

The Refrigerator Revolution

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We have a General Electric Refrigerator bought in 1926...in constant use all these years. It has never been serviced. This is a record I think even General Electric can be proud of. Mrs. H.H. Bader, 304 7th Ave., N.W. Puyallup, Wash. (LIFE 1949, pp. 4-5).

When this quote appeared in a General Electric Company advertisement in 1949, the author was probably unaware that she was indirectly referring to the decisive battle, the point-of-no-return, of a technological war that started in earnest a decade earlier and wasn't to truly end until mid-century. Even then, there would be no armistice or treaty. Victory would not be celebrated with marches. No monuments would be built to honour the martyrs. The beneficiaries of the revolution would quickly forget the battles.

When the early progenitors of today's refrigerators were introduced, acceptance wasn't instant, and for most potential customers, neither economically feasible or practicable. Without the support of a nascent electric-power generating industry and the technical achievements of a certain manufacturer of electric motors, we may still be putting a numbered card in our window to let the iceman know how many pounds to deliver today.

Prelude to a revolution

For those of us of a certain age where we remember that before modern, electric-powered refrigerators there were 'iceboxes', usually made from wood, that held a block of ice and were used to keep food cool in our grandparent's era, we will have to accept that we've been misinformed about refrigerators our entire lives ('Baldwin Dry Air Refrigerator' 1890). The term refrigerator is not modern. It didn't come about with the advent of electric-powered iceboxes. As a reference to a box for preserving food, the term goes back at least as far as the start of the nineteenth century ('refrigerator, n.' 2015). Long before refrigerators were the subject of patents and department-store sales, they were simply boxes designed to keep foodstuffs cool.

The harvesting and use of natural ice, whether from ponds or glaciers, goes back at least to fifth-century BCE Persia (Jackson 2015, p. 19). By the eighteenth century, New England farmers were harvesting and selling natural pond ice. Ice was shipped as far south as the southern colonies and the Caribbean Islands so the well-to-do could have iced drinks and chilled desserts during the hot and humid summers. The New England farmers also preserved ice for their own use to extend the life of certain summer crops (Butler 2016).

During the first half of the nineteenth century, the distribution of farmed ice expanded. Ice was shipped down the Ohio and Mississippi Rivers as well as by ocean to points south (Butler 2016). Europeans mostly purchased their farmed ice from Norway, but the New Englanders supplied the rest of the world (Blain 2006).

As towns began to establish local ice-storage facilities, individual households could obtain a block of ice once or twice a week. The earliest refrigerators were simply insulated boxes designed to house these newly available blocks of ice (Burns 1837). The insulation was sawdust, cork, charcoal, or even seaweed. It was quickly learned that the insulation needed to remain dry so tin- or zinc-plated metal became the liner for the inside. The melted ice had to be removed from the box each day so it wasn't long before drains were introduced (Gold 1841). By the time manufactured ice production overtook farmed ice towards the end of the nineteenth century, hundreds of refrigerator designs have been proposed and many patented. Some of the patents seem to make sense and their influence on late-nineteenth century refrigerator design can easily be seen in advertisements of the period (Stanard 1891). Other designs could have benefitted from a little more knowledge of thermodynamics and a little less of the inventor's imagination (Sheldon 1880).

By the end of the nineteenth century, even small villages had ice delivery. Whether in a village, town, or city, the family cook could simply post a sign in a window to let the iceman know how much ice was needed. The order would be delivered directly into the refrigerator in the pantry or screened in kitchen porch. The refrigerator was mainly used to extend the life of fresh milk for the household's juvenile occupants. Other items were of less in need of the minor chilling abilities of ice-chilled refrigerators (Plante 1995, p. 146).

