ASHRAE Journal

100 Years of Air Conditioning

By Bernard Nagengast, Member ASHRAE

In 1902, heat and humidity was ruining a publication being printed in color in Brooklyn, N.Y. At that time, the art and science of air conditioning was just beginning to evolve. Solving this printing problem lead to the start of industrial process air conditioning, as nurtured by a young engineer named Willis Haviland Carrier.

Carrier had recently graduated from Cornell University and was working at Buffalo Forge Company, a manufacturer of fan-type heating systems. He was busy with heating system and fan design problems but soon realized that data for fan and steam heater sizing was inadequate, inaccurate or non-existent.

Research in this area began to consume his spare time, which was limited because his job required him to work ten hours a day, six days a week. Carrier convinced Buffalo Forge management that accurate data meant saving money by reducing the amount of "cut and try" engineering. They allowed him to assemble a small research facility to do experimental engineering.

Carrier's experimental facility was hardly operational when he was asked to solve a unique engineering problem. The Sackett-Wilhelms Printing and Publishing Company in Brooklyn, N.Y., was known for its high quality color printing, which involved feeding paper through printing presses multiple times, each color printed separately. If the heat and humidity changed during the process, the paper size changed slightly, causing some colors to print slightly off the mark, resulting in "off-registry."

Off registry caused much waste, and sometimes the presses couldn't be run at all on very humid days. Sackett-Wilhelms asked consulting engineer William Timmis if he could solve the printing problem.

Timmis recognized that the answer was to accurately control the humidity within certain limits. Since this had never been done before, he contacted J. Irvine Lyle at the New York sales office of Buffalo Forge. Lyle realized that a solution to accurate humidity control would open up a sales opportunity in industrial applications. Lyle asked Carrier to find the answer.

Carrier later recalled the uniqueness and difficulty of his task, "We went at the subject backwards. A more normal approach, the front way, would have been to humidify the air and control its moisture content at a level higher than in outdoor air. But here we were, designing a system to hold the moisture content at a specified level that was lower than in air out of doors. We started the hard way."[1]

Carrier set up experiments to see what would result in effective humidity control. First, he tried using calcium chloride brine as a hygroscopic agent.

"I rigged up a burlap cloth on two rollers. A fan pulled air through the cloth. The cloth was wetted continuously with

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Timeline of Air-Conditioning History

1902: Willis Carrier designs a spray-type temperature and humidity control system for a Brooklyn printing plant.

1906: Stuart Cramer, a North Carolina textile engineer, coins the term "air conditioning."

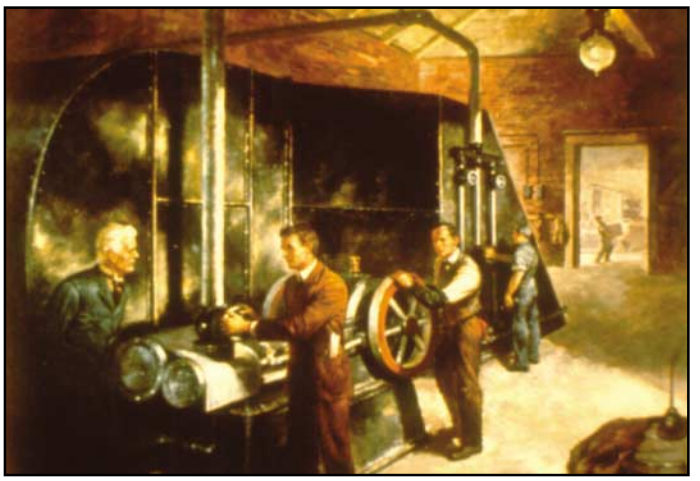
1911: Carrier presents his paper, "Rational Psychrometric Formulae," to the American Society of Mechanical Engineers.

1928: Thomas Midgley and others synthesize CFC refrigerants for Fridgidaire at the General Motors Research Lab.

1928: Electrically refrigerated vending machine by Vendometer Corporation of New York.

a saturated solution of calcium chloride brine. Everything except the fan was manually operated. As I thought the tests would not take more than four or five days.... Manpower was cheaper for a short test; a man to dip brine from a barrel and pour it over the cloth, and a man to turn the rollers."[1]

Although the test revealed some new relationships to Carrier, the experiment was suspended when Carrier realized that the exiting air was dehumidified, but contained minute salt spray droplets, an unwelcome contaminant in a printing plant.



First air-conditioning plant at Brooklyn, N.Y., printing company.

Next, Carrier constructed an apparatus to cool the air below its dew point. Air was fan-induced over a cast iron steam heater. Cold Lake Erie water was substituted for steam. Using weather bureau data, Carrier decided on a dew point to obtain the humidity level he wanted, and designed a system, through experimentation, specifying the amount of dehumidifying surface, its operating temperature, the quantity of air and the resulting air temperature.

Carrier turned over the design to Lyle, who convinced Sackett-Wihelms to buy the system, which was the first system designed to maintain a constant humidity level.

The Dehumidification Plant

Carrier's dehumidification plant was intended to condition the second floor of the printing plant, where the multicolor printing presses were located. The cooling plant was retrofitted to an existing "hot blast" or fan-type heating system, and was supposed to maintain 80°F (27°C) and 55% relative humidity in summer.

To reach the design condition, Carrier installed galvanized pipe coils before the fan. The coils were designed to provide 60 tons (211 kW) of cooling, half from cold well water and half from mechanical refrigeration.

