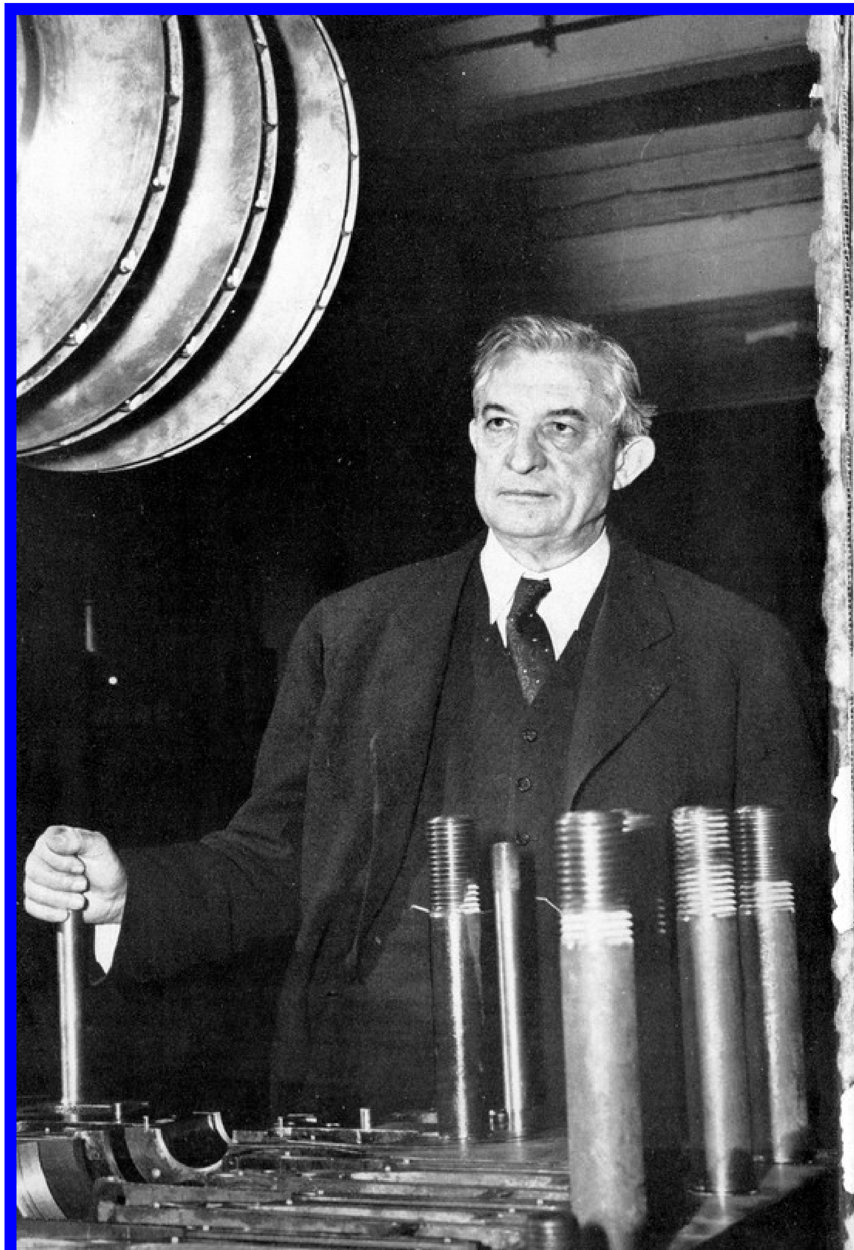

WILLIS HAVILAND CARRIER

Father of Air Conditioning

by Margaret Ingels

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VIII

WHEN Willis Carrier first recognized the inadequacy of existing refrigerating machines, he was not able to tackle the problem immediately. He carried it with him several years, thinking about it on trains and at meals, once talking about it for an hour or more while standing in the rain with Murphy on a New York City street corner. As was characteristic of him, he had seen a need and evaluated what its solution would mean to engineers, to industry, and to business. Had his assay been less promising, he would have discarded the idea and proceeded no further with it. He described this pattern of action with these words: "I fish only for edible fish, and hunt only for edible game—even in the laboratory."

Carrier also had the characteristic of undertaking so many projects that he had insufficient time for all of them. But though he often postponed action on a problem, he never abandoned one that promised to be worth-while. A psychologist might argue that his carrying a problem around in his head for years, letting it simmer, may actually have facilitated his discovering a solution.

