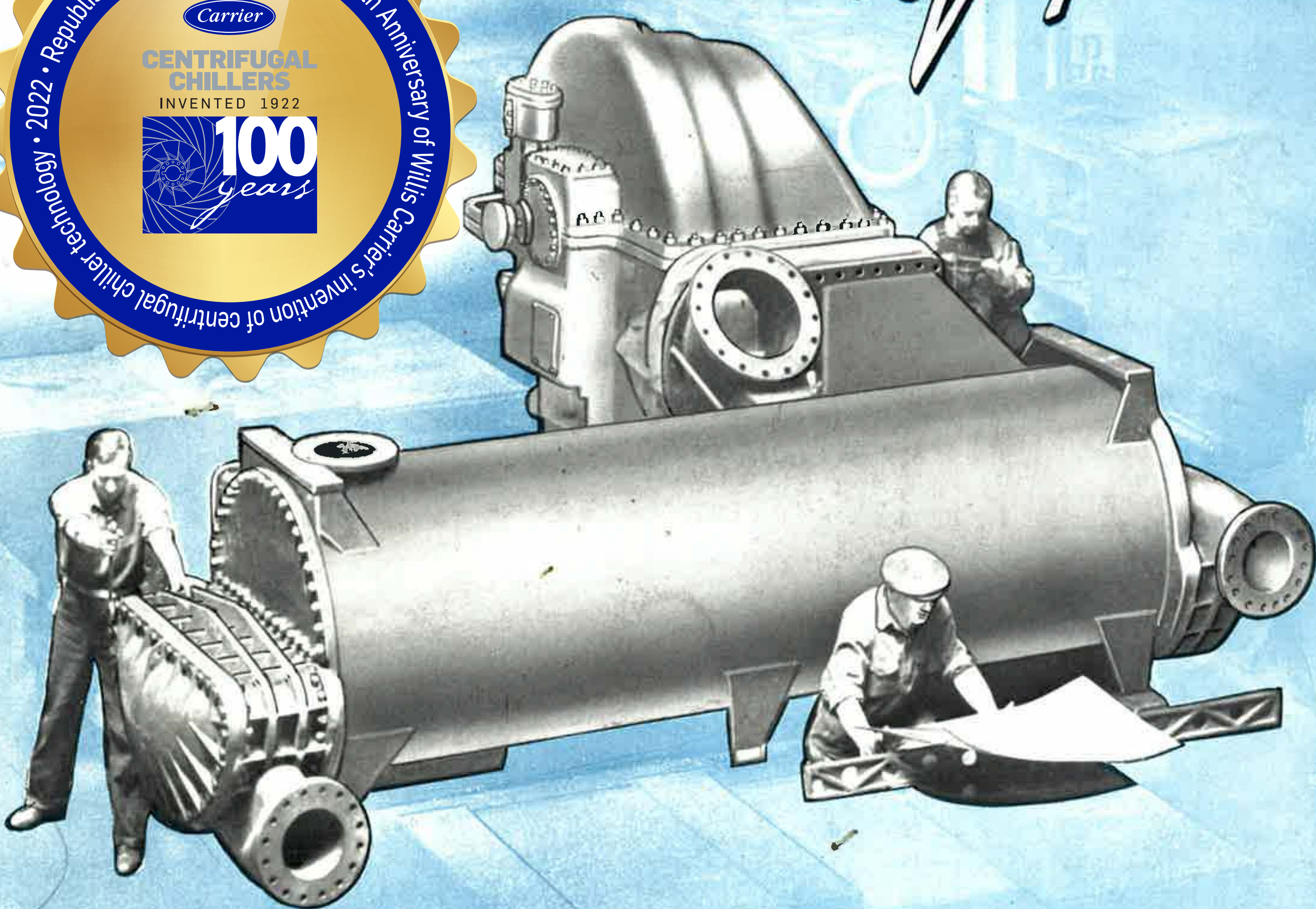
20 years CENTRIFUGAL Refrigeration

Republished to commemorate the 100th Anniversary of Willis Carrier's invention of centrifugal chiller technology • 2022 •

Carrier
CENTRIFUGAL CHILLERS
INVENTED 1922
100 years



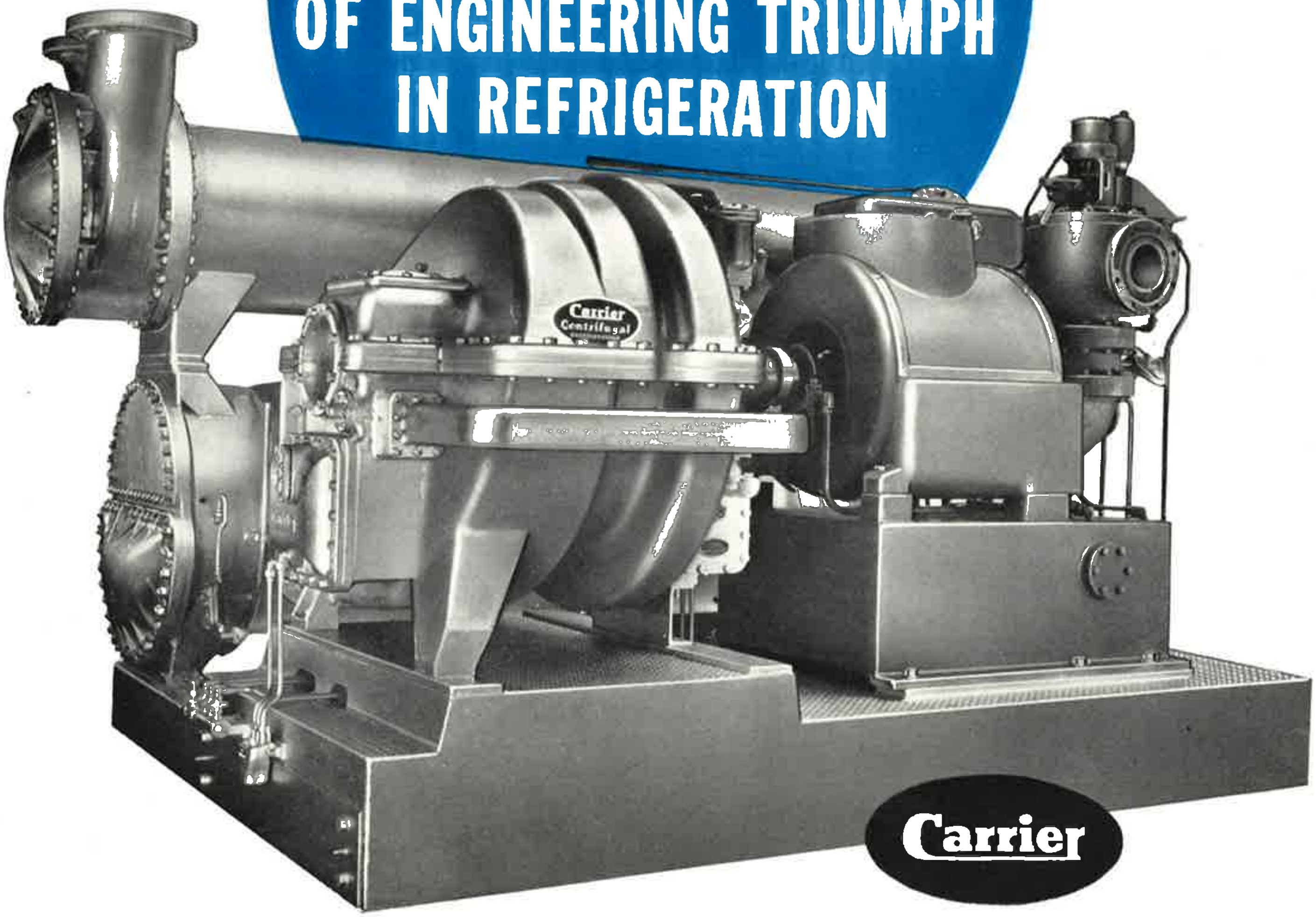
Carrier

INDEX

THE MACHINE

ILLUSTRATIONS

20 Years OF ENGINEERING TRIUMPH IN REFRIGERATION



Carrier

Carrier

Centrifugal Refrigeration

WIDE RANGE OF CAPACITIES—A complete range of sizes; capacities up to 1200 tons.

WIDE RANGE OF TEMPERATURES—Requirements as low as *minus* 130° F. are satisfied.

APPLICABLE TO ALL REFRIGERATION REQUIREMENTS—To chill directly any liquid, or to condense any vapor at a temperature level above minus 130° F.

DEPENDABILITY—Inherent characteristics of self-contained machine assure dependable, reliable service, proved by long use in hundreds of installations.

ECONOMY OF POWER AND REFRIGERANT—High sustained efficiency, economizer, automatic purge, oil-free refrigerant, and corrosion-resisting tubing assure minimum power consumption and unusually small refrigerant loss.

LOW MAINTENANCE COST—Few wearing parts, absence of erosion, and simplicity in design keep maintenance cost lower than for any other type of refrigeration machine of comparable capacity.

INSTALLATION ADVANTAGES— No special foundations necessary, due to relatively light weight and absence of operating vibrations. Space requirements small as equipment is compact.

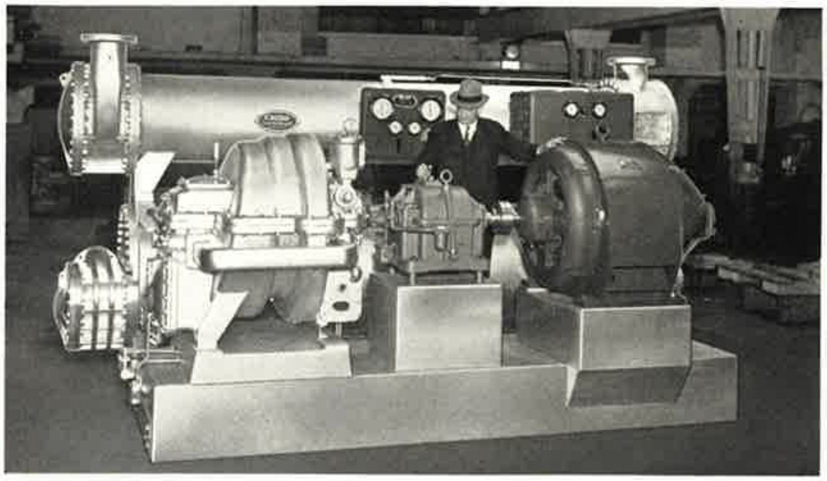
SUPERIOR OPERATING PERFORMANCE—Inherent "temperature stability" and non-overloading power characteristic. Only slight changes in speed for wide variations in capacity.

SAFE REFRIGERANT—Highest A.S.R.E. safety rating. Entire refrigerating cycle at low pressures. Parts are not subjected to shock in centrifugal compression. Static and dynamic balance of rotating parts, plus a safe, low pressure refrigerant, assure safe, dependable refrigeration.

OIL ECONOMY—Small oil charge. Only an annual change is recommended. Small losses as oil does not enter compression chambers.

ADDITIONAL ADVANTAGES—The Carrier Centrifugal Machine can be made a part of existing ammonia installations, replacing, with improved economy, the reciprocating compressor.

Adaptable to direct turbine drive as well as to motor drives. Especially favorable for turbine drive using processing steam, with refrigeration as a by-product.



The newest design of Carrier Centrifugal Refrigeration and its creator, Dr. Willis H. Carrier.

THE CARRIER CENTRIFUGAL REFRIGERATING MACHINE has again attained new heights resulting from years of research. The progress-packed, fascinating history of the delivery of thousands of tons of refrigeration to many industries is recorded in the following pages.

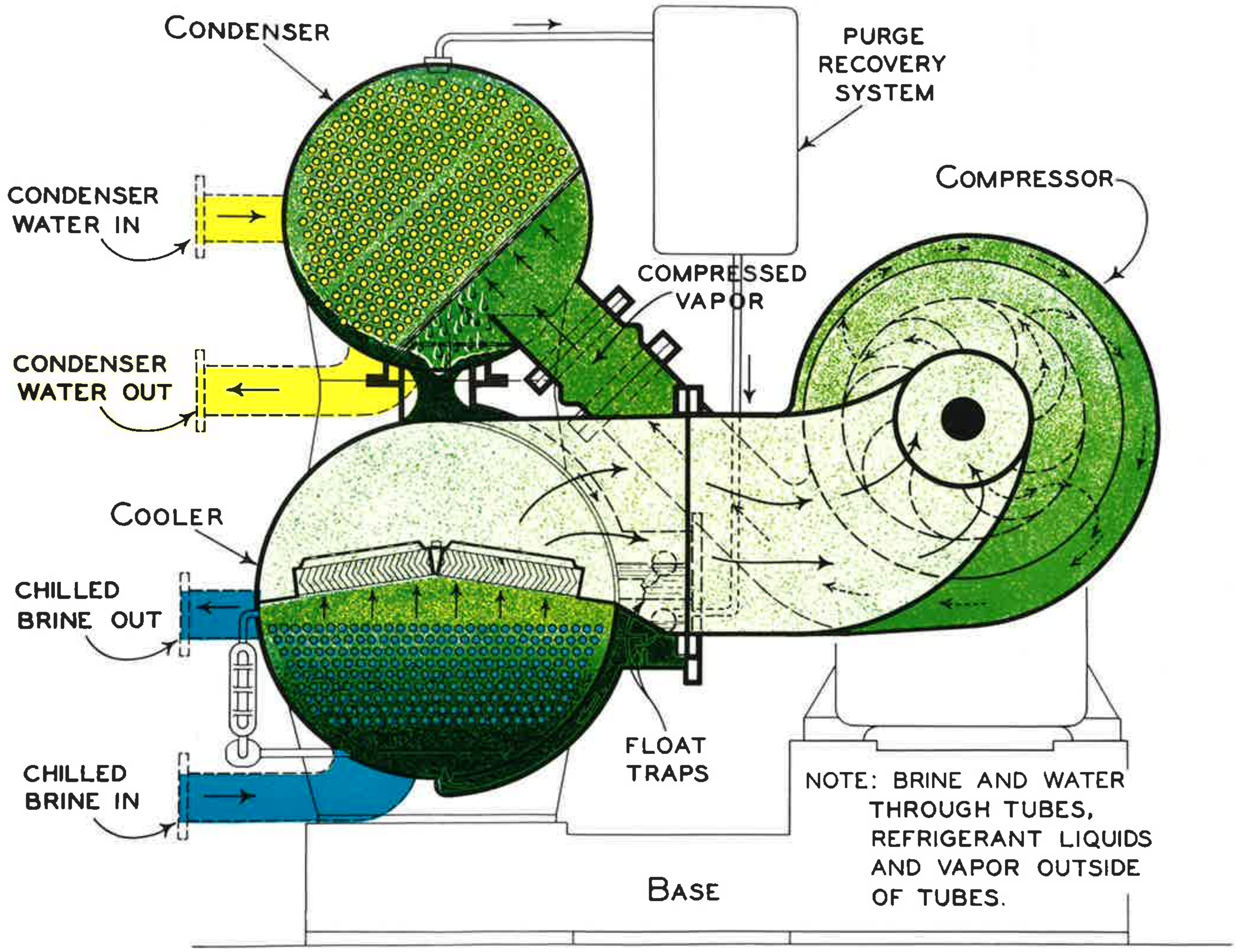
Dr. Willis H. Carrier anticipated the modern trend toward centrifugal, instead of reciprocating, compression for large refrigeration requirements as early as 1918, at which time he began the design of the Carrier Centrifugal Refrigerating Machine. With the installation of the first machine in 1922, the story of centrifugal refrigeration closely parallels that of the steam turbine, as both units are endowed with the same inherent characteristics of high rotating speed which promote efficiency, compactness, long life and freedom from rubbing parts.