About the same time the refrigerator got its name, American inventor Jacob Perkins obtained a patent in London for the first mechanical refrigeration machine based on compression (Balzhiser 1906, p. 32). Almost forty years later, John Gorrie, a physician attempting to keep yellow-fever patients cool, built a prototype refrigeration system using air as the refrigerant (Gorrie 1851). Unfortunately, Gorrie wasn't able to go into commercial production because of a combination of his investors dying or backing out, pressure from the farmed-ice industry, and in a couple of years, his own death (Morse 2002). In 1859, Ferdinand Carré demonstrated in France the superiority of ammonia as a refrigerant and a viable method of using it to produce refrigeration (Regnault, Balard, & Pouillet 1864,

pp. 109-114). Driven in part by a growing German-beer industry combined with a series of individual technological advances, such as Carl von Linde's methods for producing commercial amounts of anhydrous ammonia and Frederic Wolf's machinery designs, commercial refrigeration and commercial ice production became a significant industry in late-Victorian America. Even moderate-sized communities now had access to commercial ice (Nagengast 2004, p. S3).

The early 1900s was a period of discontent and reform in the the United States. The progressives came to power. Now was the time to improve food safety and labour laws, to bust apart the giant trusts, and to expand the scope of government to ensure the progress of society and the welfare of its citizens ('USA History in Brief' n.d.). The home refrigerator had become a multi-door, wooden cabinet finished in either dark-brown, varnished oak or clinically clean white paint. At first glance, the advertisements for one model looked the same as the those for another. The entire unit could be built-into a wall or left free-standing. Ice could be loaded from the front, side, top, or back. Back loading meant the that if the refrigerator was placed along an exterior wall in a free-standing home or along a wall facing a common hallway in a multi-unit building, the iceman could load the ice into the refrigerator without having to enter the home ('Prevent waste of perishable food' 1918, p. 54). The interior surfaces were now opal glass or porcelain enamel. Cheaper models were available with zinc-plated, plain-wood, or painted interiors. Refrigerators could be bought premade or ordered custom to fit your space. Sizes ranged from a simple top-loading low-boy to commercial versions designed to fill an entire wall in a grocery store ('Illinois refrigerators' 1898; 'Cold storage in the home' 1907).

In August of 1915, The U.S. Bureau of Standards published the results of a series of tests performed on nine consumer refrigerators. In a nominal 90 °F room, the coldest point in the refrigerators ranged from 44.1 °F to 57.2 °F while the warmest point ranged from 64.0 °F to 72.1 °F. All the test refrigerators melted about 1.5 pounds of ice per hour, and each box circulated its total volume of air about once per minute (Stevenson 1923, p. 171). The modern refrigerator of 1915 wasn't much of a refrigerator.

At the turn of the twentieth century, there were about 16 million families in the United States. Unfortunately, the census doesn't tell us how many of those families had a kitchen and whether that kitchen was home to some form of refrigerator ('Table 95' 1902, p. 605). Ownership of a refrigerator meant that your kitchen was located in proximity to an ice house. It meant that someone in your household would be available a couple of times a week to tell the iceman how much ice you needed and then to provide access to the refrigerator. Finally, your income had to be sufficient to pay the iceman for his service.

Even though inexpensive refrigerators could be obtained, the smallest and least expensive model in the 1897 Sears Catalogue was just \$2.93, most were above the

comfort level for a working family (1897 Sears Roebuck & Co Catalogue 2007, p. 118). It was not uncommon for kitchen pantries, if the kitchen was large enough to have one, to provide other means for keeping food cool. Pantries were often placed along an exterior wall. A screened-in hole or box would be located so vegetables could be exposed to cool breezes but protected from insects. In moderate climates, the rear entrance to the kitchen would either be screened-in or a cabinet would be fashioned out of wire cloth to keep vegetables cool and away from insects. For the families living away from densely populated city centres, the yard may contain a spring house, a cold room, or a root cellar. For families without the availability of these standard means of keeping vegetables cool, the alternative was to shop on an as needed basis (Plante 1995, p. 88, 171).

Commercial milk, which was mostly sold unpasteurized, was a primary reason for some users to own a refrigerator ('Heat Treatments and Pasteurization' 2016). Advertisers made much of the ability of their refrigerator model to keep milk fresh. As we've seen in the earlier tests of these refrigerators, the claims may have been a bit exaggerated. For those wishing to avoid sour-milk issues with infants, canned milk was shown to be shelf-stable and never to sour (Crowley 1999).

