It's a Cool Story!

Refrigeration and air conditioning in the 20th century

By Bernard Nagengast

One hundred years ago, folks suffered and sometimes died from a failure to mitigate heat. Though welcome in winter, heat could and did destroy the human race's food and their productive spirit. Sickness from improperly preserved food in summer was more deadly as the stricken suffered in hot, humid hospital rooms. The healthy suffered, too, from summer doldrums. Offices, their furniture sticky, saw worker creativity and productivity drop as temperatures--and tempers--soared. Heat waves brought heatstroke in crowded cities. Folks who could flee the South every summer did so, while the general trend in permanent southern U.S. population was down. Why stay there? Why move there? Even Washington, D.C., all but shut down in summer.

That's the way it was before mechanical engineers perfected two of the 20th century's technical marvels—domestic refrigeration and comfort air conditioning. This story is one of alchemy—not lead into gold, but fantasy into necessity.

From Ice House to Ice Cube

Last year, more than 1,000 people were asked which appliance would be the hardest to live without. The answer: their refrigerator.

Modern life is unthinkable without supermarket fresh food, available any time of the year, purchased at one's convenience an hour, week, or month before the meal is actually eaten.

Our forefathers lived differently. Certain foods were unavailable in some seasons. Most folks had no means of keeping perishable food cold in summer. Meat and milk were purchased and consumed daily because the only refrigerator in town was at the butcher's or the dairy.

Although the 1880s saw commercial perfection in mechanical refrigeration, it served almost exclusively a non-household clientele. Refrigeration equipment was large and smelly with ammonia, and required manual operation by skilled personnel. It served the cold storage, ice-making, brewing, dairy, and meat-packing industries. The average Joe saw benefits only indirectly.

Refrigerated perishables could be purchased locally in larger cities, but they had to be used quickly, unless one could afford an icebox and weekly ice delivery. A little more affluence permitted one to rent a food locker in a cold storage plant, where frozen fish and meat could be stored. The really rich were able to persuade refrigeration manufacturers to design relatively small systems for their mansions. They could afford to have trained handymen to keep the systems in operation.

At the beginning of the 20th century, refrigeration engineers were discussing their problems at ASME meetings. One of those problems was how to make mechanical refrigeration reliable and affordable enough for the average person. Solving this problem proved no easy task.

Cassier's Magazine noted in 1901, "The facts as they stand at present preclude the possibility of small domestic ice or refrigerating plants." At that time, refrigeration systems were principally of the vapor-compression type, operated as start-stop machines using steam engines with open drive compressors subject to leaking noxious or dangerous refrigerants. They were too big, unreliable, unresponsive to changing system loads, dangerous, and expensive for the average home. Within 30 years, these objections were gone. The solutions were found in electric motors, sealed systems, automatic control, and nontoxic, nonflammable refrigerants.

Alternating current power systems saw rapid growth after 1900, as more cities and their households installed electric lighting systems. At the same time, fractional horsepower electric motors were being perfected, seeing some of their earliest household application in sewing machines.

Refrigeration engineers introduced eccentric shaft, closed-crankcase reciprocating compressors, replacing crosshead or crank types, allowing higher operating speeds and smaller size. Leaky stuffing boxes were replaced with rotary mechanical shaft seals that minimized leaks. By the late 1920s, externally driven systems began to be replaced with hermetically sealed motor-compressors that further reduced size, weight, and cost, all but eliminating refrigerant leaks.

Thermostatic controls were applied to refrigeration systems, making them responsive to the vagaries of system load that varied with room temperature, frequency of door opening, and so on.

Until 1930, engineers had only toxic or flammable refrigerants to choose from for their systems. Sulfur dioxide, methyl chloride, ethyl chloride, or isobutane were used in virtually all household systems until the General Motors Research Laboratory synthesized chlorofluorocarbon refrigerants at the request of Frigidaire in 1928.

The discovery was announced in 1930, and Frigidaire magnanimously sold the new refrigerant, called Freon, to anyone who wanted to use it. Before long, the other refrigerants disappeared and the chlorofluorocarbons dominated nonindustrial refrigeration until recently, when scientists discovered that the CFCs damage high-altitude ozone.