Much of the progress of the centrifugal machine is a result of major improvements in the equipment. New low pressure cycle, non-toxic, non-inflammable refrigerants, especially suited to the improved characteristics of the centrifugal machine, have been selected.

The oiling system assures protective, reliable and adequate lubrication of all parts.

An achievement as great as the original idea of using centrifugal compression for refrigeration is the shaft seal which prevents refrigerant leaks during operation and shut-down. Without this practical and ingenious solution of the seal problem the centrifugal principle of refrigerating would have existed only as a theory.

Many installations illustrate the wide range of application of Carrier Centrifugal Refrigeration, its continuous growth reaching a total capacity of 182,395 tons by Nov. 1, 1940.



DIAGRAMMATIC DRAWING OF
CARRIER CENTRIFUGAL REFRIGERATING MACHINE

REFRIGERATION CYCLE

Operating on the compression cycle, the Carrier Centrifugal Refrigerating System utilizes Carrene No. 2 (Trichloromonofluoromethane) as a refrigerant. A colorless liquid, boiling at 74.8° F. at atmospheric pressure, Carrene No. 2 may be handled safely, and with little loss, in open containers when necessary. Steps of the cycle, all at low operating pressures, may be identified with relation to equipment in drawing.

EVAPORATION—The cooler transfers to the refrigerant the heat which must be removed in the refrigeration process. Chilled brine, or water, acquires the heat from the load and is circulated within the tubes of the cooler. Liquid refrigerant in the shell contacts the outside of the tubes, transferring the heat from the brine to the refrigerant. This heat then becomes the latent heat of evaporation when it changes the refrigerant from the liquid to the vapor state. In this way, the refrigerant vapor acts as a vehicle by which the heat is conveyed to the point of disposal.

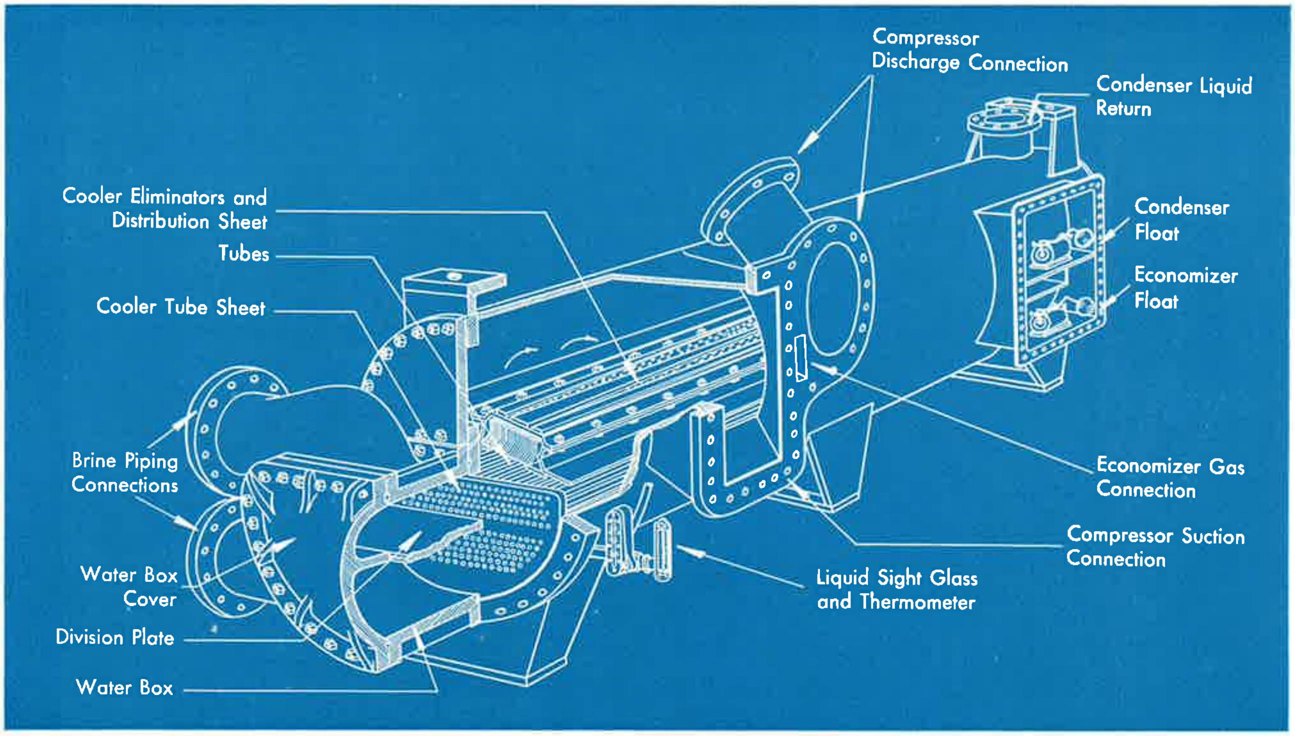
COMPRESSION—The compressor draws vapor from the cooler, compresses it in two or three stages and delivers it at a higher pressure into the condenser. This compression raises the temperature level of the heat from the low level of evaporation to the higher level of condensation. At the end of the compression period, the temperature of the discharge vapor is higher than that of the cooling water used in condensing and the heat flows through the walls of the tube into the water. Power is supplied to rotate the shaft and impellers. The pressure of the vapor is increased because of the centrifugal force and because kinetic energy of the gas leaving the impellers at high velocity is converted into pressure. Flash gas from the inter-stage cooling of the liquid is admitted to the second stage.

CONDENSATION—The condenser rejects the heat which has been absorbed in the process of refrigeration and also the heat which has been added to the gas during compression—an amount of heat equivalent to the work done upon the gas. The condenser water from the selected source is circulated within the condenser tubes. Hot gas from the compressor enters the condenser shell and impinges upon the outside of the tubes. Heat is then transferred from the refrigerant to the condenser cooling water. Removal of heat—latent heat of condensation—causes liquefaction of the refrigerant, and the condensate drains into the cooler. The heat is carried by the water to some suitable point of disposal and the cycle of refrigeration is thereby completed.

REFRIGERANT FLOW CONTROL—To promote a continuous process of refrigeration, the compression cycle is completed by returning the liquid refrigerant to the evaporator. The liquid drains from the condenser to the upper float trap which allows only liquid to flow and prevents gas blowing through. The liquid then enters the economizer, where it is cooled to a temperature corresponding to the pressure between the first and second stages. A part is evaporated to cool the remaining and larger portion of the liquid delivered to the cooler. The flash gas is conducted to the second stage of the compressor, and the liquid is drained through the lower float trap of the cooler. The amount of refrigerant charged into the system is sufficient to make all cooler tubes active and effective.

ALL PARTS DESIGNED FOR CO-ORDINATED OPERATION

The appraisal and understanding of the machine as a unit must be based on a knowledge of its parts. Efficient performance is derived through quality built into individual parts. Well known to present owners are the qualities and characteristics that have made Carrier machines universally successful for the last twenty years. Precision and quality in all details are responsible for the purchase of 29 machines by one corporation, with a total refrigerating capacity of 5,990 tons and the purchase of 43 machines by another company, with 10,700 tons capacity.



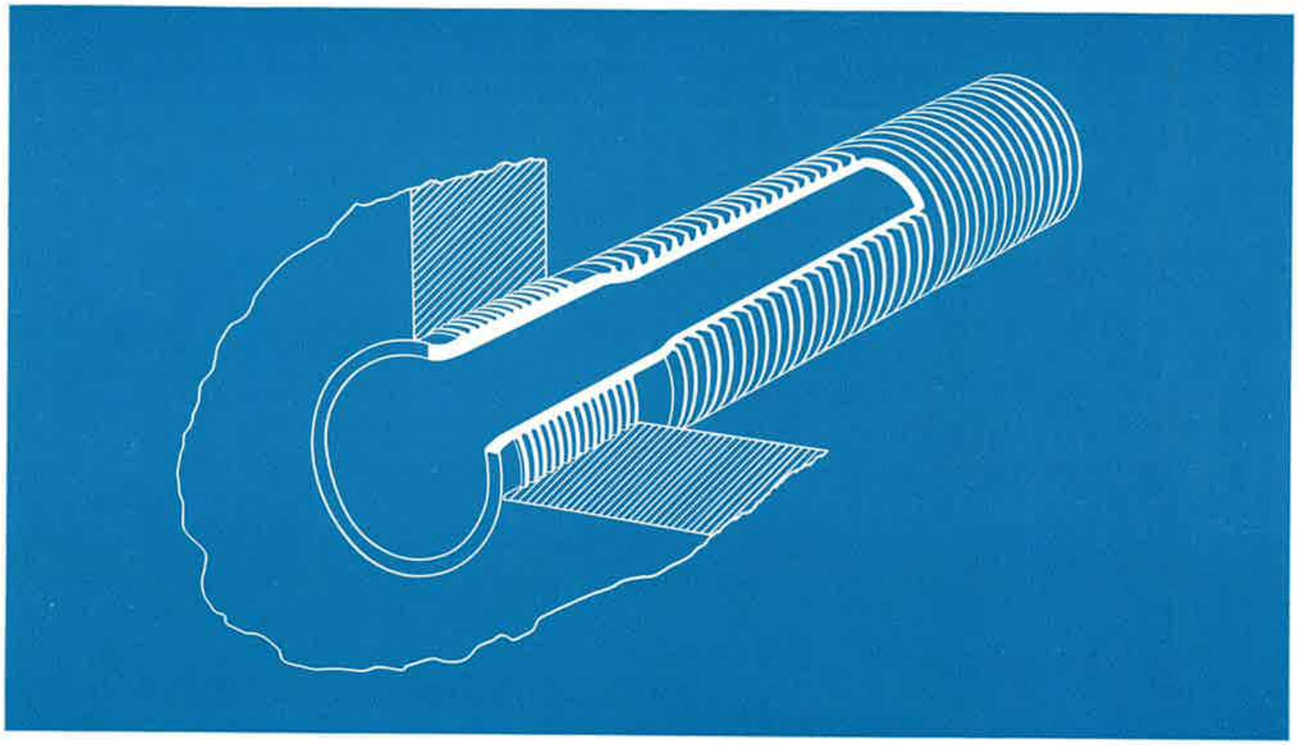
COOLER

SHELL AND SHELL FLANGE—Hot-rolled, low-carbon steel, electrically welded, in typically modern construction. Low-carbon nickel steels, especially selected to resist embrittlement, are used for very low temperature applications.

TUBE SHEET—Cupro-nickel, welded to shell flange—Selected for its resistance to corrosion, and high structural strength, the cupro-nickel tube sheet welds readily to steel and is proof against leaks. Of the same electrical potential as non-ferrous tubes, the cupro-nickel sheet is insurance against electrolytic corrosion. For expanding the tube into the sheet, holes are drilled, reamed and multiple-grooved.

TUBES—Copper for standard construction; non-ferrous alloys for special conditions—A special extrusion process provides an extended surface of low, closely-spaced fins which are integral with the tube wall, known as "Lo-Fin" tubes. Slightly belled tube ends permit removal and replacement in the same manner as plain-surfaced tubes. Belling of the ends improves entrance conditions and (by velocity reduction) minimizes erosion at this point. High, sustained heat transfer efficiency is maintained by non-ferrous tubes through the characteristics of corrosion resistance, longevity and remaining clean over longer periods.

Closely nested in the lower half of the shell and immersed in liquid refrigerant are the "Lo-Fin" tubes. This "Lo-Fin" tube and cooler design was determined after thorough development. Compact and space-saving, this design is low in maintenance cost. Extraordinarily high rates of heat transfer increase the performance of the cooler and permit operation at low temperature differences. The high transfer rate permits the use of a minimum number of passes for brine flow and low friction losses. No liquid refrigerant pump is required with this cooler.



Tubes

TUBE SUPPORT SHEETS—Cast Brass—Adequate tube support prevents tube vibration and at the same time enhances the strut support of tube sheets by the tubes. These tubes are expanded into the hole in the support sheet, which provides two intermediate supports for the tubes.

LIQUID DISTRIBUTION SHEET—Steel—Provides equal distribution of liquid and flash gas under the cooler tube bundle.

GAS DISTRIBUTION SHEET—Steel—This sheet, located above the eliminators, is perforated in such a way that the flow of vapor through the eliminators is equalized throughout the length of the cooler. This equalization of gas flow also equalizes the ebullition of the violently boiling refrigerant and each square foot of surface carries its share of refrigeration duty.

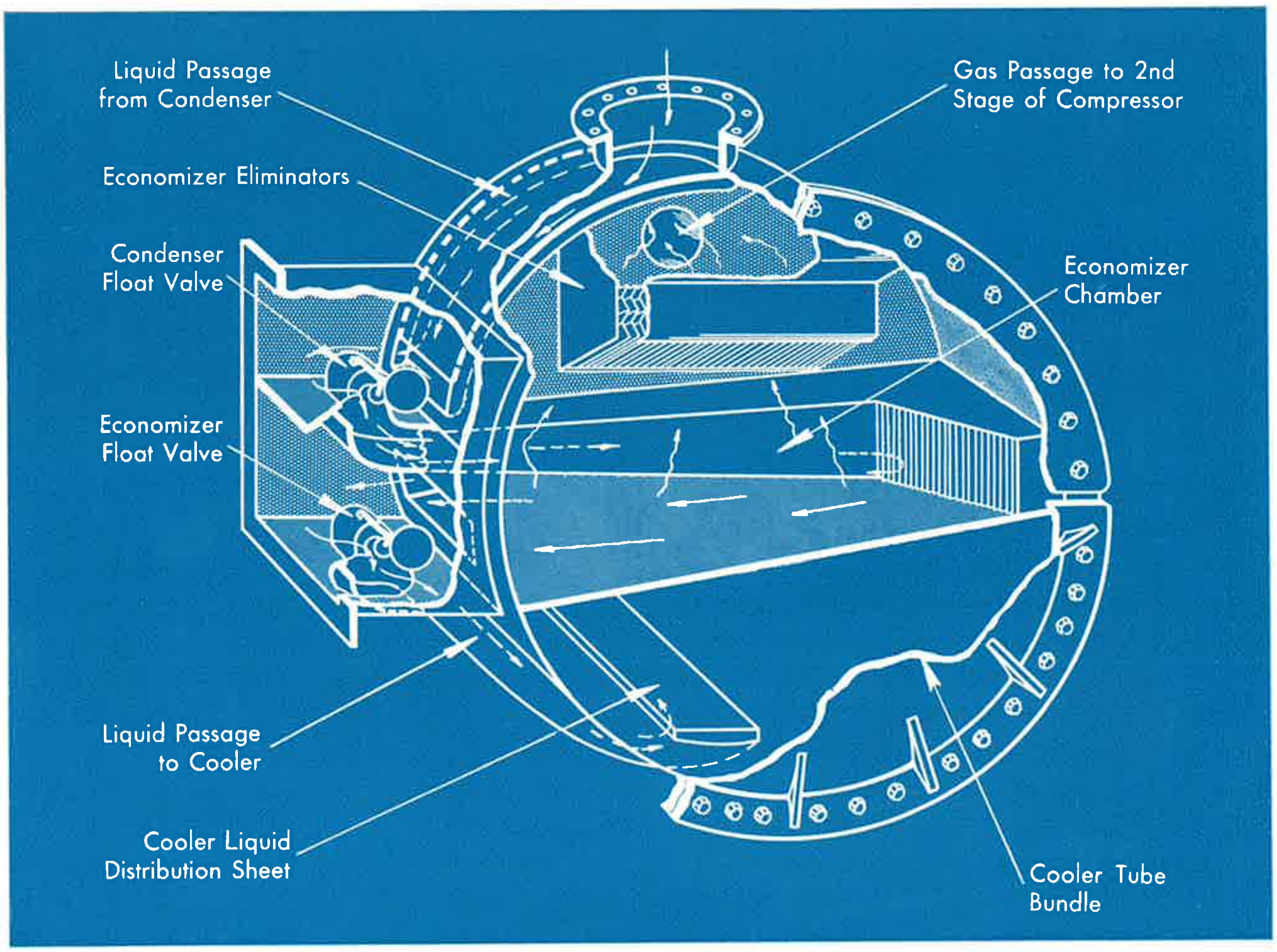
ELIMINATORS—Brass—An important feature of the design. With equalized flow of gas provided by the gas distribution sheet, overloading of the multi-bend eliminators at any point is obviated and entrainment of liquid in the suction vapor prevented.