In any event, some time after sensing the need for an improved refrigerating machine he tried to interest existing manufacturers in improving their apparatus. When he informed one of these that the Baudelot coil was the most "unmechanical" piece of equipment in the entire system, the answer was, "It's

the best we can do." Carrier said, "Some day I'll find a means to cool water as simply as we now heat it." Two years later, in June of 1920, Carrier had his thoughts on paper, in an eleven-page memorandum which Lyle passed on to the company's senior engineers with a most unusual injunction: "Please see that no one but you reads the attached discussion, and return it to me as soon as you have read it." The memorandum, titled "Development Possibilities for Improvement in Refrigeration," told of plans for a new type of machine. Carrier wrote:

> The entire system of electric transmission has been developed from nothing to an enormous industry with relatively simple motors that are high-speed rotative equipment. Industry has gone from low-speed reciprocating steam engines to high-speed rotative turbines. Pumping machinery is rapidly changing from reciprocating types to high-speed rotative pumps for both liquids and gases. Modern power plants have installed high-speed, direct-connected, centrifugal, boiler-feed pumps almost exclusively in replacing the old type of steam-driven reciprocating machines.
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> Refrigeration, though classed among the older mechanical arts, has shown no such material progress. The same improvements that have taken place in electrical transmission and in steam machines and pumps must come in refrigerating machines.

Carrier then visualized the improvement to come: a refrigerating machine with a centrifugal compressor and direct drive suitable for the same high operating speed; the heat exchangers —compact, simple, effective, and low cost in comparison with the cumbersome equipment then used; and new refrigerants—non-toxic and having characteristics adaptable for operation with radically improved mechanical equipment. The memorandum of 1920 was a perfect example of Carrier's lifelong practice of analyzing a problem before taking action, building experimental equipment, and conducting tests.

In this preliminary stage Carrier and Lyle were compelled to consider a number of questions: whether the machine, when invented, should be built by others for their company to sell, and if so, how the company would then fare in the highly competitive refrigerating market—or whether their company should build the machine itself despite lack of experience in manufacturing. Carrier said:

> No matter what answer we reached, we were taking a chance on losing all we had built up over the years. But Lyle was willing to take the chance. We decided not to answer the question definitely until designs were better formulated. I marvel at the faith Irvine had in me even when my ideas approached the revolutionary in engineering thinking at the time.

To obtain experimental equipment with the least expenditure, Carrier considered existing rotary pumps and centrifugal compressors. Meanwhile he studied refrigerants, as the success of one depended upon the selection of the other. He later said:

> All I knew at the time was that I wanted a liquid with a high boiling point, around 110 degrees F, so I'd not have to employ high pressures or excessive vacuums in compressing the gas. I also knew I wanted a gas with as high a molecular weight as I could find, to keep the number of stages of compression to a minimum.
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> The refrigerants in general use were not practical for my purpose. Ammonia would require many stages for centrifugal compression, and carbon dioxide more than I wanted to use. Pressure requirements for ammonia and carbon dioxide also ruled them out of my considerations. I had no choice but to find something new.

Carrier began combing a chemical dictionary for chemicals that met his specifications. He discarded sulphur dioxide, since disaster could follow if leaks occurred. He considered carbon tetrachloride but decided against it because it attacked metals, especially in the presence of water. In obtaining additional data on carbon tetrachloride, Carrier turned to a chemical textbook—presumably "General and Industrial Inorganic Chemistry" by Dr. Ettore Molinari—and there learned about dielene—$C_2H_2Cl_2$. He decided this was it, with the final decision contingent, of course, on exact knowledge of its chemical characteristics and physical properties. Dielene was not manufactured in the United States but the textbook mentioned a firm in Geneva as a source of supply. Carrier said:

> It looked as if dielene might be hard to get, but we determined to try it. When I wrote to the firm in Switzerland, the company informed me that dielene was manufactured in Germany and in industrial quantities, as it was used there as a cleaning fluid. Being manufactured in commercial quantities was certainly an advantage to us for it should be less costly than if produced for laboratory purposes only.

With the refrigerant tentatively selected, Carrier drew up specifications for the centrifugal compressor based on a capacity rating of fifty tons—a ton of refrigeration producing a cooling effect equivalent to the melting of a ton of ice during twenty-four hours. He then asked two American manufacturers to quote prices on building the unit. One quoted a price so high it would forbid competition with reciprocating machines then on the market. The other was not interested at all. Carrier said:

> I felt, as Carrier Engineering Corporation was basically an engineering and contracting firm, we did not have the necessary experience to become manufacturers, especially of heavy machinery where each part represented big money

to us at that time. But, when we could not interest a refrigeration manufacturer in building our machines, we had to build them ourselves. That was what Irvine Lyle wanted all the time. He felt we could build them—and with a profit.

