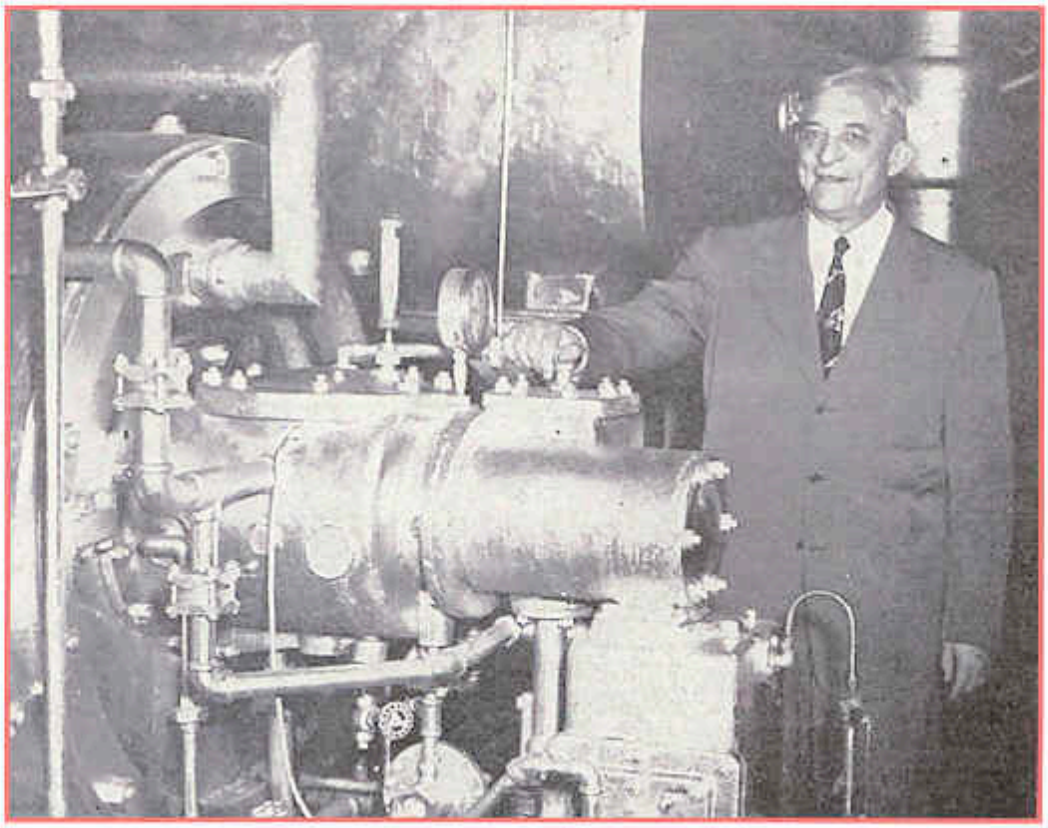
Willis Haviland Carrier

Father of Air Conditioning

VOLUME-1
Willis H Carrier: The Man and His Message



1.2 The Mature Designer of the Centrifugal Refrigeration Machine, 1911-1922

CARRIER - THE MAN AND HIS MESSAGE

CHAPTER TWO

THE MATURE DESIGNER OF THE CENTRIFUGAL REFRIGERATION MACHINE

During the period that Carrier was concentrating on the technical analysis that was to result in the formulae for the psychrometric theory, he was at the same time laying the foundations on his business career and cementing himself in a research. In November 1907 his discussions with the management of Buffalo Forge Company had resulted in papers being approved for a subsidiary company, Carrier Air Conditioning Company of America, wholly owned by the Buffalo Forge Company. The name was chosen so that if unsuccessful there would be no stigma to the name of Buffalo Forge Company. Willis Carrier was not at all averse to his name being used and he was supported in this by his friend, Irvine Lyle, who had a great belief in the young Carrier's inventive genius.

During the period 1908 to 1914 there were considerable sales by this small group of men from a figure of sixty three in 1912 the orders rose to 130 in 1914 and sytems were being installed for paper and textile mills, malt houses, department stores, hotels, pharmaceutical plants, soap, rubber and tobacco factories, candy and processed food plants, film studios, breweries, bakeries and meat packing houses.

