

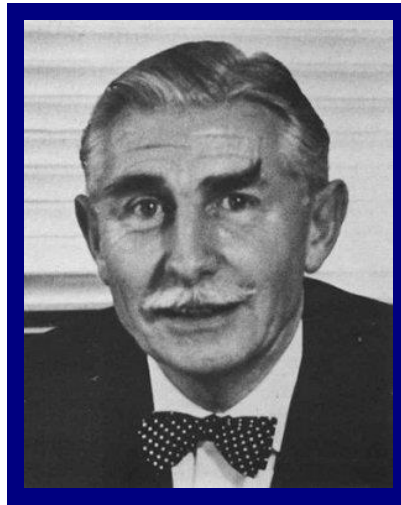
Willis Carrier at the Smithsonian Museum in 1950 to see again centrifugal "Number 1" of 1923.

# **REFRIGERATION PART THREE**

**THE CENTRIFUGAL & WILLIS HAVILAND CARRIER**

**BRIAN ROBERTS**

## ABOUT THE BOOK



J.A.E. "Archie" Heard

This book traces, with photographs and illustrations, the development of the Carrier centrifugal refrigeration water chiller from 1922 and how by employing new safe refrigerants it transformed comfort air conditioning in the following thirty years. Prior to this nearly all refrigeration compression-type machines used ammonia (NH<sub>3</sub>) as the refrigerant. But this was toxic, making air conditioning unsuitable for occupied spaces where people gather. Ammonia machines were limited to ice-making, cold stores, industrial applications and to U.S. breweries. The centrifugal was able to be manufactured with higher capacities and provided effective part-load operation. In the U.S.A it proved particularly suitable for comfort air conditioning in movie-theatres and led to the incredible growth of the film industry coinciding with the introduction of the "talkies". By 1950, 2000 Carrier centrifugal machines had been manufactured.

The development of comfort air conditioning is due largely to the work of Willis Haviland Carrier. For this he is regarded as "The Father of Air Conditioning". His work and that of the Carrier Corporation, the Company he founded in 1915, in air conditioning has been well documented elsewhere. This includes the development of psychrometrics, load calculations, air handling equipment, controls, air conditioning for passenger-trains, ships and skyscraper offices (the high velocity induction unit system). This book concentrates on Carrier's introduction of centrifugal refrigeration.

Information has been taken from the Archives of the CIBSE Heritage Group which holds some 100 items on Willis Carrier and both the U.S. and U.K. Companies. The majority were collected and donated to the Archive by the late Archie Heard; he did his training with Carrier in the U.S.A, worked for Carrier in India and then for Carrier Company in London becoming Managing Director. He joined the IHVE Archaeology Working Party in 1973, serving as Chairman for around ten years, prior to it being reformed as the CIBSE Heritage Group with the writer as Chairman and Archivist. He knew and worked with Willis Carrier. His donation included American and British catalogues, brochures, photographs, personal memorabilia and the draft manuscripts of two unpublished books on Carrier, with copies of papers held in the Willis Carrier Archive at Cornell University.

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Cumberland Hotel 36, Palace Theatre 17, Empire Theatre 27, J. Lyons 29,  
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## CARRIER ENGINEERING

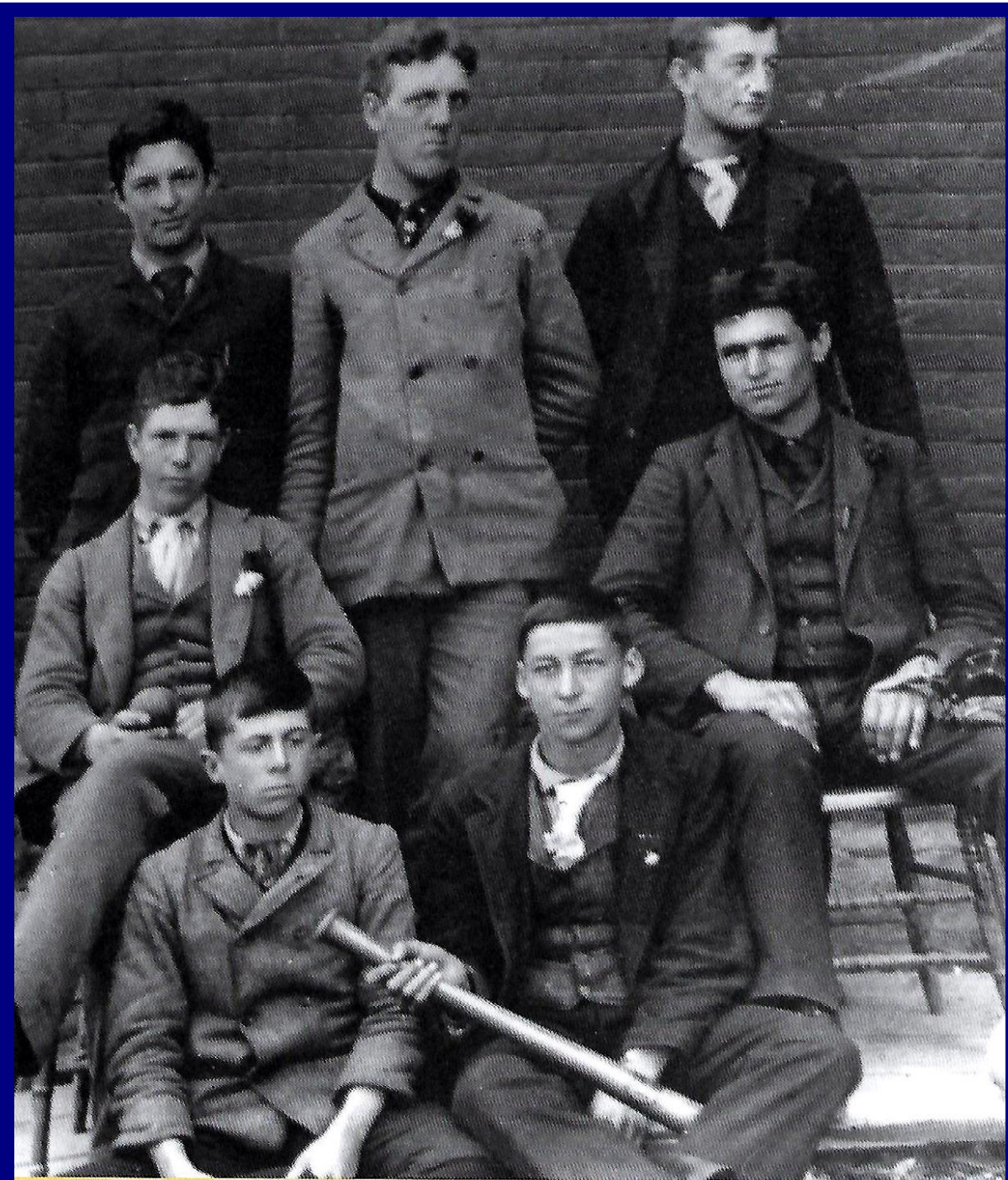


Archie Heard (3rd left front row) at 1929 Carrier Training Class.



Archie Heard (left) at a London Social Event.

## WILLIS CARRIER



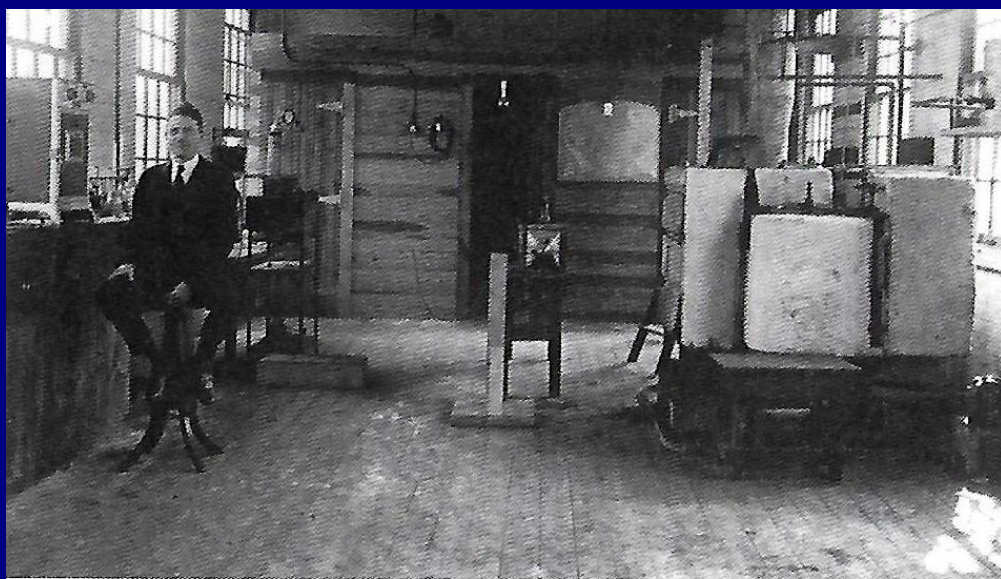
- This high school photo of Willis Carrier (top row, left) with his baseball
- teammates is a good reminder that Carrier's engineering talent was
- complemented by his enthusiasm for outdoor activities and the good
- and loyal friendships he created throughout his life.

(From "Carrier-Weathermakers to the World").

## CARRIER ENGINEERING



The founders of Carrier Engineering Corporation (1918 photo).



- This iconic photo of Carrier co-founder Alfred E. "Ned" Stacey shows him
- seated in the company's Newark, New Jersey, research laboratory shortly
- after its founding in 1918.

# CARRIER ENGINEERING



Dr. Carrier.

## Carrier Engineering Corporation

On 26 June 1915 Carrier and six young colleagues pooled their resources to start Carrier Engineering Corporation (CEC) in New York. Carrier was President of the new company. By the end of the year some forty contracts had been secured. CEC, unlike their rivals, did not guarantee their installations by horsepower capacity or air volumes but by providing specified space conditions.

About this time Willis Carrier recognised the inadequacy of existing refrigerating machines and over the next few years visualised a centrifugal compressor with direct drive and compact heat exchangers. He lacked both a suitable refrigerant and a compressor manufacturer. In 1921 on a visit to Germany he found a compressor manufacturer and a possible refrigerant (dielene). A prototype machine was unveiled at the CEC Newark factory on 22 May 1922. By the end of 1924 nine machines had been sold.

The big break came with the opening of the "comfort" market when centrifugal systems were introduced into movie theatres. CEC went on to develop a downwards supply air distribution method and a return air bypass system of control. Further centrifugal installations included a deep gold mine in Brazil and on the warship *USS Wyoming*. In 1930 CEC provided air conditioning for the railway dining car *Martha Washington* operating between New York and Washington.

In 1930 Carrier Corporation was formed by the merger of CEC with Brunswick-Kroeschell and York Heating & Ventilation. The new Company now had to survive the Great Depression and found itself able to serve all types of buildings except one –the skyscraper. Willis Carrier solved this problem by his 1939 invention of the Conduit Weathermaster System using high velocity induction units with ejector nozzles entraining recirculation room air.

However, Carrier's greatest technical achievement is considered by many to be the system he designed for the Cleveland wind tunnel of the National Advisory Committee for Aeronautics, started in 1940 and opened in April 1944, it was required to simulate freezing high-altitude conditions for the testing of prototype aircraft. The completed installations used an air flow rate of "ten million cubic feet per minute cooled to -67 degF by fourteen refrigerating machines requiring a total of 21000 horsepower." This helped NACA win the war, but afterwards Carrier semi-retired and suffered ill health.

Willis Haviland Carrier died in New York on 7 October 1950 after a long and distinguished career. He was President of the American Society of Refrigerating Engineers in 1927 and of the American Society of Heating and Ventilating Engineers in 1931. He received the Franklin Institute Medal in 1941. Carrier was inducted into the ASHRAE Hall of Fame in 1994 in recognition of his significant contributions in establishing air conditioning as an industry and psychrometrics as a science.

# CENTRIFUGAL PATENT

March 9, 1926.