SIGHT GLASS—A reflex glass by which the level of the liquid is observed.

WATER BOXES AND COVERS—Cast Iron—Normally designed for 250 pounds per square inch maximum working pressure, the water boxes and covers can be removed without breaking the refrigerant joints. Water box baffles may be arranged for one, two, three or four passes of brine flow. The heads and covers of the boxes are interchangeable end-for-end of the cooler so that piping connections can be made most conveniently. The covers may be removed for cleaning tubes without interference with piping connections.

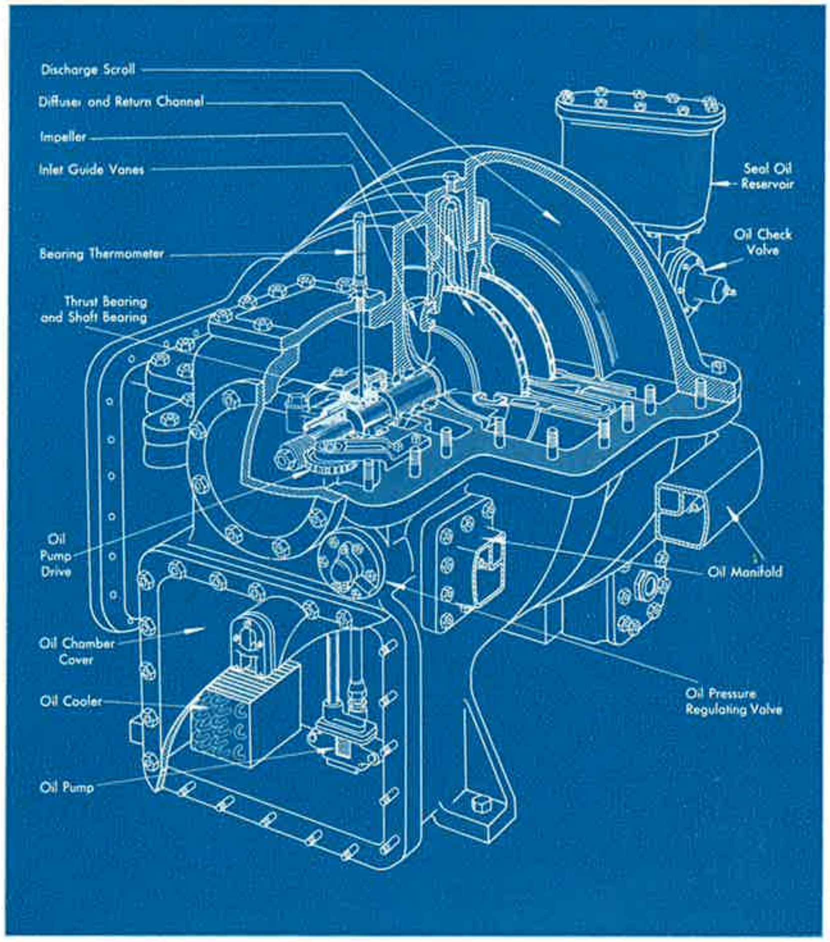
ECONOMIZER—By inter-stage cooling of the liquid refrigerant, the machine capacity is increased and the brake horsepower per ton appreciably decreased. This economy is available to every owner as the economizer is provided on every machine. Formed from steel, welded into the upper part of the cooler at the end farthest from the compressor, the economizer consists of a chamber into which liquid refrigerant from the condenser is expanded and flashed by reduction to the inter-stage pressure. The flash gas is conducted to the compressor through a pipe within the cooler and the eliminator prevents liquid entrainment in the vapor leaving the economizer.

LIQUID FLOAT TRAP—Two float traps, or valves, housed in two separate chambers, as indicated by the drawings, are provided to control the flow of liquid. A conduit conveys liquid from the condenser to the upper valve. The liquid flows through this valve to the economizer and is reduced in pressure, since the pressure in the economizer is the same as that between the first and second stages of compression. The flash-cooled liquid flows through the lower float trap and through a conduit into the cooler, the pressure being reduced to that prevailing in the cooler. A cover on the side of the housing provides easy access for inspection of the valves.



Economizer

COMPRESSOR



Compressor

The compressor is a completely modern machine. Back of it are twenty years of design, manufacturing, and operating experience. Long use and service have proved its reliability. Recent research and careful development have lowered the sound level, improved efficiency, simplified design, and reduced horsepower requirements.

With centrifugal compression, there are no wearing parts in the compressor proper. No valves, piston rings, or cylinder walls are required as in the reciprocating compressor. No erosion or wear occurs at points of clearance as in the centrifugal water pump. The life of the centrifugal compressor is greater than that of any other type of compressor or of any other rotating machine. Compressor efficiency is sustained for the life of the compressor because nothing occurs to change it.

The few bearing and seal parts that do wear are liberally designed, perfectly lubricated, and proved by actual service. Purchasers have investigated Carrier equipment installed for many years, and have been convinced that refrigeration from Carrier machines is dependable for important industrial processes. The degree of dependability is reflected in the fact that, almost universally, a spare unit is considered unnecessary.

CASING—Semi-steel castings, split horizontally at the shaft center level—Bolted flange and gasket joint—For simplification and improvement of appearance, the suction gas inlet, the interstage flash gas inlet, and the hot gas outlets, are combined in one flange connection at the side of the compressor. Access covers are provided for each bearing chamber, the oil reservoir, atmospheric oil float chamber, and elsewhere as required.

SHAFT—Forged, heat-treated, nickel steel, turned and ground—Although operation of this shaft is far below the critical speed, the size and rigidity prevent vibration at any speed. The shortest possible length of shaft between bearings is gained by the use of a thrust bearing and because only the impellers are mounted between the two bearings.

IMPELLERS—Fabricated steel—Low carbon steel, forged disks and sheet steel blades, formed for backward curvatures, are assembled with hot welded rivets to form the impeller assembly. This assembly is lead-coated and keyed to the shaft and fixed in position by lock nuts threaded on the shaft. Statically and dynamically balanced through a progressive operation of parts balancing prior to assembly, the shaft and impeller assembly is vibrationless and in true balance.

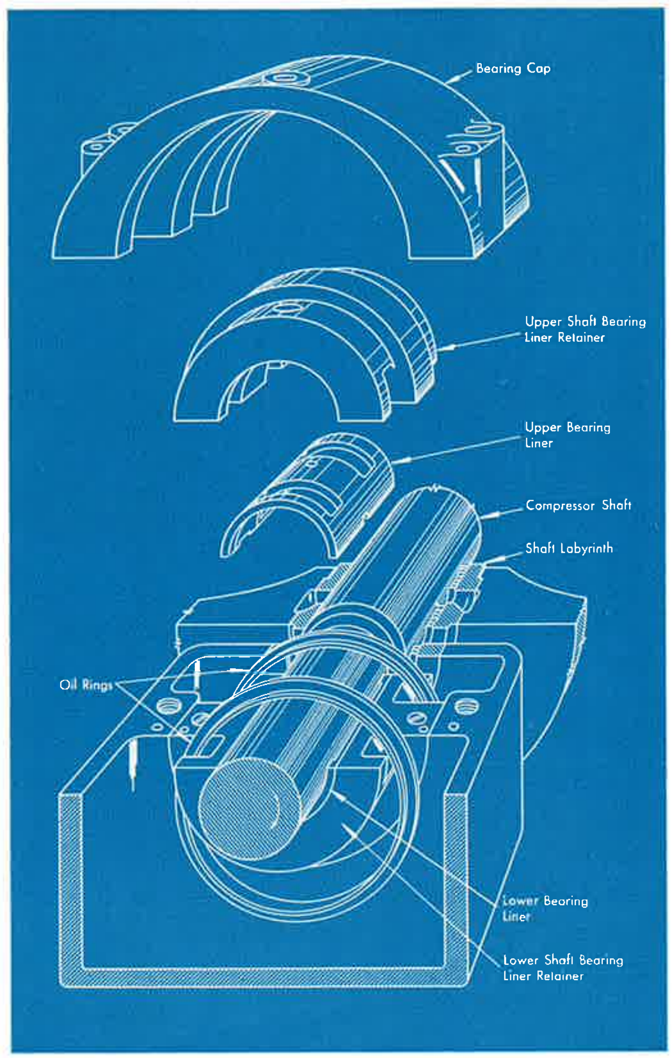
The use of fabricated steel in preference to cast impellers, coupled with low operating speed, affords a large safety factor in the impeller construction. These impellers are carefully and specifically designed for low pressure refrigerant vapors.

INLET GUIDE VANES—Castings—Horizontally split at the center, these vanes are provided at the entrance to each impeller—evidence that nothing promoting high efficiency is omitted in the construction of this equipment. A carefully formed volute suction chamber is another design feature, reducing operating losses and improving performance.

DIFFUSERS AND RETURN CHANNELS—Castings—Designed for minimum operating noise, the diffusers are passages receiving gas from the impellers, converting kinetic energy into pressure. Return channels are passages which conduct gas from the diffusers to the next stage. These passages and the vanes in the return channels are formed by castings fitted into place in the casing. All are split horizontally at the shaft center line. These parts, like all parts subject to hydraulic design, have been developed through laboratory research and test work.

LABYRINTHS—The labyrinths consist of multiple narrow strips located concentrically with the shaft at both ends of the compressor and also between stages, to stop leakage of gas along the shaft. Minimum and perfectly uniform clearance between the shaft and labyrinth is attained by boring and reaming the casting for the shaft bearing retainers while all other casting surfaces concentric with the shaft are machined.

Bearing retainers are then placed and line-reamed and are used as centers for finish reaming of all labyrinths. By this means, the labyrinths are related perfectly to shaft surfaces, assuring minimum interstage gas leakage.



Bearing Details

Obviously there can be no rubbing friction and no wear. The number of labyrinths and the proportional leakage of gas are restricted to an absolute minimum. The use of the thrust bearing makes it possible to eliminate thrust balancing devices and labyrinths.

BEARINGS—This modern type of liner, consisting of a thin bronze sheet, babbitted with high-tin babbitt and completely finished, ready for service, is inserted in the retainers. The liners do not require fitting, either on initial installation or on replacement. Oil entrances to liners are carefully machined and bearing surfaces are designed to assure an adequate oil film from the moment of first motion. Lubrication is supplied by pressure during normal operation and by two oil rings (two for each bearing) when speed is subnormal, during stopping and starting. The bearings carry no end thrust load. Temperatures are indicated by thermometers.

THRUST BEARING—The axial thrust along the shaft caused by differences of pressures on the impellers is completely absorbed by a modified Kingsbury thrust bearing. One of proved reliability, this bearing carries the thrust with less power loss than any other type. The principle of the Kingsbury thrust bearing consists of an oil film between two sliding surfaces, which tends to assume a tapering form, with the thick end at the entering side. Since the film is constantly maintained, there is complete separation of the surfaces and no wear occurs. These results are obtained by dividing one bearing element into segments supported and pivoted to tilt slightly. Thus the oil film automatically assumes whatever taper is required by speed, load and oil viscosity.

The thrust bearing is located on the shaft outside the main bearing at the intake end of the compressor. A thrust collar, or "runner," rotates with the shaft. The tilting segments, or shoes, in the base ring are so housed that the lower part of the bearing is submerged in oil. Lubrication is provided by this immersion during starting and stopping but is provided from the pressure system of the compressor during normal operation. Carrier elected to handle the thrust problem in this manner, the wisdom of which has been confirmed by many years of actual service.

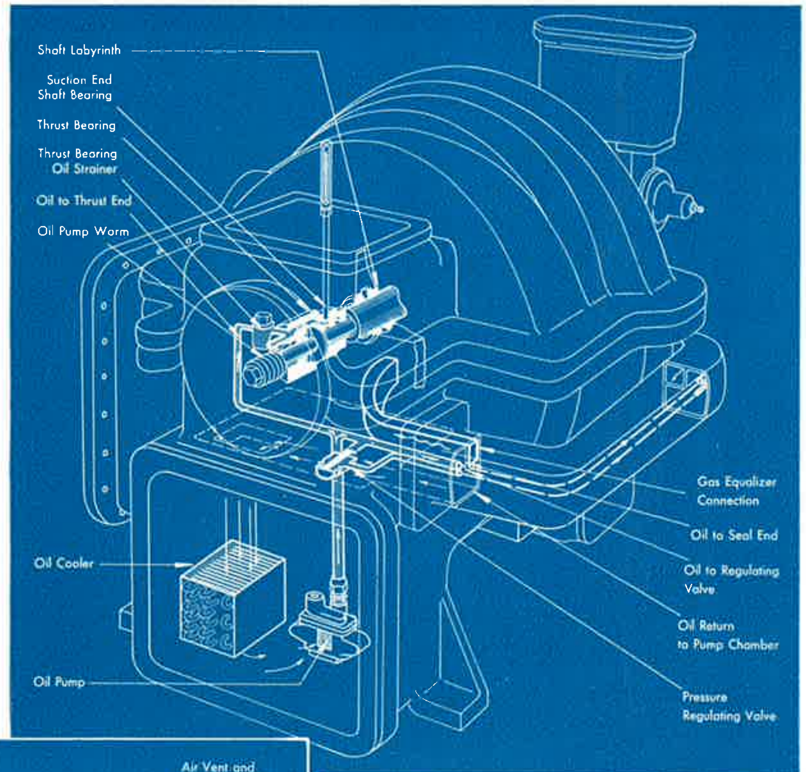
Small and reliable, the Kingsbury thrust bearing does not increase the inertia of the rotor nor affect the critical speed. Outside of the refrigerant gas zone, it does not increase the length of the shaft between main bearings, nor does it require a balancing device with increased labyrinth loss. For the same reason, devices which would increase the gas friction and compressor horsepower within the gas zone are avoided. This bearing absorbs the entire thrust, eliminating thrust friction losses on the main bearing.

OIL PUMP—An oil reservoir is located below the shaft at the suction end of the compressor. A gear oil pump is submerged in the reservoir and driven by a worm and wheel which assure complete reliability. The reservoir is cooled by water supplied under manual control to hold required oil temperatures. The cooling coil is made of finned copper tubing, attached to and removed with the access covers.