Although these installations were revolutionary in their way, and were based on Carrier's adiabatic saturation principles and the

control of humidity, Carrier was aware that the final system would require a special type of refrigeration machine. He had long expressed his thoughts in a statement "some day I will find the means to cool water as simply as we now heat it". This was a task he set himself but obviously at this juncture he was concentrating on the estalishment of this subsidiary company and ensuring that the installations were a success.

In 1914 "FAN ENGINEERING" was published by the Buffalo Forge Company, Buffalo, N.Y., edited by Richard D. Madison, under the direction of Willis H. Carrier. It was to become for many years the "bible" as a guide to design for Heating and Ventilating Engineers.

However, in 1914 the approach of World War 1 caused Buffalo Forge Company to decide to concentrate of manufacture and let all the staff of Carrier Air Conditioning Company go, except J. I. Lyle. Carrier himself was an employee of Buffalo Forge. This decision started a chain of reaction and resulted in a conference between Willis Carrier and some of his friends and they finally decided to band together and go it alone. // They did so amicably and without discord with Buffalo Forge Company and on June 26th 1914 these seven young engineers banded to - gether to start Carrier Engineering Corporation. Carrier was President of the new Company, J. I. Lyle Treasurer and General Manager, A. B. Stacey, E. T. Murphy, L. Logan Lewis and E. P. Heckel completed the team. Charles J. Staples (of the Buffalo Law Firm of Mitchell & Staples) was Carrier's friend and Legal Advisor. // Agreements was to hold an equal number of shares of stock and to have equal authority, each pledging never to attempt to usurp power from the other. It is in - teresting to note that no reference to the agreement was made until 1930 when mergers were being considered with two other companies and then no copy of that original agreement could be made, so it had to be set out from memory in order to be can -

celled.

It was decided that a capital of about $35,000 would be re - quired and although Carrier always looked on J. I. Lyle as the business partner and would always defer to J. I. on all matters concerning the running of the business at this time neither of them had any financial knowledge, nor could they think up how they were going to raise the money when they themselves personally had no capital, nor had any of the other seven engineers. However, Staples who became Secretary of the Company and their lawyer from the outset made himself re - sponsible for raising the cash on which Carrier Corporation started and this had total stock subscriptions of $32,600. It is again interesting to note that no new capital was brought into the Company until 1927. Meanwhile Staples was helpful in getting Carrier Engineering Corporation their first job which was the Government job for fuse drying. This was definitely a break through in the explosives field.

With the technical responsibility for the new company and the requirement to keep the business afloat Carrier was working in his usual concentrated manner and significantly his absorption in his problems was associated with his apparent forgetfulness which again can be interpreted as his neglect of some details whilst concentrating on important ones. This often meant that he failed to have his meals, or to recognise time , or to even be aware of other people and their connections with him whilst he absorbed his whole intellect on the problem that was upper - most in his mind. He was only too aware that the methods of refrigeration used throughout the world at that time were not

suitable for his new invention of air conditioning. Basically the type of compressors available though suitable for factories would not be particularly suitable for buildings in which there were a large numbers of people. Carrier had always thought of his invention of air conditioning as being of use not only in industry where it would be applicable to the control of the en - vironment in which manufactures took place, but also the control of the environment in which people lived and worked. So his concentration on a system of refrigeration that would match up to his ideas on air conditioning became a central theme of his thought and concentration. It covers a period extending from the middle of 1910 into the 1920's.

The motivation consisted primarily of a mixture of economic pressure and altruism. It seems perfectly clear that Carrier the Inventor and Lyle the General Manager saw that with a better and safer means of chilling water Carrier Engineering Corporation could greatly expand its market for Air Conditioning and add a worthwhile value to Company prestige. Although by this time air conditioning was not entirely new practically all of the plants were central station systems in which the air was pre - conditioned in an air washer or humidifier. Some cooling was done by the evaporation of some of the spray water, but the temperature to which the air could be cooled was variable and entirely dependent upon outside weather conditions. The ob - servation results showed that although the kind of air condition- ing was done entirely for the benefit of the industrial process, the small amount of incidental cooling brought a very favourable response from the workers. The control of humidity not only made the work easier but the incidental cooling was condusive