Lyle began looking around for a factory with a modest size manufacturing area and sufficient office space to house the company's headquarters. Late in 1920 he found such a building at 750 Frelinghuysen Avenue, Newark, New Jersey. It was what he wanted, the price was right, and Lyle could have closed the deal immediately. Instead, Lyle followed a course which Carrier later described as follows:

> When Irvine Lyle and I began our talks about centrifugal refrigerating machines, our engineering force totaled about thirty. We were like a closely knit family, and Irvine was like a father to most of the men. All of their personal problems, financial and otherwise, gravitated to his office. He always lent a sympathetic ear, and he would try to straighten things out for them. The close relationships worked both ways. When we wondered whether to expand our activities—that is, go into manufacturing centrifugal refrigerating machines—Lyle said, "Let's ask the engineers."
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> We had our annual meeting at the Old Fort Comfort Inn, Piedmont-on-the-Hudson, that year. After a dinner, Lyle told the men about our chance to buy a plant in Newark, of the amount of money involved—which was a lot for us, a small company—and of the risks we would be taking. He then called for comments. Everyone had a lot to say. All angles were discussed with vehemence. No one was timid about speaking up. When a vote was taken, it was overwhelmingly in favor of buying the plant.

The annual meeting took place early in January of 1921. The plant was purchased on March 10 and was occupied in May. Meanwhile in February, March, and April, patent claims were filed on the centrifugal refrigerating system which were finally issued in 1926: patents Nos. 1,575,817, 1,575,818, and 1,575,819. Carrier could not secure a basic patent on centrifugal compression of refrigerants because in 1913 Maurice Leblanc, a French engineer, had invented a four-stage compression machine using water vapor as the refrigerant—a machine which never got beyond the experimental stage. Carrier later explained:

> Since I could not get a basic patent, I decided to file claims for inventing a refrigerating machine using centrifugal compression. I tried to anticipate every possible patentable feature and cover them all in my claims as the inventor of the machine.

Carrier went to Europe in the late spring of 1921, ostensibly for pleasure, actually to get a manufacturer to build a centrifugal compressor to his specifications. When he called on one company in Switzerland and told the engineers what he wanted, they became so interested—"the type that would pick your brains"—that he picked up his papers and left in a hurry. He had a second Swiss company on his list but he figured their engineers might also be curious. So he went on to Germany and there arranged for the Leipzig firm of C. H. Jaeger & Company to build a compressor at less than one-sixth the price quoted by the American manufacturer. In Germany Carrier also located a dielene manufacturer and ordered two drums. In England he helped complete the organization of Carrier Engineering Company, Ltd., of England, and then returned to America. Here he found his company settled in new quarters, planning to expand into manufacturing, with everything staked on the Carrier centrifugal refrigerating machine, although it was not far beyond the drawing-board stage.

Tests, calculations, and then the design and construction of the condenser and cooler followed. The compressor arrived from Germany early in 1922. The completely assembled machine was put under tests with run-ins, alterations, more run-ins, and still more alterations. Carrier and Lyle became so confident that they set May 22, 1922, as the date for unveiling the machine. They invited three hundred engineers to have dinner at the plant and witness the ceremony. As an added attraction, they scheduled two boxing matches by local amateurs. Years later Carrier gave the following account of that historic event:

> When the day of the unveiling arrived, we had turned the machine over but we had not run it under load conditions. We did not have steam in our factory for the turbine, so we borrowed it from our next-door neighbor. By the time the steam reached us it was sufficient to run the machine when idling, but not to run it with the cooling load. By noon we had checked the steam line and fixed a leak. We started up the machine, using it to chill the water for our air conditioning system. When the guests arrived, our offices were cool and comfortable—and it was a hot day.

Following dinner in the center of the sheet-metal shop, the guests were addressed by Carrier on the development of the machine. He described the principles involved, and was explaining that the guests would later see the machine itself in the adjoining room, when a loud and continuous noise began coming from that room.

> It was terrible when I heard that long, loud, rumbling, slowly diminishing b-r-r-r-r. I visualized the rotor of the compressor tearing itself to pieces. Beads of perspiration came out on my forehead and my hands were soaking wet. But I kept right on talking, trying to act as if nothing had happened. Irvine, sitting near the back, casually left the room with an air of calmness I knew he did not feel. Directly, he came back and signaled to me that all was okay. Later he told me the cause of the noise. In arranging the space for the boxing matches, one of our men pulled a large metal dining table across a rough concrete floor. No sound effects man could have done any better in imitating the disintegration of a rotative machine.