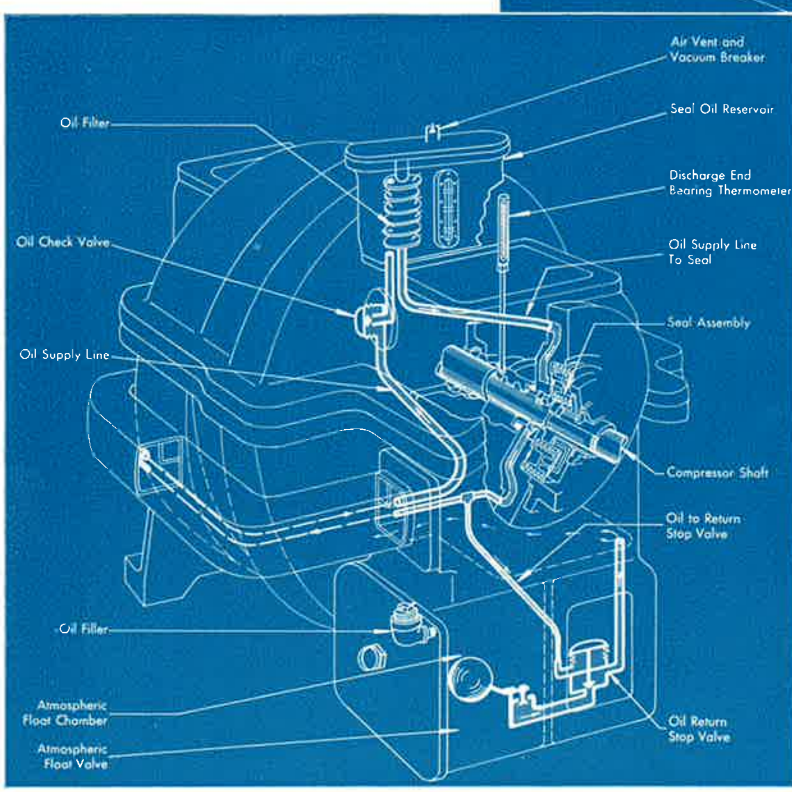
OILING SYSTEM—Carrier recognized at the outset that the centrifugal compressor must be inherently a machine of long life. Only four parts of this machine have rubbing, or wearing, surfaces: shaft bearing, thrust bearing, oil pump, and the shaft seal surfaces which contact only momentarily during starting and stopping. The long life of these parts is assured by liberal and careful design and dependable lubrication.

Each shaft bearing is equipped with two oil rings; the thrust bearing is immersed in the oil well; the oil pump is submerged in oil; the shaft seal is flooded by oil from the seal reservoir; all these operations are effective when the compressor is started. Pressure lubrication is supplied to every part, once the compressor has attained operating speed. This lubrication system is protected by a safety relief valve.

The full capacity of the oil pump is thrown initially to the thrust bearing, the adjacent shaft bearing and the oil pump worm drive. Oil pressure quickly increases sufficiently to open the diaphragm check controlling admission to the seal and seal reservoir. One filter is supplied for the first mentioned flow and a second filter is in seal reservoir for the second flow.



Compressor Oiling System—Thrust End



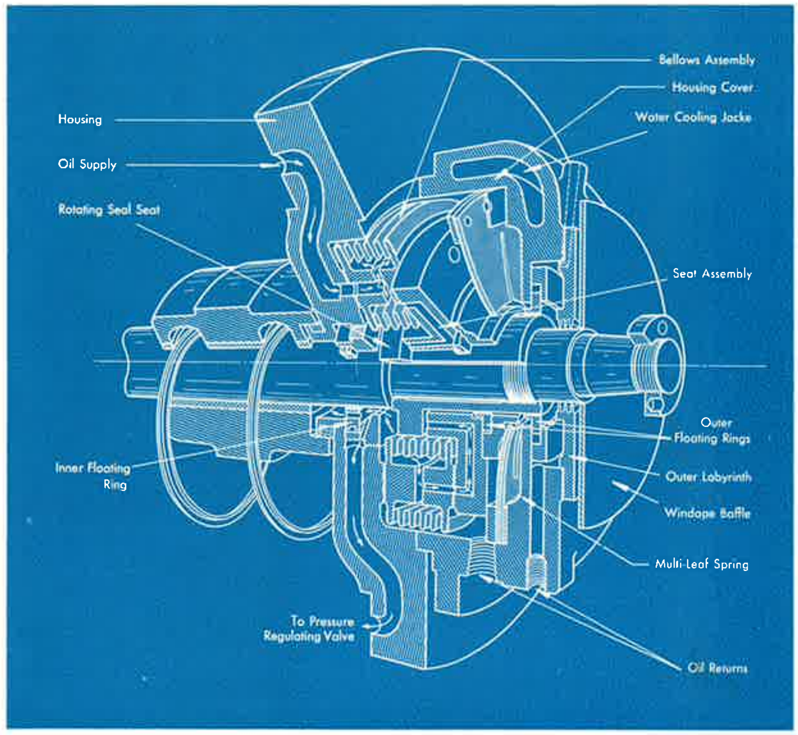
Compressor Oiling System—Seal End

The seal opens as previously described and the adjacent shaft bearing receives pressure lubrication.

Surplus oil from both shaft bearings drains to the main reservoir. Oil passes through the seal and is drained to the atmospheric float chamber. This float valve opens when the level rises, and atmospheric pressure returns oil to the machine. An automatically operated pressure stop valve is installed in the atmospheric oil return so that this connection shall always be closed tightly when the compressor is idle. Leakage of air into the system, or loss of refrigerant from the machine is thereby prevented.

Flow of oil to the seal and oil pressure at the seal is regulated automatically by the oil pressure regulator in the connection to the reservoir.

SHAFT SEAL—Lapped metallic seals are common today in the refrigeration field. But the Carrier seal is unique and a veteran of many years' service. Its life is assured because of the Carrier method of operation. Metallic contact under oil is made only when the compressor is accelerating and decelerating. During operation, wear is eliminated, sealing is achieved by a pressure oil film, and power is saved.

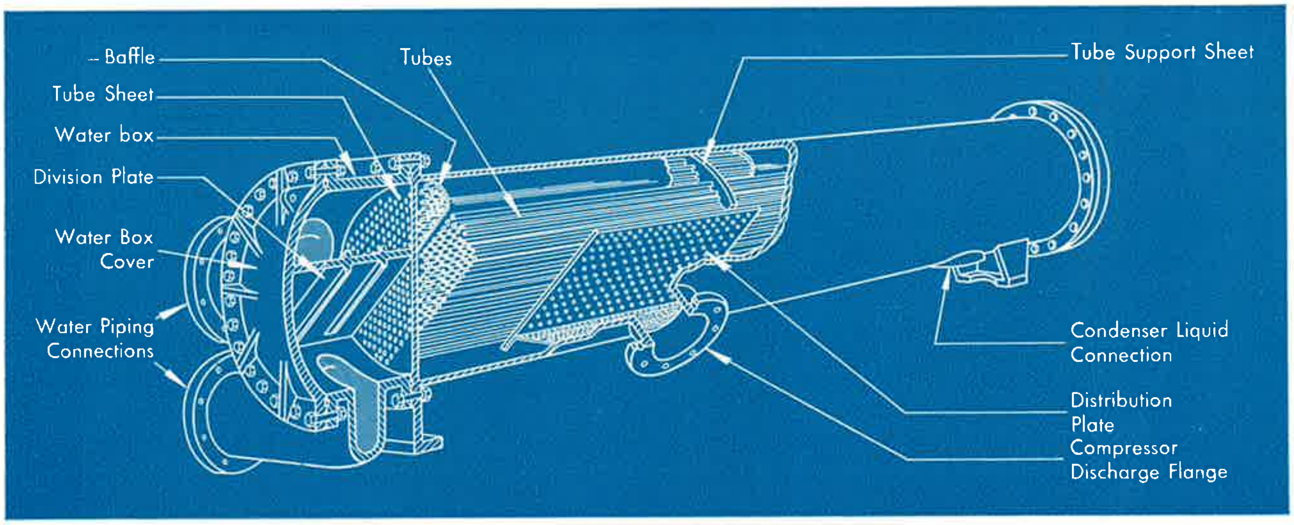


Shaft Seal

Where the shaft passes through the casing, the seal is installed to prevent the entrance of air into the system and to prevent the loss of refrigerant to the atmosphere. This shaft seal is designed, built, and operated for very long life and dependability. When the compressor is not operating, a metal-to-metal seal is made under oil. When the compressor is running, the metal seal faces are separated by oil pressure and the seal is established by the pressure oil flow through restrictions of small clearance spaces. Air cannot leak into the machine against outward flow of oil and refrigerant cannot leak out of the compressor against inward flow of oil from the seal.

Oil is supplied to the seal by pressure during operation and the oil pressure in the seal is controlled automatically. The seal oil pressure is indicated by a gauge on the control panel. If seal oil pressure reduces below a minimum required value, the compressor stops automatically. When the compressor is idle, the shaft seal oil reservoir, installed above the seal, maintains a head of oil on the closed seal.

A rotating seal seat is screwed on the shaft against a shoulder. A stationary seal is located and supported by a sylphon which allows axial movement. Oil pressure within the sylphon pushes the stationary seat away from the rotating seat and oil flows between the seal faces. Uniform contact of seal faces is assured by equal pressure from a circular multi-leaf spring bearing against the stationary seal. The inner floating seal ring riding on the shaft and the outer floating seal ring riding on the sleeve of the rotating seat, provide the restriction clearances controlling oil flow and pressure in the seal.



Condenser

CONDENSER

SHELL AND SHELL FLANGE—Steel—Hot-rolled, low carbon, steel, arc-welded, modern construction.

TUBE SHEET—Cupro-nickel—Welded to shell flange. Holes for tubes are drilled, reamed, and multiple-grooved for expanding the tube into the sheet. The tube sheets of condensers, and of coolers are permanent parts of the equipment and designed to last throughout the life of the machine. Rigid requirements relative to structural strength and resistance to corrosion are satisfied with cupro-nickel. Cupro-nickel is particularly suitable for use with non-ferrous tubes.

TUBES—The materials and construction of tubes are the same as in the cooler, described on page 8.

The extruded finned tubes are closely nested in the upper portion of the shell in a manner to promote effective impingement of gas on the tubes, to facilitate quick drainage of the condensate, and to achieve rapid and complete segregation of non-condensable gases.

In the heat transfer research work done by Carrier, it was found that the Carrier finned tube also improved condenser performance. The rate of heat transfer in the condenser equipped with Carrier finned tubes is more than double that with plain tubes. Carrier pioneered the centrifugal refrigerating compressor and has now pioneered this specially developed finned tube heat transfer equipment.

TUBE SUPPORT SHEETS—Cast Brass—Provide two intermediate supports for all tubes. The tubes are expanded to fit the hole in the support sheet. These supports prevent vibration of the tubes, stiffen the structure and increase the support value of the tube sheets.

BAFFLE—Silicon Bronze—A baffle is arranged within the tube bundle so that non-condensable gases are swept from tube surfaces by the high velocity vapor and segregated at the tubes receiving the coldest water. Thus, concentration of non-condensables is made as great as possible before evacuation for purging.

WATER BOXES AND COVERS—Materials and construction are the same as in cooler on page 9.

PURGE RECOVERY

Every centrifugal refrigerating system requires and is provided with equipment which will evacuate non-condensable gases, air, and water vapor from the condenser and which will recover refrigerant from the mixture before the gases are purged. The purge recovery unit performs this function. It is enclosed in a casing and mounted at the side of the condenser.

If air or non-condensable gases are allowed to accumulate in the condenser, the condensing pressure rises and the power for refrigeration increases. The purge recovery is operated constantly and, consequently, maintains power consumption of the centrifugal compressor at a minimum. The major items of the system are: a small reciprocating compressor, an air-cooled condenser, and an evacuator from which liquid refrigerant is trapped back into the centrifugal system. Gases are purged automatically and water is drained when necessary.

The purge compressor is a small, two cylinder, single-acting machine. The gas mixture is evacuated from the top of the condenser and is compressed to 80 pounds per square inch. Refrigerant vapor is condensed by the air-cooled condenser. The flow of gases and liquid continues to the evacuator. The evacuator has two chambers, upper and lower, with an interconnecting trap for the separation of any water from liquid refrigerant. The flowing mixture enters the upper chamber where separation takes place. Liquid refrigerant is trapped in the lower compartment, leaving water, if any is present, in the upper chamber.

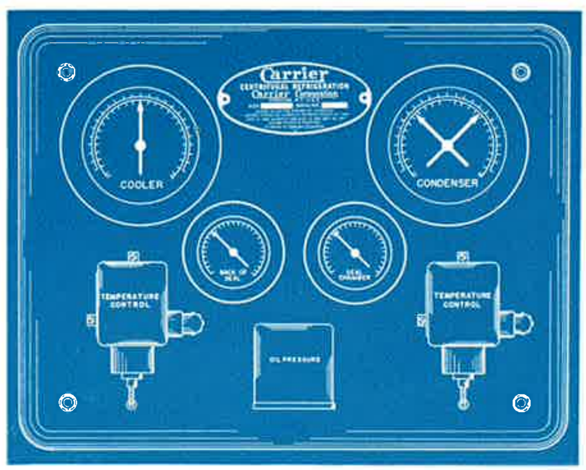
Air remains in the upper chamber until accumulated to the pressure at which the automatic relief valve opens and purges. Water floats on the refrigerant and is blown into a drain connection when the level rises to the mark at the bull's-eye. Liquid refrigerant is discharged from the bottom of the evacuator into the centrifugal system by a float valve whenever the liquid level rises.

THE AIR INDICATOR is an instrument on the control panel which indicates the presence or absence of non-condensables in the condenser. The red hand indicates actual pressure, that is, total pressure. The black hand indicates the pressure of refrigerant confined in a thermal bulb and exposed in the condenser to the temperature of the condensing Carrene. It indicates the "partial" pressure, the pressure at which condensing should take place if no air were present. When air is present, the "total" pressure will be greater than the "partial" pressure in proportion to the amount of air involved.

CONTROLS

CAPACITY—The refrigerating capacity of centrifugal systems may be balanced to the imposed load by any one of three methods: (1) The speed of the compressor may be varied. (2) The flow of vapor from the cooler to the compressor may be regulated by a throttling damper called the suction damper. (3) The discharge pressure of the compressor may be increased by reducing the condenser water flow.

(1) SPEED CONTROL—The characteristics of centrifugal performance make speed regulation the preferred capacity control. The change of speed



Control Panel

necessary for a large variation of load is relatively very small. The practical application of this control is, therefore, most satisfactory. Very exceptional and acceptable regulation can be given, even when sudden and large fluctuations of load occur. In addition, the economy of power is much better over the range of operation than for other methods.

Turbine speed variation is ideal. For a variable speed electric motor, the familiar slip ring motor with multiple steps of resistance is utilized. A constant speed motor with eddy current clutch or hydraulic coupling is also available for variable speed.

2) SUCTION DAMPER CONTROL—The suction damper is used in conjunction with constant speed machines. When the damper throttles the flow of vapor, the compressor continues to handle the same volume of vapor, but handles vapor of lower density through a greater pressure differential. Refrigerating capacity is reduced. The demand of power per unit of capacity is greater than for equivalent capacity reduction by speed control.

(3) CONDENSER WATER CONTROL—When the compressor operates at constant speed and the condensing pressure is increased, refrigerating capacity is reduced. If water used for condensing is expensive, this control is advantageous in saving water when the load is reduced. Power consumption is greater with this control than with speed variation. It is used as a supplementary control with step speed control.

