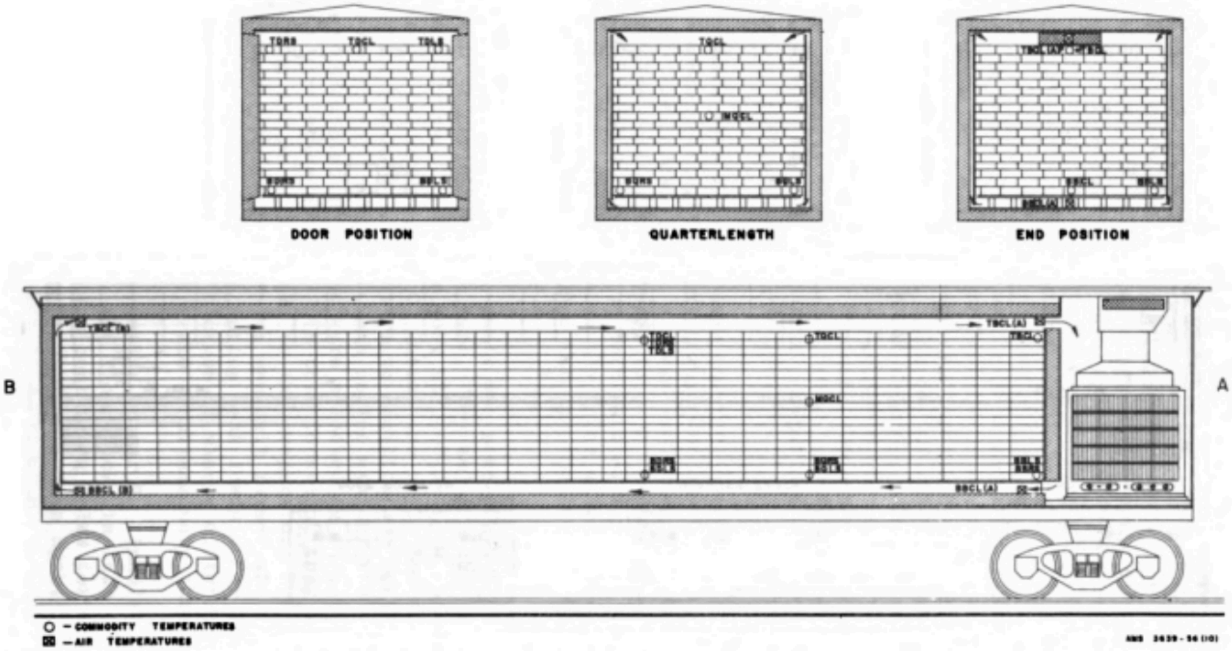


Figure 2.--Car B, a 50-foot mechanically refrigerated railroad car, loaded with packaged frozen corn. The locations of the electrical resistance and air temperature recording thermometers also are shown. For explanation of TDRS, TDCL, etc., see pages 7-8 A and B identify the ends of the car.

Mechanical car C (fig. 3) was similar to car B. Insulation and outside dimensions were the same. …Electrical power to operate the 2 cooling-heating units was supplied by a 42 hp. 4-cycle horizontal diesel engine directly connecting with a 220-volt, 3-phase, 60-cycle alternator. …They…produced 32,000 B. t. u./hr.