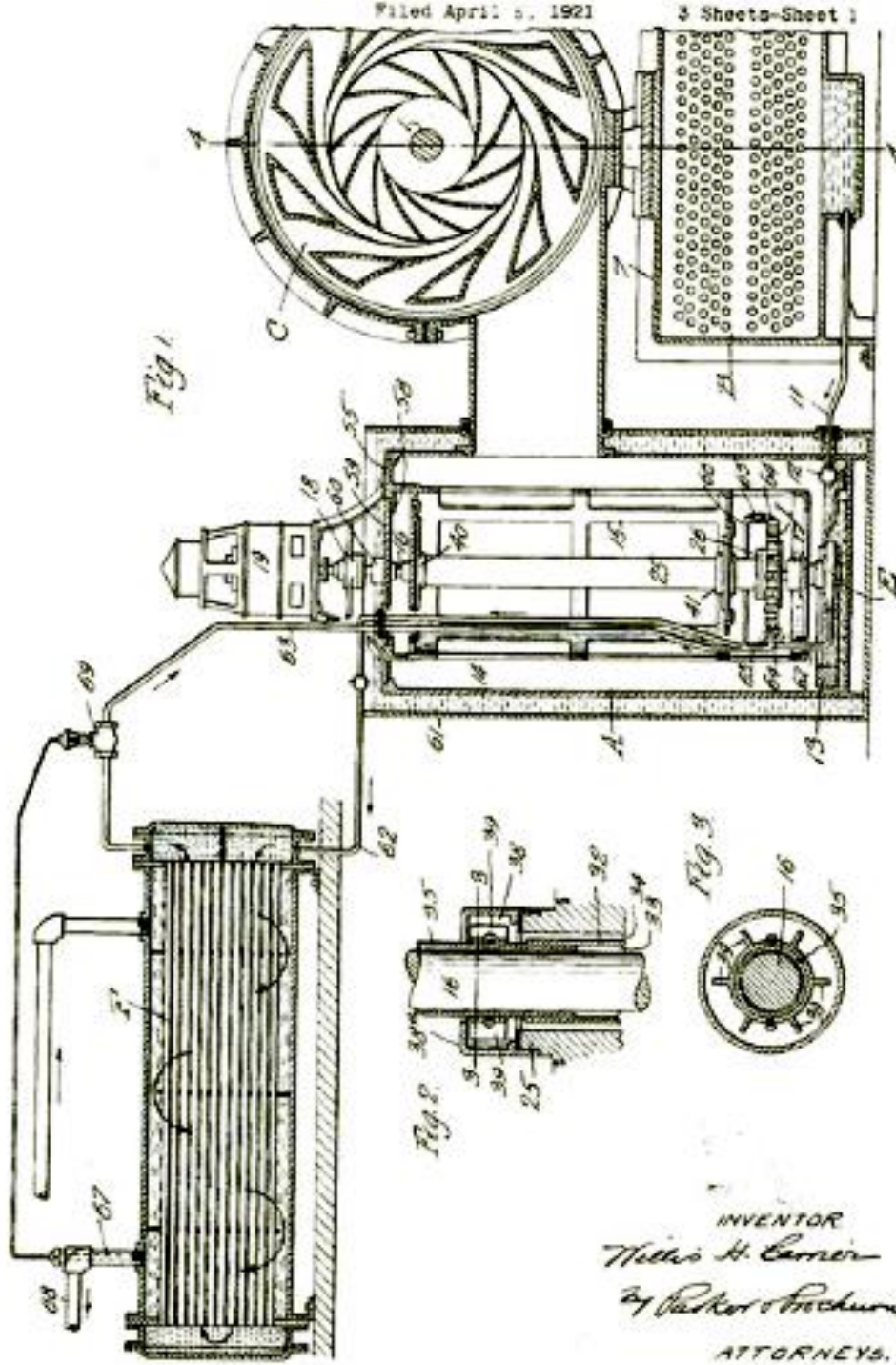
1,575,819

W. H. CARRIER

REFRIGERATING SYSTEM

Filed April 5, 1921

3 Sheets-Sheet 1

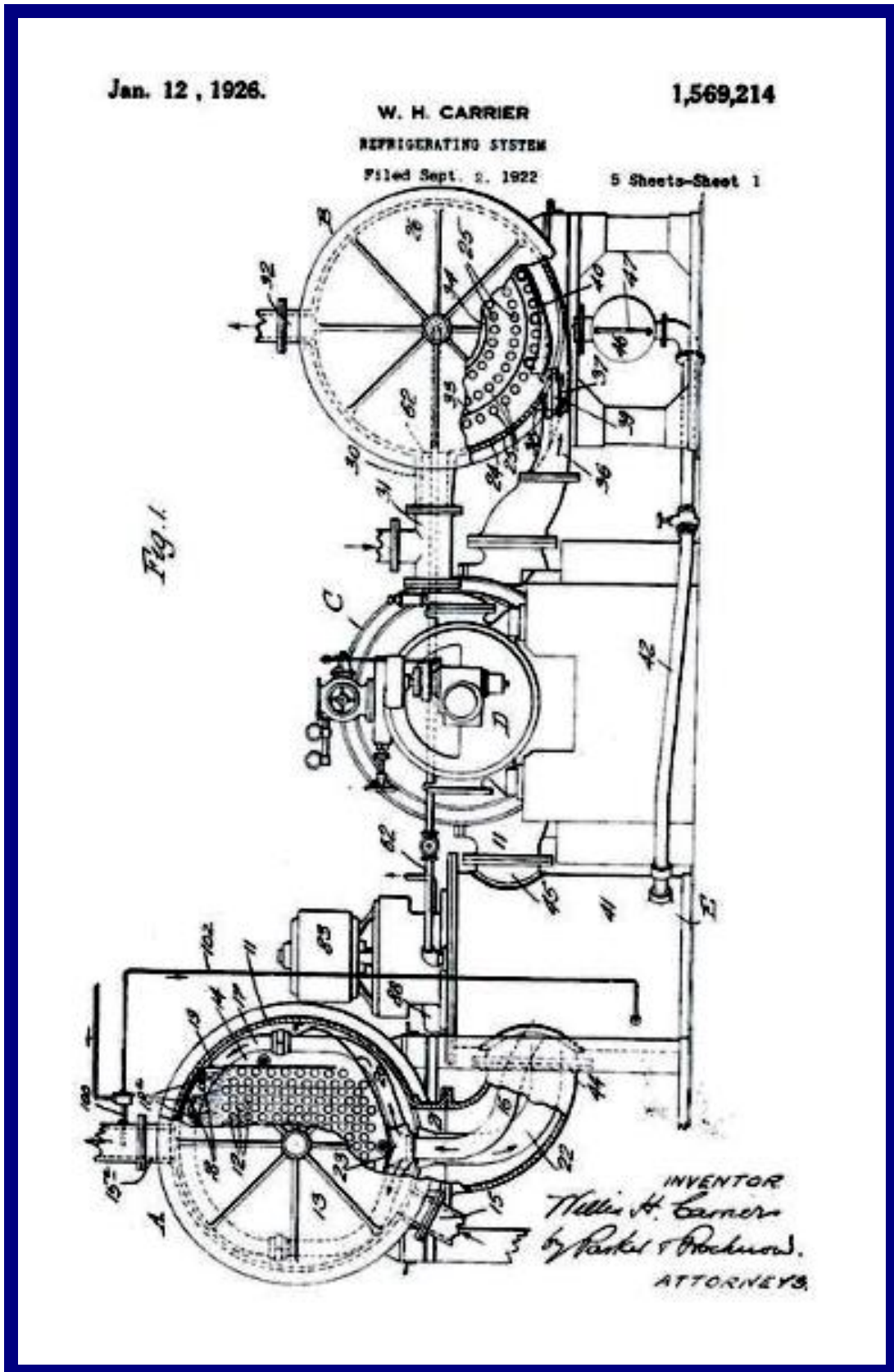


INVENTOR  
Willis H. Carrier  
By Parker & Prochman.  
ATTORNEYS.

Features the early square evaporator and condenser.



# CENTRIFUGAL PATENT



Has now adopted circular heat exchangers.

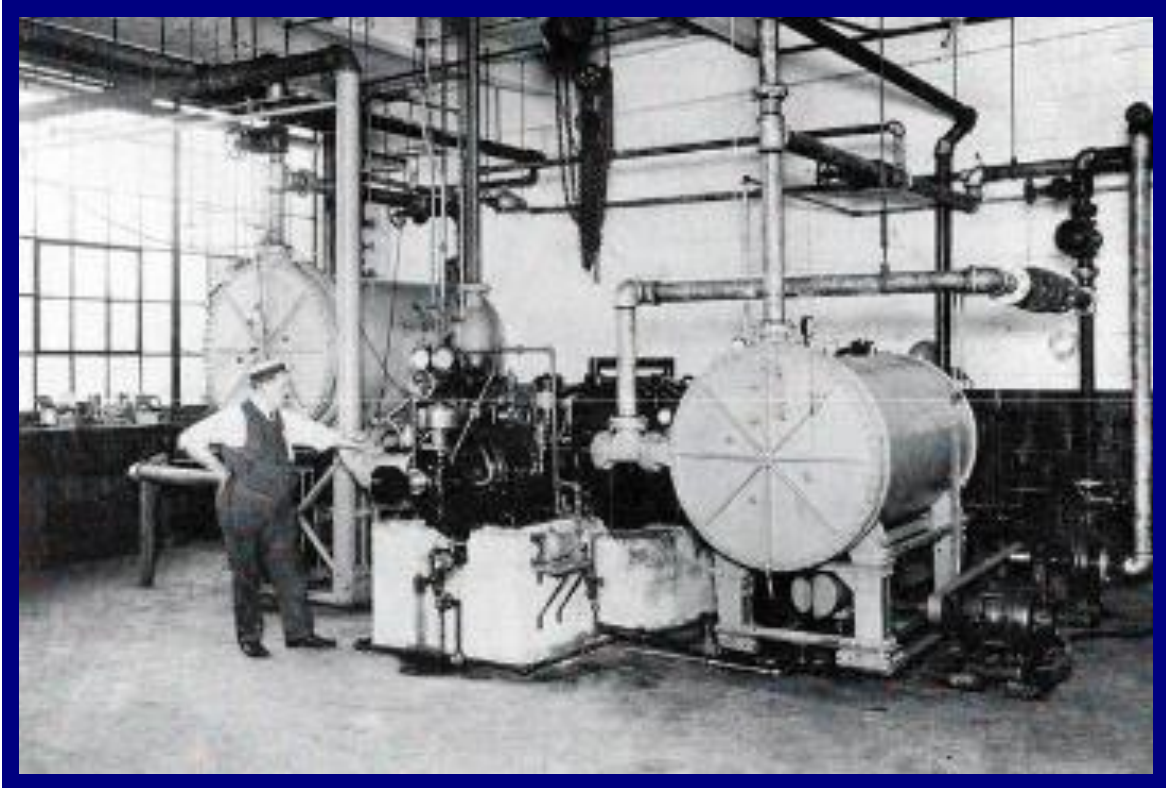
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## **WILLIS CARRIER**

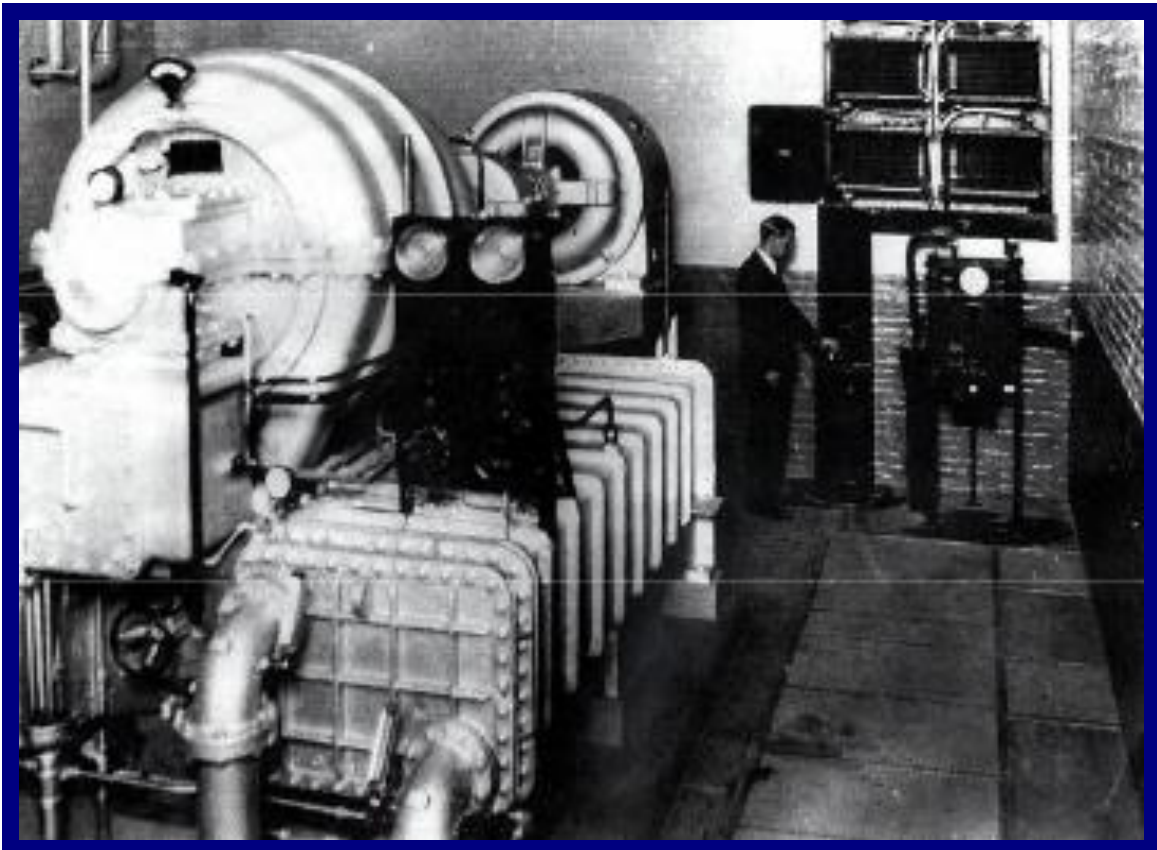


Willis Carrier (photo from Margaret Ingels 1952 Biography).

# CENTRIFUGAL REFRIGERATION

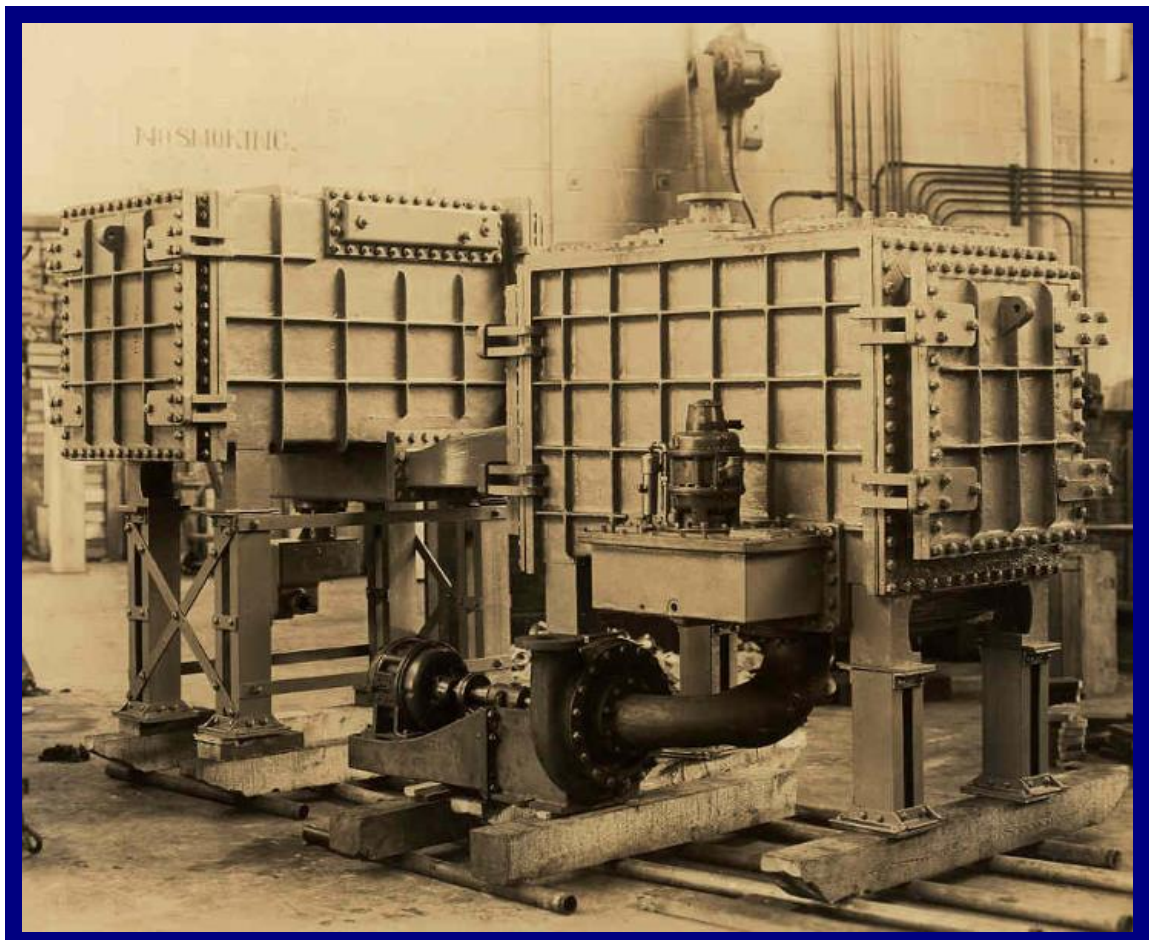
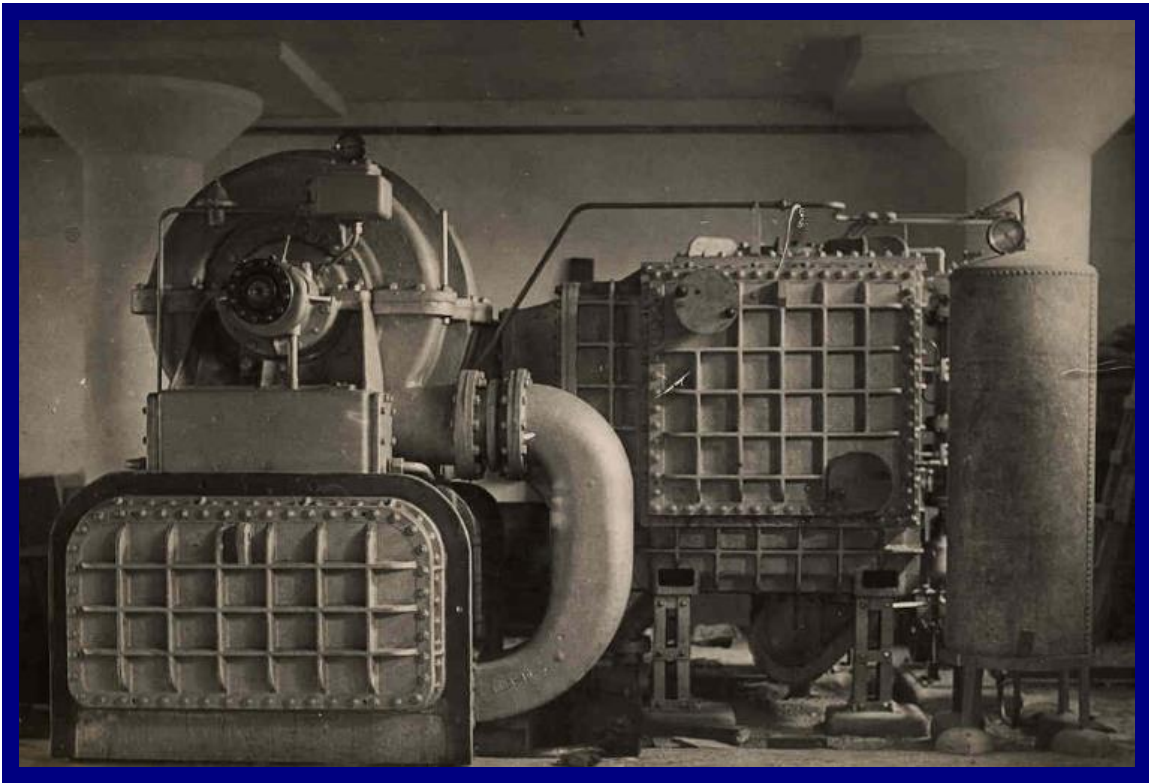


Factory demonstration of first Carrier centrifugal ASHVE/ASRE Meeting 1922



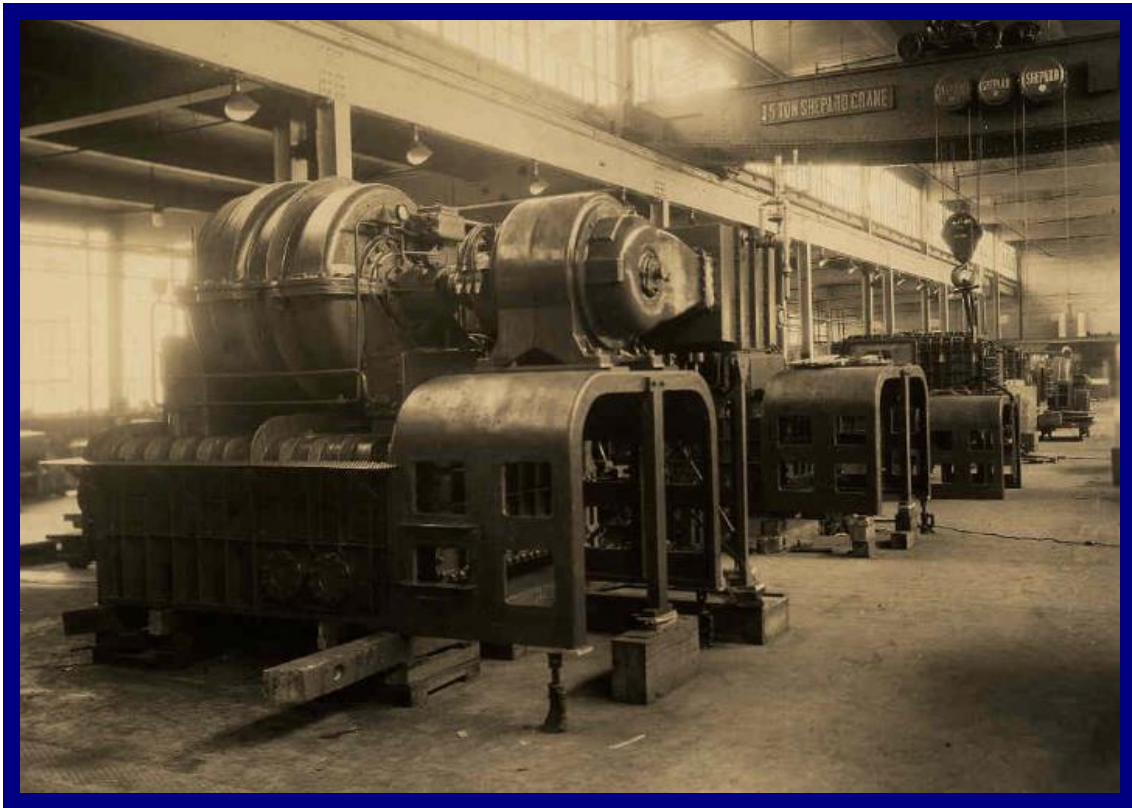
Carrier centrifugal installed in Capitol House, Washington DC 1928.  
Note square heat exchangers.

