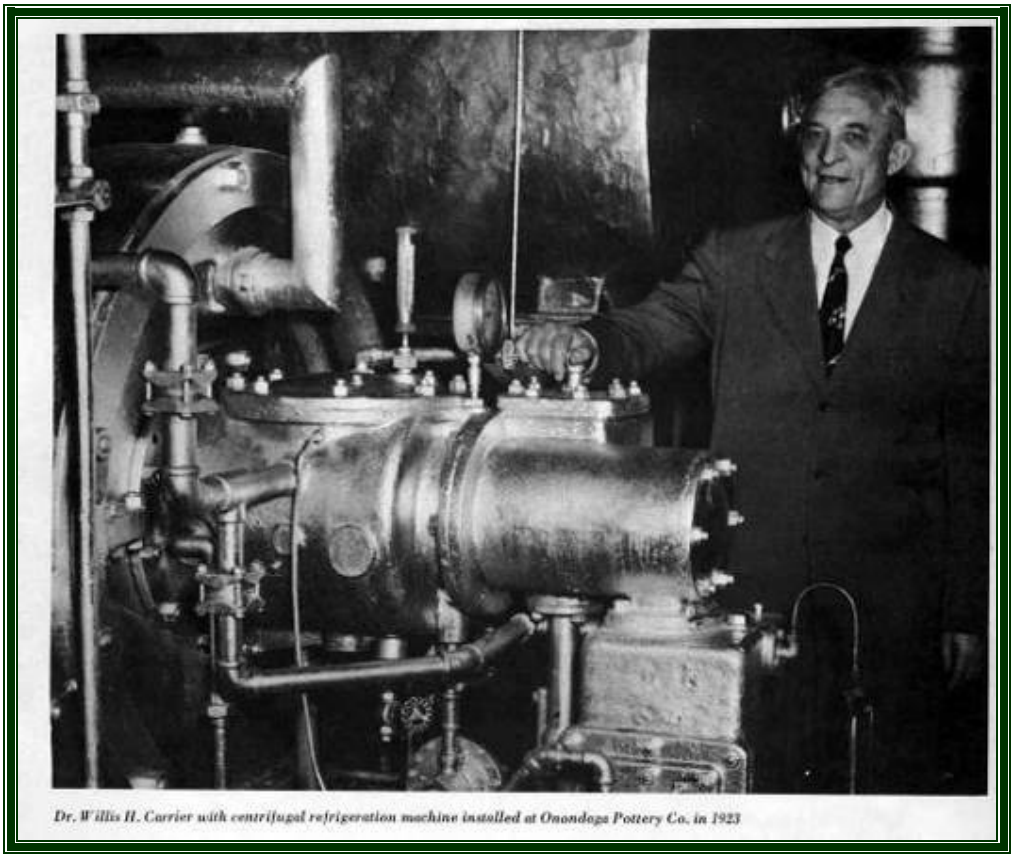
Dr WILLIS HAVILAND CARRIER
1876-1950



Dr. Willis H. Carrier with centrifugal refrigeration machine installed at Onondaga Pottery Co. in 1923

The Father of Air Conditioning
ASHRAE Journal June 1969

A detailed Carrier biography is given under **Electronic Books** *on this web site*

[101] Dr. Willis Haviland CARRIER **1876-1950**

American engineer and inventor. One of the most outstanding men of his generation. Born on a farm in Angola, N.Y. Won state scholarship to Cornell University. Graduated with a degree of Mechanical Engineer in Electrical Engineering (1904). Joined Buffalo Forge, where he met Irving Lyle [100]. Responsible for what has been claimed to be the first scientifically designed air-conditioning system, installed at the Sackett-Wilhelms Lithographing & Printing Co., Brooklyn (1902). Hailed as a "milestone in air conditioning" at the time, it is now known the installation was not a success.* Formed Research Department at Buffalo Forge. Formulated the idea of *Dew-Point Control* of relative humidity and developed spray washers and special controls. Established the subsidiary Carrier Air Conditioning Co. (1908). Presented landmark papers to ASME (1911), *Rational Psychrometric Formulae* and (with Frank Busey) *Air Conditioning Apparatus*. Produced the first famous Buffalo Forge textbook, *Fan Engineering* (1914). Started Carrier Engineering Corp. (1914). Carrier took air conditioning, which initially had been for industrial applications, into the comfort business in cinemas, departments stores, and restaurants. He patented many types of control (1907-1908). Later, he developed the ideas of Leblanc [92] to produce the first centrifugal refrigerating machine (1922), describing his work in *Centrifugal Compression as Applied to Refrigeration* (1926). Stories of Carrier's absentmindedness are legion, for when problem-solving, he concentrated to the exclusion of everything and everyone else. He pioneered air conditioning for railway coaches and passenger liners and introduced unit air conditioners to the home and high velocity induction systems (1939-1940) for skyscraper offices. President ASRE (1927) and President ASHVE (1931). First recipient of ASHRAE's F. Paul Anderson Award (1932). Carrier's achievements have earned him the title *Father of Air Conditioning*, and he was one of the first members inducted into the ASHRAE Hall of Fame (1994).