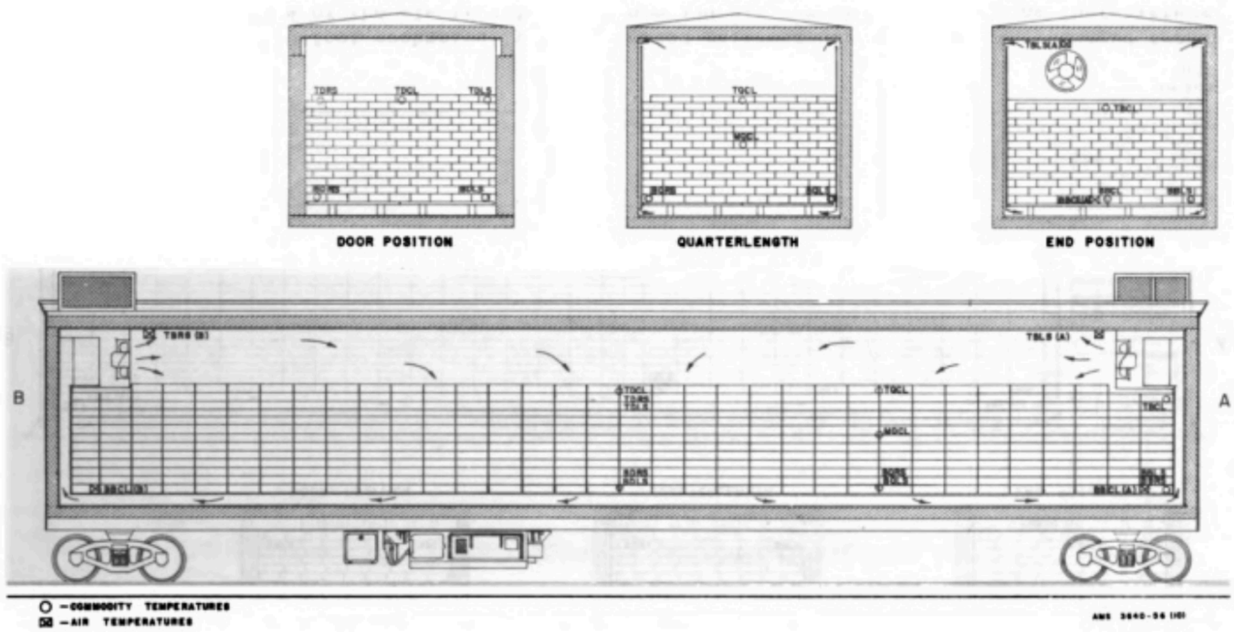


Figure 3.--Car C, a 50-foot mechanically refrigerated railroad car, loaded with packaged frozen corn. The locations of the electrical resistance and air temperature recording thermometers also are shown. For explanation of TDRS, TDCL, etc., see pages 7-8. A and B identify the ends of the car.

SOURCE: Hinds, Russell H. "A Performance Test of Refrigerated Rail Cars Transporting Frozen Food." Washington, D.C. : U.S. Dept. of Agriculture, Agricultural Marketing Service, Marketing Research Division, 1957. Hathi Trust Digital Library. Accessed November 18, 2017. https://babel.hathitrust.org/cgi/pt?id=uva.x030493218;view=1up;seq=24.

The average commodity temperature in exterior load test packages for car A at Jersey City, N. J., was +14.3° F., as compared to the midload test package temperature of +2° F. In car B the average commodity temperature of packages in the exterior of the load at destination was -8.3°, while the interior temperature was -5°. At destination, car C had an average commodity temperature of -2.1° in packages in the exterior of the load. The interior mid-quarter-centerline package had a temperature of -2°.

The data for fuel, ice, and salt consumption cover the quantities used during the preliminary cooling test and during the transit test. The total value … of the ice and salt put in car A was $214.97…. The twin gasoline-type, diesel-burning engines in car B operated … a total of 112 hours. They consumed 123.5 gallons of fuel, or 1.1 gallons per hour. At 16 cents per gallon for diesel fuel, the out-of-pocket cost for refrigeration was $19.76. The single diesel engine in car C operated continuously for 130.9 hours and consumed 97.4 gallons of fuel, or 0.75 gal./hr. At 16 cents per gallon, the out-of-pocket cost for refrigeration was $15.58….

Temperatures maintained in the water-ice car were not at the level desired for frozen foods. The commodity temperatures were fairly uniform, but never approached zero. The outer layers warmed to a dangerous level, and the interior of the load had a gradual rise in temperature. Although the performance of this car probably would have been somewhat better had both fans been operating, it seems unlikely from the recorded temperatures that they would have been brought down to a safe level for frozen foods…. It is recommended that mechanical cars be used in preference to water-ice cars when low temperatures are desired, particularly in hot weather.

SOURCE: Hinds, Russell H. "A Performance Test of Refrigerated Rail Cars Transporting Frozen Food." Washington, D.C. : U.S. Dept. of Agriculture, Agricultural Marketing Service, Marketing Research Division, 1957. Hathi Trust Digital Library. Accessed November 18, 2017. https://babel.hathitrust.org/cgi/pt?id=uva.x030493218;view=1up;seq=24.