SAFETY CONTROLS operate by opening an electric contact which stops the motor or reduces the turbine speed to its minimum, where any of the following conditions occur:

(1) Low oil pressure in centrifugal compressor.

(2) High condensing pressure.

(3) Low refrigerant evaporating temperature. Compressor is shut down at a selected temperature below the minimum design temperature.

(4) Low chilled water temperature. Compressor is shut down at a selected temperature below minimum allowable leaving chilled water temperature.

Safety controls provide protection against mishandling and accidental operating conditions. For instance, the compressor cannot be operated if the oil pressure of the lubricating system is inadequate. If the supply of condensing water should fail the machine will stop. If the load is lost, as by failure of the chilled water pump, the refrigerant evaporating temperature will reduce and the machine will stop immediately to prevent freezing of water in the tubes. If water is being chilled under conditions which would allow operation to drop into the freezing zone, in case of lack of attention, the machine will be stopped before the water can freeze.

ASSEMBLED UNIT

The drawing of the assembled Carrier Centrifugal on page 22 tells better than words the story of assembly.

BASE—The equipment is mounted upon a base of concrete as shown in the drawing, or upon an equivalent welded steel structural base. It is assumed that a suitable floor, structure or foundation is available as support for the structural base.

PHYSICAL TESTS

The compressor, cooler, and condensers are carefully tested individually in the factory. The first air pressure test is followed by a hydrostatic test of tube and water-boxes. Then a second test with air pressure is made. The final test of the part is at a vacuum of 29 inches of mercury, or more. The loss of vacuum is limited to less than one tenth of an inch of mercury in 24 hours. The compressor is operated by steam turbine and is given speed tests, the speed being increased to 32% above normal and 15% above the maximum rated speed. After the unit is assembled in the field, the equipment is dehydrated by evacuation. The vacuum test is again carefully repeated.

FIELD INSTALLATION

Aside from power equipment, only three major items, compressor, cooler, and condenser must be handled in shipment, rigging, and erection. This design makes it possible to handle the equipment without disturbing factory precision of fabrication. The actual field erection work is also very much simplified and is accomplished in greatly reduced time.

Because of the extreme care in balancing and because of the consequent lack of vibration and shock, massive foundations are not required. It is possible, therefore, to choose the location of the installation on the basis of expediency and convenience, and if necessary, to place it upon an upper floor level.

COMPACTNESS OF ASSEMBLY

Today, as never before, reduction of space requirements is of utmost importance. It is believed that Carrier Centrifugal Refrigeration provides more tons of refrigerating capacity per square foot of floor area and cubic foot of space than can be done any other way. The reward is saving of space rental charges.

UTILITY AND FLEXIBILITY

In the majority of applications, multiple machines are unnecessary. The ability of one centrifugal machine to carry anything from full load to less than quarter load, introduces a great simplification in the management of operations and also is a factor in reducing space requirements. The Carrier Centrifugal cools water and other liquids at customary temperature levels with two stage compressors and chills brines at lower temperatures with three stages.

When chemical brines are chilled or vapors are liquefied at still lower temperatures, two or more compressors are staged to give a total of four or five or more stages. Special work sometimes requires an evaporation temperature so low that good design necessitates the use of two refrigerants. In such a case, called cascading, the refrigerant of the lower temperature system is condensed in a heat exchanger by the higher temperature system. By such methods, centrifugal refrigeration covers all conceivable ranges.

OPERATION

Repeat buyers have found operating characteristics a major factor in their decision to use Carrier machines as the equipment is mechanically very simple and may be operated with less skill than required for other types of refrigerating machines. Automatic oiling, capacity control, and purging of non-condensables, contribute to the simplicity of operation and the minimum requirements of attendance.

It is often said that the "Carrier Centrifugal rides with the load". The "flat characteristic" curve is responsible for this, because of the very small change of speed over the entire range of load when the machine must operate at a given prevailing temperature. The flat characteristic reduces the frequency and amount of adjustment for balance of capacity to load. Minimum supervision of operation results from this inherently constant temperature characteristic and even manual control requires relatively little attention. Automatic controls hold the outlet temperature within very close limits.

COMPRESSOR SURGE—As the loading of a centrifugal compressor is reduced, a point is finally reached where "surging" or "pumping" occurs—a natural characteristic of all centrifugal compressors. No appreciable loss of economy and no effect on the mechanical function of the machine as a whole result from this surge.

LOW NOISE LEVEL—Many applications demand a low noise level of operation in refrigerating equipment. Extended laboratory research developed a hydraulic design which has made Carrier Centrifugal Machines acceptable in this respect and, at the same time improved their efficiency.

HIGH EFFICIENCY—The compressor efficiency is high and sustained during the life of the machine, as no valves, piston rings, cylinder walls or other parts are present to wear and reduce the effectiveness of the machine. Contributing to this overall efficiency are the coolers and condensers fitted with finned tubes by a new method developed and introduced by Carrier. This machine provides refrigeration at the lowest horsepower per ton over long, sustained periods of operation.

MAINTENANCE—Maintenance on the Carrier Centrifugal is inherently less than for other compression systems, as wearing parts are few and readily accessible. Gas is compressed by parts which have no wear. Non-ferrous tubes reduce corrosion and require infrequent cleaning. Readily reached for inspection, the tubes may be cleaned or replaced without disturbing any refrigerant joint or water connection. The access cover for the float valve is conveniently located and the cooler is comprised of non-moving parts. It is difficult to conceive of refrigeration being produced by any machine with fewer parts requiring maintenance.

ECONOMY—Highly efficient and compact, the unit reduces operating costs and space rental charges. The capacity is increased and horsepower is reduced on every Carrier Centrifugal Refrigerating Machine through interstage liquid cooling in the economizer. The centrifugal characteristics provide high average performance for the year's operation and waste of power is prevented by the automatic purge. Maintenance is less than that for other types of refrigeration. Owning and operating costs of centrifugal refrigeration can be reduced greatly whenever the steam turbine driving the compressor improves the heat balance of the plant. Refrigeration is then often a by-product of the process steam. Exhaust steam from the turbine is free from contaminating oil and is satisfactory for food and other processing.

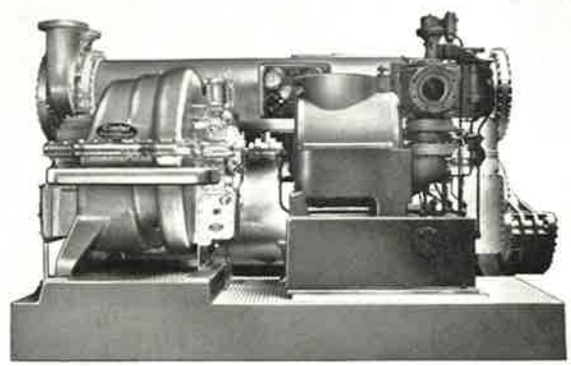
SAFETY

The refrigerants for Carrier Centrifugals are officially rated as the safest now available. Operating pressures are low and the equipment is fitted with protective devices prescribed by code. The basic design is protective—conservative speeds and liberal factors of safety in all construction.

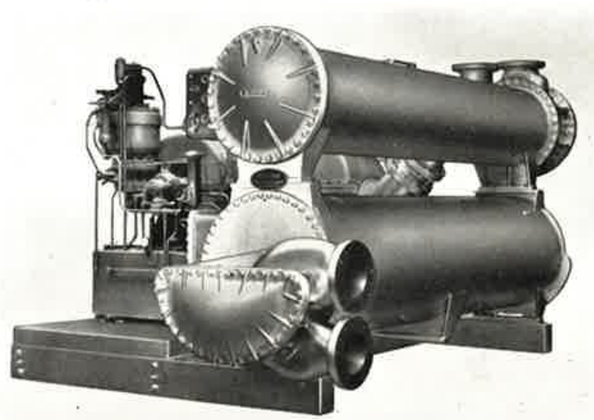
RELIABILITY

Reliability and centrifugal are synonymous terms. Carrier not only designs conservatively, but ingeniously, as is evidenced by the seal, which makes no wearing contact during normal operation. Reliability is gained, too, by the best available construction as exemplified by the use of the Kingsbury thrust bearing. Nor is expense spared to provide endurance, as is illustrated by the choice of Cupro-nickel for tube-sheets. In every case, a careful study is made to relate properly materials to service.

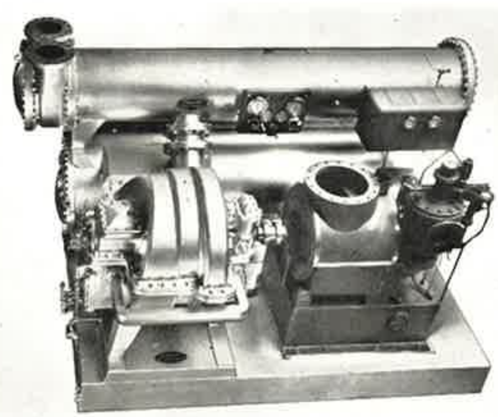
Claims for reliability carry much more weight if substantiated. Carrier can offer the demonstration of 20 years of actual experience. Repeat orders are another measure. 43 repeat orders, in one instance, and 29 in another, express the measure of the reputation which Carrier Centrifugal Refrigerating Machines have with the buyers.



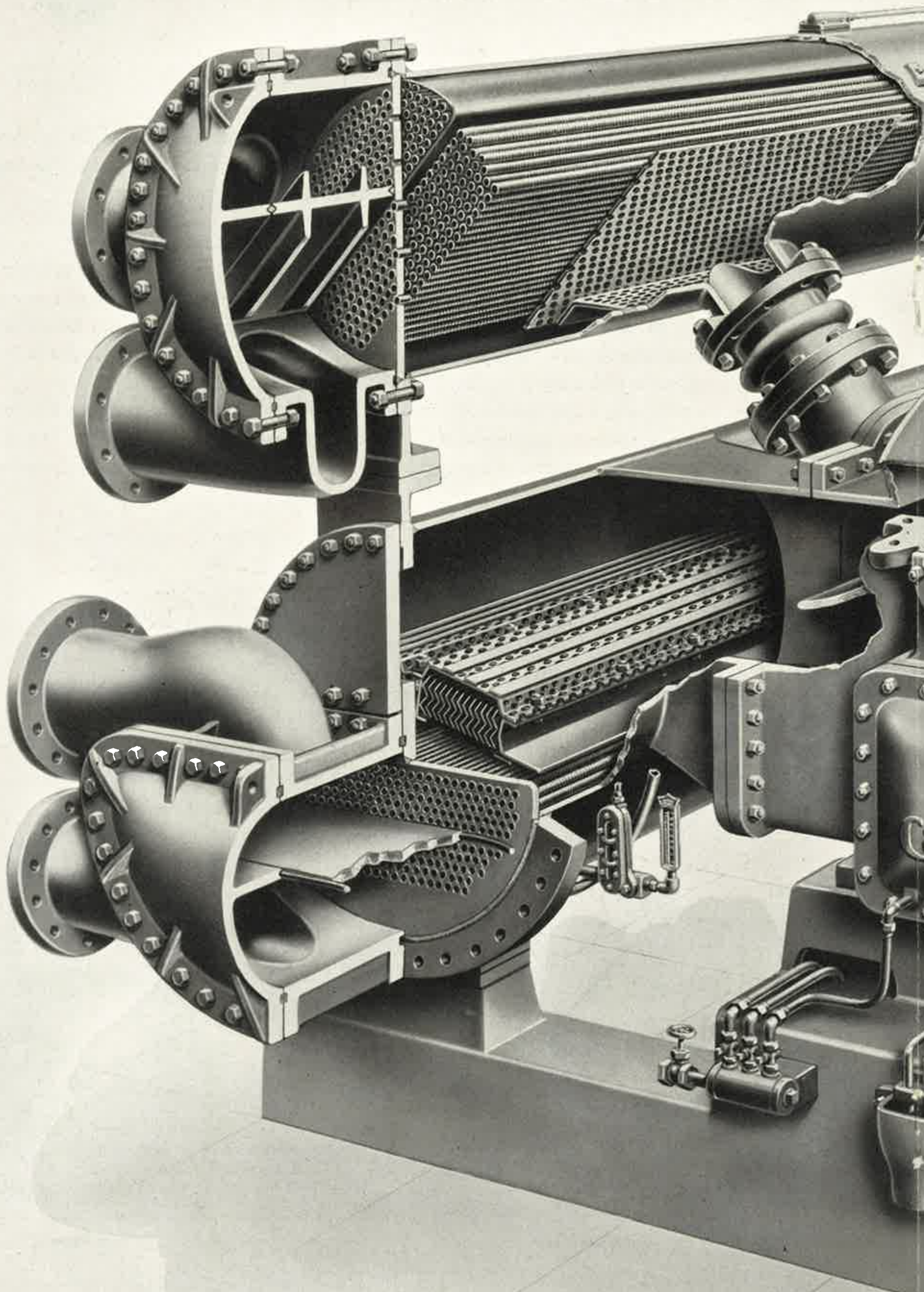
Front View

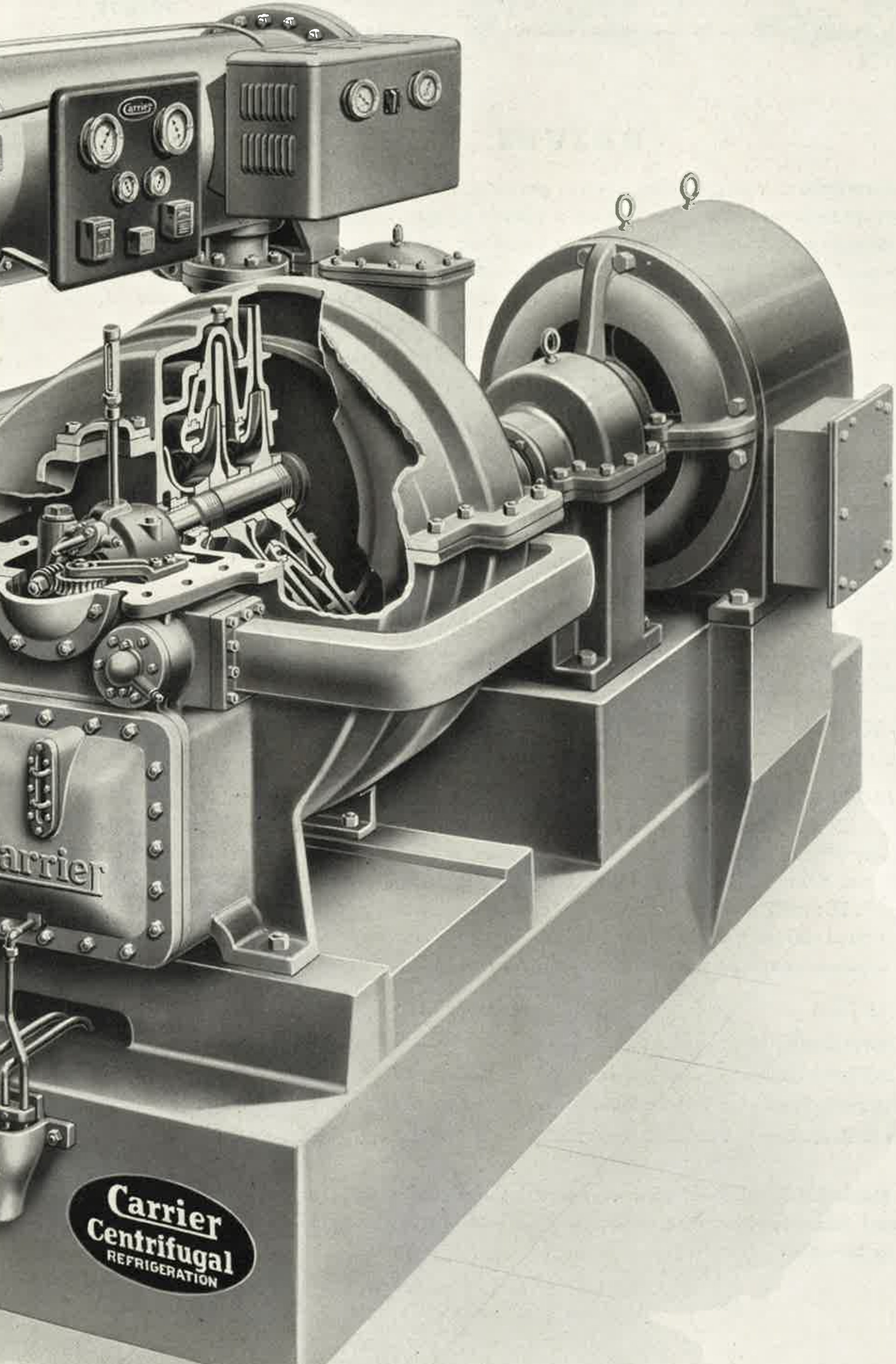


Rear View



Top View




Carrier
Carrier
Carrier
Centrifugal
REFRIGERATION

DRIVES

The centrifugal compressor may be driven by steam or gas turbines, any standard electric motor, diesel or gas engine. Direct shaft connection is made through a suitable flexible coupling. Speed-increasing gears are utilized with electric motors and engines. Variable speed was formerly available only with a slip-ring motor. Today constant speed motors, synchronous or induction, may be combined with magnetic or hydraulic slip-couplings for variation of compressor speed, either manually or automatically controlled.