(Mini-biography from "The Comfort Makers," Brian Roberts, ASHRAE, 2000)

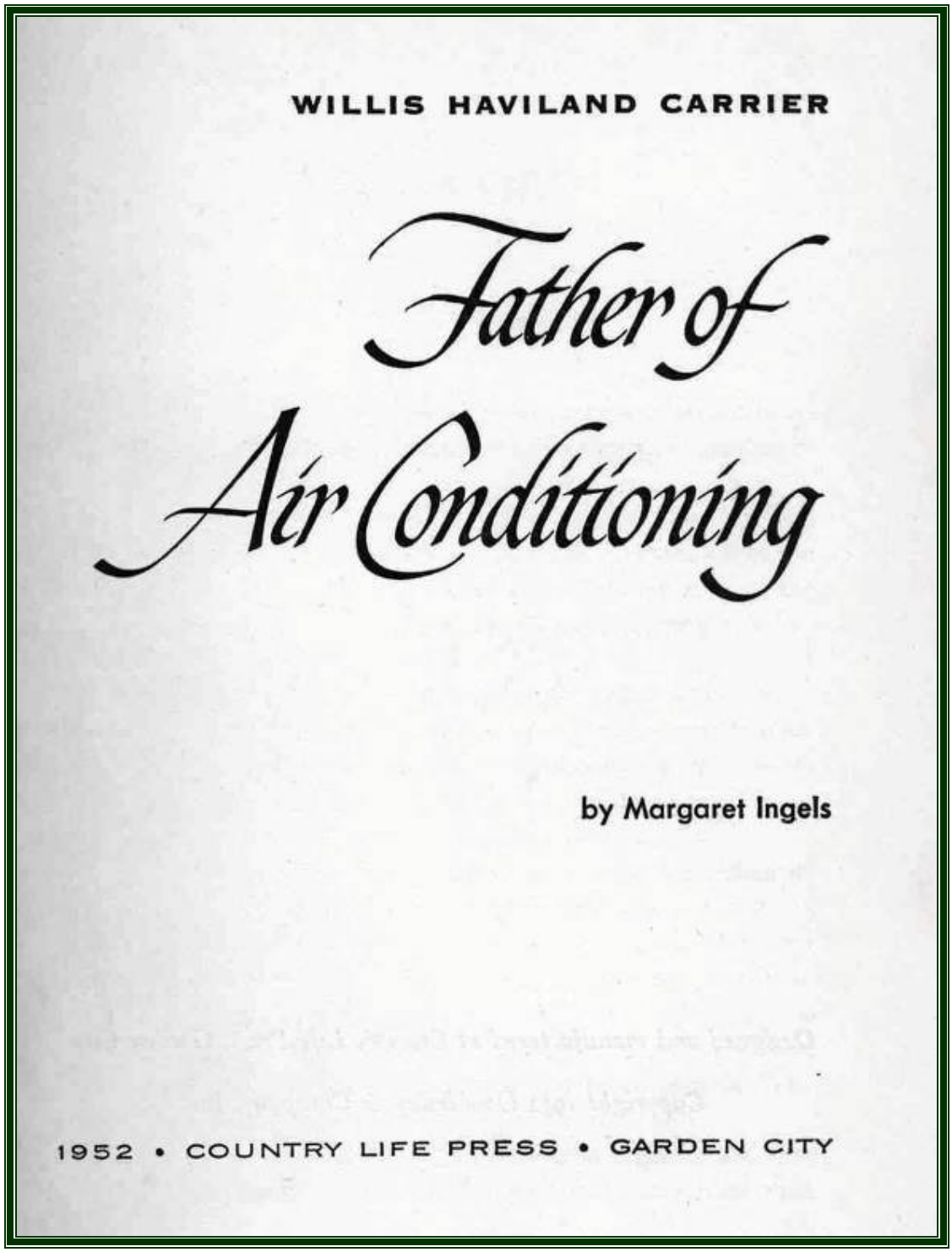
REFRIGERATING ENGINEERING

VOL. 12 FEBRUARY, 1926 No. 8

Centrifugal Compression as Applied to Refrigeration*

W. H. CARRIER,[1] Newark, N. J.

One of the many technical papers of Willis Carrier held in the CIBSE Heritage Group Collection



The definitive biography by Margaret Ingels the 2nd female to join ASHVE c.1921
(CIBSE Heritage Group Collection)

No. 1340

RATIONAL PSYCHROMETRIC FORMULAE

THEIR RELATION TO THE PROBLEMS OF METEOROLOGY AND OF AIR CONDITIONING

By Willis H. Carrier, Buffalo, N. Y.

Associate Member of the Society

A specialized engineering field has recently developed, technically known as air conditioning, or the artificial regulation of atmospheric moisture. The application of this new art to many varied industries has been demonstrated to be of greatest economic importance. When applied to the blast furnace, it has increased the net profit in the production of pig iron from $0.50 to $0.70 per ton, and in the textile mill it has increased the output from 5 to 15 per cent, at the same time greatly improving the quality and the hygienic conditions surrounding the operative. In many other industries, such as lithographing, the manufacture of candy, bread, high explosive and photographic films, and the drying and preparing of delicate hygroscopic materials, such as macaroni and tobacco, the question of humidity is equally important. While air conditioning has never been properly applied to coal mines, the author is convinced that if this were made compulsory, the greater number of mine explosions would be prevented.