Document 3E

Omaha, Neb., May 2, 2006 – Perishable foods have long moved by rail, with improved technology ensuring quicker, cooler transportation of fresh fruits, vegetables, dairy products and meat. This century-long evolution of Union Pacific Railroad's service has helped to change America's diet.
Prior to the westward railroad expansion in the United States, food moving cross country was either dried or salted for preservation. As railroads were constructed in the 1800s, agriculture producers saw markets opening for their dairy products, fruits, vegetables and meats. No longer localized, their markets expanded to 50, 100 or even more than 1,000 miles away. Railroads were able to transport most goods, but moving perishable items required development of a specialized rail car that would help keep food fresh or preserved enroute.

The first patented refrigerated car was built in 1867. Air, forced over blocks of ice in large compartments on each end of the rail car, kept the perishable commodity cool. For the day, this crude "refrigeration unit" was state-of-the-art. Ice to fill the rail cars was naturally harvested from lakes and ponds. The ice cakes were stored in insulated buildings next to the tracks. Union Pacific Railroad constructed huge, long wooden ice houses along its main lines in the late 1800s to provide the ice needed to constantly fill the refrigerated boxcars as they made their way across the country. Moving fresh meat from Kansas City to Los Angeles or strawberries from Los Angeles to Chicago required ice and a lot of it. But by the 1890s, health complications arose from the use of natural ice, its purity affected by expanding cities' pollution and sewage dumping into waterways. Refrigeration technology provided the solution: mechanically manufactured ice. Ice as the source of refrigeration in transportation would prove difficult to replace. Meanwhile, America was hungry for fresh food, and the country's demand for fresh meats, fruits and vegetables was growing by leaps and bounds. In response, the Southern Pacific and Union Pacific Railroads formed The Pacific Fruit Express Company in 1906.

Ice is king – but not for long
Sometimes as big as a barn, large refrigeration units were developed for commercial use, primarily for breweries, in the 1870s. By 1891, nearly every brewery was equipped with refrigerating machines. Refrigeration units small enough for use in transportation, though, would not be designed until the late 1940s. In the 1950s, railroads continued to be the transportation mode of choice for fresh fruits and vegetables. But by the '60s, aging refrigerated boxcar fleets combined with the completion of the Interstate highway system prompted agricultural producers to shift their time-sensitive shipments to truck. By the mid-1970s, more and more perishable food was moving by truck. In 1978, Pacific Fruit Express was dissolved and the two companies formed their own perishable transport subsidiaries, Southern Pacific Fruit Express and Union Pacific Fruit Express.

In the mid-1990s, as a result of rising fuel costs, the railroads began seeing a resurgence in perishable food transportation. Once again, rail had become an attractive mode of transportation for perishable food items. And with the revival came a redesign of rail cars to handle larger loads and refrigerated units that became more energy efficient. Union Pacific worked with eastern railroads to offer customers "seamless" service between the West and East coasts. At the same time, UP began to expand and refurbish its refrigerated boxcar fleet.

New breed of refrigerated boxcar
Since 2003, Union Pacific has purchased 1,500 64-foot cars and will complete an extensive upgrade of more than 2,600 of its 50-foot cars by the end of 2006. Union Pacific handles more than 48,000 shipments of refrigerated and frozen products each year and is the country's largest owner of

SOURCE: "From Ice Blocks to Satellite Technology, Perishable Foods Transportation Has Come a Long Way." Union Pacific: Building America. May 2, 2006. Accessed November 18, 2017. https://www.uprr.com/newsinfo/releases/service/2006/0502_reefers.shtml.

refrigerated rail cars with more than 5,500 refrigerated cars in the current fleet. The new boxcars can hold up to 40 percent more product than a conventional refrigerated rail car. A 64-foot rail car carries as much as four over-the-road trailers. The refrigeration units used in both new and refurbished cars are state-of-the-art and energy efficient. They use the latest technology, such as global positioning satellite (GPS) monitoring, not only to track rail cars' trip progress but also to check temperature, fresh-air exchange and diagnostics. Fresh-air exchange is an important feature for commodities such as onions that require fresh-air circulation. Temperature variance with the new units is as little as plus/minus two degrees. Refrigerated boxcars also are used to ship frozen commodities, such as french fries, meat, poultry and dairy products.

The rail service that forever changed diets across the United States has evolved over the years to efficiently transport fresh fruits, vegetables, dairy products and meat cross country. Union Pacific has that perfect network to run a refrigerated rail car fleet carrying fresh and frozen products from the growing areas of Northern California and the Pacific Northwest to points east, returning with meat and poultry products for export through West Coast ports.