to an increase in human efficiency. This led to a simple deduction in as much as people in all walks of life objected to excesses of temperature and humidity. The additional cooling which could be obtained with refrigeration could also be a profitable investment in such as movie theatres, department stores, restaurants and many other places catering for the general public. In short there was a market for comfort cooling and it could be even greater than the market for industrial air conditioning. This was the clear fact that was behind Carrier's concentration on his investigations for a logical refrigeration machine that could be applicable to his air conditioning equipment. It will be appreciated that the air washer had been developed into a highly efficient and satisfactory means for cooling and de-humidifying air with sprays of chilled water. Other means such as cooling coils were not un-known but non had been developed to the point at which they could be considered as satisfactory. In effect Carrier was wholly dependent on the air washer but had no satisfactory means for supplying it with chilled water.

At that time refrigeration systems utilizing either ammonia or carbon dioxide were commercially available in suitable capacities. Machines using methyl chloride and sulphur dioxide were also available but only in sizes that were much too small. All these machines could be used for chilling water but the deficiencies of the entire lot where discouraging if not prohibitive.

Ammonia systems were efficient and were acceptable as calculated risks in industrial plants. Experience, however, proved that leaks were unavoidable and consequently that ammonia would con-

stitute a panic hazard which was entirely too great for places frequented by crowds of people. Carbon dioxide systems were reasonably safe inspite of the fact that mid-Summer condensing pressures would approach a hundred atmospheres. They were efficient when supplied with condenser water somewhat cooler than 70°F but suffered sever losses as water temperatures rose into the eighties. This meant that the carbon dioxide system suffered its maximum loss of efficiency a maximum loss of capaicity at the same time that the air conditioning loads reached its maximum. This disqualified it from many down - town buildings where condenser water usually had to be taken from cooling towers.

The spaces in which the several parts of ammonia systems would be safely isolated could normally be found in industrial plants but in down-town buildings the spaces were usually unavailable or prohibitively expensive.

Compressor were massive slow speed machines either driven directly by Corliss engines or connected to electric motors by means of cumbersome leather belts. Condensers usually consisted of one and a quarter and two inch pipes, concentrically assembled in such a manner that the cooling water could be forced through the inner pipe and the refrigerant condensed in the annular space between the two. They were usually built in stands twelve pipes high by twenty feet long. Assembled on 15-18inch centres they could be placed on a roof top or in some interior space.

The water chilling coils were of the Baudelot type in which the water was flooded over vertical stands of 2 inch galvanised pipe. Normally they were placed in a shallow collecting tank and en -

closed in an insulated chamber.

Carbon dioxide systems were similar but actually required some - what less space in as much as the cooling coils could be located within the spray chamber of the washer. But nevertheless its requirements for space were also excessive.

The problem of getting the chilled water to and from the de - humidifier and the cooling coils could be either fairly simple or rather complex. If there was only one de-humidifier and it was elevated above the cooling coil, controlling the water level in both tanks was not difficult. But if there were several de-humidifiers at various levels, the problem of getting it from one open tank to another could be a tough one. And floods could be costly as the rates of flow frequently ran into hundreds of gallons per minute.

While ammonia compressors andcondensers could be remotely located and well isolated this water circulation made isolation of the cooling coils quite impractical. If a leak developed in the Baudelot chamber, the ammonia vapour would be absorbed by the chilled water and then released to the air in the spray chamber of the dehumidifier. This was an acceptable risk in industrial plants, in as much as the build up and release might be slow enough to give ample warning of impending danger - but was to - tally unacceptable in public buildings and on tope of it all both systems had operating characteristics which were quite un- suitable for air conditioning duty. They had been developed primarily for such duties as chilling brine and ice freezing tanks, holding sub-freezing temperatures in cold storage ware- houses and other similar applications. Most of these loads were quite steady and most of the systems were under the close

supervision of skilled operating engineers - whereas the air conditioning load was a volatile one, changing rapidly from hour to hour day to day. The one did not require much attention but the other demanded frequent readjustment to expansion valves and compressors rps, not to mention readjustment to the conservation of condenser water. // Carrier Engineering Corporation had, with the co-operation of the manufacturers thereof, adapted standard ammonia equipment to air conditioning duty. The results were good but in principle the practice was an expedient utilization of machinery that had been designed primarily from an entirely different kind of duty.