Pushed by the Car

The solutions did not appear all at once. Slow and expensive evolution was the reality. Before World War I, there were scattered attempts to introduce household mechanical refrigerators. It seemed that there were lots of good ideas and some breakthroughs, but these were disjointed, undercapitalized efforts. Mass production of a low-cost, "idiot-proof" refrigerator was what was needed.

In 1915, there was only one industry that had the necessary combination of capital, engineering depth, and mass-production expertise. The automobile had evolved from a curiosity to an affordable necessity for many. In the process, American automobile manufacturers had amassed a wealth of money as well as engineering and manufacturing talent. It's not surprising then, that automotive muscle gave the push to perfection of the household mechanical refrigerator.

Edmund Copeland, an engineer who was the purchasing agent for General Motors, and automotive device inventor Nathaniel Wales teamed up in 1913 to develop Wales's idea for a household refrigerator.

Copeland sought backing from his boss, "Wild Billy" Durant, but Durant told him that he was a fool to invest his money in an untried idea. Undaunted, Copeland went to Arnold Goss, president of Chevrolet Motor Car Co., and convinced him to back the venture financially.

Kelvinator Corp. was organized in 1914, but it took another four years of trial and tribulation to produce a marketable product. It cost a lot of money, too. More than $100,000 was spent to perfect the thermostat alone.

Fred Wolf Jr., the refrigeration engineer son of a Chicago brewery engineer and architect, patented an electric refrigerator design in 1913. Wolf's Domelre, a contraction of "DOMestic ELectric REfrigerator," was revolutionary. Completely self-contained, it used copper tubing with automotive-type flared joints to reduce the possibility of leaks. Designed to drop in through a hole cut in the top of an icebox, the quarter-horsepower Domelre plugged into an electric light socket to power an air-cooled refrigeration machine that needed no water connections. The device had ice cube trays, which was a first.

Wolf did have a money problem, though, and his idea only saw mass production when Henry Joy of Packard Motor Car Co. purchased the rights in 1916. Several thousand ISKOs (Joy's new name for the appliance) were sold in the next few years.

Meanwhile, GM's Bill Durant had second thoughts about household refrigeration. He purchased a defunct Indiana refrigerator manufacturer in 1918 and renamed the company Frigidaire. Durant sold Frigidaire to GM, and proceeded to pour money and talent into the company. All of GM's research and engineering divisions were ordered to assist in solving technical problems.

After millions of dollars were spent, Frigidaire had cut the 1920 refrigerator list price of $1,000 in half by 1925. Frigidaire's technical excellence catapulted its household refrigerator line to top seller by 1926. By 1928, Frigidaire had sold one million refrigerators.

In the Roaring '20s, good engineering backed with economic muscle was not limited to the automotive industry. Electrical equipment and appliances had made General Electric an economic and engineering powerhouse by the middle of the decade.

GE decided to enter the electric refrigerator arena and, after an extensive engineering effort led by Alexander Stevenson, leapfrogged everyone else with its Monitor Top refrigerator in 1927. GE's refrigerator featured a compact, totally sealed system that was quieter, more energy-efficient, and less expensive than competing models. These refrigerators were designed with such reliability that most surviving working antique refrigerators today are Monitor Tops.

Frigidaire, stung by the continuing loss of market share, struck back in 1933 with its Meter Miser refrigerator, which was advertised as consuming only as much energy as a light bulb, and costing less than $100. Frigidaire's engineers one-upped GE by using different technology—a rotary sealed compressor in place of a piston type, coupled with a simple and inexpensive refrigerant control.

And so the trend continued. Continuous engineering innovation reduced cost and energy consumption, while increasing reliability. Soon there were frozen food compartments and then freezers. Solid grid ice trays were replaced by "quick cube" trays with lever-operated movable grids, later by flexible trays, and finally by self-dispensing icemakers.