## CENTRIFUGAL MANUFACTURE

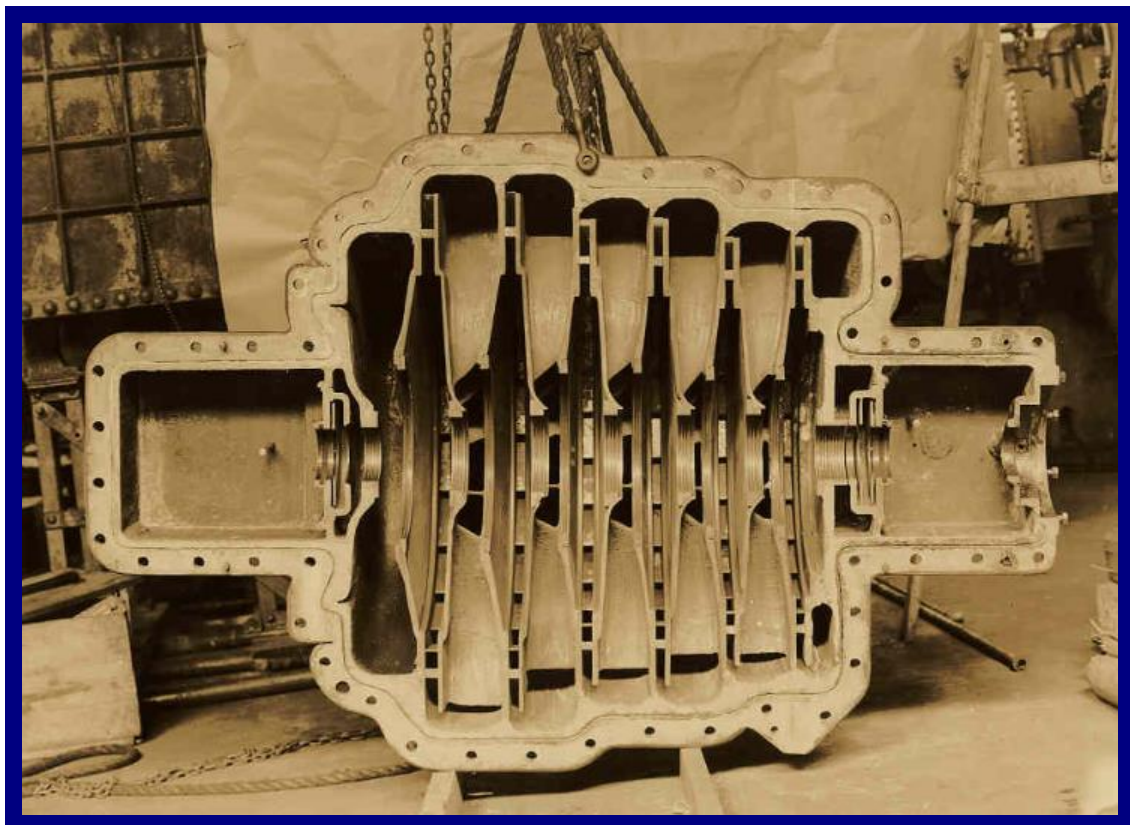


Early centrifugal machines with rectangular condenser and evaporator.

## CENTRIFUGAL MANUFACTURE



Centrifugal compressor-motor assemblies in the Newark factory.  
This and following factory photos from c.1926.

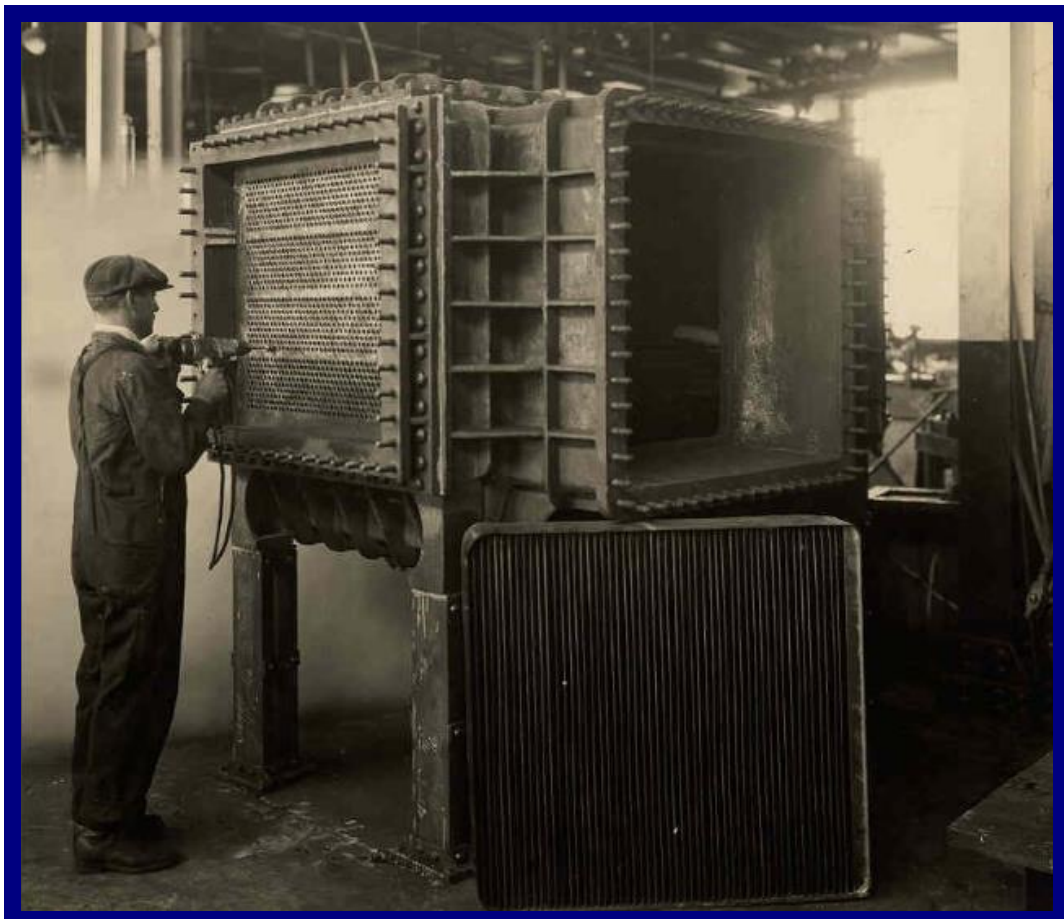


Split casing of a multistage centrifugal compressor.

# CENTRIFUGAL MANUFACTURE



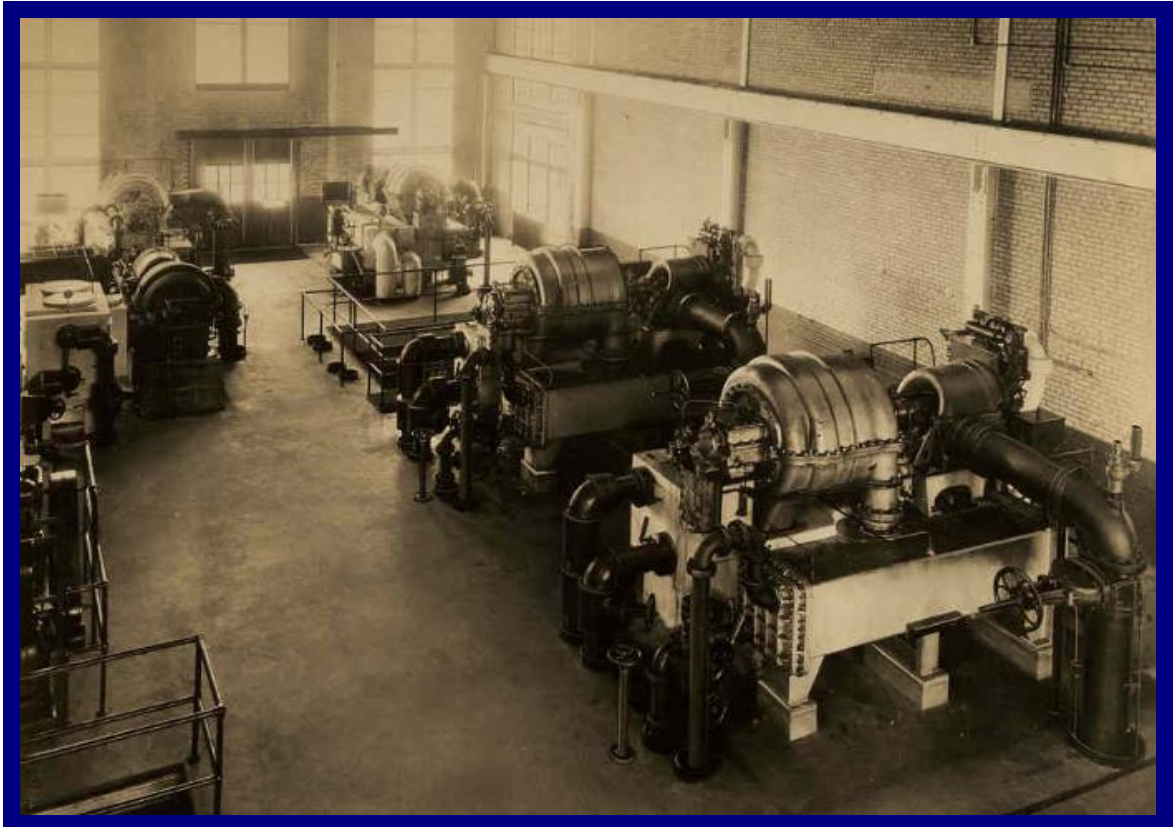
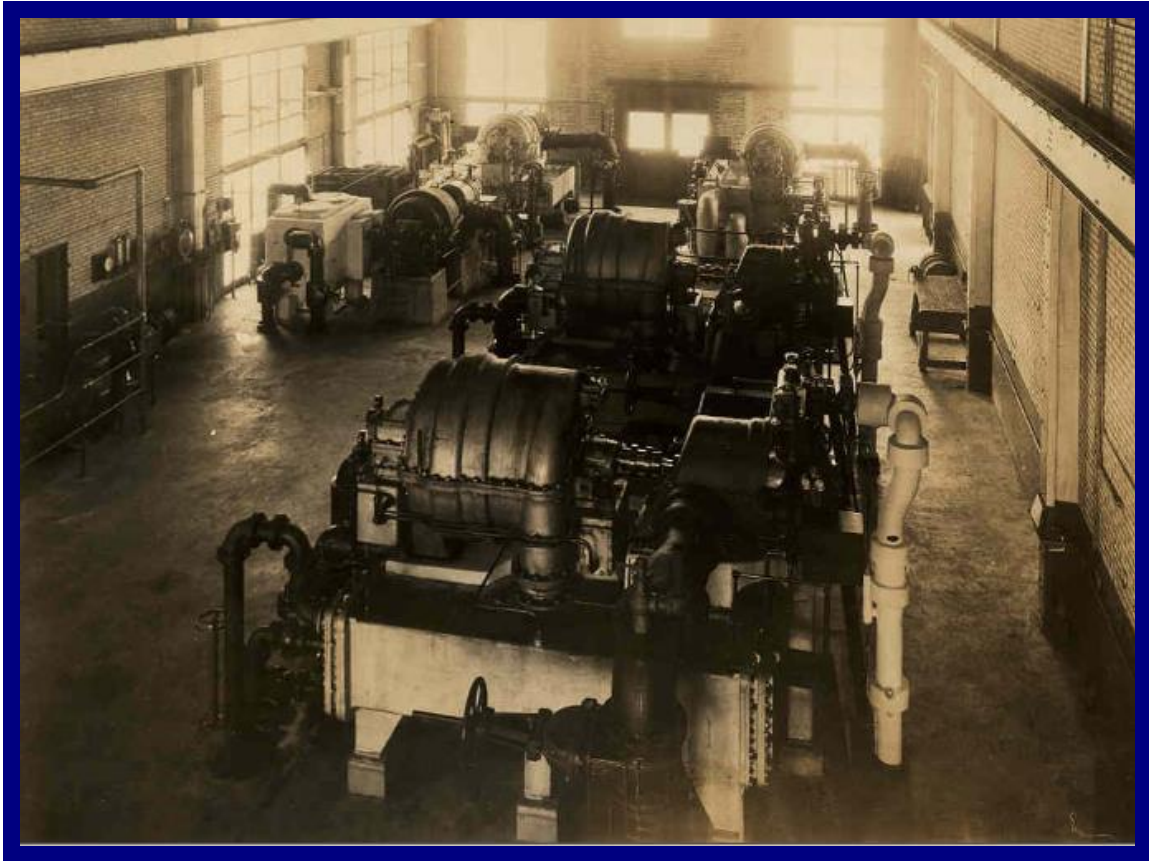
Heat exchanger production line.



Expanding heat exchanger tubes into end plate.