SOURCE: "From Ice Blocks to Satellite Technology, Perishable Foods Transportation Has Come a Long Way." Union Pacific: Building America. May 2, 2006. Accessed November 18, 2017. https://www.uprr.com/newsinfo/releases/service/2006/0502_reefers.shtml.

Document 3F

SOURCE: ABCO Transportation advertisement, https://www.shipabco.com/history-refrigerated-trucking/

The History of

Refrigerated Trucking

Early 1920s

REFRIGERATED TRAILERS WERE ALTERNATIVES TO CONGESTED TRAIN SYSTEMS

Morris and Company used a fleet of Mack refrigerated tractors and trailers to distribute dressed beef, which was faster and cheaper than shipping with the railroad system.

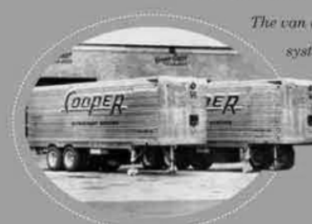
1935

FRED JONES INVENTED THE FIRST PORTABLE AIR-COOLING UNIT

The portable air-cooling units were placed on the outside of trucks that carried perishable foods. Jones went on to form the U.S. Thermo Control Company, which helped preserve blood, medicine and food during World War II.

Early 1940s

THE STEEL PRODUCTS COMPANY BUILT THE FIRST VAN WITH A WET ICE BUNKER



The van also featured a gas engine and a blower system. They soon went on to build the first factory-finished refrigerated van, also known as the Great Dane Reefer.

Today

TECHNOLOGY SETS THE PACE FOR THE REFRIGERATED FREIGHT INDUSTRY

Technological integrations allow a high level of control in each aspect of refrigerated shipping. ABCO uses these integrated technologies to ensure that temperature-sensitive freight gets to its destination on time.

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Sources: Hofstra, Wikipedia, TheOldMotor, GreatDaneTrailers, ASME, Biography

Presented By kwikturnmedia

April 2015

IEEE REACH

The trend toward geographic centralization, which in the case of slaughter for the fresh-meat trade depended chiefly on the refrigerator car, became after 1890 even more pronounced than before. The extent to which packing ceased to be a local industry was indicated by United States Department of Agriculture estimates that in 1916 over sixty-nine per cent of the cattle slaughtered in the entire country were butchered in plants engaged in interstate trade. Of the total number of these cattle eighty-one per cent were killed in twelve packing centers, the most important of which were Chicago, Kansas City, Omaha, and St. Louis. These twelve also accounted for over sixty-five per cent of the calves handled in interstate concerns, for over seventy-eight per cent of the sheep and lambs, and for fifty-eight per cent of the hogs.

The trend toward concentration of control was so strong after 1890 that it became a major public problem. By 1916 the Big Five packers – the Armour, Swift, Morris, Wilson, and Cudahy interests – butchered over eighty-two per cent of the cattle slaughtered by interstate firms as well as over seventy-six per cent of the calves, eighty-six per cent of the sheep, and sixty-one per cent of the swine.

…By 1917 the Big Five were engaged so extensively in the distribution of meat substitutes, of canned fruits and vegetables, and of staple groceries and vegetables that the Federal Trade Commission feared packer domination of all important foods.

…The privately owned refrigerator car was the most important feature of the distribution system of the packing industry….

Fruit and vegetable production in the United States expanded enormously in the twenty-five years after 1890. Several factors contributed to this. For one thing, a large market for such products was available in the swollen urban communities of the North and East. For another, these markets had been connected with remote agricultural districts by efficient rail transportation. But neither of these factors could have been decisive without refrigeration. The ice-making machine, the refrigerator car, and the cold-storage warehouse were key developments in the growth of the fruit and vegetable industry.

The refrigerator car could not be used effectively in transporting the fruits and vegetables grown in the warmer sections of the United States until factories capable of manufacturing cheap and abundant quantities of ice had been established at shipping points. About 1880 refrigerator cars came to be used regularly and extensively by the meat-packers, whose shipments originated in the natural-ice belt. But it was not until about 1890, when ice-manufacturing plants had been erected throughout the South, that the refrigerator car found general employment in the transportation of that section's fruits and vegetables. From California the first refrigerated shipments of fruits on a large scale were made about the same time as from the South, but natural ice obtained in the Sierras was used rather than the manufactured product….