In brief air conditioning was developing rapidly in the Industrial Field and was ready to advance in the Comfort Field but was being held up both by lagging refrigeration. As Carrier said "the refrigeration art had made little technical progress except in its application. The same refrigerating machines and the same refrigerants were those that had been in use for fifty years ". In 1916 he had reached the conclusion "that if the air conditioning art was to advance existing practices in refrigeration would have to be completely abandoned and a new method developed". He considered that if any great advances in refrigeration were to be made, someone outside of that industry would have to take the initiative. // At about this time 1916-1917 an upsurge in experience with ammonia systems in World War 1 munitions plans began to clarify the picture. Carrier considered that the machine that would be ideal for air conditioning should be capable of chilling water in a closed circuit, should be simple, relatively fullproof, easy to operate and above all it should be perfectly safe for Comfort Cooling in spaces that would be crowded with people.

Carrier spent several years of mulling these ideas in mind in order to develop a specific concept, or at least to put it in writing. An early record consists of a memo of about 3,500 words on the subject of "Development Possibilities for Improvement in Refrigeration". Carrier set himself the task as in his words "someday I'll find a means to cool water as simply as we now heat it" !

In this memo Carrier described the ideal machine as one which would embody six major features: 1) the compressor should be rotary, and if possible adapted to direct connection to standard motors or turbine. 2) The compressor should be non-positive in effect. With this effect to be obtained indirectly by means of a special by-pass relief or indirectly by means of a centrifugal type. 3) A refrigerant with suitable charact - eristics and commercial availability should be found. 4) The refrigerant should have no corrosive effect on non-ferrous metals such as brass, copper or solder. 5) The design of the condenser should be similar to the design of standard steam condensers. 6) The water coolers should be of the close circuit type and similar to the condenser or a feed water heater.

At this time Carrier forumulated proposals for development of two machines one was to use a Nash "hydro-compressor" to have a capacity of 25 tons or less, the other was to use a centrifugal compressor with a capacity of 50 tons or more. As the Carrier Engineering Corporation had developed by 1919 a department of Research and Development had been organised by A. E. Stacey and it was asked to initiate a search for a refrigerant to obtain and test the compressor and to help devise an evaporator all according to Carrier's instructions.

The search for a chemical compound which would meet his specifications for a refrigerant began with an examination of chemical dictionaries catalogues and similar publications and was carried on by correspondence with various chemical manufacturers at home and abroad. This led to the consideration of various compounds and incidentally uncovered the first traces of dielene as one of the possibilities. A Nash hydro-compressor was obtained and tested. Carbon tetrachloride was used in as much as it was immediately available and had properties quite similar to those of dielene.

These initial research and development projects were abandoned when Carrier made a shift from the small machine to the large one and the canvas of domestic manufacturers revealed two potential sources who would be interested in designing a centrifugal compressor, but both prompty disqualified themselves. One stated bluntly that he was not interested and the other wanted $10,000 for a compressor that was soon to be purchased for less than $900. Carrier could have applied his past experience to the design of one and the company could have built one as it did eventually, but unfortunately it was decided that such a move should be postponed indefinitely. The other components of the machine would present so many strange problems that not enough time or money would be left for work on a compressor.

Since previous correspondence on both these matters pointed towards Europe, Carrier sailed on April 10th, 1921, ostensibly for a vacation. He went to Switzerland first and promptly made two discoveries: First, that centrifugal compressors had been developed and were in use for compressing various gasses including ammonia; and second, that the Swiss were much too in-

terested in why he wanted one and what he was going to do with it. This was fortunate because it speeded his move into Germany and brought an end to the research for both refrigerant and compressor. Through a follow-up of correspondence, he found that Dielene (Dichloroethylen $C_2H_2Cl_2$) was being manu - factured there and in quantity for, of all things, a solvent for dry cleaning clothing; also that the C. H. Jaeger Company of Leipsig was manufacturing a suitable line of compressors, and was willing to co-operate without a disturbing inquisitive- ness about end uses.

