

BACKGROUND: HISTORY OF REFRIGERATION

The "Ice Age"

Seeking a way to cool the rooms of his yellow-fever patients in a sweltering Florida hospital in 1842, a Scottish-born doctor, John Gorrie, creates a device that blows air over buckets of ice. Giving up his medical practice to experiment with ice-making, Gorrie receives the first U.S. patent for mechanical refrigeration in 1851.

The mechanical refrigeration units that greet the new 20th century are basic extensions of Gorrie's 50-year-old invention. The only thing missing is a satisfactory refrigerant.

At the same time, workers fish blocks of ice off a frozen New York river. The ice is hauled to nearby commercial plants – there are more than 2,000 by 1909 – and place them in large "ice boxes" for shipment to southern states. There isn't much ice left when the shipment arrives. The ice-shipping trade proves costly, weather-dependent and unreliable.

In 1902, after noting that the printing process works less efficiently in the summer heat, Cornell graduate Willis Carrier installs the first modern air-conditioning system in a Brooklyn color-printing plant. He later develops a centrifugal compressor for refrigeration. His concept would be the industry standard for the next two decades.

All the refrigerants being tested or in use at the time have serious drawbacks in flammability, corrosion and toxicity. While carbon dioxide solves most of the danger problems, it makes the equipment bulky or susceptible to leaks. Improvements are needed before domestic or commercial refrigeration can safely be used on a worldwide scale.

Hospitality businesses including hotels, restaurants, saloons and soda fountains prove to be big markets for ice. During World War I, refrigeration in munitions factories provides the required strict control of temperatures and humidity. Allied fighting ships hold carbon-dioxide machines to keep ammunition well below temperatures at which high explosives become unstable.

The Roaring 20s

By the 1920s, the household refrigerator has become an essential piece of kitchen equipment. In 1921, 5,000 mechanical refrigerators are manufactured in the U.S. Within 10 years that number grows past one million. By 1935, there are nearly six million. While the refrigerators don't change much, the refrigerants keep improving with time. In 1921, Clarence Birdseye discovers the technique for quick-freezing.

By 1923, there are 56 companies making refrigerators, all using toxic and/or flammable materials such as sulfur dioxide, methyl chloride or ammonia gases.

As the mid-20s approach, air conditioning is installed in movie theaters, hotels and department stores but rarely in office buildings. Skyscrapers like the Woolworth and Chrysler buildings continue to rely on nature for lighting and ventilation. However, in 1928, San Antonio's Milam Building is advertised as the first fully air-conditioned office building in the U.S.

Led by 27-year-old Belgian chemist Albert Henne, scientists struggle to expand on the primitive discoveries of Scheele (1771) and Moissan, who isolated elementary fluorine in 1886.

The Fluorocarbon Boom

Frigidaire's Thomas Midgley ends his talk at the 1930 meeting of the American Chemical Society in Atlanta, Ga. with a dramatic demonstration of chlorofluorocarbon (CFC)-12, displaying the safety and efficiency of fluorocarbon refrigerants. A year later, CFC-12 is introduced as a commercial refrigerant. The fluorocarbon industry is born, with safer to use, nonflammable, noncombustible products.

DuPont and General Motors combine their resources to form Kinetic Chemicals, Inc. in 1930 at the DuPont facility in Deepwater, N.J. DuPont registers Freon® as its trademark for fluorocarbons. A year later, Freon® 12 is being produced in commercial quantities and, because of its inherent safety characteristics, is made available to the entire refrigeration industry.

In succeeding years, DuPont introduces a series of commercial Freon® products: CFC-11, CFC-114, CFC-113 and hydrochlorofluorocarbon (HCFC)-22.

Air-conditioning expands to restaurants, drug stores and larger retail stores. The first practical room air conditioners for home use appear in the early 1930s. The first window air conditioner is introduced by the Thorne Co. in 1932 but is never mass-produced.

GM's Cadillac Division starts work on a vapor compression system with CFC-12 as its refrigerant. By 1939, a prototype self-contained unit is installed in the Cadillac's trunk. Some buses have already been equipped with self-contained air-conditioning units since the mid-1930s, though mostly as test vehicles.

The War Years

World War II puts a halt to most civilian construction. A few months before the U.S. goes to war, Willis Carrier installs his first Weathermaster air-conditioning units, an "air and water" induction system utilizing high-velocity air and smaller ducts. The Equitable Building in Portland, Ore., becomes the prototype for the modern fully air-conditioned office building.

The U.S. Department of Agriculture uses CFC-11 and CFC-12 to develop new aerosol propellants for aerosol insecticides to help U.S. troops in the Pacific.

Forty million units of self-contained, pressurized packs of liquefied Freon® 12, known as "the bug bomb," are prepared for U.S. military forces, primarily for use as propellants for insecticides.

In addition, fluorocarbons are used for refrigeration transport, frozen-food production and medical applications, including frozen blood plasma. In 1945, CFC-13 is developed.

Prior to 1940, the only way to keep cool in an automobile is to open a window. The gradual acceptance of fresh air heating and the cowl ventilator starts a trend toward modern automotive air-conditioning. As the decade begins, Packard and Cadillac begin offering air-conditioning units on their luxury cars, mostly in the Southwest U.S. By 1947, many independent manufacturers have created a large aftermarket business by installing air conditioners on all makes of cars.

In 1949, DuPont buys out GM's interest in Kinetic Chemicals and creates its Organic Chemicals Department. The name is soon changed to the Freon® Products Division.

Room air-conditioners are now widely accepted throughout the country.

Patents Not Pending

World War II essentially halts the growth of automotive air conditioning. It begins anew in 1953 with a practical, affordable system. The number of air-conditioned cars jumps from 3,000 pre-war models to 36,000 by 1954, reaching one million by 1959.