The most striking effect of the refrigerator car on fruit and vegetable production was the impetus it gave to regional specialization. By making it possible to transport the most perishable of crops for hundreds and even thousands of miles, it stimulated the growing of fruits and vegetables in areas particularly well-adapted by climate and soil, regardless of how far they lay from the principal markets….

Under the influence of the car, numerous areas far from the markets of the North and East specialized in growing deciduous fruits. One of the most important of these areas was Georgia, famous for its peaches.

SOURCE: Anderson, Oscar E. *Refrigeration in America: a history of a new technology and its impact*. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.

In 1889 only 150 carloads were shipped from its orchards, but in 1898 over eleven times that many were dispatched and in 1905 about 5,000 carloads. California, the width of the continent from its market, concentrated on several fruits – grapes, peaches, pears, plums, and apples. Carloadings of these increased from over 4,500 in 1895 to between 8,000 and 10,000 in 1905, over ninety-five per cent of which were refrigerated. Among other specialized areas was the Pacific Northwest, where Washington and Oregon developed vast apple, pear, and cherry orchards and grew large quantities of raspberries.

Citrus-growing areas developed rapidly. In 1886 California shipped 1,000 carloads of oranges, protected only by ventilation. With the introduction of the refrigerator car, the traffic in oranges increased rapidly. Between 1890 and 1895 from 4,000 to 7,000 carloads a year were forwarded and between 1900 and 1907 from 25,000 to 32,000….

…The Carolinas, the Gulf states, Arkansas, Missouri, and Tennessee entered into strawberry production on a large scale. Crystal Springs, Mississippi, became the center of a great tomato-growing industry, while Rocky Ford, Colorado, became a similar focal point for cantaloupe production when in the nineties the refrigerator car made eastern markets accessible. By 1920 more than 21,000 cars of cantaloupes were shipped annually in the United States. Of these about four-fifths originated at points in Colorado, New Mexico, Arizona, Nevada, and California – six to twelve days from market. Without refrigerated transportation this would have been impossible. Many areas came to specialize in vegetable production, especially in the south Atlantic and Gulf states and in California. Refrigerator cars were not needed for all vegetables, but were important for successful marketing of lettuce, celery, cauliflower, cabbage, asparagus, and others of the more perishable crops.

By 1917 a remarkably full development of areas particularly well-suited by climate and soil to the production of fruits and vegetables had taken place….

The refrigerator ship was a comparatively minor factor in the growth of the industry in the United States. It was not used to any significant extent for transporting perishables in domestic trade, but it did open foreign markets to some American fruit-growers. Apples and oranges were the fruits exported in the largest quantities…. The refrigerator ship, of course, was a vital feature of the banana trade carried on by the United Fruit Company….

The diet of American city-dwellers benefited by the revolution which refrigeration worked in the production and distribution of food. After 1890 the nation's growing urban populations were enabled to draw upon the resources of the entire country for most of their fresh foods. The period during which they could obtain seasonal products was extended – with some perishables for a few weeks or months – with others until the yearly production cycle began once more. Accompanying this mitigation of the evils of glut and scarcity was a trend toward greater uniformity of prices throughout the year, a tendency that enabled more family budgets to include fresh foods for a greater part of the time. Under these conditions city diet became more nutritious and appetizing and city life more wholesome and alluring.

There were limits to what refrigeration accomplished. Large numbers of urbanites still ate insufficient quantities of fresh foods – partly because of poverty, partly because of ignorance, and partly, in the case of the immigrant population, because of adherence to the food habits of the country of their origin….
SOURCE: Anderson, Oscar E. *Refrigeration in America: a history of a new technology and its impact*. Princeton: Published for the University of Cincinnati by Princeton University Press, 1953.

Document 4A

Scientists at the National Physical Laboratory (NPL) and Imperial College are working to make the inefficient method of refrigeration and air conditioning - which has been relied on for over a hundred years - a thing of the past.

A new project sets out to provide a more economical, energy efficient and environmentally friendly cooling alternative. The project will utilize the electrocaloric effect to develop new methods of cooling. The electrocaloric effect is a phenomenon in which a material changes temperature under an applied electric field.

Current domestic refrigeration relies on a continuous cycle of compression and expansion of chemicals – known as vapor compression. Freon gas, for example, can be cooled and condensed into a liquid. This liquid then absorbs heat from the refrigeration area, causing it to re-evaporate, where it begins the cycle again.