At first, well water was used alone, the refrigerating plant not being installed until 1903.[2]

Timmis, who initiated the printing plant job, described the airside of the system, "Circulation of the air was by means of an engine-driven plate fan designed to give an air change every 15 minutes. The system was arranged for recirculation by means of vertical flues and the supply and return ducts were placed side by side. The supply ducts were provided at the base with mixing dampers and connected to a divided horizontal duct forming two distinct ducts for two supplies of different characteristics of temperature. The vertical return flue or ducts all connected to one main return duct and thence ran to a fore-cooler chamber and from there to the chambers in which the cooling coils were placed."

Timmis performed tests in September 1904 that showed a reduction in relative humidity from 86 to 63%.[3]

The Carrier archive records at Cornell University indicate that the dehumidification plant did not work as well as expected, possibly because of circulation problems in the pipe coils and airside problems. Apparently, these drawbacks could not be addressed satisfactorily and the system was removed. The Sackett-Wilhelms system is not featured in Carrier's first air-conditioning catalog issued in 1908, although other printing plant installations are featured.

The Significance of Sackett-Wilhelms

Carrier said later that he "realized that the design was not the final answer for controlling the moisture content of the air, so began working toward a design that would be the answer."[4] He continued to theorize and experiment, which led him to develop successful dew-point control

Air-Conditioning History (1930 – 1950)

1930: First car air conditioned by C&C Kelvinator Co. for John Hamman Jr. of Houston.

1942: Wartime Order L-38 bans the installation or manufacture of new air-conditioning systems solely for personal comfort. The ban is lifted in 1945.

1948: Textile workers strike in North Carolina over stressful temperature and humidity conditions, making air-conditioning a bargaining issue.

1950: Major study shows families living in air-conditioned homes sleep longer in summer, enjoy their food more and have more leisure time.

as a means of accurately controlling humidity levels in air. He had achieved this by 1905, and received a patent on the apparatus. By 1906, Carrier had published the first psychrometric chart in a Buffalo Forge fan catalog.

Carrier later commented on his 1902–03 experience in designing the dehumidification system for the printing plant, "These early experiments, prompted by a problem based upon a comparatively small printing establishment, started the trend of investigation through which many of the fundamental laws of evaporation, of humidity control and of heat transfer were established..."[5]

Commenting upon the experiments with calcium chloride to dehumidify air, Carrier said, "...when calcium chloride, or any other substance, absorbed moisture out of the air an exactly corresponding amount of latent heat was released in the form of sensible heat. ... the observation of this one phenomenon led to a train of thought, which eventually was to become important. This experiment disclosed the inter-relation of latent and sensible heat in the air when its moisture content was altered without the addition or subtraction of external heat. It also led to complimentary experiments upon the process of evaporation of water into air and, finally, into the development of the principles upon which air conditioning was founded."[6]

The Sackett-Wilhelms installation has been touted as "the first scientifically designed air-conditioning system" or even "the first air-conditioning system." However, the true significance of Carrier's first air-conditioning job is that it started his thought and experimentation process that ultimately resulted in his greatest accomplishments: perfection of dew point control and development of the psychrometric chart.

The Sackett-Wilhelms Printing and Publishing Company in Brooklyn, N.Y.

As Carrier said, "...I worked on the first problem of air conditioning, that of humidifying and dehumidifying a lithographic plant in Brooklyn. I then tried cooling coils and calcium chloride in laboratory experiments which, although giving a great deal of fundamental data with reference to moisture in the air and its general pervasiveness, resulted tangibly only in ruining two perfectly good pairs of expensive shoes worn by my two assistants just out of college.

"In 1906, however, four years later, the first real air-conditioning installations were installed based on practically the same principles of equipment and operation used today."[7]

References

1. Ingels, M. 1950. "Willis Carrier, the father of air conditioning." Typed manuscript at Department of Manuscripts and Archives, Cornell University, Ithaca, New York. Accession 2511, p. 59.
2. Lewis, L. 1964. "Sacket-Wilhelms Printing and Publishing Co. 1902, A technical review of some heretofore unpublished information." Accession 2511, Department of Manuscripts and Archives, Cornell University, Ithaca, N.Y.
3. Anonymous. 1914. "New York (ASHVE) chapter discusses control of atmospheric conditions in printing establishments." *The Heating and Ventilating Magazine* 11(1):48.
4. Ingels, M. 1949. Letter to Samuel Fletcher, Vice President, Sackett & Wilhelms Lithographing Corp., November 14. Accession 2511, Department of Manuscripts and Archives, Cornell University, Ithaca, N.Y.
5. Carrier, W. H. 1929. "Air conditioning — its phenomenal development." *Heating and Ventilating*, 26(6):116.
6. Carrier, W. H. 1936. "Progress in air conditioning in the last quarter century." *ASHVE Transactions*. 42:323.
7. Carrier, W. H. 1934. "Bright future of air conditioning." *Heating and Ventilating*, 31(5):24.

Air-Conditioning History (1969 – 1999)

1969: Neil Armstrong and Buzz Aldrin walk on the moon in space suits with life support and cooling systems.

1977: New technology allows heat pumps to operate at lower outdoor temperatures while heating on the reversed refrigeration cycle.

1987: Montreal Protocol is signed establishing international cooperation for the phaseout of ozone-depleting substances.

1995: Chlorofluorocarbon (CFC) production in the U.S. ends.

1999: Stay Cool! Air Conditioning in America exhibit runs eight months at the National Building Museum. ASHRAE and the Air-Conditioning and Refrigeration Institute are sponsors.