Except in extreme weather, other fresh items like butter and eggs could last quite some time without refrigeration. Other foods were only available in naturally shelf-stable forms such as sugar and flour. Many foods were available dried, canned, or pickled. For the most part, consumers knew how to deal with their food freshness issues at the time. The real need for reliable refrigeration was not with the consumer but distributors and shopkeepers. As the electric-refrigerator revolution was about to begin, it was those with the biggest needs that would be serviced first.

The revolution begins

The same entrepreneurs who had supplied the German-beer makers in the America with their refrigeration equipment went on to build systems for other industries. Companies such as M.J. Bujac and the De La Vergne Refrigerating Co. were responsible for building large ice production facilities as well as cold storage facilities (Artificial Refrigeration 1870; Mechanical Refrigeration 1890). Designing and building large facilities wasn't a problem, but small systems were initially difficult to design and build. The giant steam-powered compressors didn't adapt well to size reduction. The nature of steam engines was that they didn't fit well in a smaller scenario that required automatic controls, such as in a butcher shop (Nagengast 2004, p. S3).

To benefit from the patents of its founders, who were already significant players in the industry, the Automatic Refrigerating Company was formed in 1905. The primary company goal was the design and sales of small refrigerating systems (Nagengast 2004, p. S4). By March of

1907, an industry journal was already pointing to some of their work ('News of Companies and Plants' 1907, p. 67).

NEW YORK.—Mr. C.K.G. Billings, a well known New York millionaire, is furnishing his private residence on the west side with a one and one-half ton refrigerating system. The several refrigerators are insulated with cork, lined with opalescent glass, and the trimmings as well as shelves are of aluminium. Incandescent lights concealed in the insulation light the interior of the refrigerators through the glass linings when the doors are open. The equipment is the complete automatic system supplied by the Automatic Refrigerating Company of Hartford, Conn.

NEW YORK.—The New York Edison Company are equipping their new building on Duane Street with a 5-ton drinking water cooling plant, the installation being made by Westerberg & Williams, of this city. The system is completely automatic as regularly furnished by the Automatic Refrigerating Company of Hartford, Conn.

For most of the next decade, the Automatic Refrigerating Company, and other companies created to compete with it, continued to expand the number of custom designed and installed refrigeration systems. It was now possible for butchers and grocers to have electric-powered, non-ice-based refrigeration systems. Based on the peculiarities of each installation, the systems were custom designed from off-the-shelf parts and assembled on-site (Nagengast 2004, p. S4).

Competing with the Automatic Refrigerating Company was Fred W. Wolf Jr., a Chicago-based engineer interested in small refrigerating machine solutions. In 1913, Wolf and fellow engineer Fred Heideman designed a self-contained refrigeration system that the world now considers the first electric-powered domestic refrigerator. The following year they formed the Mechanical Refrigerator Company to manufacture and sell the device, now called DOMELRE, a contraction of 'domestic electric refrigerator'. Miniaturisation was complete. The revolution had begun (Nagengast 2004, p. S4).

What first and foremost made the new system different from the small systems installed in stores for the previous decade was that it was self-contained. In outward appearance the system was a motor and tubing sitting on top of a standard ice-based refrigerator. The nice piece of furniture had grown a vibrating dust catcher on its top (Figure 1).

The DOMELRE consisted of a standard, insulated, wooden refrigerator with a hole cut in the top of the ice compartment. The entire cooling mechanism sat on top of the refrigerator with the evaporator portion extending into and suspended in the ice compartment (Wolf 1917). The cold ice was replaced by the cold evaporator. Even when installed into a customer's pre-existing refrigerator, the