These chemicals can be harmful to the environment when disposed of or if they leak. They have a fairly low efficiency, requiring high energy input to create adequate cooling. They also require bulky apparatus, making them unsuitable for smaller applications, such as cooling electronics.

Thermoelectric and magnetic cooling technologies have been put forward as environmentally-friendly alternatives to vapor compression. However, these technologies struggle to compete with vapor-compression due to intrinsically low energy efficiency (maximum 10%) , and the need for large and expensive magnets to generate the magnetic fields needed to run magnetic coolers.

However, as Maciej Rokosz - PhD student at NPL and Imperial - explains "An electrocaloric cooler, however, could potentially deliver higher efficiency than vapor compression – as the creation of an electric field requires less energy than the compression process to create the same level of cooling. It could also offer reduced size and weight, making it viable for applications like cooling electronics."

Tatiana Correia, a scientist at NPL who is leading the project, adds: "This project builds on considerable research and expertise that has been developed at NPL. Our experience in this area makes us confident that, over the next three years, we can develop the first electrocaloric refrigerator ever to operate close to room temperature".

To support electrocaloric cooling technology, NPL is also developing and leading a new multimillion pound project funded by European Metrology Research Programme, METCO (Metrology of Electro-Thermal Coupling) which brings together Europe's leading research centers and industry to develop unique capabilities for the traceable and accurate measurements of electrocaloric effect in materials.

Correia concludes: "We are confident that our design ideas, combined with the expertise we have at NPL and Imperial, will be able to develop a viable cooler. However, we are still very keen to hear from industry who can work with us to look at the different applications this could be applied to".

SOURCE: "The future of staying cool: New project could completely change the refrigeration industry." Phys.org - News and Articles on Science and Technology. December 17, 2013. Accessed September 30, 2017. https://phys.org/news/2013-12-future-cool-refrigeration-industry.html.

Cooling is a hugely important process in today's world. But how can cooling be carried out in future in a way that does not harm the climate and that helps to conserve natural resources? The approach taken by Professors Stefan Seelecke and Andreas Schütze from Saarland University focuses on systems that use shape memory materials, also known as 'metal muscles' or 'artificial muscles'. Working together with researchers in Bochum, they are developing a new method of cooling in which heat and cold are transferred using 'muscles' made from a nickel-titanium alloy. Extensive series of tests have yielded results that are now being used to develop a prototype cooling circuit that will be used to further increase the efficiency of the process. The German Research Foundation (DFG), which has been funding the project for the last three years, has agreed to invest a further 500,000 euros. In total, the project has brought around 950,000 euros in funding to the region.

Cooling is carried out in all parts of the world. Refrigerators operate around-the-clock, air conditioning units cool offices, cooling systems help to keep computers and motors running smoothly. And the demand for cooling is being driven both by climate change and global population growth. But more cooling systems come at a price – and not just a financial one. Increased cooling means increased consumption of electrical power and therefore higher emissions of greenhouse gases into the atmosphere, driving global warming even faster. A more environmentally friendly cooling method has been developed by the research teams led by engineers Stefan Seelecke and Andreas Schütze in conjunction with the materials scientists Gunther Eggeler and Jan Frenzel at Ruhr University Bochum. The cooling process that they are developing does not require climatically harmful refrigerants and should consume less energy than the conventional cooling technologies used thus far.

'In our systems, shape memory alloys (SMAs) are used to remove heat,' explains Stefan Seelecke, Professor for Intelligent Material Systems at Saarland University. 'Shape memory means that wires or sheets made from a nickel-titanium alloy have a certain ability to remember their original shape: If they undergo deformation, they will return to their earlier shape. So they are able to tense and flex like muscles. The fact that they absorb and release heat when they do so is something we exploit to achieve cooling,' explains Seelecke.

If a nickel-titanium wire or sheet is deformed or pulled in tension, the crystal lattice structure can change creating strain within the material. This change in the crystal structure, known as a phase transition, causes the shape memory alloy to become hotter. If the stressed sample is allowed to relax after temperature equalization with the environment, it undergoes substantial cooling to a temperature about 20 degrees below ambient temperature. 'The basic idea was to remove heat from a space – like the interior of a refrigerator – by allowing a pre-stressed, super-elastic shape memory material to relax and thus cool significantly. The heat taken up in this process is then released externally to the surroundings. The SMA is then re-stressed in the surroundings, thereby raising its temperature, before the cycle begins again,' explains Seelecke.