The choice of drive is made with respect to conditions at the installation. Requirements of refrigeration regulation, process control, plant heat balance, waste steam utilization, power cost, power demand rates, and many other factors must receive consideration.

STEAM TURBINE—Since steam turbines are designed for the same high speeds as centrifugal compressors, turbines are an ideal drive. Direct connection is utilized and variations of speed can be obtained with very close and satisfactory control.

The use of steam can be utilized often with great economy when the proper type of turbine is selected. Waste steam at low pressure may be used in a condensing turbine. High pressure steam may supply the necessary power for refrigeration with a back pressure or bleeder turbine and then be used for manufacturing processes or for heating purposes.

SYNCHRONOUS MOTOR—The motor is constant speed but an eddy current or hydraulic clutch may be used with the motor for variation of compressor speed. Electrically, this motor often has advantages, improving the power factor and receiving favorable rate consideration.

INDUCTION MOTOR—The motor is constant speed. Variation of compressor speed can be arranged by use of an eddy current or hydraulic clutch.

SLIP-RING MOTOR—The slip-ring motor, with resistance speed control, is often used for a variable speed electric drive. Electrical losses for speed reduction are small. This fact is not always realized, largely because the characteristics of the centrifugal compressor are not well known. When load on the centrifugal compressor is reduced, the reduction of speed that is required for the balancing of operating conditions is relatively very small. The relation of load and speed is a very "flat" curve. In consequence, the maximum speed reduction is small and the corresponding resistance losses low. Actual figures are of interest in connection with an installation having a full load capacity of 600 tons and driven by a 700 horsepower motor.

% Full Load	100	75	50
% Brake Horsepower	100	68	46
% Full Load Speed	100	94	90.4
KW Input—% Full Load Motor Rating	92.3	66.7	47.0
Loss in Resistors—% Full Load Motor Rating	....	4.0	4.6

DIESEL OR GAS ENGINES—If it becomes advantageous to adopt diesel or gas engine power, the engine may be used with speed-increasing gears. The speed and size of the engine will largely determine the engineering of this drive.

PERFORMANCE

Carrier Centrifugal Refrigerating Machines have given notable satisfaction for nearly twenty years. Exacting standards for materials and workmanship have contributed greatly to this success. Operating advantages and performance have also been most important economic factors, especially in winning repeat orders. Owners found that their Carrier Centrifugal Machines were eminently suitable for their service. They also discovered a most satisfactory economy of ownership and operation. Hence, consideration of characteristics of operation and performance is essential.

CAPACITY—Thought regarding capacity of centrifugal refrigerating machines should relate capacity to volume of gas compressed. Capacity expressed in tons of refrigeration varies with suction temperature. Capacity decreases when suction temperature is reduced because the required volume of gas per ton increases. The centrifugal compressor is a machine adapted to relatively large volumes. Applicable to any temperature level and low gas density, it affords the only practical means for commercial refrigeration at abnormally low temperatures and for large volumes.

HEAD—For the sake of simplicity and convenience, the "head" against which the compressor must work is often expressed in degrees of temperature. The temperature-head is the difference between the condensing temperature and the evaporating temperature. This temperature-head is also closely proportional to height of a hypothetical gas column which will afford the same ratio of compression by purely gravitational effect, or to its equivalent in centrifugal acceleration. The centrifugal compressor may be thought of as a centrifugal pump lifting heat from one level of temperature to another. Refrigerant vapor is the vehicle for this heat. It is apparent then that the temperature head of operation depends upon diameter of impellers, speed of rotation and kind of refrigerant. It is also obvious that the temperature "lift" at a given speed may be increased by the addition of one or more stages.

HEAD vs. CAPACITY—The Carrier Centrifugal Compressor has an extremely wide range of application and can be adapted to practically every requirement because of its flexibility with respect to both capacity and head. Moreover, it has inherent characteristics of performance which satisfy the exacting purchaser with respect to economy. "Head" plotted against "capacity" at constant speed is an essentially "flat" curve. At any given speed, capacity may reduce from full to about one-quarter load and head will vary only a very small percentage. This means that a centrifugal refrigerating machine operating at a constant speed and constant condensing temperature will reduce the suction temperature very little when capacity varies over the entire range. By virtue of the same characteristic, the speed need be changed a very small percentage for the full range of capacity variation when the suction temperature is held very closely to specification. When the temperature of condensing water varies periodically, the temperature head (and the temperature of outlet chilled water or brine) may be maintained reasonably constant by regulating flow of condensing water.

This "flat characteristic" makes the Carrier Centrifugal Refrigerating Machine easy to operate, easy to control automatically, and exceptionally desirable for variable loads. Control by variation of speed is economical because speed change is small and resistance losses with variable speed motors are correspondingly small. Economy with manual control is greater than otherwise because the machine inherently compensates partially for delayed attention by the operator. It is often said that the centrifugal "rides with the load." In this respect it is comparable in performance to an electric generator under variable load.

POWER—The torque, and therefore the power required to turn the compressor shaft, reduces rapidly as speed of the compressor is reduced. Another point of great practical importance is that the Carrier Centrifugal Refrigerating Machine, at any given speed and suction temperature, has a non-overloading characteristic. For instance, if the supply of condensing water should fail, the compressor will drop its load so rapidly when the head tends to increase, that the motor will not be overloaded. The centrifugal machine, however, may be overloaded when loads greater than the "design" or "selection" load are imposed at the evaporator or cooler. If higher than "design" suction temperatures are to be expected occasionally, adequate power must be provided for the exceptional rather than for the normal operation.

EFFICIENCY—The Carrier Centrifugal Refrigerating Machine uses a refrigerant having the highest available cycle efficiency. In addition, every machine is equipped for interstage cooling of liquid refrigerant. The overall efficiency is appreciably increased by this means. To illustrate these points, cycle efficiencies are shown graphically for various operating conditions and for the common refrigerants.

Chart No. 1 shows the comparison of cycle efficiencies of Carrene No. 2 with ammonia and "Freon-12" for a 30° suction temperature. This is in the range in which the refrigerants are used for air conditioning. Since the Carrier Centrifugal Refrigerating Machine using Carrene No. 2 is always employed with a built-in economizer and since "Freon-12" employs a single stage compressor in which the economizer is not used, it is proper to compare these two efficiency lines. As an illustration with 30° suction temperature and 100° condensing temperature, the cycle efficiency of "Freon-12" is 82.8% while the corresponding cycle efficiency of Carrene No. 2 with the economizer is 94.3%. Assuming these conditions of operation and equal compression efficiency for both the centrifugal compression system and the "Freon-12" compressor, the power requirement for "Freon-12" will be nearly 14% greater than for Carrene No. 2. (94.3/82.8 = 1.139.) Although the loss in cycle efficiency decreases for each of the two refrigerants at lower temperature heads, these respective losses in economy remain nearly proportional to each other throughout all ranges of operation, approximately three to one. (100% − 82.8% : 100% − 94.3 :: 3 : 1).

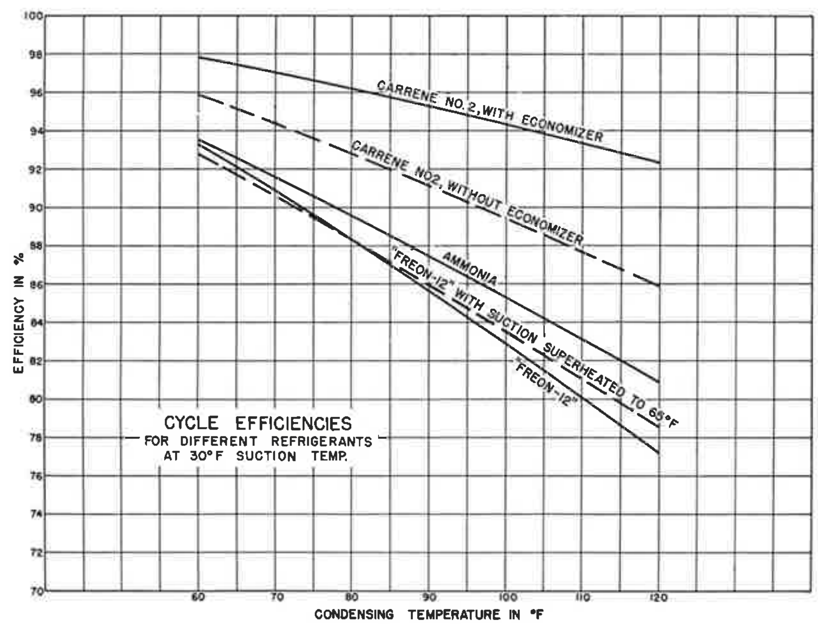


Chart 1

Chart No. 2 shows the cycle efficiencies for the same refrigerants at 0° suction temperature and various condensing temperatures. Here the advantage of the refrigerant Carrene No. 2 is even more marked than in the previous example. Since this range applies to industrial work, it is proper to compare Carrene No. 2

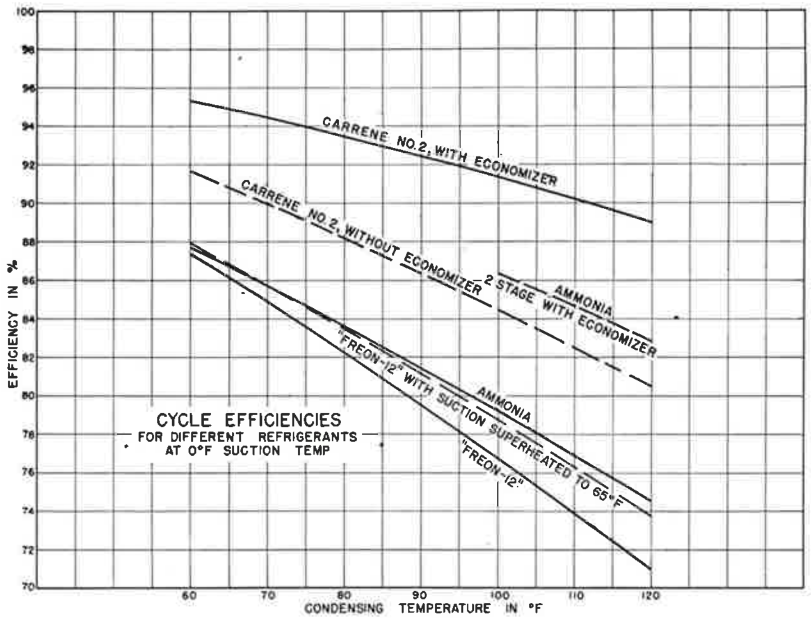


Chart 2

with ammonia. The cycle efficiency of ammonia at 100° condensing temperature is 79.2% while the corresponding cycle efficiency of Carrene No. 2 in the Carrier Centrifugal System is 91.3%. Assuming equal compression efficiencies, ammonia requires 15% more power under these conditions of operation than Carrene No. 2

$$\left(\frac{91.3}{79.2} = 1.15\right).$$

However, ammonia may be economically employed in two stage compression in this range. Here the comparison for ammonia is somewhat more favorable. With two-stage compression using an economizer, the cycle efficiency of ammonia, under the same conditions, is increased to 86.4%, but this is still considerably lower than the cycle efficiency of Carrene No. 2 in the Carrier Centrifugal Machine.

The inherently high compression efficiency of the centrifugal compressor has been markedly increased through extensive research work and laboratory tests during the past eighteen years in which this system has been on the market. As a result of this continuous and a recent intensive development program, the efficiency of the Carrier Centrifugal Compressor today ranks with the efficiency of the best centrifugal pumps. This efficiency is sustained for the life of the machine, because no wear or change takes place in the path of the refrigerant flow which can reduce this efficiency of compression.

High operating efficiency is also gained in part by maintaining the lowest possible head of operation. The automatic purge eliminates the loss due to the presence of air in the condenser. The improved heat transfer of the cooler and the condenser also reduces head and improves performance.

ECONOMY

MAINTENANCE AND SUPERVISION—The importance of economy warrants the emphasis that is given to every factor influencing economy. Carrier makes the equipment as a compact unit in order to reduce space rental charges. Painstaking design, high quality materials, excellent workmanship and good engineering assure low maintenance costs and minimum depreciation. The labor costs for operation and supervision are less than for any other type of refrigerating machine.

REFRIGERANT—In the Carrier Centrifugal System the cost of refrigerant is exceedingly low, much lower than for the usual high-pressure compression systems. There are three principal reasons for this:

1. While operating, the condenser is slightly above, and the rest of the system is below, atmospheric pressure. During shutdown, the entire system is under vacuum. Also, the shaft seal is under vacuum

with an oil seal interposed, so that there is normally little loss of refrigerant through the seal either during operation or shutdown.

2. The compactness of the system and the comparative freedom from external valves and gadgets diminish the chances for leakage.

3. Since, in the Carrier Centrifugal Refrigerating System, any leakage that might occur is generally air leakage inward, loss of refrigerant through leakage is minimized by the purge recovery system. This purge recovery removes refrigerant from the air and returns the refrigerant to the system.

Through long experience in design and operation of the Carrier Centrifugal Machine, great improvements have been made in refrigerant economy. While in many systems the refrigerant loss is an important factor in the cost of operation, in the Carrier Centrifugal System the refrigerant make-up is normally a negligible item in relation to the total cost of operation.

POWER—Power costs with the centrifugal system are low, usually lower than for reciprocating systems under comparable conditions of operation. This is not only because of the high efficiencies under full load previously discussed, but also because of its very high sustained efficiencies at partial loads. Economy in partial load performance is of exceptional importance in air conditioning work and in industrial processing work where there are rapidly varying loads.