2 Although of so much practical as well as scientific importance the laws governing many of the phenomena of atmospheric moisture are but partially understood, while the present engineering data pertaining thereto are both inaccurate and incomplete. Accepted data used in psychrometric calculations are based largely on empirical formulae, which are incorrect as well as limited in their range. Recent investigators have determined the most important properties of water vapor with final accuracy. At the same time, sufficient error has been shown in previous steam data, especially at atmospheric temperatures, to warrant the revision of all calculations based thereon.

Presented at the Annual Meeting 1911, of The American Society of Mechanical Engineers.

Example of Carrier Corporation brochures from 1921
(CIBSE Heritage Group Collection)

Dr. Willis H. Carrier

Father of Air Conditioning

CLOUD WAMPLER

MEMBER OF THE NEWCOMEN SOCIETY
PRESIDENT
CARRIER CORPORATION
SYRACUSE
NEW YORK

THE NEWCOMEN SOCIETY OF ENGLAND
AMERICAN BRANCH NEW YORK
1949

(CIBSE Heritage Group Collection)

Carrier found there were many applications where "the dewpoint system of humidity control cannot be applied to advantage". So he developed the differential hygrostat (Fig. 11.10). This incorporates an expansive dry-bulb member and a wet-bulb member (constructed of hard rubber tube). Carrier recognised that "the difference between the dry and wet bulb temperature for a given percent of humidity is not constant at different dry-bulb temperatures", and made clever use of differential screw threads in the mechanism to compensate for this.

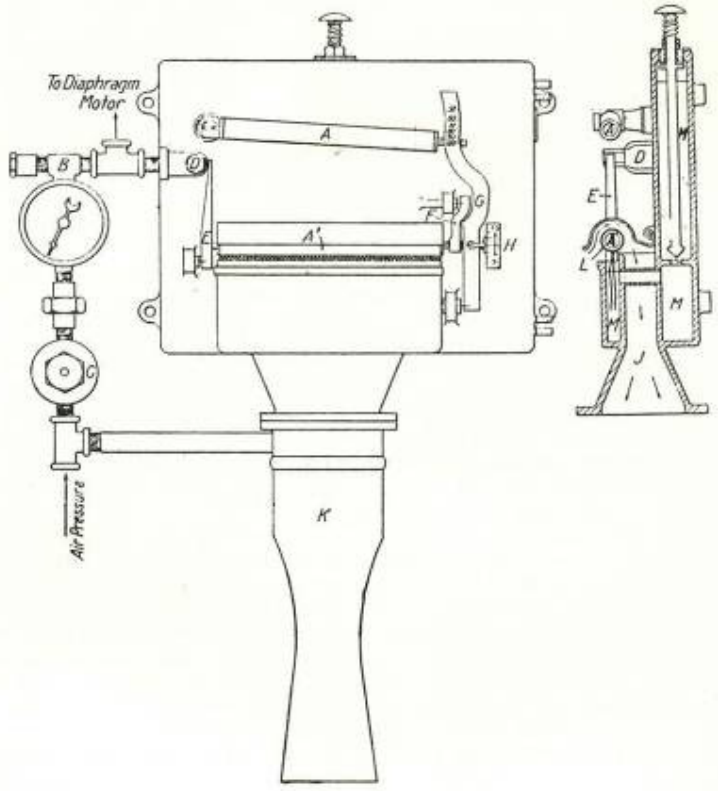


Fig. 11.10. Carrier differential hygrostat (1911).

An improved form of hygrostat was operated by the relative pressures of a volatile liquid (sulphur dioxide), subjected to the wet-and dry-bulb temperatures in the so-called "vapour pressure hygrostat", acting through suitable diaphragms on a common lever at variable distances from the fulcrum. Carrier went on to apply the same principles in the design and construction of his recording hygrometer.

(From "Building Services Engineering,"
Neville S Billington & Brian M Roberts, 1982)

The Father of Air Conditioning

WILLIS H. CARRIER WAS BORN ONE HUNDRED YEARS AGO

With many scientific and engineering developments it is impossible to put a name on the inventor, as the progress from original conception through crude first attempt to final perfection has been a long affair, perhaps extending over centuries, and involving many people. With air conditioning, although many people were concerned with early attempts to improve environmental conditions by controlling atmospheric humidity, only one person has been accorded the title "Father of Air Conditioning". This is Willis Haviland Carrier, who was born a hundred years ago.

Carrier is justly considered to be in the mainstream of the world's great inventors, for the way in which he considered the need for humidity control and the way in which he brought his work to a successful and practical conclusion. In fact his combination of farsightedness, inspired guesswork, and patient research is reminiscent of James Watt's work in developing the separate condenser for the steam engine, which gave such an impetus to the Industrial Revolution. We have since heard much about the second Industrial Revolution, and, however one defines this, Carrier's achievement is crucial in the engineering development of the 20th Century.

The following is a brief outline of Carrier's life:

Born on 26 November 1876, on a farm near Angola, in the Western part of New York State.

State Scholarship to enter Cornell University.

June 1901: graduated with degree of Mechanical Engineer in Electrical Engineering.