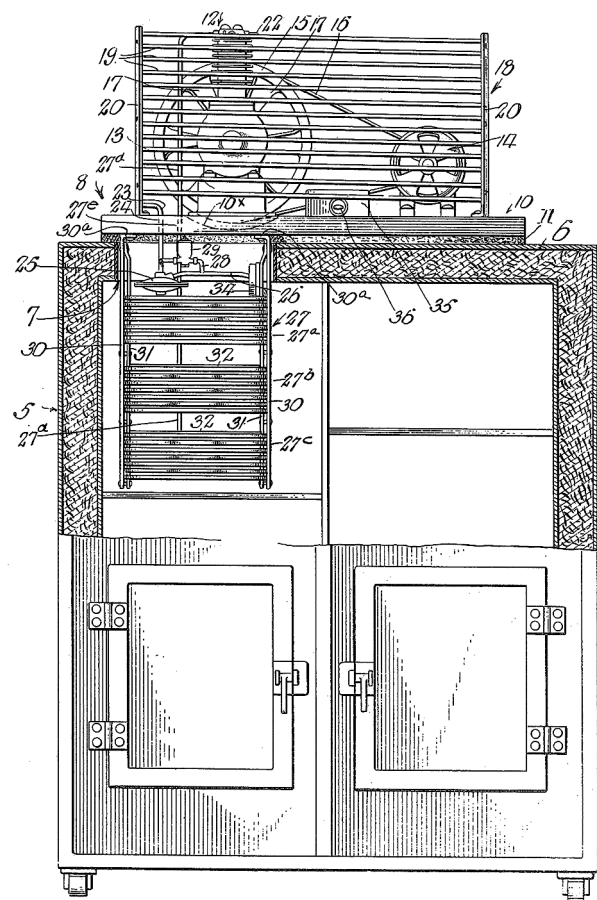


Figure 1: Schematic illustration of DOMELRE refrigerator from second figure of the original patent. (Wolf 1917)

system came from the factory fully charged and tested (Stevenson 1923, p. 401). For the customer, there wasn't much more to do except to plug the motor into a convenient electric light socket. (It was rare in 1914 for a house to have any electric wall sockets since electricity was primarily used to replace gas lighting jets with incandescent lighting.)

The condenser, which sat exposed on the top of the unit along with the motor and compressor, consisted of a series of bare-copper tubes. The engineers borrowed a flared, gas-tight fitting technology from the new automobile industry. The evaporator extended into the ice compartment and was made from similarly connected tubing except in this case, the interior of the tubing was tin-plated. The copper tubing was acceptable because the engineers were using sulphur dioxide refrigerant instead of ammonia, which necessitated the use of steel piping and screwed connections.

The ¼ hp induction motor only required 4 amps at full load. The motor could develop the necessary high torque at low starting voltages so it was unlikely to overtax the poorly served electrical systems of its day. A bimetallic thermostat turned the motor on and off.

Although probably not designed for this purpose, the evaporator could hold a couple of carefully-balanced ice-cube trays. There could now be a celebratory, chilled drink to celebrate the start of the home-electric-refrigerator revolution, assuming the celebrants could get the ice cubes from the trays. Flexible ice-cube trays were still more than a decade away (Copeman 1928).

The early days of the conflict

The Mechanical Refrigerator Company was poorly capitalised and their product had excessive service issues. In 1916, the rights to the DOMELRE were purchased by Henry Joy, president of the Packard Motor Company, and the manufacturing and design operation moved to Detroit under the name ISKO. The system was steadily improved, but it never achieved the degree of reliability required by the public. The price in 1916 of \$385, later dropping to \$275, plus the cost of the refrigerator, meant that the ISKO was an appliance still mostly for the upper economic classes. Only about a thousand of the systems were sold before the company's bankruptcy in 1922 (Nagengast 2004, p. S5).

Within the same time frame that Wolf and Heideman had started their electric refrigerator company, Nathaniel Wales, an inventor of automobile devices, and Edmund Copeland, a former purchasing agent for General Motors, began working on a home electric refrigerator. Major financing came from Arnold Goss, director of the Chevrolet Motor Car Company. In 1914, he decided to name the company Kelvinator (Nagengast 2004, p. S5).

It took another four years of designing and testing before a prototype was ready to install in a home for field testing. The system moved the motor, compressor, and condenser to the basement. A long tubing run was then made through the floor above the noisy, vibrating equipment to the evaporator mounted in a repurposed conventional, ice-chilled refrigerator (Figure 2). An improved, bellows-type thermostat was used to reduce the cycling issues of the ISKO refrigerators.

The field test was successful and the Kelvinator refrigerator was placed on the market. Sixty-seven units were sold that first year. Kelvinator continued to sell systems with the condensing unit remote to the refrigerator. In the mid-1920s, they also began selling self-contained systems. Kelvinator advertisements from 1925 depict a self-contained refrigerator with what appears to be the capacity of a modern bar refrigerator ('Kelvinated foods just beg to be eaten' 1925).