The economy at partial load, first, with a constant temperature of condenser water and of chilled brine, is indicated in Table 1; second, in Chart 3 is shown the actual power input required on a typical air conditioning load in which the data is based on an existing air conditioning plant in one of the largest office buildings. This table and this chart emphasize the fact

TABLE NO. 1

Economy of Carrier Centrifugal Refrigerating Machines applied to varying industrial loads.

Load	%	100	90	80	70	60	50
*Temperature Head	%	100	96	92	88	84	81
Speed	%	100	94	90	88	86	84
Bhp	%	100	80	68	59	49	41
Bhp/ton	%	100	89	85	84	82	82
Kw Input	%	100	86	76	67	57	49
Kw Input/ton	%	100	95	95	95	96	98

*Leaving chilled water and entering condenser water temperatures are constant; gpm of chilled water and condenser water are also constant.

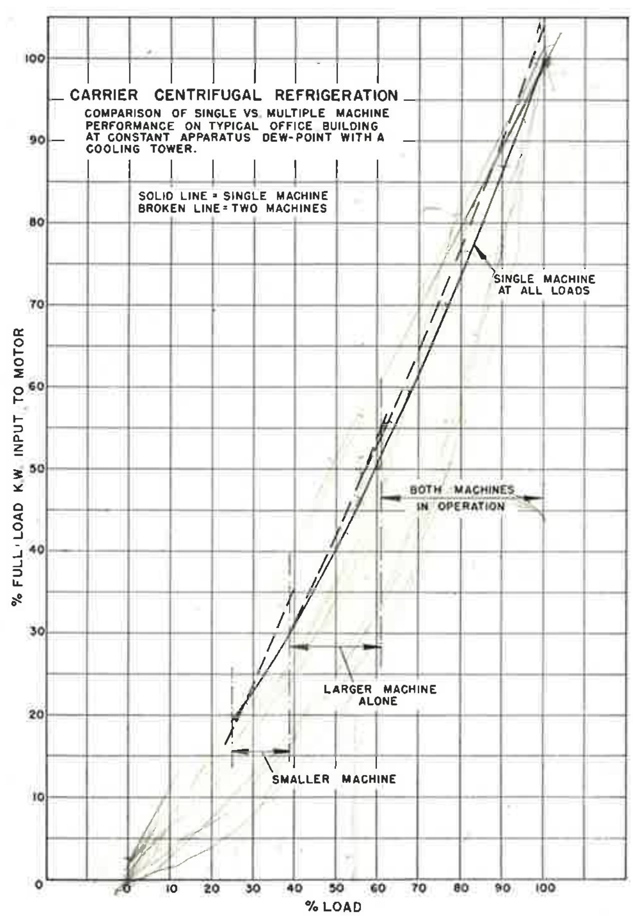


Chart 3

that the economy of performance generally improves at partial loads, and also that speed control with electric motors is inexpensive when applied to the Carrier Centrifugal Compressor. This is in contrast to the lack of economy when such control is applied to a reciprocating compressor system of refrigeration.

Table No. 1 applies particularly to the performance of Carrier Centrifugal Machines on industrial loads where the load has no relation to the outside wet bulb temperature. On the other hand, Chart No. 3 shows the performance applied to characteristic air conditioning loads. In such applications the tonnage and condenser water temperatures are both related to the outside wet bulb temperature.

A study of Chart No. 3 shows the surprising power economy obtained with the centrifugal machine as applied to air conditioning loads with a cooling tower. As a matter of fact, the centrifugal refrigerating machine, owing to its peculiar "capacity-head" characteristic and to its flexibility, is ideally suited to the typical air conditioning load. It is also shown in this chart that one machine, operated with an optimum of variable speed control, may be slightly more economical in power input than the combination of two or three machines at their best conditions of operation.

Furthermore, with one machine operating through the entire range of load, automatic control can be applied to either induction or synchronous motors to insure this economy without operating attention. At the same time, the overall installation cost with one machine and automatic control will be less than for a combination of two or three compressors approximating the same performance theoretically but lacking automatic control to insure such performance. It will be seen from Chart No. 3 that a single machine operating under variable load in an air conditioning system with a cooling tower affords a remarkable economy in power.

TURBINE DRIVE—The centrifugal refrigerating machine alone of all compression systems is ideally suited to directly connected turbine drive. The speeds of the compressor are suitable for the normal economical speeds of the turbine when directly connected. It not only affords a very simple and effective means of temperature control, but also provides very great economies.

These economies are obtained either by the utilization of exhaust steam from other power sources which might otherwise be wasted or, more usually, by the utilization in process work of the exhaust from the turbine-driven Carrier Centrifugal Machine. In the latter case, the only power cost of operating the Carrier Refrigerating System is the relatively few heat units which are converted from heat into useful work—the steam turbine acts as a pressure-reducing valve.

This adaptability of the Carrier Centrifugal Refrigerating Machine to steam turbine drive is of great value to all industries requiring both refrigeration and steam for processing. In such plants, the use affords an ideal heat balance.

CHARACTERISTICS OF COMMON REFRIGERANTS

	AT 5° SAT. EVAPORATION AND 86° SAT. CONDENSING								AT 40° SAT. EVAPORATION AND 100° SAT. CONDENSING					
	Ammonia	"Freon-12"	Methyl Chloride	Sulphur Dioxide	Carbon Dioxide	Carrene No. 1 (Methylene Chloride)	(Carrene No. 2) "Freon-11"	Carnot Cycle	Ammonia	"Frecn-12"	(Carrene No. 2) "Freon-11"	Water	Carbon Dioxide*	Carnot Cycle
Gauge Pressure Corresponding to Sat. Evap.	19.6	11.8	6.46	5.89" Vac.	317.5	27.55" Vac.	23.95" Vac.	—	58.6	36.98	15.61" Vac.	29.75" Vac.	553.1	—
Gauge Pressure Corresponding to Sat. Cond.	154.5	93.2	80.00	51.75	1028.3	8.35" Vac.	3.58	—	197.2	116.9	8.90	28.07" Vac.	1054.7	—
Specific Volume of Vapor at Sat. Evap.	8.15	1.49	4.47	6.42	0.266	49.90	12.27	—	3.97	0.792	5.45	2438	0.1444	—
Latent Heat of Evaporation	565.0	69.47	180.70	169.38	117.5	162.10	84.00	—	536.2	65.7	81.2	1068.8	95.0	—
Liquid Circulation Lb/Min/Ton	0.42	3.92	1.33	1.41	3.53	1.49	2.96	—	0.43	3.88	2.90	0.198	5.04	—
Theoretical Displacement Cu ft/Min/Ton	3.44	5.82	5.95	9.08	0.94	74.5	36.4	—	1.70	3.07	15.8	482.0	0.727	—
Refrigerating Effect Btu/Lb	474.4	51.1	150.25	141.37	56.7	134.1	67.5	—	467.8	51.6	68.8	1008.9	39.7	—
Compression Ratio Cond. Pres. Lb Abs. / Suc. Pres. Lb Abs.	4.93	4.07	4.48	5.62	3.14	8.59	6.24	—	2.89	2.54	3.36	7.78	1.885	—
Theoretical Hp/Ton	.989	1.007	.963	.970	1.84	.965	.936	.822	.649	.667	.625	.665	.867	.566
Coefficient of Performance 200 / Theoretical hp x 42.4	4.77	4.69	4.90	4.86	2.56	4.89	5.04	5.74	7.28	7.07	7.55	7.08	5.45	8.34
Efficiency % Carnot Cycle	83.2	81.6	85.4	84.7	44.6	85.2	87.8	100	87.3	84.9	90.9	85.0	52.0	100.0

*For Sat. Evaporation at 40° F. and Sat. Condensing at Critical Point = 87.8° F.

COMMENTS OF OPERATORS

"The compressor installed in 1929. No parts needed so far except the usual gaskets, rubber unions on water lines, etc."

"Have run machine 11 complete summers without service or break-down. Inspection about 26 hours in 11 years. Can't say too much for this equipment."

"In 13 years, used one new oil cooler iron head which corroded."

"Practically no repairs needed in past four years."

"The Carrier machine best for service, cheap operation, maintenance. Was installed in 1927; in operation since, with no trouble at all."

". . . no material has been purchased due to defects of machine; in operation since May, 1930."

". . . that he has spent only a total of $46.00 for repair parts in the nine years that he has operated the machine."

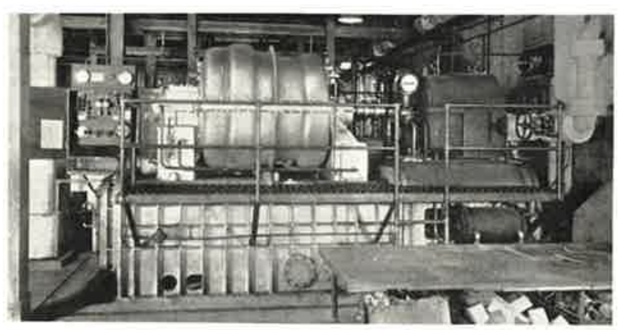
"Nothing has been done but change the oil and clean the tubes once each year." Machine installed early in 1933.

LOW OPERATING COSTS MADE LOWER WITH EACH MAJOR IMPROVEMENT IN MACHINE SHOWN BY FACTUAL DATA REPORTED.

A survey for obtaining actual operating figures on Carrier Centrifugal Refrigerating Machines was made by sending to owners and operating engineers a questionnaire covering items which are tabulated below. Factual data on 112 machines were obtained. A summary of the survey substantiates the long service, low cost of repair parts and the small losses of refrigerants with Carrier Centrifugal Refrigeration.

Number of Machines Reported	Average years in operation when reported	Average size of machine in tons	Average hours operated per year per machine	Pounds of refrigerant lost per hour operated per machine	Cost of repair materials per year per ton installed capacity
Original Machines—Still in satisfactory operation					
Machines: 1924-1927 Eleven owners reported on 15 Carrier Centrifugal Refrigerating Machines using Dielene as a refrigerant.	13.4	148	1,015	.534	20¢
1st Major Improvement—Improved Design—New Refrigerant					
Machines: 1927-1933 Forty owners reported on 54 Carrier Centrifugal Refrigerating Machines using Carrene No. 1 as a refrigerant.	9.5	163	2,100	.39	11¢
2nd Major Improvement—Improved Design—New Refrigerant					
Machines: 1933-1939 Thirty-four owners reported on 43 Carrier Centrifugal Refrigerating Machines using Carrene No. 2 as a refrigerant.	3.55	266	2,250	.14	8¢
3rd Major Improvement—New Goals Attained					
Latest Machines 1939 A still further reduction in refrigerant losses and repair costs due to simplification, and an additional reduction of more than 10% in power costs due to improvements in compressor design.					

Onondaga Pottery, Syracuse, N. Y. Decalcomania. 1st Carrier Centrifugal Refrigeration Machine first placed in operation in 1922. Capacity, 67.5 tons.



Park Davis and Co., Detroit, Michigan. Pharmaceutical. Capacity, 261 tons, installed in 1928.

USES OF CARRIER CENTRIFUGAL REFRIGERATION

(Partial List)

DIRECT APPLICATIONS

Cooling of Liquids

Cooling of special brines to low temperature, range −50° F. to −130° F., using such brines as Methylene Chloride, Trichlorethylene, etc., for the manufacture of synthetics and recovery of Ethyl Chloride and similar high vapor pressure solvents.

Cooling of salt brines, temperature range −40° F. to +35° F., for general industrial and process air conditioning applications.

Cooling of water, range +34° F. to +70° F., for general air conditioning and comfort cooling applications.

Direct cooling of beverages.

Direct cooling of sugar solutions.

Direct cooling of absorber oils.

Direct cooling of acid emulsions (Alkylation Process).

Direct cooling of hydrocarbon liquids.

Liquefaction of Vapors and Gases

Liquefaction of chlorine.

Liquefaction of high and low pressure hydrocarbons.

Liquefaction and separation of gasoline from high pressure natural gas (Recycling Process). Liquefaction of high pressure solvents at temperatures down to −130° F.

Direct cooling and liquefaction of low pressure solvents at normal refrigerant temperatures.

Liquefaction of refrigerants such as ammonia, CO_2, propane, etc. for indirect and cascade applications of refrigeration.

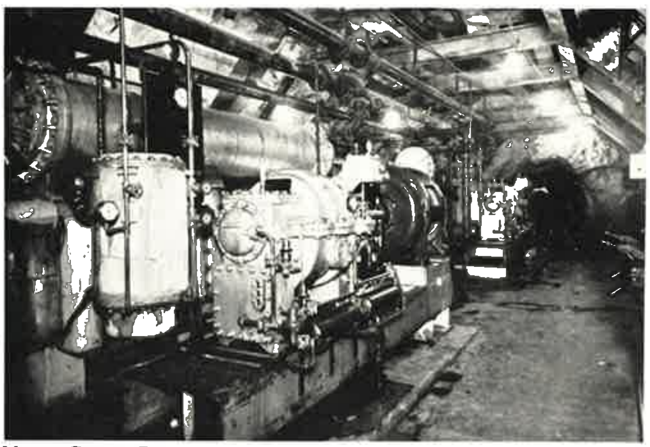
INDIRECT APPLICATIONS OF REFRIGERATION USING BRINES OR CHILLED WATER

Airports
Alcohol—Manufacturing
Apartments
Aquariums—Water Cooling
Artificial Rubber Manufacturing
Auditoriums
Beverages—Refrigeration
Blast Furnace Air Dehydration
Brewery Refrigeration
Chemical Plant Refrigeration
Chewing Gum Manufacturing
Cigarettes—Industrial Processing
Cigars—Industrial Processing
Commodities—Storage of Perishables
Confections Manufacturing
Distillers—Industrial
Department Stores
Film Manufacturing
Hospitals
Hotels
Lithographing—Process Conditioning
Meat Packing Plant—Refrigeration
Mine Cooling
Nylon Manufacturing
Office Buildings
Optical Instruments Manufacturing
Pharmaceuticals
Pottery
Precision Instruments
Rayon Manufacturing
Razor Blades
Rubber Processing
Ships
Soap Manufacturing
Theatres
Tobacco Plants—Process Conditioning
Watch Making—Industrial Conditioning

One Carrier Centrifugal Machine produces approximately 40 tons of refrigeration, cooling a special brine to a temperature of *minus* 94° F. Another unit of 12-ton capacity cools calcium chloride brine to approximately *minus* 22° F. The other machine produces 200 tons of refrigeration, cooling calcium chloride brine to a temperature of *plus* 5° F.

Later, two similar units were installed, having a capacity of 50 tons at *minus* 94° F., and a slightly larger capacity than the original unit at the *plus* 5° F. level. Recently, six new refrigeration units of much larger size were added. The new units increased the refrigeration at the *minus* 94° F. level by 110 tons. The *plus* 5° F. system was augmented to the extent of 780 tons.

—minus 94° F.



Magma Copper Co.