In the experimental and modelling studies carried out so far, the researchers at Saarland University and the Center for Mechatronics and Automation Technology (ZeMA) in Saarbrücken have demonstrated that this type of cooling works and that it can be used in practice. They used a model system to determine how to optimize the efficiency of the cooling process, examining such factors as how strongly the material has to be elongated or bent in order to achieve a certain cooling performance, or whether the process is more effective when carried out slowly or more rapidly. A thermal imaging camera was deployed to analyze precisely how the heating and cooling stages proceed.

SOURCE: "Engineers develop the refrigerator of the future." Phys.org - News and Articles on Science and Technology. February 2, 2016. Accessed September 30, 2017. https://phys.org/news/2016-02-refrigerator-future.html.

'We're currently using these results to construct an optimized prototype for an air-cooling system. We are creating a cooling cycle in which hot air passes over one side of a rotating bundle of shape memory wires. Multiple wires are used in order to enhance cooling power. The bundle is mechanically stressed on one side as it rotates, thus heating up the SMA wires, as it rotates further the SMA relaxes and cools. The air to be cooled is guided past the cold wire bundle, thus cooling an adjacent space,' says Professor Schütze from the University's Measurement Technology Lab. The team of engineers are currently fine tuning the process to optimize its efficiency. 'Further optimization of the cooling process will involve modelling all component stages and then refining these models by comparing the predictions with experimental results. The data from the modelling and experimental work should allow us to determine the ideal number of shape memory wires for our rotating wire bundle as well as the optimum speed of rotation,' explains Schütze.

SOURCE: "Engineers develop the refrigerator of the future." Phys.org - News and Articles on Science and Technology. February 2, 2016. Accessed September 30, 2017. https://phys.org/news/2016-02-refrigerator-future.html.

Freight railroads keep America moving. From the food on our tables to the cars we drive to the shoes on our children's feet, freight railroads carry the things America depends on, according to the Association of American Railroads (AAR) , Washington, D.C.

"America's railroads account for 40% of intercity freight volume—more than any other mode of transportation—and provide the most efficient and affordable freight service in the world," says AAR. "Every year, America's freight railroads save consumers billions of dollars while reducing energy consumption and pollution, lowering greenhouse gas emissions, cutting highway gridlock and reducing the high costs of highway construction and maintenance. In addition, America's freight railroads sustain 1.2 million jobs, including more than 180,000 well-paying jobs in the freight rail industry itself."

That's why today's rail providers, port authorities and boxcar manufacturers are teaming up to provide America with the most efficient and sustainable ways to transport goods from Point A to Point B.

Reducing emissions while maintaining efficiency

In order to keep today's supply chains moving in a sustainable fashion, freight and railroad operators have introduced a number of state-of-the-art technologies that allow cold food processors and distribution warehouses the ability to reduce emissions while maintaining efficiency.

For example, Union Pacific built new 72-foot refrigerated boxcars that are equipped with GPS-monitoring software to remotely manage reefers from its Omaha, Neb., headquarters.

"We can view hundreds of data points relative to the location and function of these cars and can remotely troubleshoot issues from our desks," says Nick Langel, senior business manager, agricultural products. "Powered by high-efficiency refrigerator units, these boxcars also feature a forced fiberglass liner filled with polyurethane pour foam for extra insulation and temperature readers. They are checked upon completion with an infrared camera to assure there are no voids in the insulation."

Union Pacific also re-launched its refrigerated trailer-on-flat-car and container-on-flat-car products. "This included upgrading our fueling options for carriers and looking at additional lanes of traffic that were not traditionally temperature-control friendly," says Shane Blair, senior business director, intermodal. "In the past 21 months, we have gone from moving 200 intermodal loads per month to more than 6,000 loads per month."

Additionally, Union Pacific can place 3-4 trucks' worth of product in one refrigerated boxcar, which reduces emissions by three times when compared to trucks in a similar lane, says Langel.

"The benefit to customers is that they receive greater value for their transportation dollar along with a reduced carbon footprint," adds Langel. "In 2013, the refrigerated boxcar shipments we handled for our customers reduced their overall carbon footprint collectively by 350,000 metric tons. That savings is equivalent to the carbon removed by more than 75,000 acres of U.S. forests."