The Kelvin-et is a compact refrigerating unit for small homes and apartments, priced at \$250 f.o.b. Detroit. It is Kelvinator and refrigerator, all in one. It is delivered to your home like an ordinary refrigerator, and requires only an electric connection. The Kelvin-et is ideal for the small family.

The Kelvinator catalogue for the following year still shows the refrigerator and compressor as separate units located in separate rooms ('Kelvinator: The oldest domestic electric refrigeration' 1926). The Kelvinator refrigerator appears to be custom assembled for each customer depending upon room situation, family size, and refrigerator cabinet selected. The customer could now purchase the cabinetry in the same order as the machinery although it appeared to be made by a separate company. Described as being of 'the famous "Leonard Cleanable" construction', the cabinets were possibly made by the Grand Rapids Refrigerator Company ('Announcing the new 1926 model Leonard cleanable refrigerator' 1926).

A number of small, now-forgotten companies were created about the same time as DOMELRE unit was being introduced. One of the defunct Detroit companies, the Guardian Frigerator Company, was purchased by William Durant, the president of General Motors, in 1918. Durant

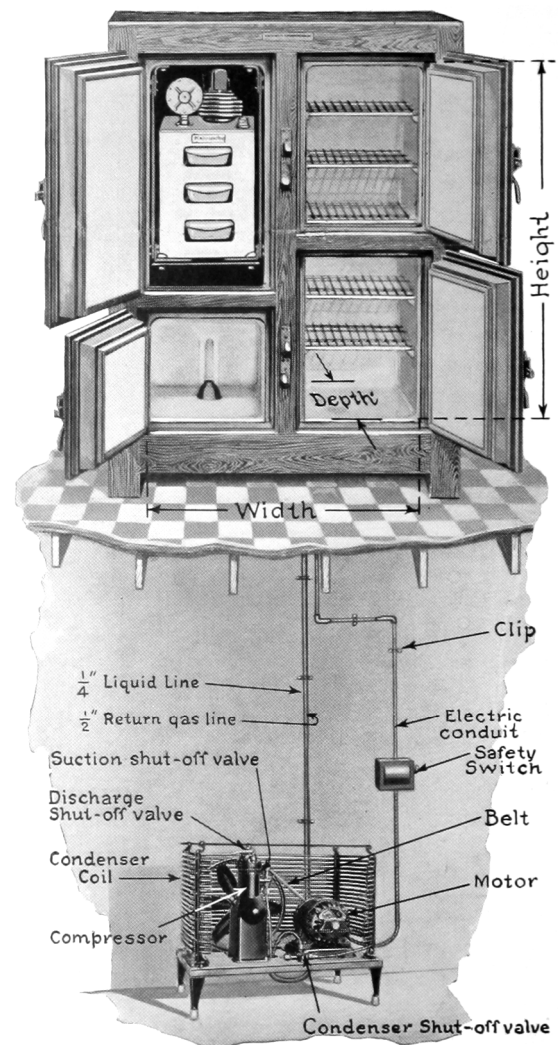


Figure 2: Arrangement of original Kelvinator refrigerator with basement-mounted compressor and with the evaporator concealed in a brine tank in the ice compartment. ('Kelvinator: The oldest domestic electric refrigeration' 1926)

renamed the company Frigidaire and restarted production of systems similar to the Kelvinator system of the time (Howald 1980).

Apparently, the early Frigidaire systems sold better than they worked. Luckily, even with the technical issues, Frigidaire customers were loyal. The company was moved to the Delco Light Company division in Dayton, Ohio, so it would have ready access to the newly established General Motors Research Laboratory. The effort apparently was successful since as of 1923, the group was profitable. It was also in this time period that the company began producing self-contained systems. In 1926, the wooden cabinets were replaced by metal ones and the resemblance of modern electric refrigerators to the old ice-filled refrigerators came to an end.