Joined Buffalo Forge Company.

17 July 1902: formed Research Department to work on designs for air conditioning system.

1905: Carrier produces the first catalogue to cover the Buffalo Air Washer and Humidifier.

November 1907: Buffalo Forge Company approved formation of wholly owned subsidiary Carrier Air Conditioning Company of America with Carrier in charge.

1911: in the American Society of Mechanical Engineers Carrier published his "Rational Psychrometric Formulae".

1914: "Fan Engineering" published by the Buffalo Forge Company Buffalo by Richard D. Madison NY edited under the direction of Willis H. Carrier.

1914: decision by Buffalo Forge due to World War circumstances to close down Carrier Air Conditioning Co.

26 June, 1914: Willis Carrier leaves Buffalo Forge Company and with seven of his friends starts Carrier Engineering Corporation.

1914-1920: Air conditioning; initially developed for industrial applications, is expanded by Carrier Engineering Corporation into comfort for people in movie theatres, stores, restaurants.

1920-1921: Research for a new form of refrigeration resulting in the decision in 1921 to manufacture.

22 May, 1922: The first centrifugal refrigerating machine unveiled.

1922-1929: Formation of Carrier Engineering Co. Ltd. of London and Luftechnische Geschellshaft of Stuttgart. Development of International connections and the decision to start the Carrier School to cover the training of engineers for the world-wide market and the promotion of Carrier's international interests.

1930: Carrier Air Conditioning Systems applied to Railway Coaches and Ships.

Formation of Carrier Corporation with Carrier as Chairman of the Board after the merger of Carrier Engineering Corporation with Brunswick-Kroeschell and with York Heating and Ventilating.

1930-1935: Development of new refrigerant and re-design of the centrifugal refrigeration machine.

1930-1940: Development of unit air conditioning and induction high velocity plant for mass production.

Expansion of Carrier Corporation into a world manufacturing and distribution organisation.

1940-1944: Design and construction of the special refrigeration requirements of the high altitude engine testing wind tunnel at the Cleveland Laboratory of the National Advisory Committee for Aeronautics—research required to make the high flying planes of World War II practical.

1945-1949: World visits including an address to the Institution of Mechanical Engineers in London.

7 October, 1950: Willis Haviland Carrier died in New York.

The above information was supplied by Mr. J. A. E. Heard, who helped Carrier to found the (British) Carrier Engineering Company in the twenties.
Mr. Heard is Chairman of the Institution's Archaeology of Building Services Working Party.

Article by the late J A E (Archie) Heard, sometime MD Carrier Engineering, UK and former Chairman CIBSE Heritage Group

Fig. 1 The first scientifically engineered air-conditioning system was installed in 1902 in the Sackett-Wilhelms lithographing and printing plant in Brooklyn, N.Y.

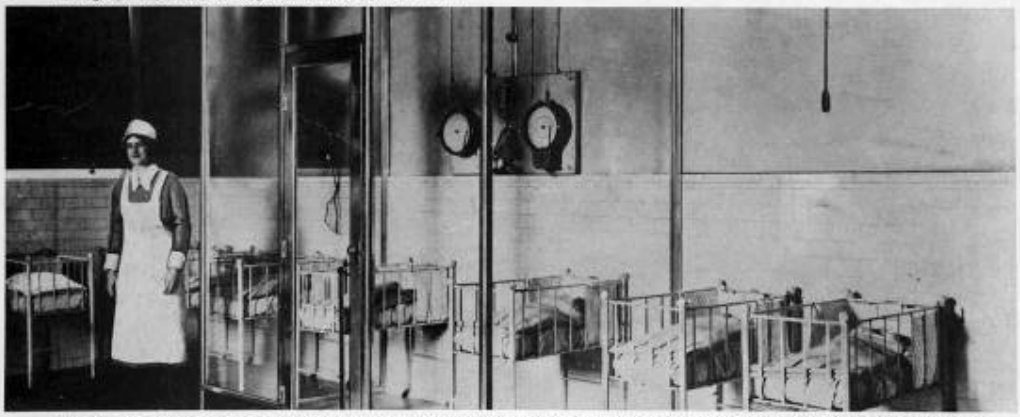


Fig. 2 Air conditioned premature baby ward installed in 1913 in the Allegheny General Hospital, Pittsburgh, Pa.