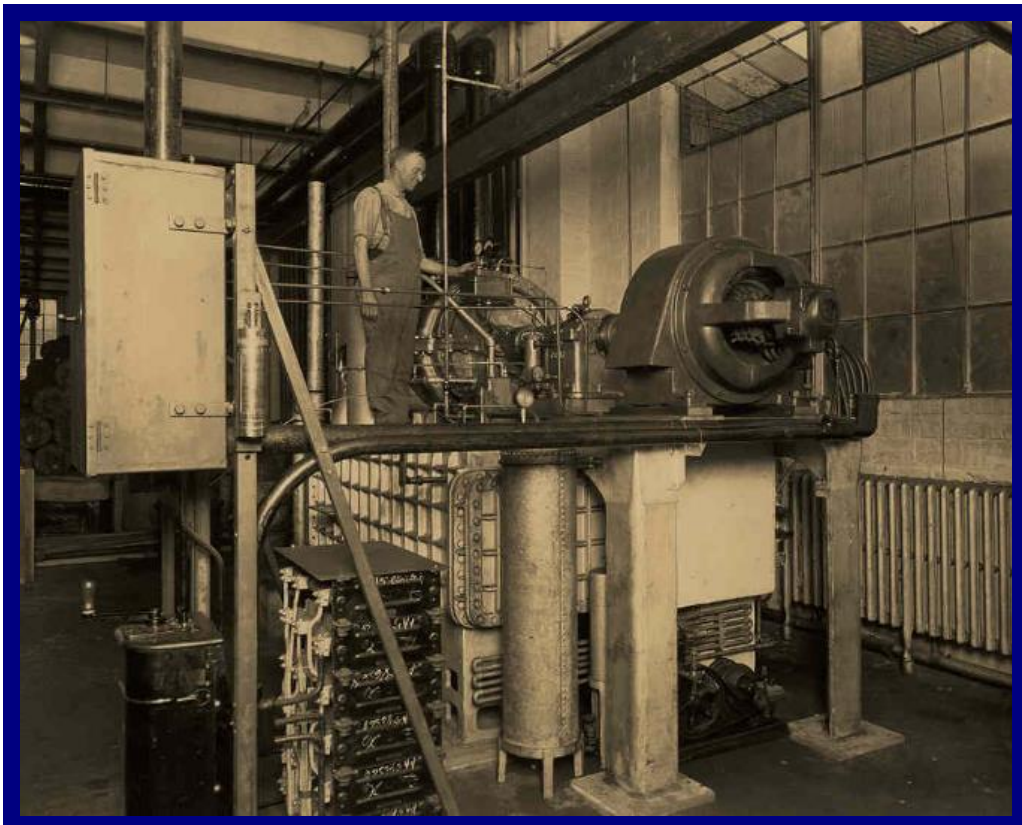
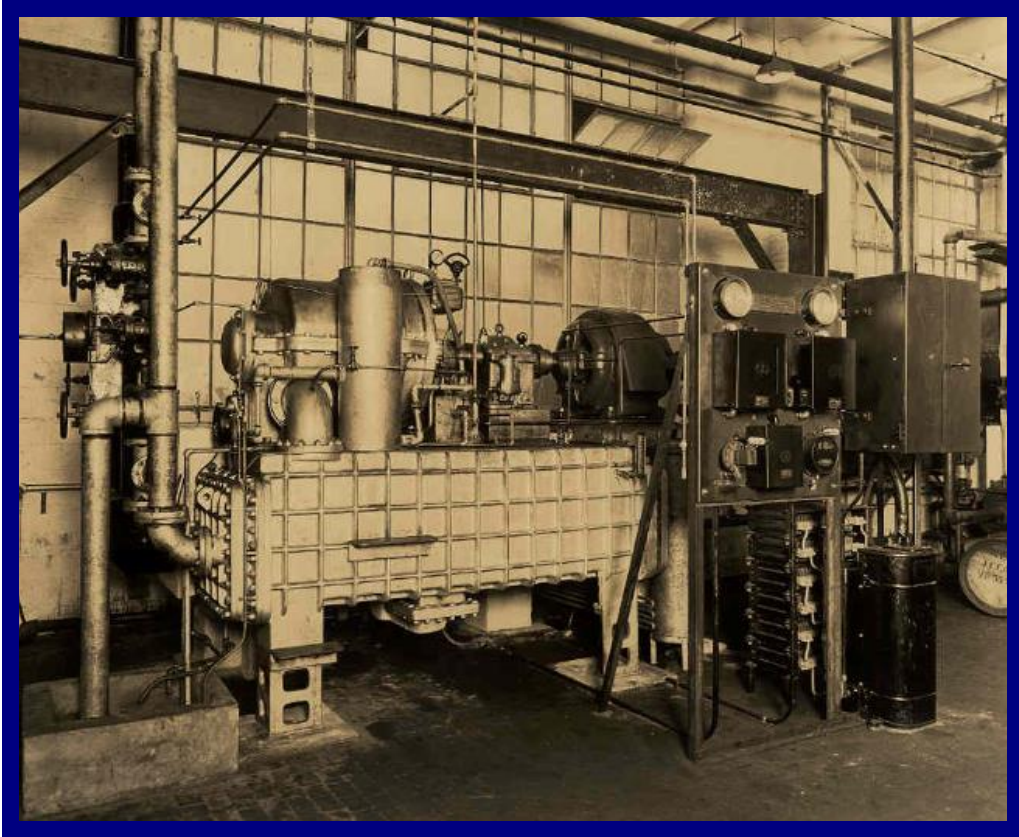
<15>

# SCHRAFFT BOSTON



Schrafft & Sons, Boston, 1923.

# ABERFOYLE FACTORY



Aberfoyle Manufacturing Company, Pennsylvania 1926.

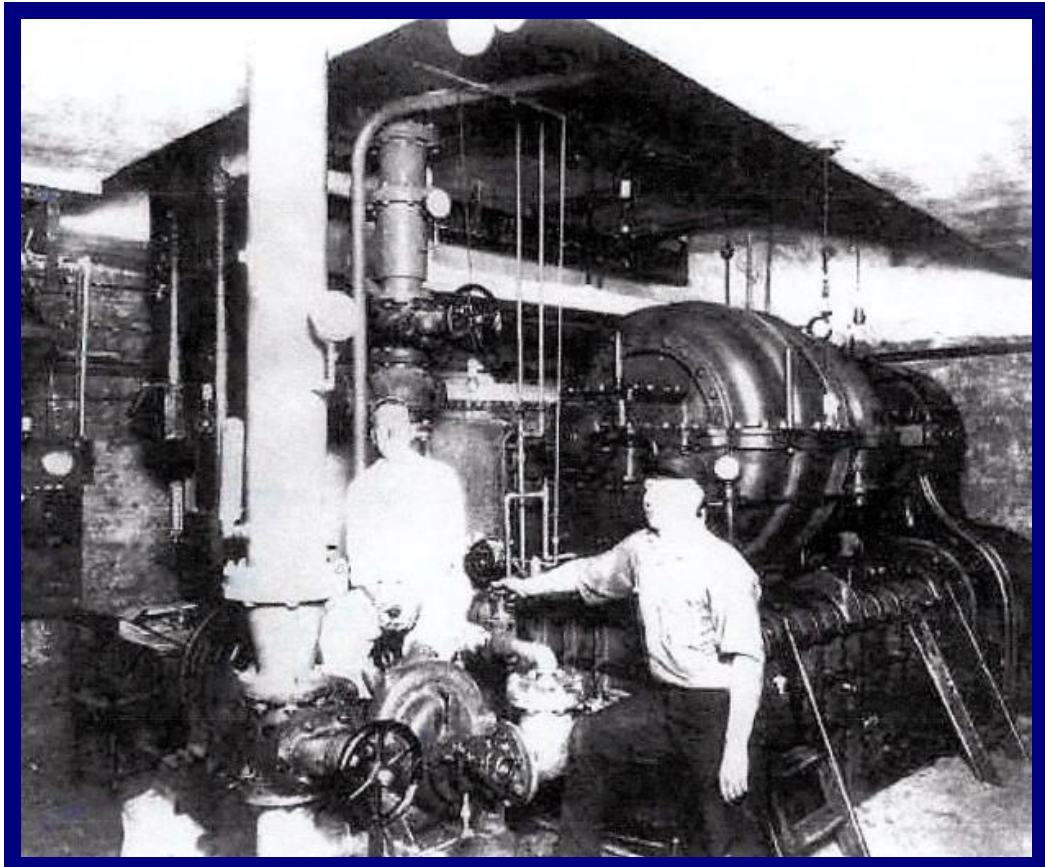


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## **PALACE and MISSOURI THEATRES**



**Palace Theatre, Dallas 1924.**



**Carrier centrifugal in an unknown Missouri theatre mid-late 1920s.**

# CARRIER CORPORATION

**THEATRE COOLING**  
by  
**Carrier**  
Centrifugal Refrigeration  
and  
Air Distribution

**Carrier**  
AIR CONDITIONING  
AND  
DRYING EQUIPMENT

**Carrier**  
AIR CONDITIONING  
AND  
DRYING EQUIPMENT

TEMPERATURE  
DEGREES

HUMIDITY  
PER CENT

**RIVOLI**  
DAN'S NIGHT LIFE OF NEW Y  
DONS NEW YORKERS & EVILS  
BE THE AMERICAN TRAIN EVOLUTION  
A CARRIER COOLED THEATRE

*A Restful Refuge  
Summer & Winter*

The advertisement features a central illustration of a theatre scene. The scene is framed by two large, stylized gauges. The left gauge is labeled 'TEMPERATURE DEGREES' and ranges from 40 to 110. The right gauge is labeled 'HUMIDITY PER CENT' and ranges from 40 to 100. The central illustration shows a theatre stage with a large audience in the foreground. The stage is set with a backdrop of a mountain range and a large, ornate structure. The text 'RIVOLI' is prominently displayed above the stage. Below the stage, there is a sign that reads 'DAN'S NIGHT LIFE OF NEW Y', 'DONS NEW YORKERS & EVILS', and 'BE THE AMERICAN TRAIN EVOLUTION A CARRIER COOLED THEATRE'. The background of the entire advertisement is a blue, textured pattern resembling a window with many small panes.

## WILLIS CARRIER

# The Carrier COURIER

Carrier Corporation Number



His Majesty, the King of Siam, Visits Carrier

Left to right: D. E. French, C. L. Willard, representing the State Department at Washington, Sydney B. Carpender, C. R. Lyle, W. H. Carrier, Major Prasobhsri, aide-de-camp, Thornton Lewis, His Majesty, King Prajadhipok, E. T. Murphy, Dr. Yada, the King's personal physician, Roy Chandler, Mom Smakman Kridakarn, private secretary to the King, and J. I. Lyle.

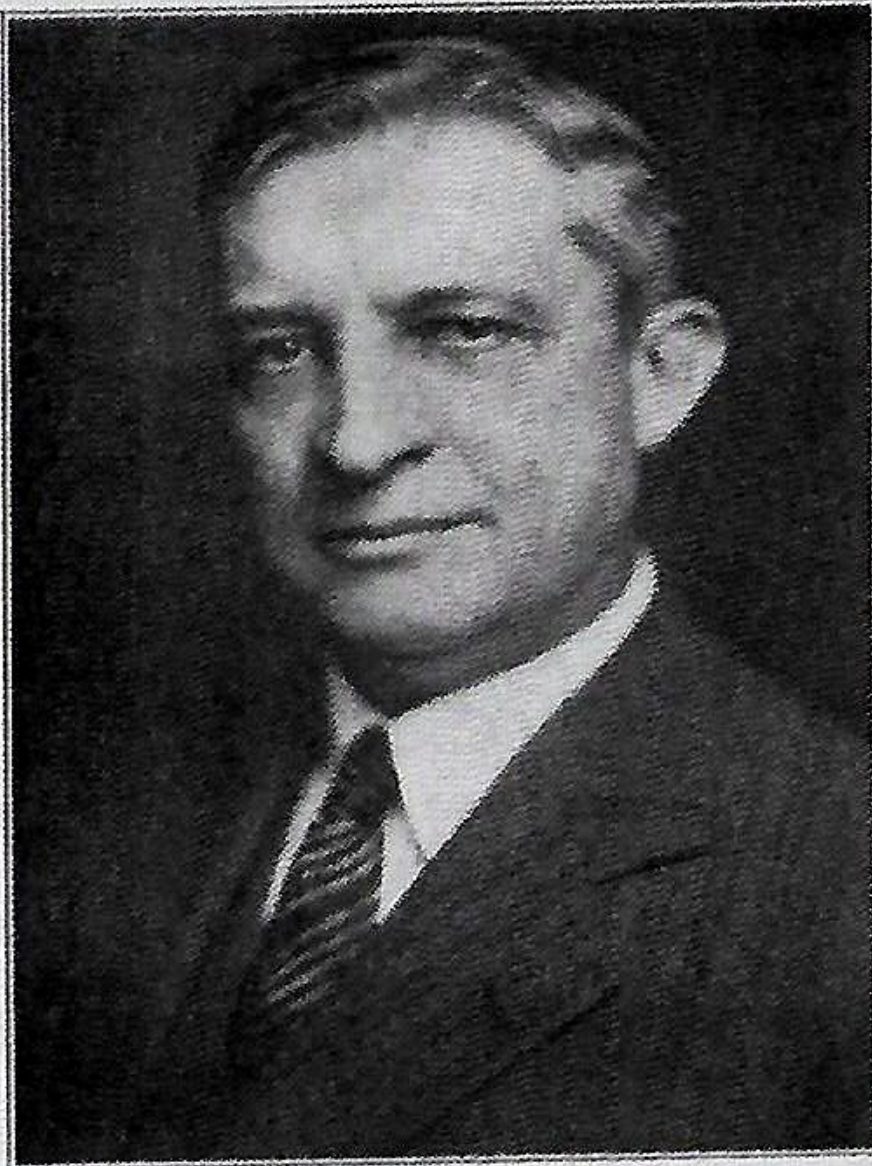
Vol. III  
No. 4

August  
1931



## WILLIS CARRIER

*The Weather Vein* →

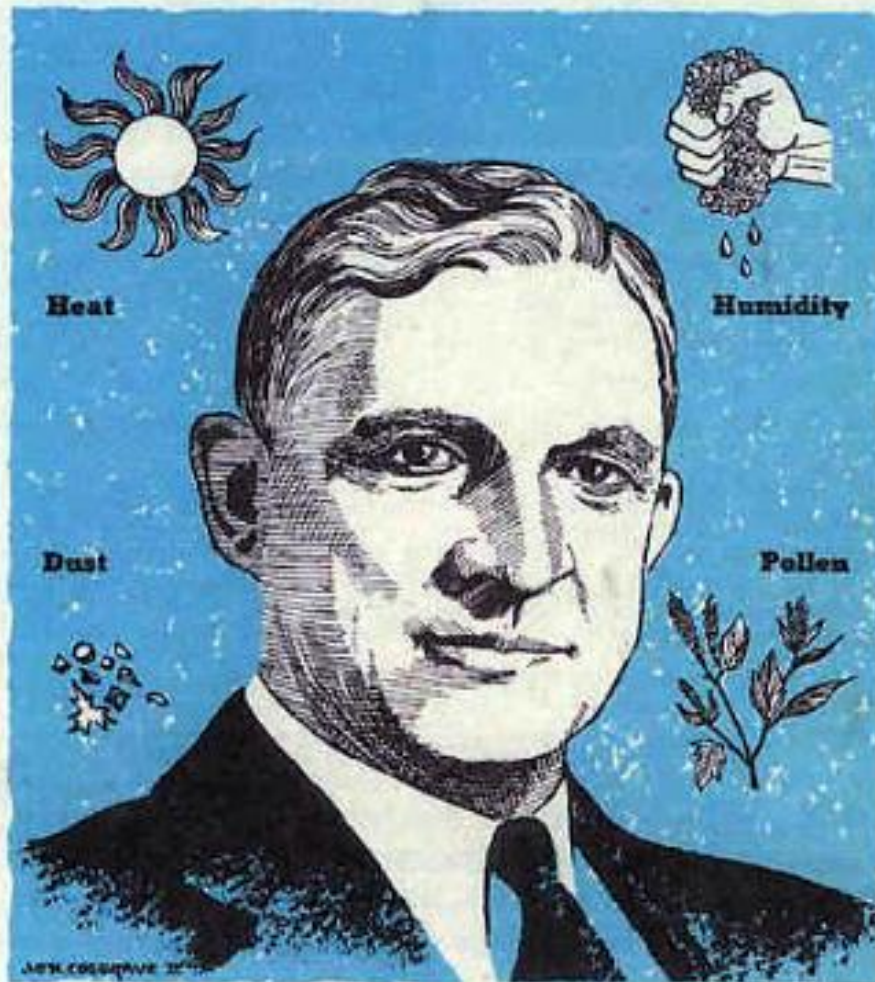


*Willis H. Carrier  
Chairman of the Board  
Carrier Corporation  
and of  
Carrier Engineering Corporation*

# WILLIS CARRIER

## WILLIS HAVILAND CARRIER

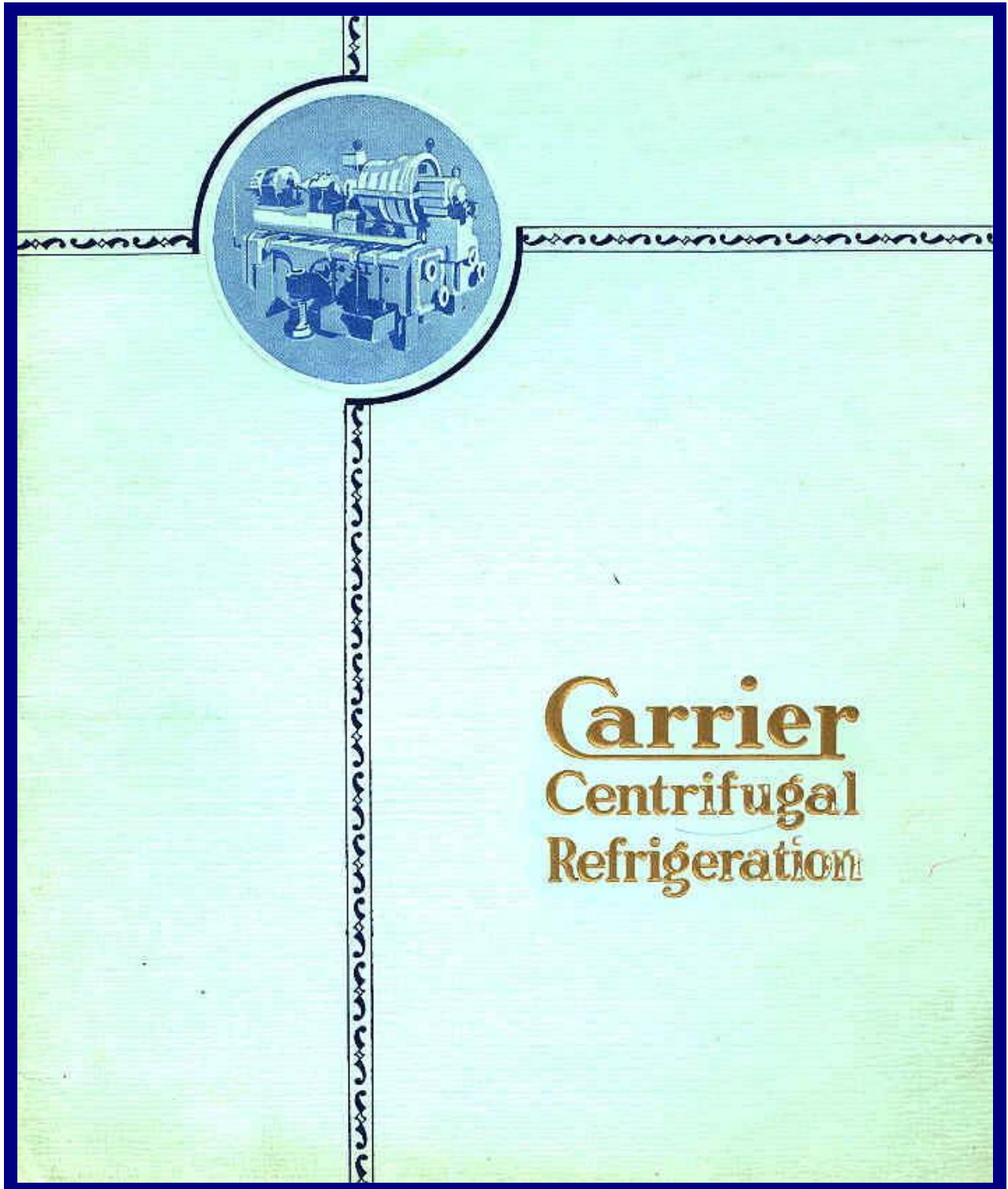
Father of the  
Air Conditioning Industry



by Leonard M. Fanning

"FATHERS OF  INDUSTRIES"  
SERIES

# CARRIER CENTRIFUGAL



U.K. Catalogue early 1930s.