An absorption-type refrigerator was introduced by the Swedish company Electrolux during this time frame. The system had distinct advantages, such as no moving parts and no requirement for a pump or compressor, all of which were the source of continuous service issues with the vapour-compression-type refrigerators. The Electrolux only required a small heat source, which could be either electric or gas ('The Gas Refrigerator' 1926). Its major failure was that it couldn't be repaired in the field. The system didn't catch on in the United States until forty years later when it became the ideal system for portable refrigerators.

In all, there was about a hundred companies at the time developing or manufacturing some form of mechanical refrigeration. Seventy-one of the refrigerators used vapour-compression systems like the Kelvinator, 22 used absorption systems like the Electrolux, 4 used compressed air, and the remainder were of unknown description. Almost all brands were primarily sold by the same companies that sold the customer their electricity (Stevenson 1930, p. 9).

Common among most of the refrigerator designs was to now submerge the evaporator coils in a tank of brine. Bare evaporator systems, such as on the original Kelvinator, tended to cycle on and off too often. The Kelvinator bellows-type thermostatic switch was an improvement, but the rate of cycling was still too rapid for efficient control of the compressor. By using the lag in latent heat of up to 100 pounds of brine, the on-off cycling could be reduced.

Also at this time, the food issues from earlier in the century were still the same. Most homes had no refrigerator, whether one that required ice or one using electricity. In 1920, when there were approximately 20 million households, an article in Westinghouse's house organ, *Circle*, predicted 10,000 electric refrigerators would be sold that year ('Output of Motor-Driven Appliances in 1920 Estimated at 2,000,000 Units' 1920, p. 708). That still leaves most homes without a refrigerator. Milk still soured at the same rate as before the first electric refrigerators. Butter and eggs were still seasonally effected. If the electric-refrigerator revolution ceased in 1926, life for the average person would have changed very little. Then a



Figure 3: Period advertising illustration of 'monitor-top', Model DR-2, General Electric refrigerator. Note the frost building up on the glycerine-filled evaporator. (Greene 1929)

critical point was reached, and there would be no turning back the clock to simpler times.

The critical battle begins

In 1923, Alexander Stevenson Jr., an assistant to the vice-president of engineering at the General Electric Company, was tasked with writing a report on the state of domestic refrigerators. In August, five months after being tasked, Stevenson presented a five-hundred-plus page report. Upon reading it for the first time, the report appears to be a business plan for General Electric to dominate the household-refrigerator market (Stevenson 1923). The effect of the report within the company doesn't appear to have been immediate as it was updated in 1924 and again in 1925. All the while, General Electric continued to market less-than-perfect refrigerators based on the French Audiffren air-cooled compressor (Audiffren & Singrun 1915). Finally, in 1927, General Electric introduced to the marketplace a refrigerator that would be the gold-standard for refrigerators for the decade to come (Figure 3) (Stevenson 1930, p. 12). The 'monitor-top' refrigerator met most of the design goals put forth in the report, and proved to be the reliable, long-lasting electric refrigerator envisioned by Mr. Stevenson four years earlier. The introduction of the General Electric Model DR-2 refrigerator, the official designation of the 'monitor-top' refrigerator, was the point in the refrigerator revolution

where a ho-hum appliance became a must-have appliance. Once the 'monitor-top' refrigerator was introduced to the marketplace, there was no going back to ice-based refrigerators or even having no refrigerator.

Stevenson (1930, p. 13–15) lists seventeen specific improvements present in the new refrigerator that differentiated it from previous models of all brands. The most significant of these improvements include:

- The motor is close-coupled to the compressor and both are hermetically sealed in a common housing. This eliminated the stuffing box and other sources of unreliability. The housing was filled with clean oil so everything stayed lubricated. Dirt couldn't get inside the housing.
- By mounting the machinery directly on top of the evaporator, all service valves and pipe joints were eliminated. Since all the machinery was compacted together into a single package, it could be lowered as a pretested unit in the refrigerator box.
- The heat produced by the machinery was all above the level of the food in the refrigerator, making the box more efficient.
- All joints and interfaces between the refrigerator box and the machinery were insulated in various novel means to eliminate loss of heat.
- The sealed design eliminated most service issues.
- The spring-mounted compressor, being fully encapsulated in oil, was extremely quiet.
- The freezing chamber was easy to clean since it was coated with vitreous enamel.
- The refrigerator could maintain a 50 °F interior temperature in a 100 °F room. It actually functioned like a refrigerator should.
- The machines were built on an assembly line for better manufacturing consistency.
- The single-door system meant less infiltration of warm air through door gaps. New, crushable gaskets were developed. The all-steel exterior construction was easier to insulate than the previous wooden construction.
- The initial monitor-top refrigerators replaced the brine-box with higher latent-heat materials, such as glycerine. Later models eliminated this method of regulating the temperature of the box.