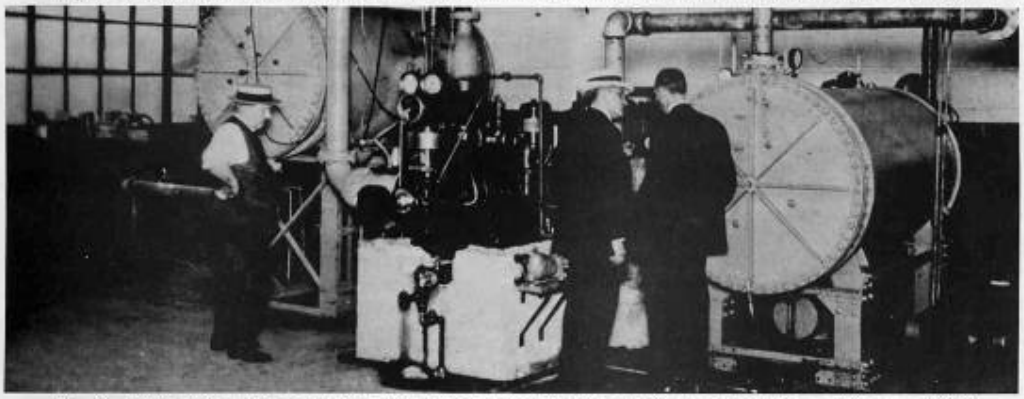
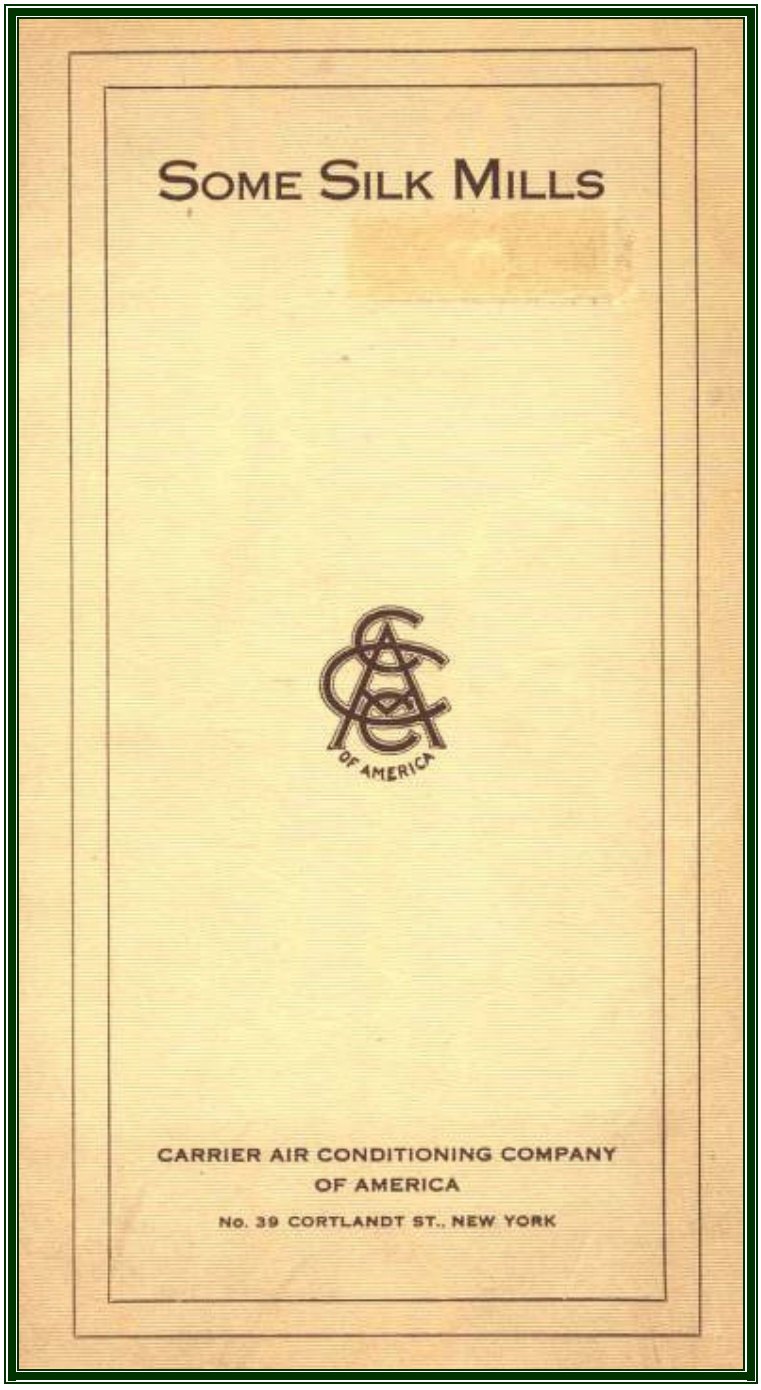


Fig. 3 Willis H. Carrier (second from left) demonstrates the first centrifugal refrigerating machine to an ASRE member in 1923

Willis Carrier was a brilliant but also creative engineer who had gone to work in 1901 for Buffalo Forge Co., one of the principal manufacturers of hot blast heating apparatus, and soon had been assigned to research and development. Buffalo Forge was very weak in the R&D area, even to the extent of having few performance data on its own equipment. The company was asked to solve a humidity control problem at a printing company in 1902, and the job was referred to Carrier. It had been suggested that dehumidification could be accomplished by use of a desiccant (calcium chloride) or by use of refrigerated pipe coils. Instead of taking a hit-or-miss approach, Carrier took a scientific approach—he investigated these ideas theoretically and experimentally in his newly established research laboratory. He decided to control the humidity by use of cooling coils, and the system was designed and installed at the Sackett and Wilhelms Co. in Brooklyn.[62] Unfortunately, the dehumidifying system was retrofitted to an existing hot blast heating system instead of being designed from scratch



Brochure of 1910 (CIBSE Heritage Group Collection)

FAN ENGINEERING

AN ENGINEER'S HANDBOOK ON AIR,
ITS MOVEMENT AND DISTRIBUTION
IN
AIR CONDITIONING,
COMBUSTION, CONVEYING
AND OTHER APPLICATIONS
EMPLOYING FANS

PUBLISHED BY
BUFFALO FORGE COMPANY
BUFFALO, N. Y.