## **CARRIER CENTRIFUGAL**

# **Carrier Centrifugal Refrigeration**



**Carrier Engineering Company Ltd**  
24 Buckingham Gate, London.

## CARRIER CENTRIFUGAL

# The Carrier Centrifugal Refrigerating Machine

**B**EFORE the development of the Carrier Centrifugal Refrigerating Machine the only refrigerants employed in commercial machines were ammonia, carbonic acid, and sulphur dioxide. All these involve comparatively high operating pressures and small vapour volumes, so that positive piston type compressors and heavy pipe evaporators and condensers must be used.

The mechanical and other advantages of a centrifugal refrigerating compressor are obvious by the contrast between the old-fashioned positive piston type pump and the modern centrifugal pump, or the reciprocating steam engine and the steam turbine. The Carrier Centrifugal Refrigerating Machine is, in fact, as great an advance in its sphere as they were in theirs. Before the Carrier Centrifugal Machine could be perfected, however, it was necessary to find an entirely new refrigerant, because the usual types cannot be economically employed with centrifugal compression.

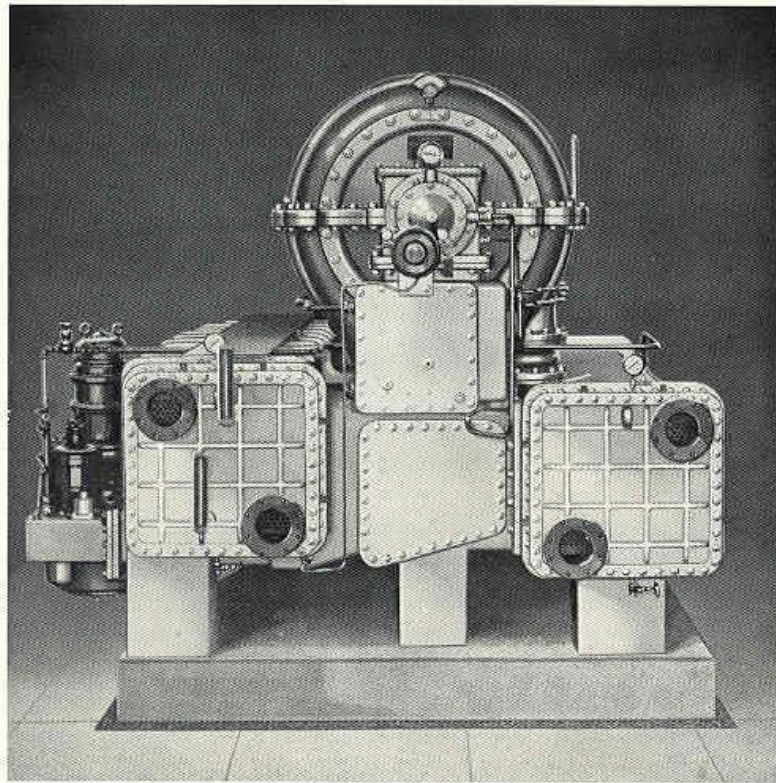
Research yielded a hydro-carbon which not only possessed the required characteristics, but was thermo-dynamically more efficient than ammonia, the best previously known refrigerant. Further, over the whole range of operating temperatures, the pressure exerted by this substance is less than that of the atmosphere. Hence, there is no danger of bursts or explosions, and no outwards leakage can occur. Neither has the machine to be designed to withstand any considerable pressure, consequently compact tubular evaporator and condenser surfaces similar to steam condenser construction can be employed, resulting in great savings in space and weight.



# CARRIER CENTRIFUGAL

## CARRIER CENTRIFUGAL REFRIGERATION

In addition, this new refrigerant is entirely innocuous, being non-poisonous, non-explosive, non-inflammable, and non-corrosive. It is also a perfect solvent for oil, so that the internal surfaces remain clean, and, unlike the older systems, the efficiency does not fall off



A view of a complete Carrier Centrifugal Refrigerating Machine, showing the compressor mounted above the condenser and evaporator.

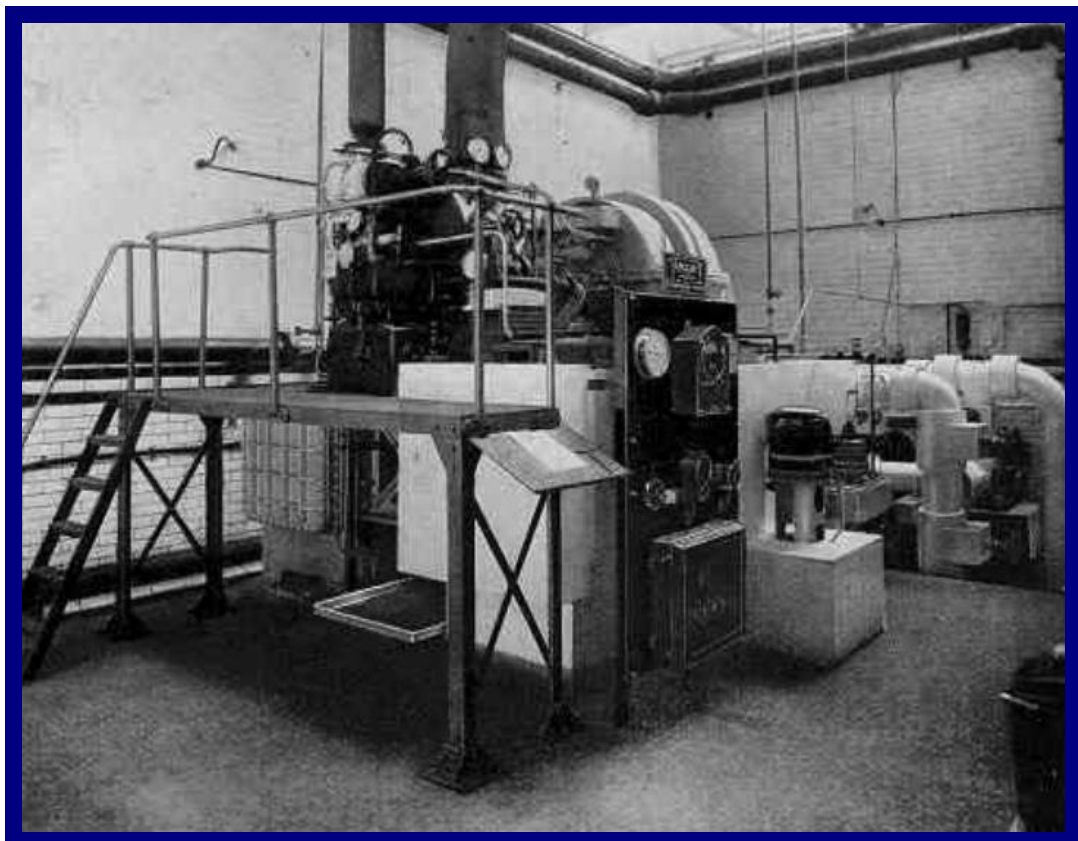
owing to the accumulation of an oil film in the evaporator and condenser.

We therefore have an ideal refrigerant, and the machine employing it is equally ideal and simple.

## WRIGLEY and TERRY FACTORIES



Wrigleys Products Ltd, Wembley c.1928..  
Three Carrier centrifugal chillers total capacity 350 TR.



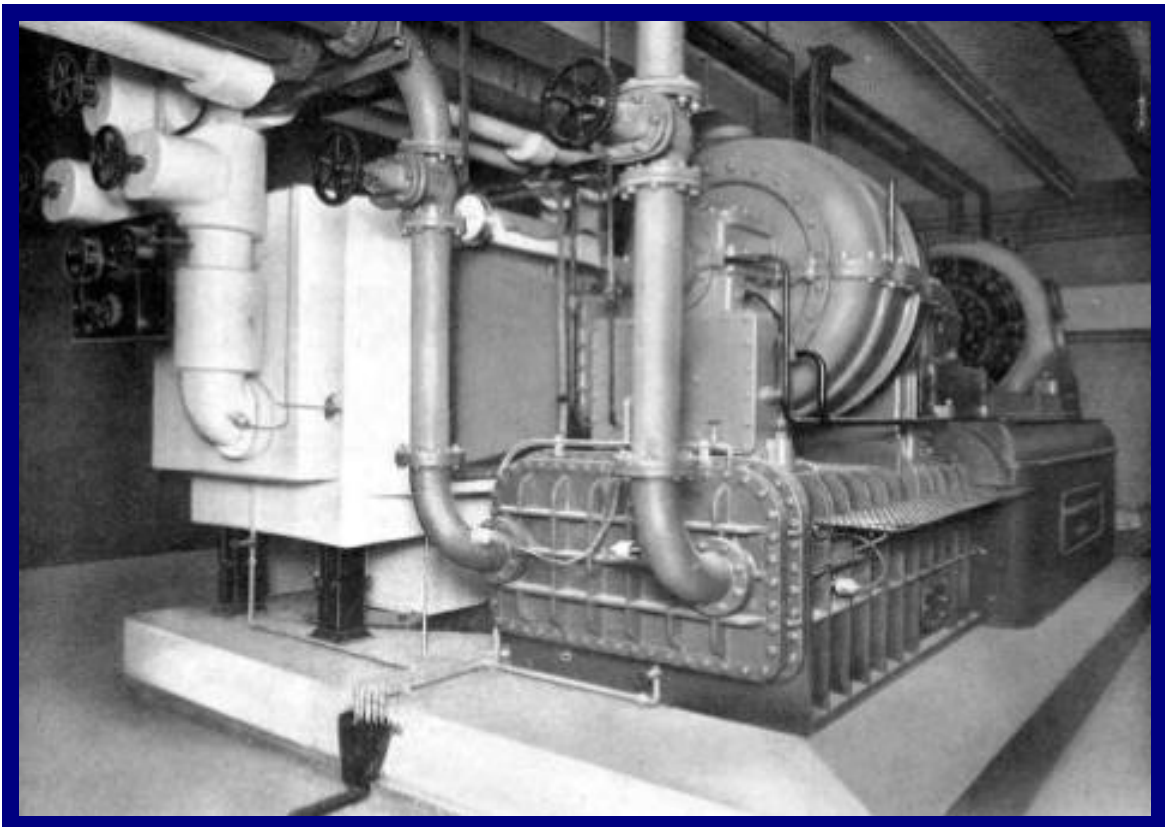
Joseph Terry & Sons, York c.1928. Steam turbine centrifugal chiller 200 TR.

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## CARLTON and EMPIRE THEATRES

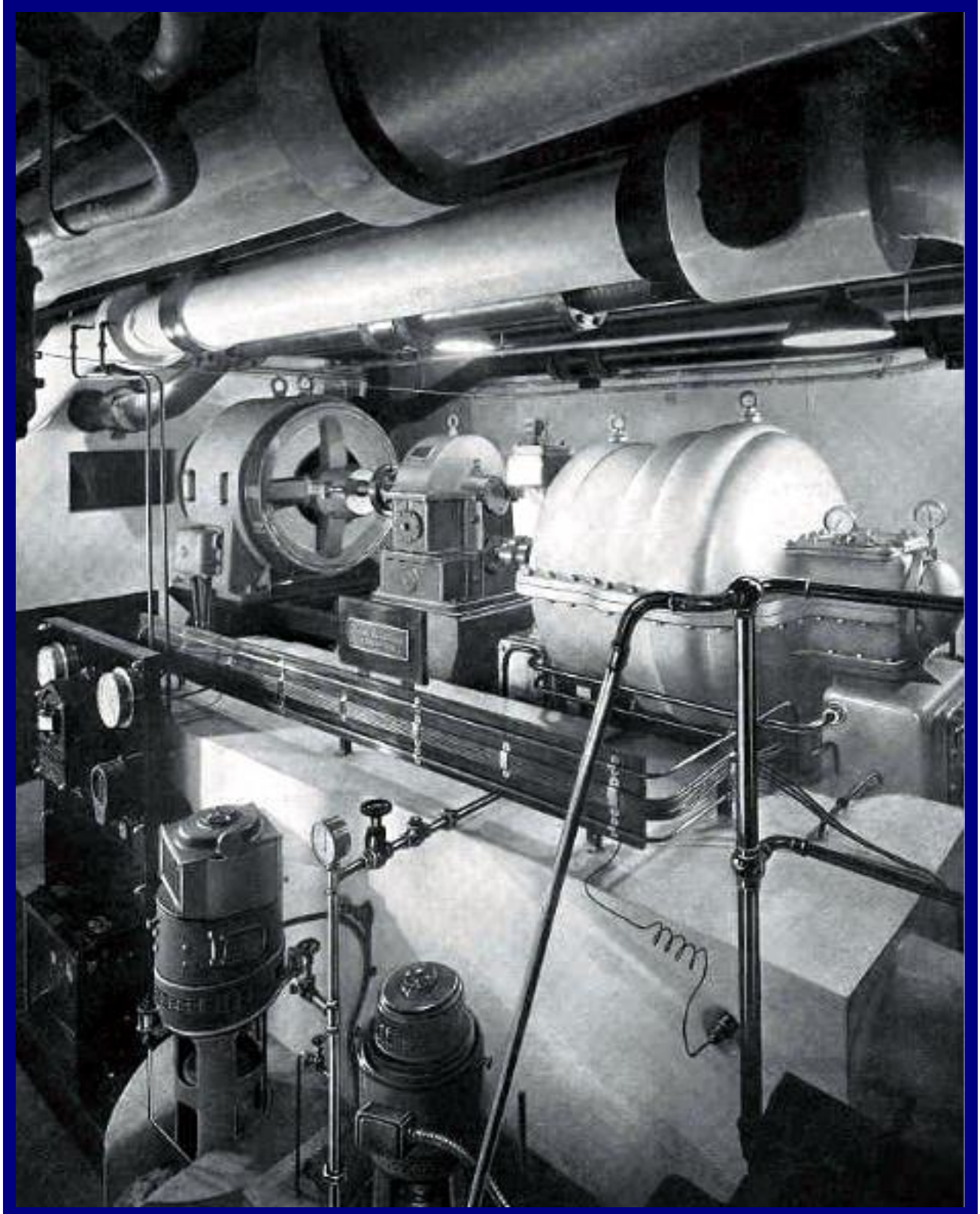


Carlton Theatre, London 1927 (4th UK centrifugal)