Thus was introduced the first major advance in mechanical refrigeration since David Boyle designed the original ammonia compressor in 1872. On March 26, 1923 the first sale of centrifugal refrigerating machines was made to Stephen F. Whitman and Sons of Philadelphia. This candy manufacturer bought three of them. A month later the second sale was made—to Wm. F. Schrafft and Sons of Boston. By the end of 1924 nine machines had been sold, including the experimental apparatus which was purchased by the Onondaga Pottery Company of Syracuse, New York. Twenty-eight years later this first machine is still serving a commercial purpose, cooling 238 gallons of water a minute to condition air in the pottery's lithographing plant.

When each machine was installed, Carrier operated it as test apparatus during the run-in periods. Each test brought modifications and changes, including more reliable means for removing air from the system and more complete elimination of moisture and foreign elements from the inner chambers. By the end of 1924 he decided a major change was needed in the design of the seal—the mechanism which, while preventing the refrigerant from leaking out where the drive shaft enters the unit, still permits free well-lubricated rotation of the shaft.

Carrier sent the German manufacturers instructions to separate the thrust and seal and suggested how to do it. When it came time for factory tests, he went to Germany to try out the new idea, but the seal did not operate as he had hoped. There in

Leipzig in early 1925, he worked day and night until one evening in his hotel room it came to him. He said:

> It was so simple I didn't know why I had not thought of it sooner. I put a valve, a sort of "doodad," in the oil line so that, as the compressor started up and the rotor moved axially toward the thrust end, the valve opened a little to let the oil through—a little oil at first and, as the speed picked up, the valve opened more, letting more oil through.

The "doodad" was a "restriction disc," thereafter installed on all compressors built to use dielene, and was not changed until a new refrigerant, Carrene 1, was adopted for the centrifugal machines.

Meanwhile, working with Lawrence C. Soule, Carrier had helped perfect lightweight finned coils, which presented a larger surface for heating, cooling, or dehumidifying air.

> Irvine Lyle worked out a wonderful plan. He reasoned that, if we built the coils for our air conditioning contracts exclusively, the sales would be much less than if we built them for the entire fan-heating industry. He proposed forming a sales organization made up of fan companies. As a result, Aerofin Corporation was founded in 1923. The company sells finned-tube coils. Our company manufactures them. Irvine's plan was a stroke of business genius and everybody concerned profited, including the customer.

IX

THE Carrier centrifugal refrigerating machine opened vast new fields to air conditioning. Prior to its introduction industrial plants comprised air conditioning's main market; most installations were made to condition air for products and processes, not for persons. The first sales of centrifugal machines to candy manufacturers and the like helped the company financially and enabled its engineers to develop refinements and improvements. But the sales represented no entry into the practically untouched market which Carrier, Lyle, and associates had visualized—comfort air conditioning.

The door to this market was partially opened in 1924 when Irvine Lyle made the first "comfort job" sale of the centrifugal refrigerating system to the J. L. Hudson Company department store in Detroit. This store had found that on bargain days the ventilating system in its basement was of little help. Temperatures soared; customers fainted. The manager feared he would have to discontinue bargain sales unless he could keep temperatures down when the crowds poured in. Lyle persuaded him to install an air conditioning system using three centrifugal machines, each of 195 tons capacity. The result was a cool basement, increased sales, and in a few years the extension of air conditioning to other floors. This was the first air conditioning installation in the department store field and it began a relationship which has continued through the years.

The real opening of the "comfort" market came, however, when centrifugal systems were introduced into motion-picture theaters. Carrier later said:

> Movies closed during hot weather or showed to such small audiences that they operated at a loss. Even on cool days the inside of the theater was hot if there were many people in the audience. The heat from the people was enormous. A ventilating system did not help much. We argued that, with air conditioning, the theater need never be dark and would do a box-office business in summer because people would go there to cool off—to be comfortable. With our air conditioning, we believed we could sell the theater market without much resistance.

So, with Carrier and Lyle encouraging them, the company's sales engineers began concentrating on theater owners. The engineers not only had Carrier's new, safe, and simple refrigerating system, but also a method for introducing cleaned, cooled, and dehumidified air into a theater, without causing drafts or cold feet. This no-draft feature was achieved through a system of by-pass down-draft air distribution which Logan Lewis had designed in 1922 for Grauman's Metropolitan Theater in Los Angeles. Designed, sold, and installed before Carrier's centrifugal refrigerating machine was available, this installation used a carbon dioxide refrigerating system to cool the air. The air flowed through outlets located in the ceiling, diffused slowly downward, then entered return grilles located in the floor. Thus, Lewis accomplished the seemingly impossible feat of circulating a large volume of cooled and dehumidified air without the audience being aware of any air movement. This has caused many persons to refer to Grauman's Metropolitan Theater as "the birthplace of theater air conditioning." However, the crucial test of theater air conditioning, and one of the most decisive moments in all

air conditioning history, was to come at the New York Rivoli Theater in 1925.