THIRD EDITION
REWRITTEN AND RESET
TOTAL ISSUE 23,250

PRICE $3.00

EDITED BY
RICHARD D. MADISON
UNDER THE DIRECTION OF
WILLIS H. CARRIER

Textbook of 1933 (CIBSE Heritage Group Collection)

First published in 1914 it became known as the "Fan Engineers' Bible" due to its black leather cover and gold-edged pages

as a total system. The system failed to maintain the design conditions and was removed shortly after installation. Carrier "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."[63]

Carrier was good at visualization upon observation. When conducting the experiments for the printing plant job with refrigerated pipe coils, he

> . . . observed that as dehumidification was taking place, the air was in contact with water on the pipe surfaces; in other words, we had the apparent paradox of reducing the moisture in air by bringing it into contact with moisture. Of course, the explanation was simple. The temperature of this water was below the dewpoint or condensation temperature of the entering air. Why should we not, then, spray the cold water into the air stream, thus increasing the surface of contact and reducing the resistance to air flow.[64]

Carrier had concluded what Hermann Rietschel had written about eight years before—that an air washer could be used to dehumidify air. But Rietschel had also said that control of this process to achieve a desired result needed to be investigated further. Carrier's observations led him to scientifically approach the question of humidity control experimentally. "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. . . ."[65]

Carrier's process of thought during the 1902-1903 experiments was revealed sometime later. Commenting on 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 complementary experiments upon the process of evaporation of water into air and, finally, into the development of the principles upon which air conditioning was founded. . . .[66]

Willis Carrier the scientist was theorizing, experimenting, and observing results from which he learned, leading to more theorizing, experimenting, and observation. But Carrier was also an engineer and a businessman. His scientific process

> . . . also led to a further study of the need for devising suitable equipment for carrying out air conditioning processes,

> as well as to thought upon the need of various industries for maintaining atmospheric conditions, independently of external weather variations.[67]

Carrier the engineer then designed a spray-type air conditioner, a very sophisticated air washer with which he could control the absolute humidity of the air leaving the conditioner, and, ultimately, the relative humidity of the conditioned space. On September 16, 1904, Carrier applied for a patent on the device, "Apparatus for Treating Air," receiving U.S. Patent 808,897 on January 2, 1906. The Buffalo Forge Company began manufacture of the air washers in 1905 (Figure 11-39).

One of the Buffalo Forge engineers, I.H. Hardeman, had studied textile engineering, and Hardeman supposedly told Carrier that his spray conditioner would revolutionize the textile industry, where control of humidity was very important in spinning factories. Carrier the businessman recognized the opportunity, began to study this area, and brashly wrote an article on humidity control for *Textile World* in 1906 "without having ever been in a textile mill." Hardeman sold one of Carrier's spray conditioners to the Chronicle Cotton Mill[68] in Belmont, South Carolina, to control humidity but the very large heat load of the equipment had not been properly taken into account, and the device did not work quite as well as Carrier had hoped. Carrier astutely observed the results, took measurements at the plant, and studied the data.[69] He later said:

> In this study an interesting fortuitous relationship was discovered between the cooling capacity of saturated air and the relative humidity which could be maintained with varying temperature, that is the differential between the dew point of air introduced and the temperature of the room was practically constant for any relative humidity irrespective of the variation in basic temperature. For a fixed room temperature, of course, this would be obvious and was the foundation upon which the basic patent for the dew point method of controlling relative humidity was obtained.[70]

Once again, Carrier had experimented (this time in his customer's plant), observed results, and, upon studying the results, advanced the science of air conditioning to a higher level.

Carrier utilized what he had learned from the cotton mill experience and all he had observed before formulating what many believe was his greatest accomplishment—the development of rational psychrometric formulas and the psychrometric chart. Carrier tells how this came about:

> All of these early experiences in the laboratory and in practical application brought to our attention fundamental relationships and natural laws which we investigated and finally succeeded in rationalizing on a mathematical basis. For instance, it was noticed that the saturation temperature of the air, when passed through a chamber in which the spray water was simply recirculated, was exactly the same as the wet-bulb temperature of the entering air. This same fact subsequently was observed in tunnels in which wet material was being dried. Under these conditions it was noted that the wet-bulb temperature remained essentially constant throughout the length of the tunnel while the dry-bulb temperature of the air was being reduced, due to absorption of sensible heat by evaporation, and coincidentally the dew-point was increasing.

An analysis of this showed that the total heat of the air remained constant throughout such a saturation process and that the wet-bulb temperature could be taken under any condition as a measure of the total heat of the air. These facts were rationalized and formulated, establishing the basis for the Psychrometric Chart, now in general use.