Another significant difference between General Electric and its competitors was that it developed a direct sales force and system of franchisees to market all of its electric appliances.

Almost immediately, the competition imitated or duplicated the steel-wall construction of the Model DR-2, and smaller competitors began to duplicate or imitate many of its other features. It would take six years before Frigidaire and Kelvinator refrigerators appeared to look more like the General Electric model on the inside.

It has to be assumed that the concept of hermetically sealing the motor and compressor was such an advantage that the other companies adopted this system as soon as they could, even if their advertising failed to reflect the

improvement directly. By the start of the Second World War, all refrigerators were using hermetically sealed compressors.

The aftermath ensues

In 1930, General Electric's most direct competitor in electric equipment and appliances, Westinghouse Electric Company, entered the refrigerator market ('Westinghouse introduces new electric refrigerator' 1930). Initially, there was nothing to particularly differentiate their product from the others in the marketplace, but in the post-war period, two decades later, they would become an industry leader by introducing concepts such as self-defrosting, and later, frost-free refrigerators (Buchanan 1957; Foley 1957).

Other improvements to follow the mass-acceptance of the 'monitor-top' refrigerator, a design that General Electric would drop after eight years, included shelves in the refrigerator door (Nagengast 2004, p. 58). The space for ice-cube trays in the centre of the evaporators was enlarged, and eventually, after a couple of stumbles, separate freezing compartments were introduced with a flat evaporator mounted between the freezing compartment and main portion of the refrigerator.

In 1930, General Motors announced the development of chlorofluorocarbon refrigerants, commonly called Freon (Hempstead and Worthington 2004, p. 673). This class of refrigerant eliminated the health and safety hazards of the existing refrigerant materials being used in the available refrigerator brands. General Motors and DuPont created a joint venture to manufacture the new refrigerant. Initially, they restricted its use to refrigerators built by General Motors' Frigidaire division, but within a few years, profits won out, and the refrigerant was made available to all manufacturers. Its use became universal. (It was banned worldwide in 1995.)

In 1934, General Electric offered a squat, top-loading refrigerator for a mere \$77.50 plus freight ('Now! A General Electric refrigerator at the lowest cost in history!' 1934). A companion electric range was offered for an additional \$72. Although still a significant amount of money for most workers, especially at that point in the Great Depression, time payments were now available as appliance companies found that there was money to be made by becoming money lenders.

The revolution is over

Following the end of the Second World War and the beginning of the post-war boom, few people still used their root cellars, cold rooms, spring houses, or even screened-in areas for vegetable storage. The iceman still existed in a few locals, but it was a dying career choice. The supermarket was still a decade in the future but more and more grocery businesses were becoming self-service and consolidating vegetables and canned goods with butcher shops. Bread

was baked by factory bakeries and purchased through the grocery store along with other baked goods. Frozen food was becoming common, now that there was a place in the home to store it (Mike Herzen, personal communication, 15 February 2016; John Scopazzi, personal communication, 28 February 2016).

Americans were beginning to buy replacement electric refrigerators to take advantage of the new features and larger sizes being offered. Used units were making their way to those less able to pay for the newest version. One of the features that companies were emphasizing was how well earlier models had survived the previous twenty years. All memory of the first, shaky decade of electric refrigerators in the home, during the beginning of the refrigerator revolution, was all but forgotten.

On June 10th, 1930 I purchased a General Electric Refrigerator. It has run continuously since then and is still going strong. It has never caused me one bit of trouble and the motor is as quiet as the day I bought it. I think this is a wonderful record and I wanted you to know about it. You may be sure I shall always buy General Electric products. Mrs. Agnes D Ey, West Warren, Mass. (LIFE 1949, pp. 4-5).

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