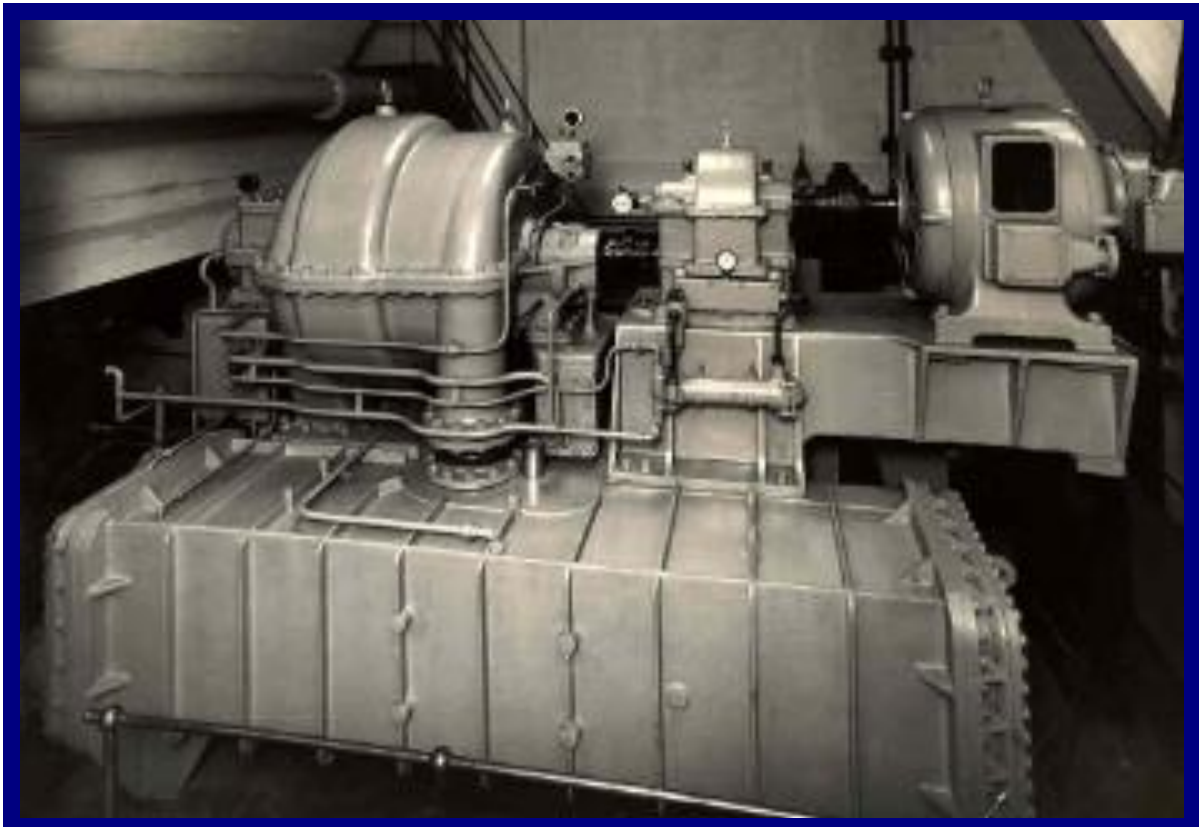
Empire Theatre, London 1928 (200 TR)

## PRINCES HOUSE



Carrier centrifugal machine at Princes House, Gresham Street, London 1930.

## LYONS CORNER HOUSE



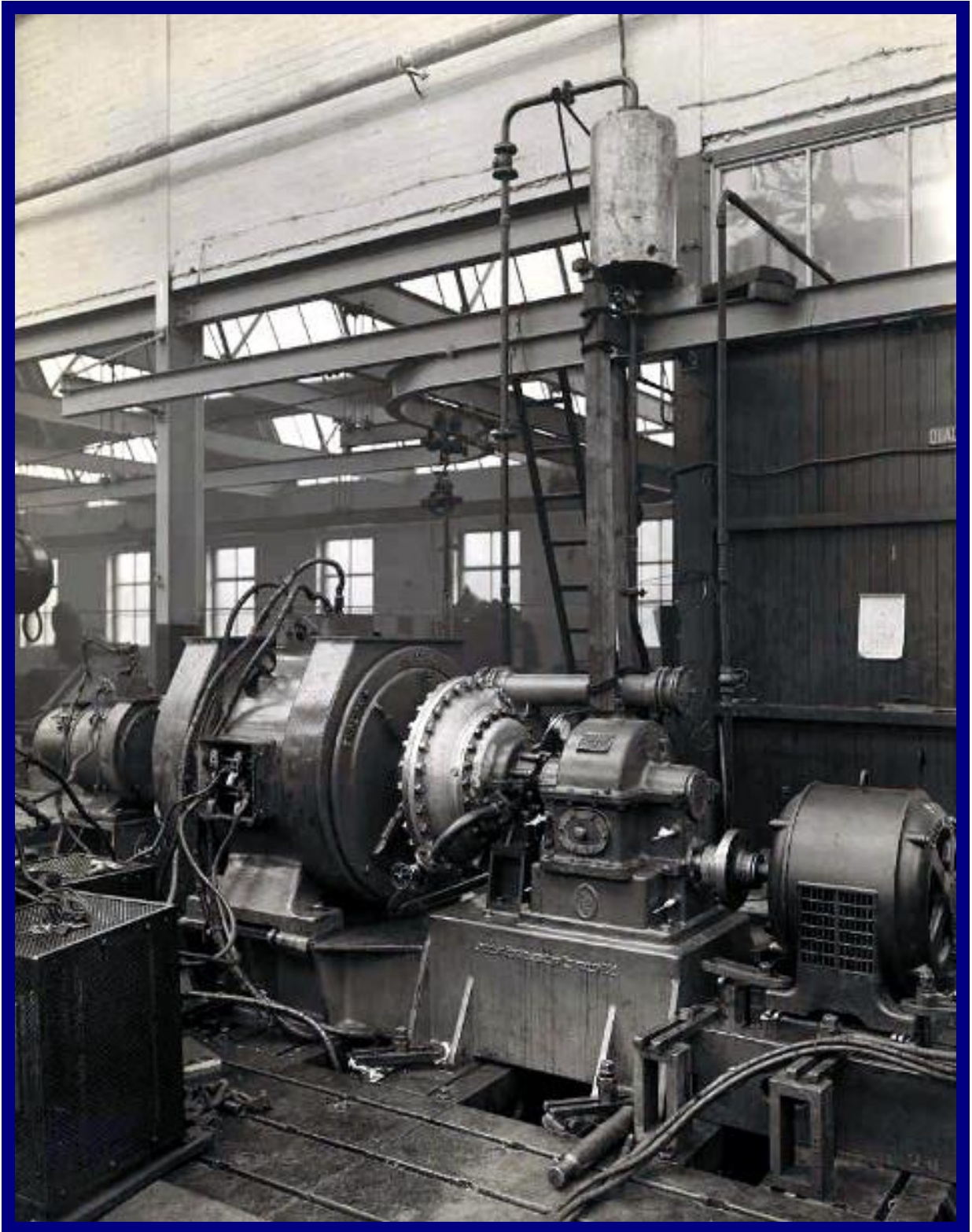
Centrifugal refrigeration (300 TR), J. Lyons Oxford Street Corner House, London 1936.

## CENTRIFUGAL TESTING



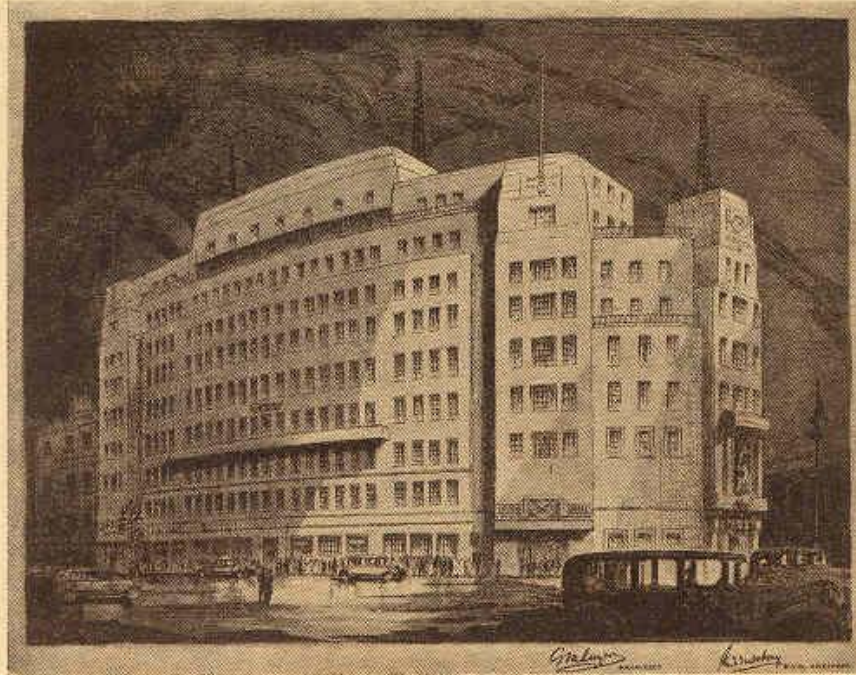
Centrifugal compressor and motor on test at English Electric, early 1930s.

## CENTRIFUGAL TESTING



Centrifugal compressor and motor on test at English Electric, early 1930s.

# BBC BROADCASTING HOUSE



*An*

AIR CONDITIONING  
ACHIEVEMENT BY

**Carrier**



MANUFACTURED WEATHER FOR BROADCASTING HOUSE

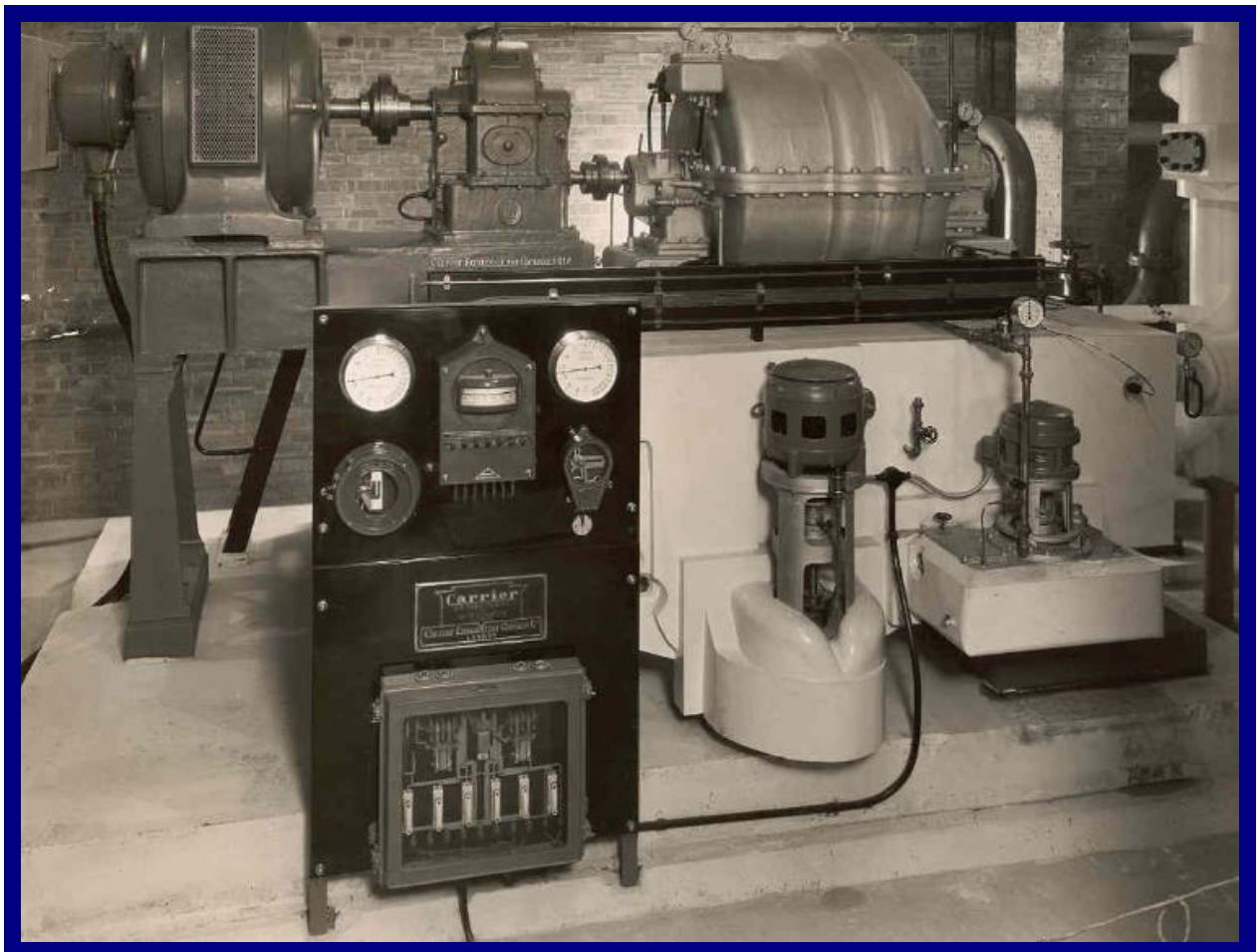
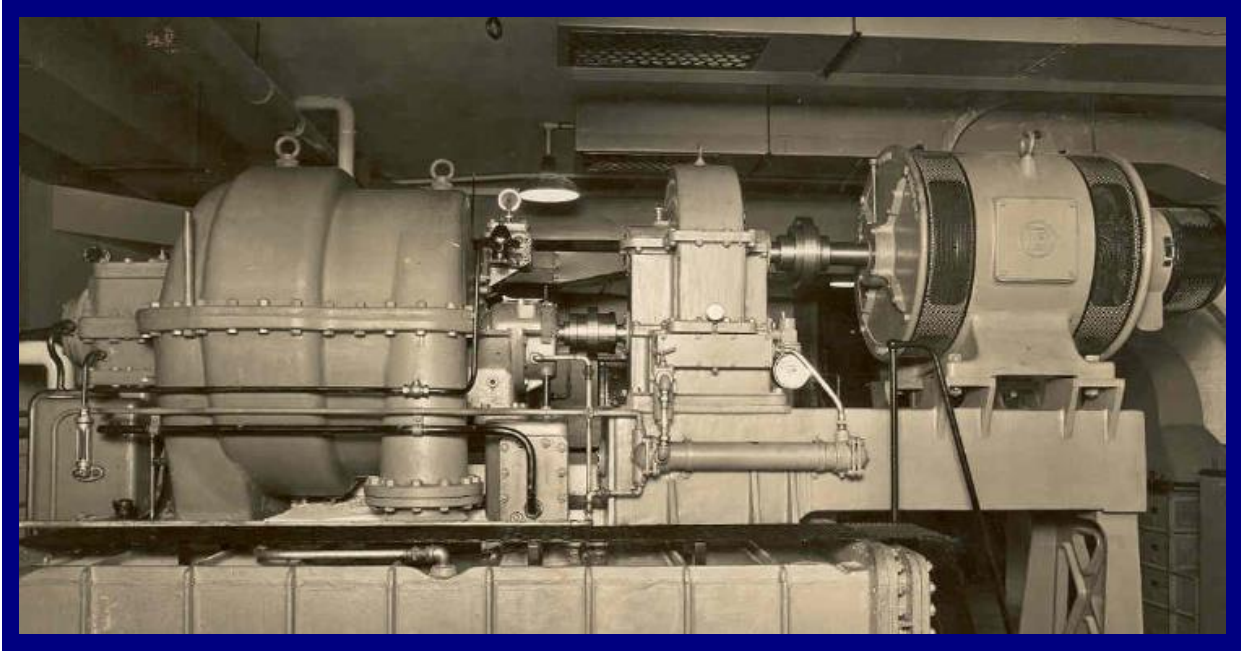