Florida East Coast Railway (FECR), Jacksonville, Fla., acquired 500 new 53-foot containers, 100 chassis and 50 refrigerated trailers that are equipped with GPS technology, providing real-time tracking capabilities.

SOURCE: Mayer, Marina. "How America Depends on Rail." Refrigerated Frozen Food RSS. November 7, 2014. Accessed November 18, 2017. https://www.refrigeratedfrozenfood.com/articles/88696-how-america-depends-on-rail.

"FECR's refrigerated equipment has safeguards that are monitored 24/7 for temperature control," says Robert Ledoux, senior vice president. "Necessary adjustments are made remotely via software, limiting the potential of human error in the process. FECR [also] maintains strict security protocols to protect all of our customers' shipments. To that end, FECR has its own well-trained and skilled police force."

Meanwhile, Maersk Line, Florham Park, N.J., upgraded its reefer unit microprocessor technology.

"This updated software continues to optimize reefer unit performance while improving energy consumption," according to Barbara Pratt, director, reefer management. "We also have placed updated devices on many of our gensets to provide the information needed to further optimize their performance and improve their utilization/logistics."

Riding the express lane

To transport product from California to Illinois via rail, McKay TransCold, Edina, Minn., launched TransCold Express, a hub-to-hub refrigerated boxcar service that runs bi-directionally between Wilmington, Ill., and Selma, Calif. Dubbed to be the first refrigerated boxcar unit train connecting the Midwest and West Coast in over half a century, TransCold Express presents produce growers and meat and dairy producers the opportunity to distribute products more cost-effectively to all U.S. destinations. "It makes economic sense to ship over 800 miles via rail," says Jason Spafford, vice president of business development. "In the McKay TransCold boxcar unit train, where heavier products can lead to four truckloads in one boxcar, there tend to be even more advantages for refrigerated and frozen products that are heavier."

TransCold Express operates on BNSF Railway with cargo being transferred from truck to boxcar through a new refrigerated building operated by National Logistics and Cold Storage. It hauls products such as vegetables, fruit, cheese and butter from California to the Midwest and carries meat, eggs, cheese, butter, finished goods and dairy creamers westbound. The 49,000-square-foot refrigerated facility is approximately 700 feet long, allowing for eight boxcars to be unloaded at once, and only 70 feet wide, providing a minimal transfer distance between the two modes of transportation.

Meanwhile, the Port Authority of New York and New Jersey approved a re-development of the Greenville Yard to include a new ExpressRail facility to support the adjacent Global Marine Terminal. This will allow the terminal to ship and receive containerized cargo by rail, a capability that it lacks today. The new facility will also allow for transloading of containerized cargo from ship to rail, offering ocean carriers and their customers a more efficient and environmentally friendly option for moving goods. The facility will have an initial capacity of at least 125,000 cargo container lifts a year, and is expected to be operational in July 2016.

The board also approved a series of improvements to the cross-harbor car float system operated by NY-NJ Rail that moves freight more efficiently by both water and rail as opposed to truck between New Jersey and markets east of the Hudson River, including New York City and Long Island. The NY-NJ Rail operation allows freight to be loaded on rail cars, as the cars are moved by marine rail barge (carfloat) from Greenville to rail yards at 51st Street and 65th Street in Brooklyn, N.Y. When completed, the program will provide significant environmental benefits, including reductions to vehicle travel time, fuel consumption and a reduction in air emissions.

Regardless of the distance or type of cold food product, freight railroads keep America moving in a more efficient, sustainable and economical manner.

SOURCE: Mayer, Marina. "How America Depends on Rail." Refrigerated Frozen Food RSS. November 7, 2014. Accessed November 18, 2017. https://www.refrigeratedfrozenfood.com/articles/88696-how-america-depends-on-rail.

HANDS-ON ACTIVITY

Objective: Students will assess the insulating qualities of various materials.

Process: Students create an “ice box” using a square tissue box lined inside with some insulating material. They place an ice cube into the center of the box (surrounded by the insulator) and let sit for some prescribed time. Using displacement, students measure the volume of the ice cube before and after the experiment and calculate the amount that melted. By comparing the results across multiple experiments, students will conclude which insulator was most effective and predict the maximum time before all the ice melted.

Materials: tissue boxes, sawdust, shredded paper, felt, bubble-wrap, sand, (other insulating materials), ice cubes, clear liquid measuring cup, water (for displacement measurements)

For a more in-depth version of this Hands-On Activity, please visit the click here.

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