By 1934, an innovation, the Shelvador refrigerator, was introduced by the Crosley Radio Corp., but only after its inventor had been turned down by all the big-name manufacturers who said his idea was crazy. (Is there any refrigerator now that doesn't have shelves in the door?) Self-defrosting refrigerators were introduced also. This progression continues today.

Once we had to pop a big cube of ice into a refrigerator to keep it cold. Now our refrigerator is cooled electrically and mechanically—and it pops ice cubes right out the front into our glass. The household refrigerator, that modern engineered marvel, only gets more marvelous.

Refrigerated Rooms

Before 1900, when engineers were laying the groundwork for the household refrigerator, the idea that room air should be refrigerated for comfort (the term "air conditioning" did not exist until the 20th century) seemed farfetched to all but a small number of undaunted engineers.

Rolla Carpenter, a Cornell University professor of experimental engineering, was one of that minority. "Cooling of rooms É bids fair to be at some time an industry of considerable importance," he wrote in 1896 in his book Heating and Ventilating Buildings.

Carpenter probably could not have imagined just how important that industry would prove to be. In the last century, comfort air conditioning would become of such considerable importance that daily life, and even population trends, would be affected.

Air conditioning is usually thought to refer to the cooling of air, but it is really much more. True comfort air conditioning maintains the total indoor environment, keeping it at a livable level. It encompasses heating and cooling, humidification and dehumidification, as well as indoor air quality. Modern air conditioning systems do all of this, but it wasn't always so.

By the 20th century, the heating side of air conditioning was well developed. Large buildings were reliably heated and frequently humidified, with many systems circulating filtered fresh outside air. This technology was beginning to be applied to residences as well.

However, cooling of buildings was a curiosity. The idea had been proposed periodically, and some cooling systems had been installed using ice and, in a few cases, mechanical refrigeration. By 1900, refrigeration technology had matured to the point that it could be considered for applications such as building cooling.

The first complete comfort air conditioning system was engineered in 1901 for the New York Stock Exchange. ASME member Alfred Wolff, considered the leading heating and ventilating engineer of his day, had designed heating and ventilating systems for many famous New York buildings, such as Carnegie Hall, The New York Public Library, and the Plaza Hotel. Wolff convinced the stock exchange building committee to include summer cooling. He said in correspondence with the committee: "If the refrigerating plant is instituted É and the entering air is cooled É and the percentage of moisture lowered, the result will be É superior in atmospheric conditions to anything that exists elsewhere."

Wolff's system was incredible for the time. It boasted a cooling capacity equivalent to 300 tons of melting ice, the cooling provided free by using the waste steam from the building's electric power plant to operate the refrigerating machines. Filtered, cooled air was gently diffused through an ornamental ceiling over the heads of the stock traders. Wolff had already predicted the result: "Instead of sticking to your traders' shirt collars, the moisture will run down the drain." The system performed successfully for the next 20 years.

Wolff designed other comfort cooling systems, for the Hanover National Bank and the Metropolitan Museum of Art, before he met an untimely death in 1909.

Wolff's Metropolitan Museum design required close control of temperature and humidity, but it was Willis Haviland Carrier who really perfected the art of precision cooling.

Carrier, newly graduated from Cornell University in 1901, was put in charge of research engineering at Buffalo Forge Co., a leading manufacturing engineering firm for the heating and ventilating of large buildings. After he was asked to design a cooling and dehumidification system for a Brooklyn printing plant, Carrier became so enamored of the prospects for temperature and humidity control that he applied his unique combination of business, engineering, and scientific smarts to environmental control.

Carrier designed a specialized type of apparatus to condition air using controlled temperature water sprays. He was able to accurately control the air's dew point, and sold his systems to customers with a promise of specific temperature and humidity performance. Carrier convinced his employer in 1907 to launch a new company division, The Carrier Air Conditioning Co. of America, with himself as head and chief engineer.

The term "air conditioning" had been coined only two years before, by Stuart Cramer, a textile engineer.

All of Willis Carrier's early work centered on process air conditioning for industrial applications, but his theoretical work provided the scientific underpinning for his own and others' later work in comfort cooling.