# BBC BROADCASTING HOUSE



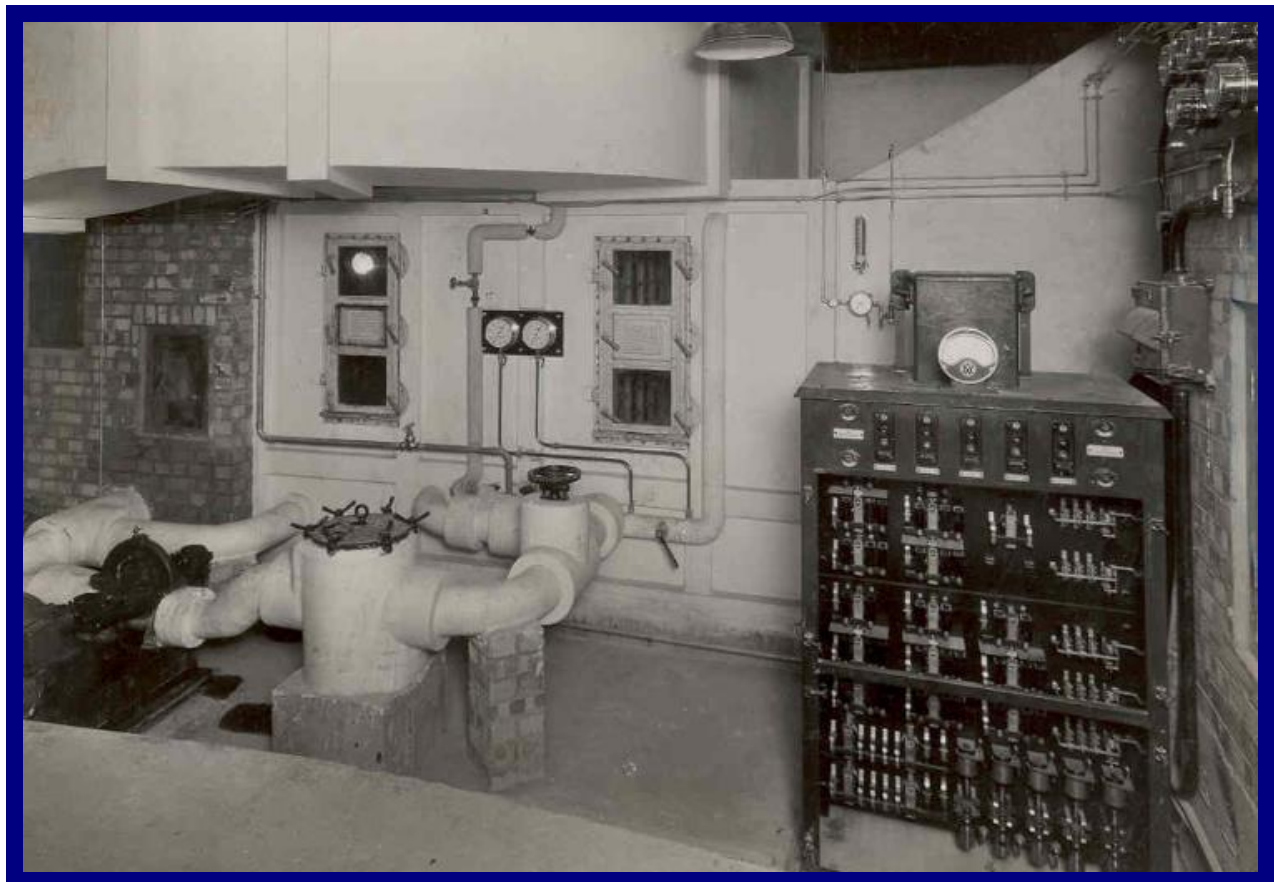
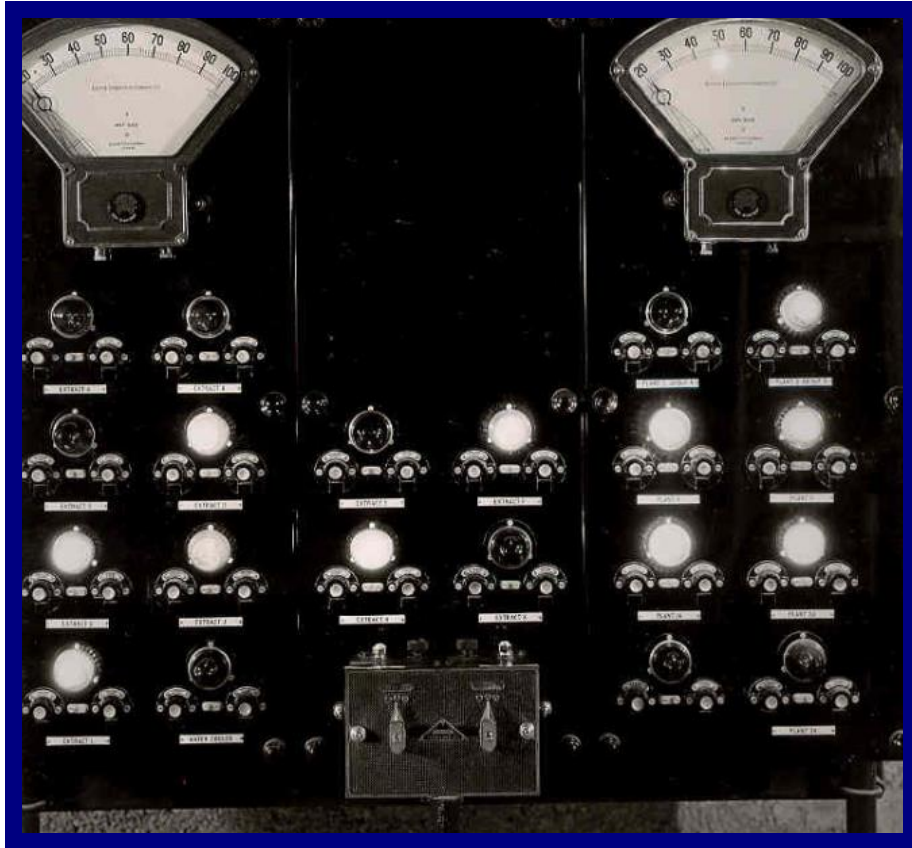
THE BROADCASTING HOUSE  
OF THE B.B.C.  
PORTLAND PLACE, W.1  
AIR CONDITIONED BY  
CARRIER

# BBC BROADCASTING HOUSE



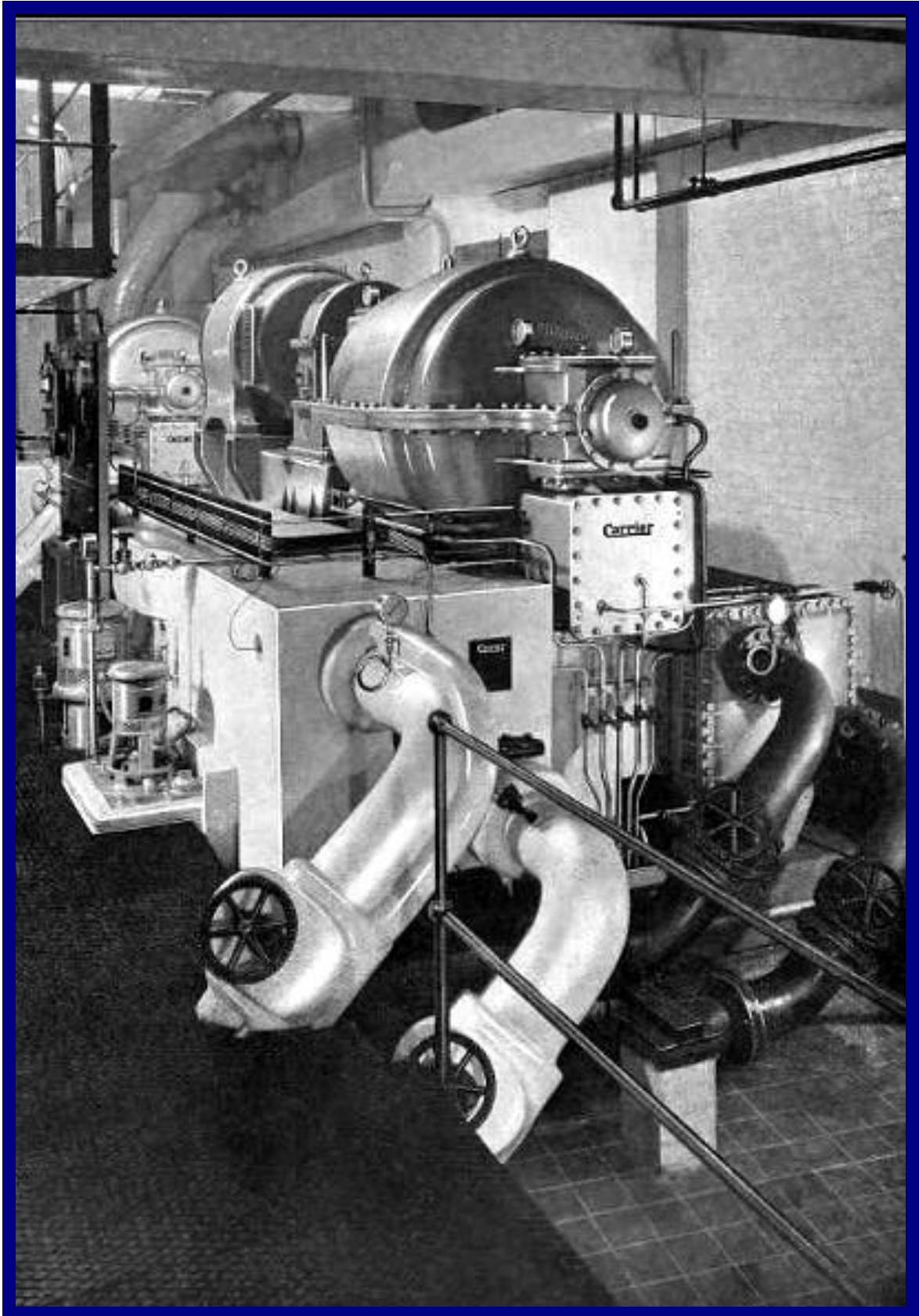
Centrifugal chiller 250 TR, BBC Broadcasting House, London 1931

# BBC BROADCASTING HOUSE



BBC air conditioning plant with chilled water spray air washer.

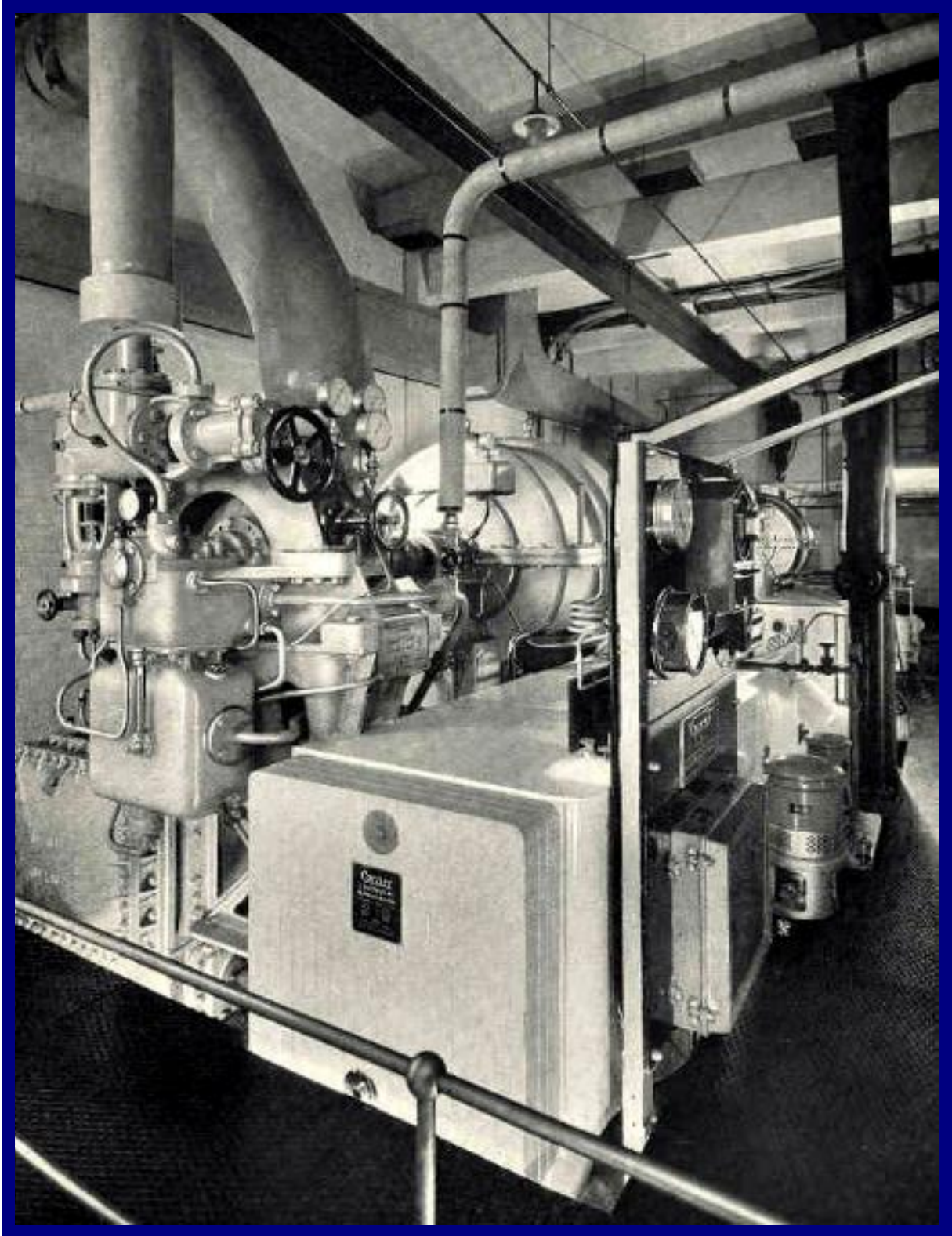
# CUMBERLAND HOTEL



Carrier electric motor-driven centrifugal 250TR, Cumberland Hotel, London 1933.

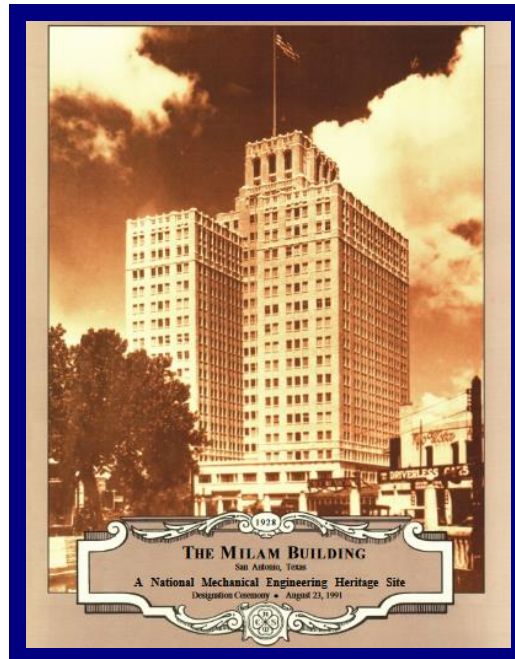
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## CUMBERLAND HOTEL

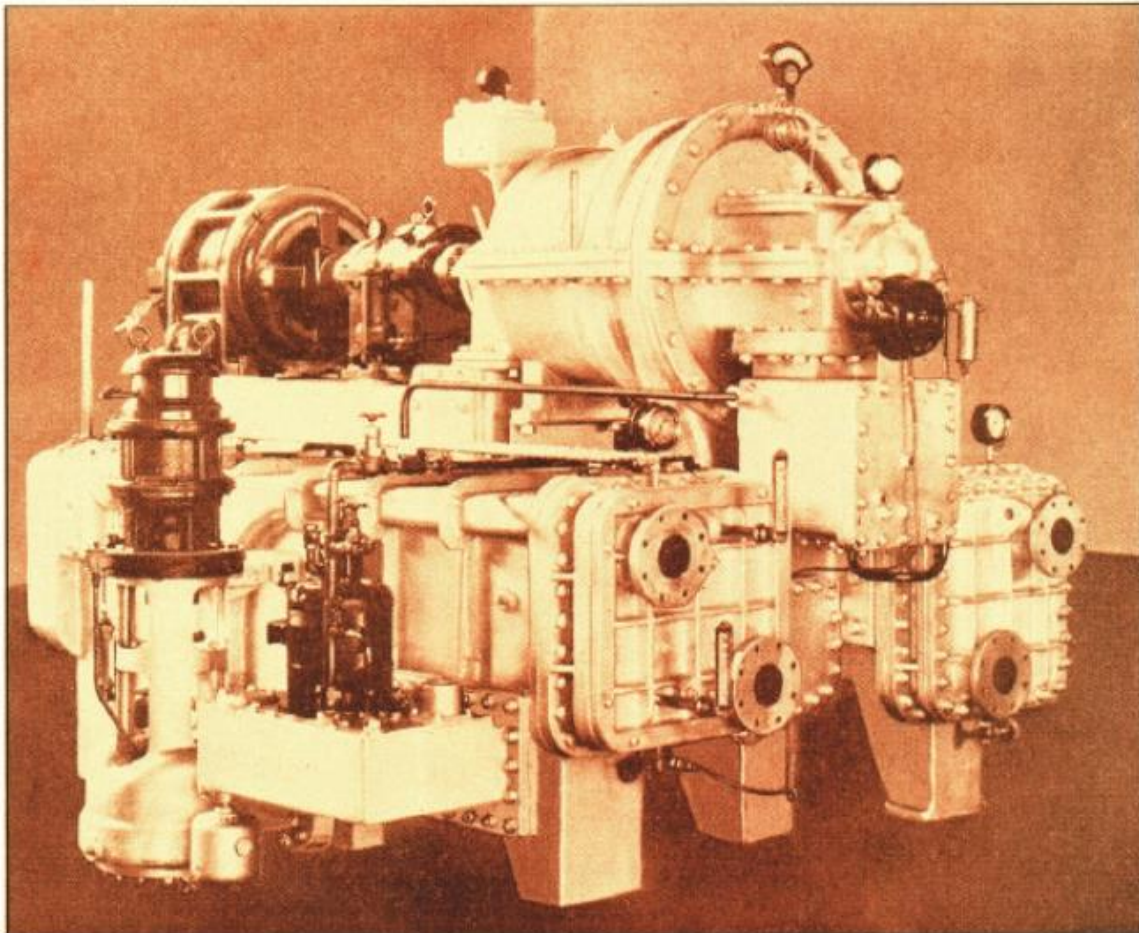


Carrier steam turbine-driven centrifugal 250 TR, Cumberland Hotel, London 1933.