Stuart W. Cramer of Charlotte, North Carolina, independently discovered this same law relating to the wet-bulb when he found that the air leaving his heated humidifiers was the same temperature as the wet-bulb of the room. He utilized this principle in 1906 in the wet- and dry-bulb hygrostat upon which he obtained a basic patent.[71]

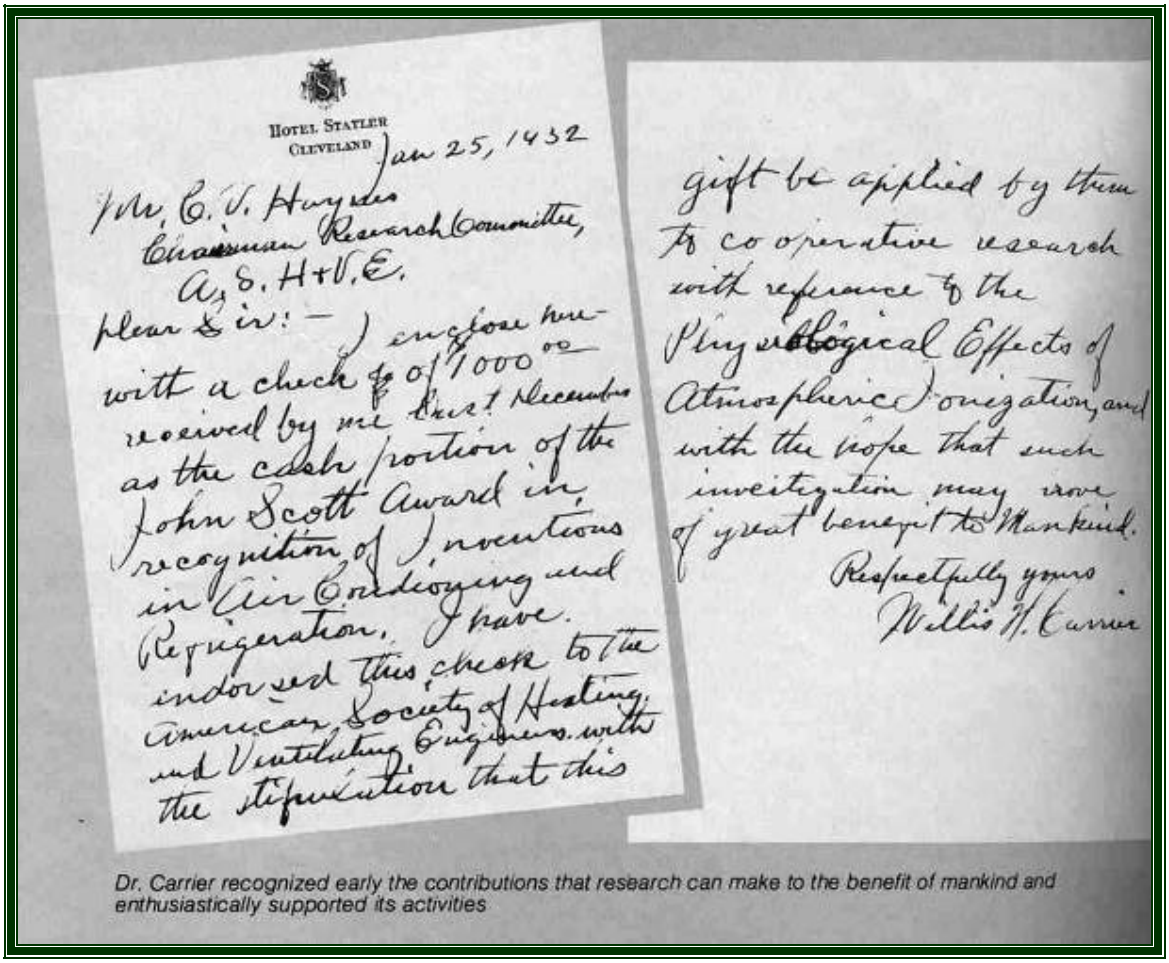
Carrier patented his device for dew-point control, filing on July 16, 1906, and receiving U.S. Patent 854,270 on May 21, 1907. During this time, he began development of his psychrometric chart and formulas.[72] The first psychrometric chart was published in 1908[73] (Figure 11-40). His formulas, psychrometric chart, and apparatus for controlling air were discussed in two papers presented before the American Society of Mechanical Engineers in 1911.[74]

In the meantime, Carrier was busy continuing his experimentation both in the lab at Buffalo Forge and at customer sites as each humidity control system was designed and sold. The feedback Carrier obtained from his experiments and installations allowed him to learn and make improvements in his design approach and in the equipment. Carrier had convinced the Buffalo Forge management that humidity control for industry could make money for the company and that Buffalo Forge should be the first manufacturer to pursue this new field and manufacture equipment for it (Figure 11-41).