Many of the original organic fluorocarbon patents held by DuPont expire, opening the field to new companies. Within 15 years, five new companies enter the fluorocarbon market and the products become commodities.

DuPont releases its registered refrigerant numbering system for general use, to avoid confusion and proliferation of different names for similar products.

Mass production of modern refrigerators begins in earnest after World War II. By 1950, more than 80 percent of American farms and more than 90 percent of urban homes have one.

Carrier's Weathermaster system is incorporated in Dallas housing developments in the early 1950s. Units that heat in the winter and cool in the summer are being developed, though early models are bulky and expensive. CFC-14 is made available for use in 1955.

The use of aerosol-propelled insecticides greatly increases throughout the world.

Lighter, Safer, Better

The wartime "bug bomb" becomes the post-war aerosol container that, by the mid-1960s, is consuming more than half the fluorocarbons being produced.

CFC-502 is introduced as a commercial refrigerant, packed in lightweight cylinders for greater safety and easier handling. It is quickly installed in over 10,000 supermarkets across the country.

Freon® 13, used for ultra-low temperature refrigeration of -100 degrees F and lower, is introduced.

Compact cars, with no air conditioning, make their debut in 1960. Large luxury cars are cooler and more appealing. Within a year, car models Corvair and Falcon offer air conditioning, and sales soar. By 1967, 40 percent of new cars have factory-installed air conditioning. A year later, it is standard equipment on the more-expensive cars.

European demand for fluorocarbons greatly increases.

The Space Age

In the 1970s, the "energy crisis" leads to the development of energy-efficient air conditioners. Congress mandates thermostat settings, though compliance with the new law is sporadic.

Still the leading global supplier of refrigerants for the commercial and industrial air conditioning and refrigeration industries, DuPont begins its own studies for alternative refrigerants after questions arise about possible harmful effects of fluorocarbons on stratospheric ozone. The first product DuPont develops is hydrofluorocarbon (HFC)-134a, a non-ozone-depleting refrigerant that is nonflammable, safe to use and better for the ozone layer because it has no chlorine.

Mario Molina and Sherry Rowland publish their ozone depletion theory in 1974. The theory suggests that continued use of CFCs could eventually deplete the ozone layer. It will be more than a decade before the scientific theory is proven. The debate continues.

Automotive air-conditioning units become lighter, more efficient and more compact. Concerns about ozone depletion reach the automotive industry. By 1976, HFC-134a is being considered as the replacement for CFC-12.

Because of the issue and subsequent media coverage, U.S. production of aerosol products declines. The European aerosol market flourishes.

A Changing Environment

In 1980, 72 percent of new cars sold in the U.S. have air conditioning. Within 10 years, it grows to 94 percent. Two-thirds of all cars and light trucks in operation in the U.S. are air-conditioned.

The "ozone hole" is discovered over Antarctica in 1985 but the cause is uncertain.

With evolving scientific evidence suggesting a link between increasing emissions of CFCs and potential future ozone loss, an international agreement is reached in 1987, the Montreal Protocol, which requires a 50 percent decrease in CFC consumption over a 10-year period.

In March 1988, a distinguished panel of scientists comprising the International Ozone Trends Panel, releases its summary report linking the "ozone hole" and, potentially, seasonal ozone losses in the northern hemisphere, to CFCs. It is the first scientific consensus linking CFCs to ozone loss. Within 10 days, DuPont unilaterally commits to phase out CFC production through an orderly transition to alternatives.

In the interest of accelerating the transition to alternatives, DuPont shares its safety and environmental information, and leads in the formation of consortia to complete the testing. The objective: alternative products that are safe to use, environmentally superior and require only minimal changes to equipment.

Faced with the prospect of an impending phase-out of CFC-12, carmakers put their money on a non-ozone-depleting alternative refrigerant, HFC-134a. New components such as condensers and compressors are developed, as well as new lubricants and desiccants.

The First Family of Refrigerant Alternatives

The Clean Air Act Amendments of 1990 established a production phase-out schedule and yearly reduction percentage for ozone-depleting chemicals. In 1996, CFCs are phased out in the U.S.

Accelerating a process that normally takes 15 to 20 years to develop, test and commercialize, DuPont spends over \$500 million and takes only four years to introduce the first in a series of alternatives. DuPont's family of Suva® refrigerants are launched in Jan, 1991. These low- or non ozone-depleting products, called HCFCs and HFCs, help enable an economical, non-disruptive global transition that is still underway in developing countries.

DuPont™ Suva® refrigerants provide high-performance alternatives for automotive, residential and commercial air-conditioning systems, home refrigerators, supermarket display cases and other commercial refrigeration uses. Other families of alternatives follow, for foams, fire extinguishants, cleaning agents and aerosol propellants, for which DuPont already has several commercial products.

By 1994, Suva® refrigerants are globally accepted as environmentally superior alternatives to the CFCs that had been the backbone of the refrigeration and air conditioning industry for more than 60 years.

2000 and Beyond: The Future Beckons

DuPont introduces the family of ISCEON® refrigerants, non-ozone-depleting products for use in retrofit and new systems.

DuPont manufactures the broadest portfolio of alternatives for refrigeration and air conditioning, fire extinguishants, foam expansion agents, aerosol propellants and cleaning solvents and is focused on developing the next phase of sustainable products to meet evolving needs for climate change, particularly as developing nations continue to grow.

DuPont manufacturing facilities are located in Corpus Christi, Texas; Louisville, K.Y.; Deepwater, N.J.; Maitland, Ont. Canada; Chiba, Japan; Shimizu, Japan, and Dordrecht, The Netherlands.

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