Willis Haviland Carrier

Father of Air Conditioning

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

18 A World War II Inventor
-The Cleveland Wind Tunnel, 1940-1945

CARRIER, THE MAN AND HIS MESSAGE

CHAPTER EIGHT

Carrier as a World War 11 Inventor

Although Carrier had scaled many scientific development peaks in his search for engineering truth, always dedicating himself to solve some immediate problem that arose from his own ideas, he himself referred to the world war 11 peak as the impossible. In his words; "Once, I accomplished the impossible. That is the task seemed impossible when I first tackled it."

The task arose out of the requirement by the National Advisory Committee for Aeronautics (N.A.C.A.) In 1940, N.A.C.A. proposed a wind tunnel at Cleveland Ohio designed to stimulate freezing high-altitude conditions for the testing of proto - type planes. In the wind tunnel complete engine assembly and propellers were to be tested under flying conditions. This necessitated a vital air conditioning and refrigerating system, the basic details of which would have to be designed from scratch. Ten million cubic feet of air per minute had to be cooled to a temperature of 67 degrees F below zero. Carrier backed his centrifugal machines for the project and was convinced that special coils would have to be designed to fit into the space available.

Once the financial expenditures were agreed by Congress, Government engineers drew up plans and specifications for an experimental cooling coil using stream line tubes (coils of aeronamic design. Carrier was not convinced by their approach to the problem but had to prove it and set up his own experimental work based on his own ideas of the coil design.

So you had two sets of experimental work on the same project. Those who were working with Carrier and were responsible for the enquiry negotiations were often alarmed at the vehemence of the Chief's rejection of the government engineers' work on the streamline tubes but Carrier was adamant that his reasoning was correct, that the experiments on the streamline tubes were a waste of time and that if there was any doubt in anyone's minds then "heat transfer experts should be called in" to avoid further loss of time and money.

Meanwhile Carrier concentrated on his own recommendations for the cooling coil and its design for the wind tunnel. This involved research on the refrigerating system as well as on the cooling coils. Freon - 12 specified as the refrigerand had never been used in any sizeable system to reach minus 67° and so tests on the refrigerant itself were required. It was also necessary to devise a way to ensure vaporization of the refrigerant throughout the full length of the cooling coil.

Carrier calculated a direct expansion coil with a face area of approximately 8000 square feet. The wind tunnel, 51 feet in diameter, had only 2000 square feet of cross-sectional area. Carrier's answer was to fold the sections down "like a collapsed accordion" until the coils fitted into the tunnel. Experiments on a minature wind tunnel showed Carrier that the vaporization of the refrigerant could be achieved by distributing the refrigerant in such quantities and such pressures that there would be an excess of liquid for each tube. The redesign of the centrifugal compressor Freon - 12 was completed by January 1942. Fourteen 1,500 horsepower refrigerating machines, in addition

to maintaing conditions of air simulating altitude up to 30,000 feet, had to cool fifty pounds of gasoline per minute for the engines, cool the make-up air to the tunnel, chill water, and refrigerate the coils for an icing tunnel located nearby when the wind tunnel was shut down. Carrier's ideas proved acceptable and in March 1942 the Carrier Corporation were awarded contracts for both the cooling coils and the refrigerating system.

There followed a most intensive period of planning and checking to guard against any failure especially as many new were involved any one of which could cause failure of the whole system. Valves were researched and built by Carrier's engineers, expansion joints for 36 inch diameter pipes had to be originated, tested and manufactured. The Chief was so wrapped up in the problems that he continued to discuss a particular point of design unaware of the fact that the project engineer who had been sitting opposite him had excused himself and someone completely different on a completely different project had taken his place.

It was as well that this particular peak had so fascinated the Chief at this period. He was utterly immersed in his inimitable way in obtaining solutions to the problems. In June of that year, 1942 J. Irvine Lyle died, aged 68 years. Lyle and Carrier had been friends and partners for more than forty years - colleagues at Buffalo Forge - joint collaborators in the first air conditioning ventures - companions in every sense of the word as they faced up to the many decisions that traced the growth and development of their air conditioning industry.