# MILAM BUILDING

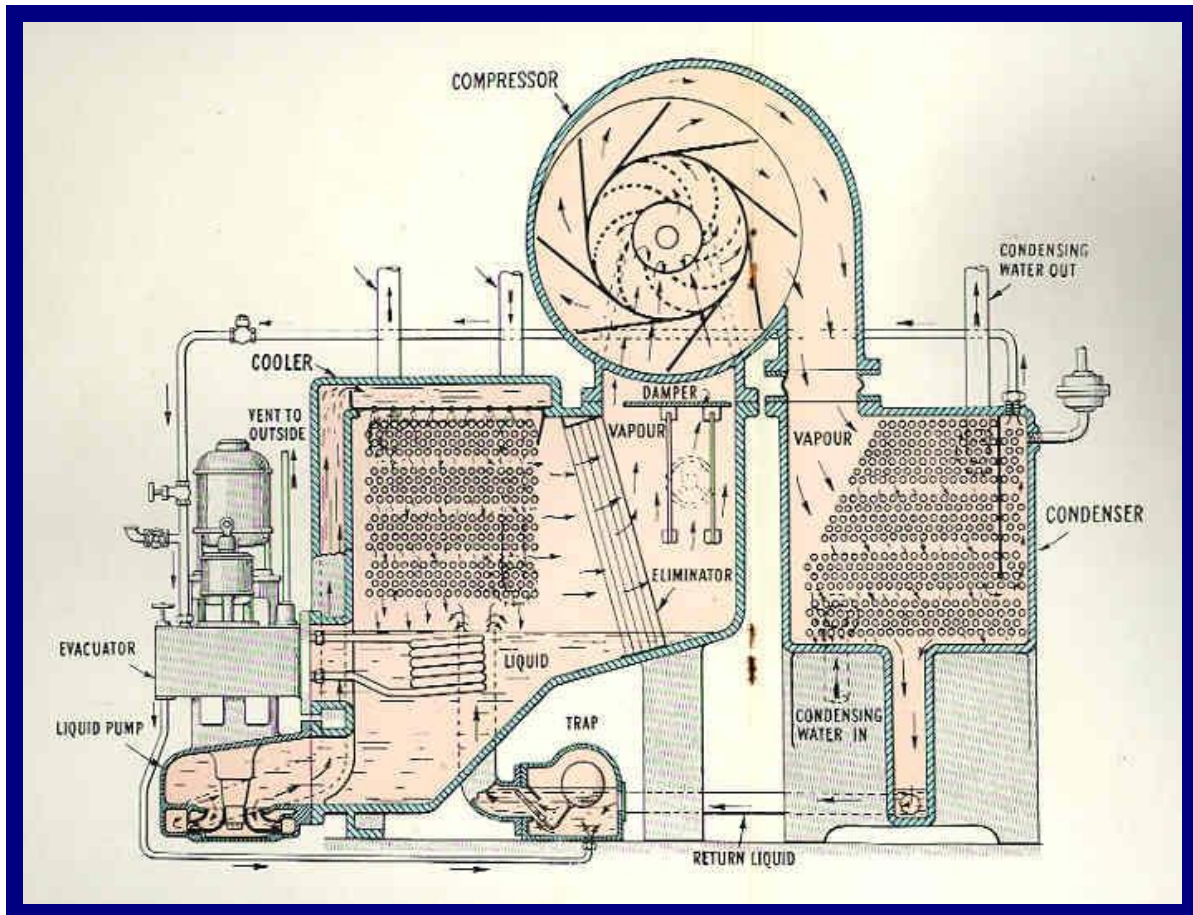


ONE OF THE TWO ORIGINAL CARRIER CENTRIFUGAL REFRIGERATION UNITS USED IN THE MILAM BUILDING. EACH UNIT HAD THE CAPACITY TO CHILL 650 GALLONS OF WATER PER MINUTE AND OCCUPIED APPROXIMATELY 215 SQUARE FEET OF FLOOR SPACE.

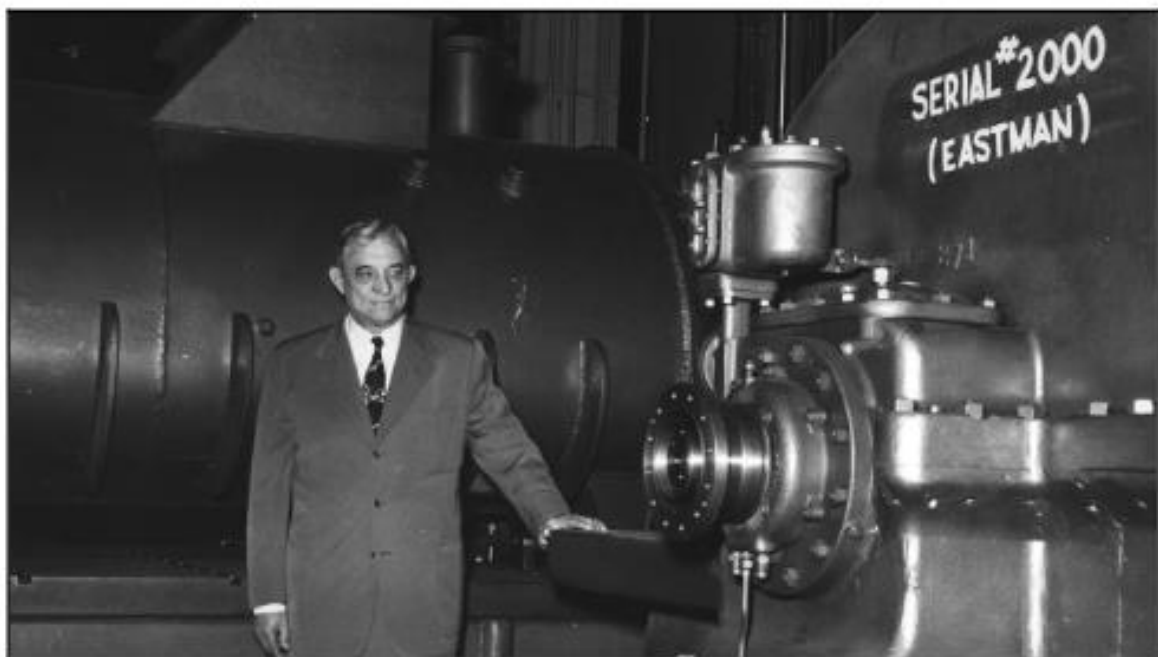


Carrier centrifugal in the Milam Building, San Antonio, Texas 1928.

# CENTRIFUGAL and WILLIS CARRIER

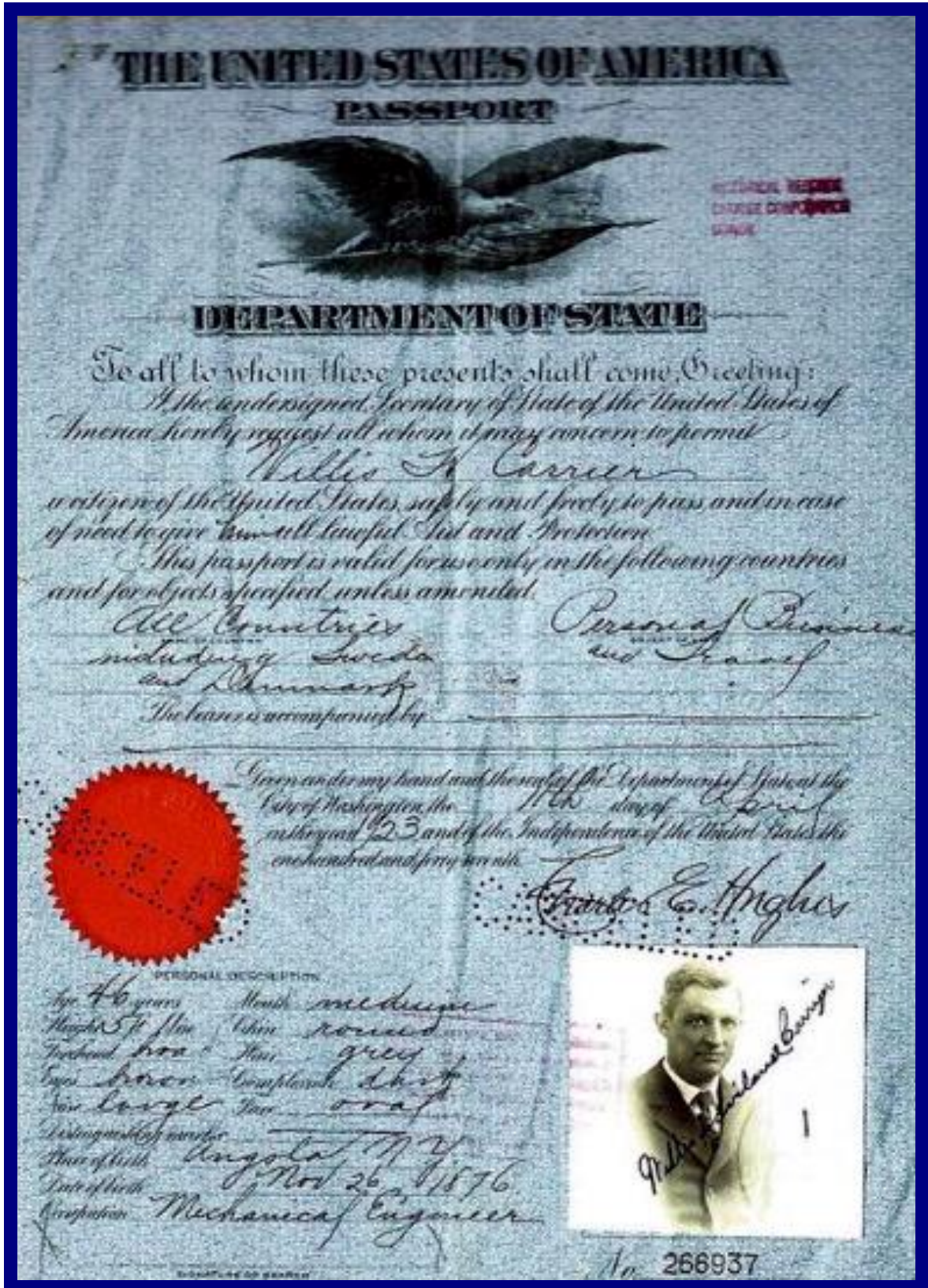


Schematic of Carrier centrifugal from early 1930s Catalogue.



Willis Carrier in 1950 with the 2000<sup>th</sup> centrifugal chiller

# WILLIS CARRIER



Willis Carrier Passport 1923.



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## **WILLIS CARRIER**

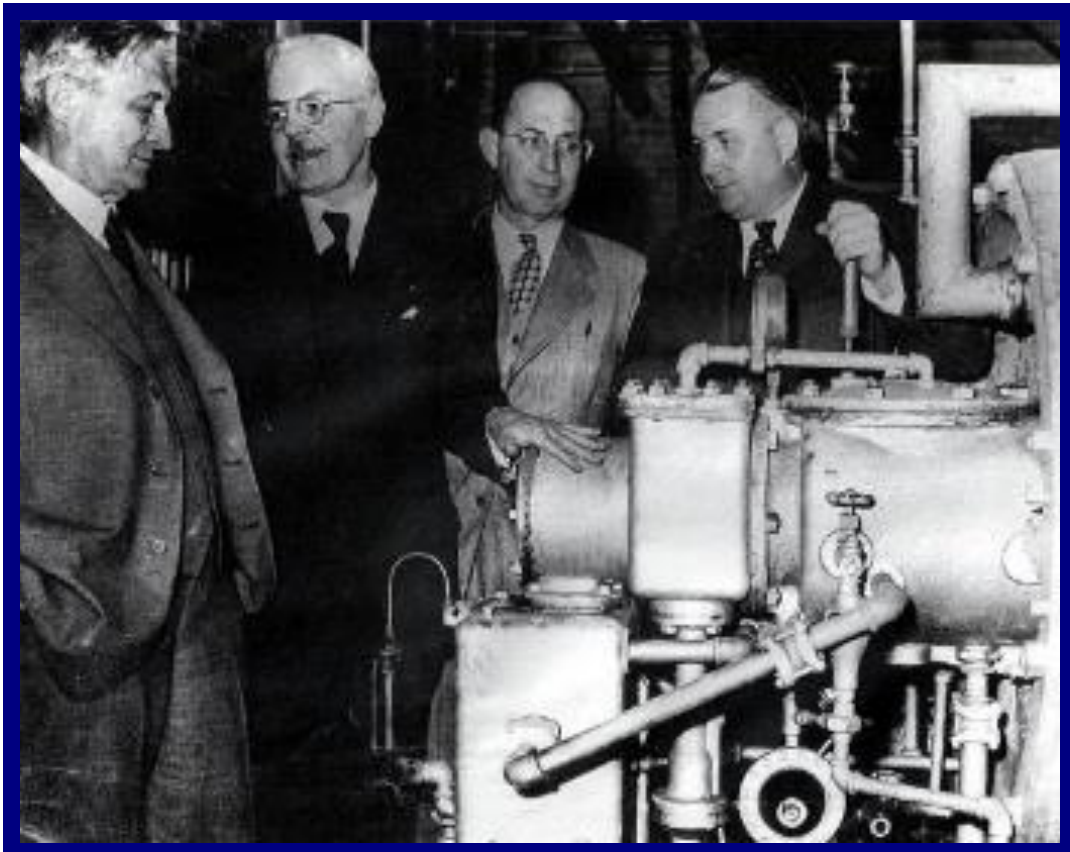


**Dr. Willis Haviland Carrier 1876-1956.**

## WILLIS CARRIER



Willis Carrier with his biographer Margret Ingels.



Around 1950 Willis Carrier (left) visited the Smithsonian Museum to view centrifugal chiller No.1 of 1922.

## WILLIS CARRIER

A POEM by Dr ALBERT KLEIN  
IN TRIBUTE TO WILLIS HAVILAND  
CARRIER

*Bad Teinach, Germany  
14 February 1947*

Seventy years have passed away  
Since a cold November day,  
Came to life a black-haired boy,  
Loud and lusty was his cry.

Willis Haviland he was named,  
He became well-known and famed,  
As the man who made, I say:  
"Every day a perfect day."

But before he could do that-  
In young years he grew not fat,  
For he had no easy start,  
Had to work long hours and hard.

School and college he passed, swift,  
Nobody gave him a lift,  
But his indomitable will  
Drove him upwards the steep hill.

So he made his later way,  
Worked and studied night and day,  
Till he drew his famous chart  
That gave air conditioning its start.

Out of his inventive mind  
Fans and washers he designed  
Autoregulation too  
From imagination grew.

Centrifugal compressors came  
Through his work to widest fame,  
He made, I state, short and tart:  
Air conditioning an art.

He wrote books about the air  
And its technique and with rare  
Knowledge, intuition told  
Of its problems manifold.

How to cool it, how to heat,  
Whether fast or slow the speed,  
Where the pressure high, where low,  
Whether strong or soft the blow.

Whether air was much too dry  
Or humidity too high-  
"Health and comfort through good air"  
Was his watchword everywhere.

All the places where man slaves,  
Suffers from cold and heat waves,  
Cold air, hot air, dusty, mean  
He made warm or cool and clean.

But not only he improved  
Air where workers sat or moved,  
Theatres, movies with great care  
He gave well conditioned air.

Thus, not only USA-  
Europe, Asia, Africa  
Soon called Willis Carrier:  
"Air conditioning's pioneer."

He brought help to all mankind,  
Lessening the daily grind;  
May he long live, healthy, strong  
Many, many years to come.

[1/487a]

# WILLIS CARRIER



Carrier Grave Marker at Forest Lawn Cemetery, Buffalo, New York.