This test was preceded and to some degree produced by air conditioning sales to three Texas theaters owned by Will Horwitz, Jr.—the Palace in Dallas and the Texan and Iris in Houston. In the Palace Theater between June and August of 1924, Carrier's centrifugal refrigerating apparatus was installed for the first time in any theater, combined with Lewis's by-pass down-draft system. The theater advertised "cool and clear" weather and a consulting engineer on the job later reported that "as proof that it was easy to operate, the man who had previously been a sort of janitor was taught to run this unit and did it well."

In Houston the two Horwitz theaters were cooled by one large centrifugal machine, located in the Texan. Chilled water was pumped to a storage tank in the Iris across the street. Horwitz wrote:

> The cooling plant is revolutionizing picture show attendance in Houston. Each patron exclaims with delight when he gets inside the doorway. The plant is working perfectly. Our engineer says he has nothing to do on the job but loaf.

Word of the Texas installations spread. The Rivoli in New York decided to discard its ventilating system and install air conditioning. On November 20, 1924, the Rivoli contracted for a 133-ton machine and the Carrier Engineering Corporation was faced with a critical test. The company's whole future in theater air conditioning was at stake. To be sure nothing was overlooked that would affect results, Carrier himself and the company's top engineers all worked on the job, drawing up layouts, checking, and re-checking—aiming at the finest comfort air conditioning system that could be designed.

Meanwhile, it developed that the New York City Building Code barred this type of installation because dielene was not listed as an approved refrigerant. In fact, it was not listed at all. The Carrier engineers undertook to get a permit. They called on the safety chief, told him of fifteen machines then in operation, all with no-accident records, showed him reports from independent consulting chemists and engineers who had run three types of tests on dielene. The safety chief was unconvinced. Later Carrier said:

> I then tried an experiment. Right in his office I poured some dielene into a container and dropped a lighted match in it. Well!—the safety chief got mad—and scared, too, I think. He said if we were going to try such stunts, we would have to go elsewhere. All the while the dielene burned downward very slowly, no flare-up, no explosion. Finally he was sufficiently convinced that dielene was safe, and granted the permit with the stipulation to isolate the machine and take many precautions beyond the code requirements.

The Rivoli was scheduled to open on Memorial Day in 1925. Partly because of the delay in getting a permit, there was difficulty in meeting the deadline. Carrier and three other top men stayed up practically the whole night of May 29 seeing that everything was set up and ready to go. An unsigned, undated memorandum in Carrier's files, presumably written by him, records:

> Typical of show business, the opening of the Rivoli was widely advertised and its air conditioning system heralded along Broadway. Long before the doors opened, people lined up at the box office—curious about "cool comfort" as offered by the managers. It was like a World Series crowd waiting for bleacher seats. They were not only curious, but skeptical—all of the women and some of the men had fans —a standard accessory of that day. . . .
>
> Among the spectators was Adolph Zukor. I recall distinctly how quiet and reserved he was when he walked in and took a seat in the balcony. Zukor may have come from California, but he was there to be shown!
>
> Final adjustments delayed us in starting up the machine, so that the doors opened before the air conditioning system was turned on. The people poured in, filled all the seats, and stood seven deep in the back of the theater. We had more than we had bargained for and were plenty worried. From the wings we watched in dismay as two thousand fans fluttered. We felt that Mr. Zukor was watching the people instead of the picture—and saw all those waving fans!
>
> It takes time to pull down the temperature in a quickly filled theater on a hot day, and a still longer time for a packed house. Gradually, almost imperceptibly, the fans dropped into laps as the effects of the air conditioning system became evident. Only a few chronic fanners persisted, but soon they, too, ceased fanning. We had stopped them "cold" and breathed a great sigh of relief.
>
> We then went into the lobby and waited for Mr. Zukor to come downstairs. When he saw us, he did not wait for us to ask his opinion. He said tersely, "Yes, the people are going to like it." That was a jubilant moment for us—we had passed the "acid test."

On July 3, 1925, the managing director of the Rivoli wrote that, "Although the apparatus has only been in operation four weeks, it is the talk of Broadway." Subsequently, the architects for the new Paramount in New York, who had specified an up-draft ventilating system, were persuaded that their designs were obsolete even though the drawings were still on the drafting board. They discarded the up-draft for by-pass down-draft air distribution and specified air conditioning in place of ventilation. The $91,148 Paramount system, sold January 25, 1926,