Alike in their dedication to truth and honesty of purpose, complimentary in their capabilities - Lyle, the administrator, Carrier, the engineer - each always acknowledged the other's superiority and never interfered with any decision made, though often such decisions whether of a financial nature or anengineering involvement were the subject of intense dis - cussion. Lyle's death resulted in Cloud Wampler becoming President and he was to prove the right man for the post war developments, so that the growth of the Corporation could continue under a new leader. To the Chief, Lyle's death was a great blow and if it were possible he immersed himself more than ever into the problems of the equipment for the N.A.C.A. wind tunnel and there were many difficulties to be surmounted; false starts increased the time factor so that more than a year passed before the entire tunnel was ready in April 1944 for the formal run-in test.

I think that there can be no better way of expressing this particular work of Carrier than by quoting from a letter written by J. O. Jackson, Vice-President Engineering and Research Pittsburgh Des Moines Company who had been particularly familiar with the whole N.A.C.A. Cleveland wind tunnel overall project:-

"One of the outstanding contributions to the winning of World War 11 was the five million dollar high altitude engine testing wind tunnel at the Cleveland Laboratory of the National Advisory Committee for Aeronautics. This wind tunnel was the only one in existence capable of testing the operation of engines and pro - pellers in an atmosphere simulating the actual operation of an airplane at altitudes up to 50,000 ft. The velocity of the

tunnel can be controlled at speeds up to the speed of sound. The temperature can be controlled from plus 125°F to minus 67°F, and the desnity of the air can be regulated to from atmospheric pressure to 3.43 in. of mercury, corresponding to an altitude of 50,000 ft. The test section of the tunnel is 20 ft. in diameter and may be quickly isolated from the remainder of the circuit for making model changes. The tunnel is arranged to remove a core of air, including the combustion products of an engine operating in the test section; and equipment is provided to replace the air removed with pure air, dried and cooled to the operating conditions of the tunnel. Balance systems are provided for making complete measurements of model forces during operation."

"The design and construction of this tunnel required equipment beyond the capacity and limitations of any that had been previously used. The completed tunnel includes the largest air drier which had ever been built. The tunnel also involves the largest refrigeration plant ever built, both in terms of tonnage of refrigeration and the very low temperature level involved."

"The circulating air in the tunnel is driven through banks of finned copper cooling coiles, 7,650 square feet of surface area, which by conduction through the heat transfer surfaces cools the air to as low as minus 43°F. Adiabatic expansion in the throat further cools the air in the test section to temperatures corresponding to that of the upper stratosphere. The heat exchanger and refrigeration eqiupment for the tunnel and the auxiliary coils was furnished by the Carrier Corporation. Six thousand five hundred tons of refrigeration was accomplished with fourteen 4-stage centrigual compressors, each driven by a 1,500 horsepower motor with speed increasers from 1,700 rpm

to 6,700 rpm. Freon-12 is used in the direct expansion system as a refrigerant and operates at partial vacuum, entering the compressors at 100 psi in the condensers. Fuel for the operating model is cooled by an intercooler from this system.

The refrigerant and cooling system for this tunnel were far beyond anything which had previously been built. Dr. Carrier desiged special 4-stage compressors to compress the Freon-12 refrigerant used in the system. He also created the novel design of the condensers used with each refrigeration unit, which made the installation compact and give it the required flexibility to operate under the many specified conditions of temperature and pressure.

No cooling coils had ever been designed for use in a wind tunnel of this kind, and Dr. Carrier outlined the required research work to determine the proper construction of the cooling coils, that is, the tube size, the tube area, the tube spacing, the plate size and spacing, the metal thickness, and general design to meet the extreme requirements of temperature and time, and size to provide storage space in the coils themselves for the water to be removed from the tunnel air during the specified operating periods. The cooling coils themselves are an immense structure, the equivalent of a six story building in height, with complicated piping arranged like the branches of a tree to feed the refrigerant uniformly to all parts of the coil.

Dr. Carrier's designs have been fully justified by the operating results of the tunnel. It has performed within the prescribed limits of the specifications. This tunnel is

credited with the perfection of the multirow aircraft engine which made the B-29 possible, and which was one of the most important factors in the winning of both European and the Asiatic wars. Since that pioneering work, the tunnel has been almost exclusively engaged in the perfection of turbo-jet engines and has contributed much to the continually in - creasing efficiency and length of flight of jet propelled planes."

"As the designer of this complete wind tunnel installation, it is my opinion that Dr. Carrier's contribution to this project was of outstanding importance and represents a very great technical advance in the art of low temperature refrigeration, which was soundly conceived and brilliantly executed with the result that there was provided a new type of wind tunnel not previously available, just in time for the important type of high altitude aviation research required to make the high flying planes of World War II practical."