All of this pioneering air conditioning work hardly affected the sweltering masses of people at first. The public was first exposed to the cooling side of air conditioning at the Louisiana Purchase Exposition, the St. Louis World's Fair, in 1904. Fairgoers were treated to the comfort cooled Missouri State Building with its 1,000-seat auditorium.

Although many thousands experienced air conditioning for the first time at the fair, most average folks didn't get a taste of it until movie theaters began installing cooling plants after 1917. Until then, city dwellers simply endured.

A 1920s Chicago newspaper headline shouted: "Fifteen dead in Chicago as mercury soars." The article summarized the suffering: "While beaches and parks were thronged with fugitives from stuffy rooms and apartments, hundreds of persons moved their beds to porches, roofs, and in some cases into yards. The boulevards and highways were congested with motorists trying to get out of the sweltering city."

Movie theaters began to serve as a summer refuge in the 1920s. Theaters could afford the mechanical equipment when it enhanced their bottom line. The public thronged to refrigerated theaters sporting banners that read, "It's 20 degrees cooler inside." As patrons sat in comfort, dreading a return to hot houses and apartments, many of them wondered, "Why can't my house be cool, too?"

The subject of home, office, and store air conditioning was also on the minds of engineers. Some office buildings and department stores had comfort cooling by 1930, and this trend continued to accelerate. Air conditioning for homes and small offices and stores presented another challenge. Mechanical equipment was simply unaffordable and too large.

The solution lay in the technology of the household refrigerator. Could the engineering that provided low cost and small size for refrigerators be successfully crossed over to comfort cooling? Naturally, it was the refrigerator manufacturers who saw the potential, and they applied their engineering and manufacturing expertise to the task.

Frigidaire introduced the first "room cooler" in 1929. General Electric and Kelvinator followed soon after. By the 1930s, these companies were combining cooling and heating technology with central home air conditioning systems that were automatic, circulating filtered, tempered air to all of the rooms in a house, office, or business. These central systems were still too expensive for most folks. The majority of the systems were installed in new homes; few could afford to replace their heating systems.

Once again, engineering provided a solution to the needs of the many. The window air conditioner was introduced in the 1930s and refrigerator manufacturers applied their mass-production talent to it. As with the refrigerator, continuous technological improvement reduced cost and increased reliability, effectively democratizing air conditioning. Window air conditioner innovations were then applied to central heating-cooling systems, making them so affordable that today few houses are built without air conditioning.

The same thing happened with autos. After Packard introduced an air-conditioned car in 1938, auto air conditioning grew steadily. Now, a car without air conditioning is almost unheard of.

Comfort air conditioning changed working conditions and habits, influenced the way we shop in stores, and altered architecture, allowing windowless buildings and porchless houses.

Before year-round air conditioning, work and leisure were dictated by outside conditions. During the 20th century, our lives were no longer dependent on the weather. Our indoor weather is controlled by engineered technology that has become so reliable and low in cost, that it operates silently in the background, being totally taken for granted, but at the same time is considered an absolute necessity for modern living.

Work and play are possible in any climate in any type of building that an architect can dream of. Life is bearable in the tropics or the Arctic. In the United States alone, year-round air conditioning after 1950 reversed a century-long pattern of migration out of southern cities. From 1990 through 1995, in excess of two million people moved to the southern states, a population boom that would not have been possible without the existence of air conditioning.

Luxury to Necessity

Engineering brought us those old refrigerators in the garage that still run after 50 years. Those that we buy now we plug in and forget—except when the power goes out. Engineering brought us indoor environmental systems that operate so well and are so well hidden that one might think heating or cooling were nothing more than a thermostat on the wall.

An ice cream cone once was a rare luxury meant to relieve the heat. Now our freezer is at arm's length, the ice cream eaten for sheer pleasure. From impossible dream to luxury, and finally to necessity, refrigerators and air conditioners were indeed a feat of modern technical alchemy that made our lives better. But isn't that what we engineers are all about?

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