As a result, the Carrier Air Conditioning Company of America was established as a subsidiary of Buffalo Forge Company in 1907. Now Carrier had a sales staff to sell the new product and an engineering staff to design systems. The Buffalo Forge subsidiary was apparently the first manufacturing-engineering combine in the history of air conditioning, and it came about because one man had a vision of an entirely new industry. Certainly, Carrier did not invent air conditioning nor was he the first to take a scientific approach to it.[75] However, Carrier's work in air conditioning was unlike what anyone had done up to that time. Hermann Rietschel had postulated the early science of air conditioning, but recognized its limits and suggested experimentations. Alfred Wolff had applied a calculated approach to the design of the year-round air-conditioning system at the New York Stock Exchange, but paused until he was asked as a consulting engineer to design another comfort cooling system. Wolff did not design the equipment itself, but utilized what was available in the marketplace. Willis Carrier, when given the printing plant job, had been able to not only define the problem, but came up with what he thought was a workable solution. When that solution did not give the desired result at a cotton mill, Carrier learned from that failure and further observations and experiments to further refine both the theory and the apparatus, ultimately resulting in dew-point control and the psychrometric chart. Carrier's keen powers of observation; his ability to see relationships among various theories, data, and results; his ability to learn from each experiment and job design (a feedback mechanism of sorts); an abstract

thinking ability coupled with a very creative mind; and a very good business sense were combinations rarely seen in one person. Willis Carrier's great contribution was his ability to see that air conditioning could be an industry, and he took the steps to establish such an industry by combining scientific method, engineering, and business.

(Text extracts from "Heat & Cold: Mastering the Great Indoors," Barry Donaldson & Bernard Nagengast, ASHRAE, 1994)



HOTEL STATLER
CLEVELAND

Jan 25, 1932

Mr. C. V. Hunges
Chairman Research Committee,
A. S. H. & V. E.

Dear Sir:—

I enclose herewith a check for $1000.00 received by me this 1st December as the cash portion of the John Scott Award in recognition of inventions in Air Conditioning and Refrigeration. I have indorsed this check to the American Society of Heating and Ventilating Engineers with the stipulation that this gift be applied by them to co operative research with reference to the Physiological Effects of Atmospheric Ionization, and with the hope that such investigation may prove of great benefit to Mankind.

Respectfully yours
Willis H. Carrier

Dr. Carrier recognized early the contributions that research can make to the benefit of mankind and enthusiastically supported its activities

From an ASHRAE Journal Supplement

Catalog 13

Carrier Air Washers *and* Humidifiers

Applied to Public Office and Industrial Buildings

With Notes on Humidity

Patented in the United States
Canada and Foreign Countries

Carrier Air Conditioning Company
of America
39 Cortlandt Street, New York, N. Y.

Catalogue of 1913 (CIBSE Heritage Group Collection)

1927

ASRE

WILLIS H. CARRIER

1876-1950

NEWARK, NJ

"Thus we see that the economic, industrial, and engineering problems of the Heat Engineer and the Refrigerating Engineer are becoming more... interlocked...They are both engaged in the pursuit of the elusive thermal unit. Their engineering processes and methods of analysis are identical. Some day...they will be joined in a common Society, the Society of Thermal Engineers." (p. 17, Jan. 1928, *RE*)

1931

ASHVE

WILLIS H. CARRIER

1876-1950

NEWARK, NJ

"An effort has been made to eliminate the rule of thumb craftsmen who by virtue of years of experience and cut-and-try methods, can arrive at tolerable results with uncertain and unforeseen materials and methods, and to replace him with standardized methods and materials which give, in effect, their own control." (p. 335, April 1931, *ASHVE Journal*)

(From "Proclaiming The Truth," ASHRAE, 1995)

Willis Haviland Carrier, father of air conditioning, 1876-1950. The year 1977 marked the 75th anniversary of his design of the first air conditioning system.

"The Two Faces of Janus," Carrier Corporation, undated
(CIBSE Heritage Group Collection)

INVENTOR OF AIR CONDITIONING IS HONORED

Shown are Joseph Davis, President of Niagara Frontier Chapter (left) with Alfred E. Stacey, Jr., one of the original founders of the Carrier Corp

Marker reads "Birthplace of Willis Haviland Carrier, 1876-1950, Teacher –Engineer –Man of Science –Inventor of Air Conditioning"
(ASHRAE Journal, August 1968)

WILLIS H CARRIER **1876 – 1950**

Dr Carrier received a degree in mechanical engineering from Cornell University in 1901, and a doctorate degree from Lehigh University in 1935, and a doctor of science degree from Alfred University in 1942. Known widely as "The Father of Air Conditioning," he installed what is often claimed as the world's first scientifically designed air conditioning system in 1902.

In 1907, Dr Carrier and a group of his colleagues formed Carrier Air Conditioning Company of America as a subsidiary of Buffalo Forge Company. After the company became independent in 1915, he served as President until 1931, at which time he became Chairman of the Board.

Dr Carrier was associated with many "firsts" during the infant stages of air conditioning, including the design of the centrifugal refrigeration machine. Some of his notable accomplishments include the Gold Achievement Medal as a member of ASME; served as President of ASRE and ASHVE; had many patents and authored of numerous publications; member of ASRE Advisory Board and edited the first publication of Refrigerating Data Book; published "Fan Engineering" in 1914; presented paper in 1915 to ASRE entitled "Centrifugal Compression as Applied to Refrigeration" which described his work leading to the development of centrifugal refrigeration machines; presented paper to ASME entitled "Rational Psychometric Formulae," which set in place the science of air conditioning; and received the F Paul Anderson Award in 1932. He was inducted into the National Inventors Hall of Fame in 1985. Dr Willis Haviland Carrier was inducted into the ASHRAE Hall of Fame in 1994.

(Edited extract from ASHRAE "Hall of Fame" Citation)