Carrier put the two together and decided to proceed. The avail- ability of Dielene seemed to be well assured by its own local market. It had never been used as a refrigerant, but the meagre data that was available indicated that it would meet his specifi- cations. The volume of the vapour and the ratio of compression were suitable for centrifugal compression; molecular weight was favourably high; boiling point was suitable low; and it was non-toxic and sufficiently nonflammable to be safe. Enough was known about its properties to enable him to make a fairly good guess at the size and type of compressor.

Dielene was indeed a low pressure refrigerant: So low, in fact, that the pressure throughout the entire cycle would be con - siderably below atmospheric - and this, in itself, presented a new requirement: the inward leakage of air around a shaft turn- ing at 3500 to 4000 rpm would have to be reduced to an absolute minimum.

Carrier's solution was to make arrangements with the Jaeger Company for three modifications in their standard: One was the simple

matters of enlarging the casing of the compressor so that the outboard bearing would be completely enclosed; the second was the substitution of a special seal for the standard stuffing box; the third was a forced-feed lubricating system to supply oil to the seal and to the enclosed bearing.

These alterations were planned by Carrier with the head of Jaeger's Engineering Department during the several months which he spend in Germany. Then with blueprints of the compressor and specimens of Dielene, he returned to the U.S.A. to undertake the design of the other components of the experimental machine. During this visit he had also met up with Dr. Klein, with whom he developed a great friendship and whose poem concludes this chapter.

THE FIRST CENTRIFUGAL REFRIGERATING MACHINE was unveiled on May 22nd, 1922, following the decision to manufacture rather than to license the First Commercial Model.

Before that could be done, he knew how much vapour the compressor would handle, but had only an approximate idea of its latent heat - and, without that, he could not be reasonably sure of what its refrigerating capacity would be - and, consequently, how much heat transfer surface to pur in the condenser and the evaporator.

Accordingly, his first step was to determine the latent heat of Dielene. And, to make assurance doubly sure, he and Stacey made independent tests, each employing a somewhat different technique. The idea was a good one; but in the end, their results had to be reconciled by a compromise, and the machine designed on an approximation.

The first commercial sale of a centrifugal refrigerating machine was to Stephen F. Whitman and Sons of Philadephia and during the period 1922 - 1924, NINE centrifugal machines were sold.

The first machine, unveiled on May 22nd, 1922, was used for experiments and demonstration for about two years and then sold to the Onondayer Pottery Company in 1924 where it gave 26 years of regular service in air conditioning their Syracuse China Plant.

This whole story reveals the maturity that was developing in the character of Carrier, The Young Inventor.

By 1925, the Rivoli Theatre in New York had been air conditioned with Centrifugal Refrigeration and, in that same year, Carrier had designed the system for the Ice-making rink at the new Madison Square Garden in New York.

In 1927, Willis H. Carrier was elected President of the American Society of Refrigeration Engineers.

During the years of development of the first Carrier Centrifugal Machines, two important business decisions were made by the Chief. As already mentioned his investigations into the European field led him to meet Dr. Klein, whose ejector nozzle patent was to form the basis of many drying systems including the enormous paint drying ovens in the automobile industry. This meeting with Dr. Klein progressed and eventuated in the formation of Carrier Lefttechnische Gesellschaft - later the Carrier was to be dropped and the company in Stuttgart became familiarly known as L.T.G. and a substantial business was

created.

And during a stopover in London, Carrier had met up with Stanley L. Groom, a young English engineer already representing Buffalo Forge in fans and heaters. The friendship and respect that developed between Carrier and Groom resulted in their fifty fifty partnership in the British Company, Carrier Engineering Company Limited of London which had its first Board Meeting in March 1921. This partnership also produced Carrier Continentale in France and the technical support of these companies was the free use of the Carrier patents and know-how. Events, which changed these associations, were, however, to come in the future and will be dealt with in another chapter.

The Chief's attachment to London is illustrated by his election as a Fellow of the Royal Society for the Encouragement of Arts, Manufacture and Science in 1923, remaining a fellow all his life.

The way in which Willis H. Carrier inspired men of the ability of Dr. Albert Klein and Stanley L. Groom to follow his technical lead into the new business venture of Air Conditioning is another example of his capacity for working with men and obtaining their admiration respect and loyalty.