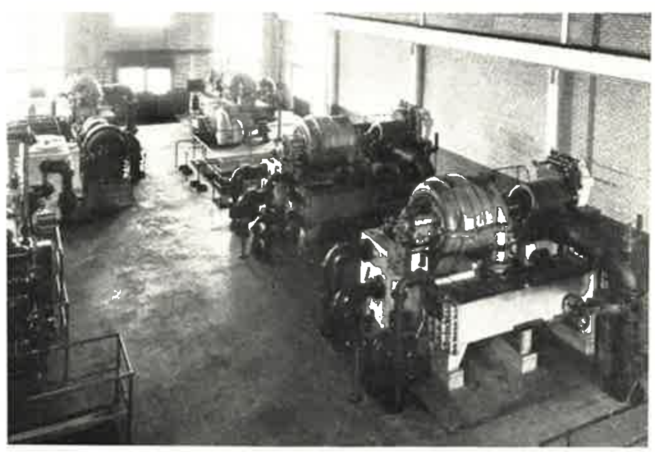
—mine cooling

A total of three Carrier Centrifugal Refrigerating Machines have now been installed in this mine, each with a capacity of 140 tons. The two in the photograph are located on the 3600 foot level. The third unit is on the 4000 foot level. Only 200 gallons per minute of 90° condensing water were available for each unit. A low pressure refrigeration system, using a non-toxic, non-inflammable refrigerant is required for the safe operation of mine cooling installations.

The Carrier Corporation pioneered in mine cooling, installing the first Centrifugal Machine in 1929 for the St. John del Rey Mining Co., Morrow Velho, Brazil. The machine installed continues in daily use. The present installed capacity of centrifugal refrigeration for mine cooling totals approximately 4500 tons.

This company pioneered with Carrier Centrifugals, installing in 1923 the second machine manufactured. With a capacity of 100 tons, it chills water to a temperature of 37° F. Five years later five machines were installed. The two machines on the right have a capacity of 200 tons each, cooling water to 37°. The two units in the background have a capacity of 75 tons each, cooling brine to a temperature of 15° F. All five machines have been in continuous service since their installation. Not one has required a major compressor overhaul. The compressor casings have never been opened except for inspection and maintenance at bearings, shaft seals, and minor wearing parts.

Other confectionery manufacturers having obtained long, satisfactory service are Beechnut Packing Co., New England Confectionery Co., Nunnally Co., S. F. Whitman's Sons, and Stedman Chocolate Co., Australia.



W. F. Schrafft and Sons Corp.

—long service

Enterprise Brewery Co.

— wort cooling

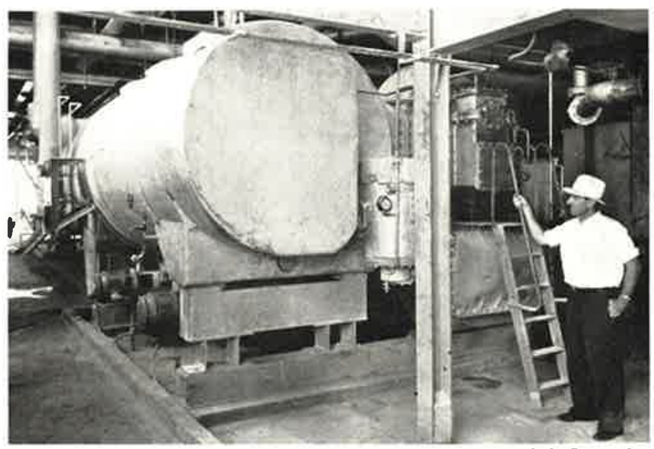
These two Carrier Centrifugals have a total capacity of 108 tons. One cools brine to a temperature of 20° F. using 55° well water for condensing purposes. The other may be used, either for cooling wort to a temperature of 45° or for cooling beer or ale to a temperature of 32° F. The cooling of the wort, beer, or ale, is accomplished directly in the cooler of the machine, constructed for sanitary handling of beverages.

The two machines, totaling greater capacity than the previously used steam-driven ammonia compressor, occupy only a small fraction of the space required by the ammonia *compressor only*.

Five nationally known brewing companies use Carrier Centrifugal Refrigeration on the ammonia condensing cycle. Refrigeration and operating costs have been substantially reduced by improvement of heat balance.

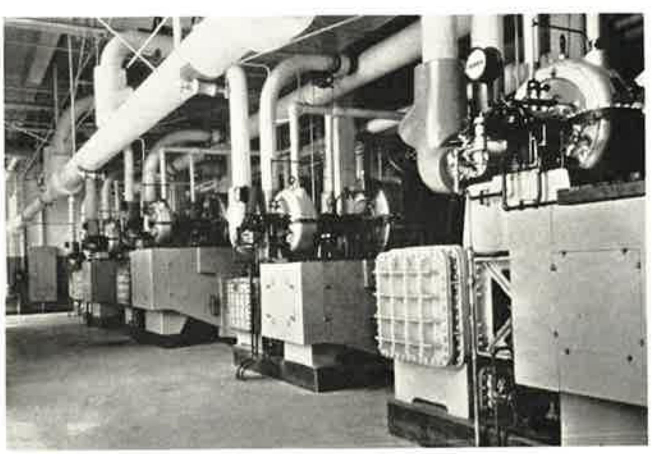
The manufacture of beet sugar, requires the cooling of 366 gallons per minute of sugar solution from a temperature of 76° to 40° F. The Carrier Centrifugal Refrigeration Machine, installed for this duty, has a capacity of 575 tons and is driven by a steam turbine whose speed is automatically controlled from the temperature of sugar solution leaving the cooler. Close control of this temperature is important since small variations materially affect the ultimate recovery of sugar from the sugar solution. The control of temperature is within plus or *minus* 1°F.

In addition to the installation shown in photograph, is a similar system using Carrier Centrifugal Refrigeration for refining beet sugar in plant of the Holly Sugar Company. Here a machine with a capacity of 335 tons cools the sugar solution from 76° F. to 40° F.



Spreckels Sugar Co.

—sugar-solution cooling—direct



American Viscose Co.

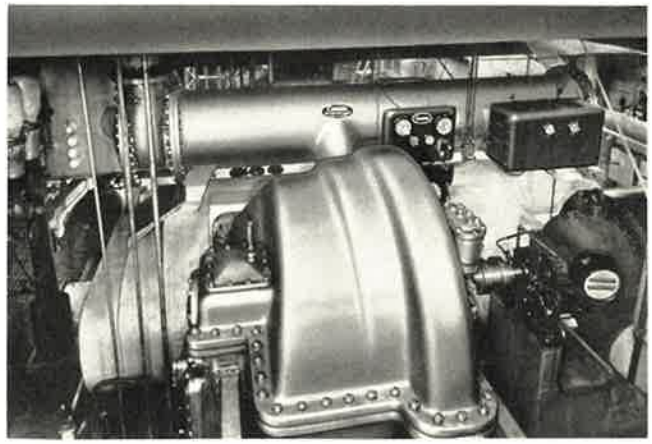
—manufacturing rayon

Five machines installed in 1929 have been in operation 24 hours a day, 365 days a year, since the time of their installation. Cooling water to a temperature of 34° F., they perform an important process in the manufacture of rayon. A total of ten machines are now used in this Meadville, Pennsylvania plant.

A large amount of centrifugal refrigeration has been installed for the rayon industry by Carrier. There are 66 of these machines which furnish a total of 14,083 tons used in processing of rayon. In addition to American Viscose, American Bemberg, Celanese Corporation of America, Courtaulds, Ltd. of England, Ducilo, S. A., of Argentina, E. I. du Pont de Nemours and Skenandoa Rayon Corporation are large users of Carrier Centrifugal Refrigeration.

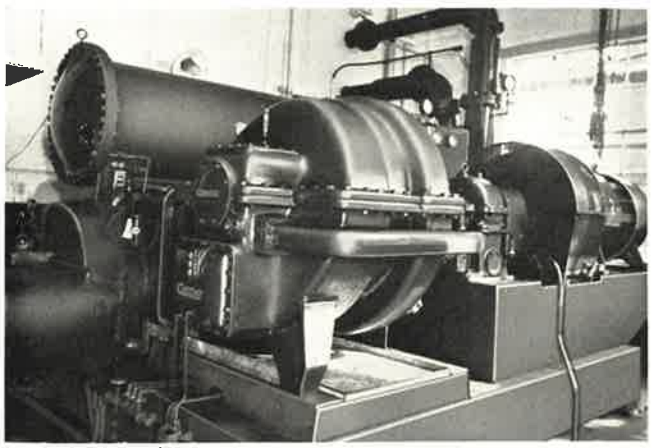
Increased refrigerating capacity was required in this meat packing plant. The 470 ton Carrier Centrifugal Refrigerating Machine was installed because it could be driven by a non-condensing steam turbine and use steam which was being generated for manufacturing processes. Power for refrigeration costs practically nothing. Steam leaving the turbine is clean and perfectly satisfactory for process uses. The increase of plant refrigerating capacity is made without corresponding increase of steam boiler capacity.

The Carrier machine condenses ammonia at 13° F. It works in parallel with the old reciprocating ammonia compressors. In any meat packing plant, the Carrier Centrifugal can be installed for increased capacity of the existing ammonia system, as in this case, or it can be installed as replacement of all old reciprocating compressors.



Geo. A. Hormel & Co.

—ammonia condensing for meat packing



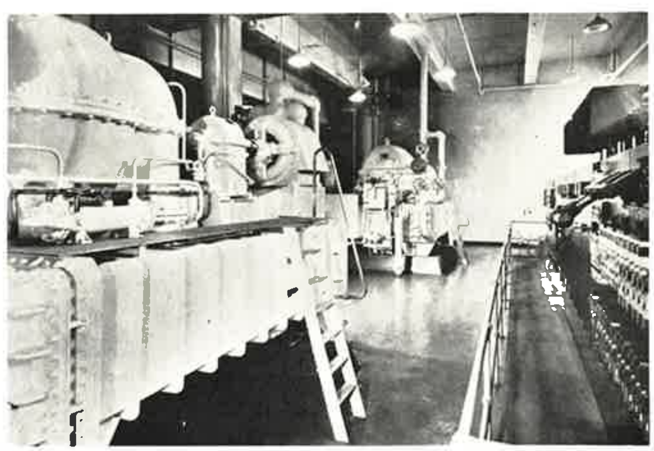
Standard Oil Co. of N. J.

—anti-freeze

Two Carrier Centrifugal Machines, each with a capacity of 325 tons, cool 1.10 gravity calcium chloride brine to a temperature of 35° F. for use in the manufacture of automotive anti-freeze. These machines are of the latest type design. Automatically controlled variable speed drive, is achieved with 6600-volt, constant-speed motors and dynamatic eddy current clutches. Brine at 35° is also supplied to small aklylation plant for the production of high octane aviation fuel.

This photograph shows two of the five Carrier Centrifugal Machines of a refrigeration plant. The machine in the foreground has a capacity of 200 tons, cooling brine to a temperature of approximately 15° F. The compressor is five stage and uses Carrene 2 as the refrigerant. It is driven by a 350 horsepower motor, connected through speed-increasing gears.

In another beverage plant, Carrier Centrifugal Refrigerating Machine of 125 tons capacity delivers chilled water at 45° F. for process cooling and air conditioning. Driven by a 125 horsepower motor through an eddy current clutch, refrigeration output is automatically controlled to deliver a substantially constant, chilled water temperature. A pneumatic temperature controller automatically varies excitation to the eddy current clutch and increases or decreases machine speed as required.



Hoffman Beverage Co.

—beverage processing

Ice Palais, Sydney, Australia

—ice-making or air conditioning

Ice-making for a skating rink in Australia is similar to other installations of this type in the United States, as in the Atlantic City Convention Hall, Chicago Stadium, and Madison Square Garden.

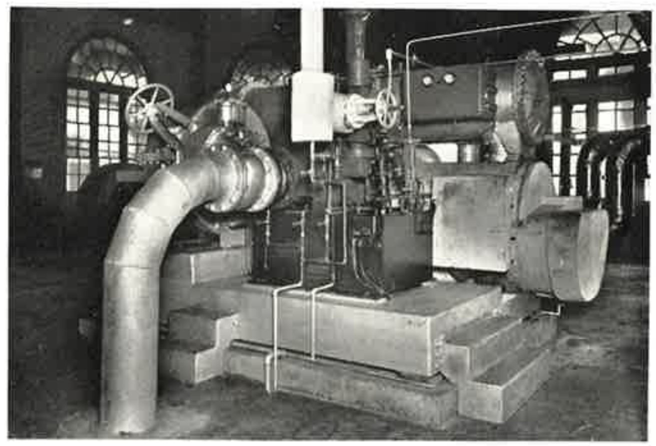
The ice at Madison Square Garden, New York, is frozen by three Carrier Centrifugal Machines which furnish calcium chloride brine to coils under the rink floor at a temperature between 5° and 10° F. Installed in 1925, each unit is driven by a steam turbine with steam at 115 pounds gauge, and condensing at 26 inches vacuum in summer and exhausting at 5 pounds gauge for heating in winter.

Operated year after year, summer and winter, the machines have never had a major overhauling. They provide refrigeration for air conditioning during the summer.

This Carrier Centrifugal Refrigeration Machine is part of a plant which produces 1040 tons of cooling effect for the purpose of drying and cooling the air necessary for two blast furnaces.

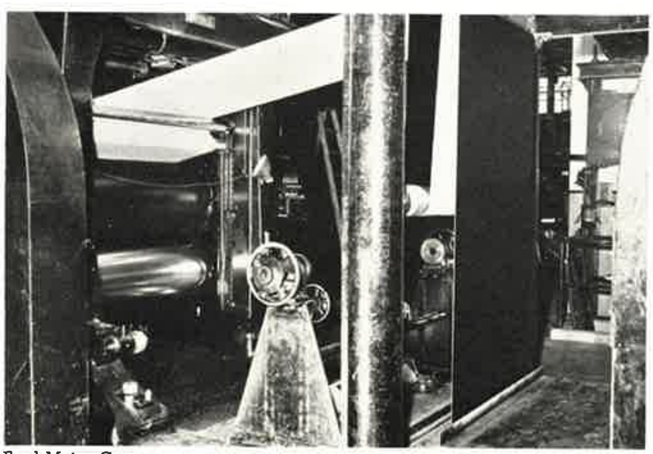
The machines are driven by steam turbines whose speed is automatically controlled to maintain a chilled water temperature of 38.5° leaving the cooler.

With controlled dry blast in the furnaces, the results shown soon after the operation of the equipment, were (1) greater uniformity of product, (2) reduced coke consumption, and (3) increased production. Within one year after the first installation of the Carrier Centrifugal Machine, a duplicate was installed proving the value to the customer of control for blast furnace air. A third machine was ordered soon after the second installation.



Woodward Iron Co.

—drying blast furnace air



Ford Motor Co.

—cooling rubber rolls

Here Carrier Centrifugal Refrigeration Machine is one of the largest installed. At relatively high temperature, refrigerated water delivered by this unit cools calendaring mills and other rubber-processing machinery. Automatic control of the turbine and compressor speed delivers substantially constant temperature water to the load.

In another rubber mill a Carrier Centrifugal Refrigerating machine delivers 150 tons of refrigeration to chill Latex during a churning operation. The machine chills water for the Latex churn to a temperature of 35° F. Automatic control of the leaving-chilled-water temperature is achieved with a pneumatically operated throttling damper in the compressor suction.

The total capacity of the three Carrier Centrifugal Refrigerating Machines is approximately 2300 tons, each driven by a 700-horsepower motor, one being a slip-ring type, variable speed. The cooling supplied by the equipment chills water for air conditioning 800,000 square feet of floor space where the normal peak load occupancy is 12,500 people.

The refrigeration equipment, located across the street from the building it serves, includes a cooling tower on the roof handling approximately 10,000 gallons per minute.

The three machines are connected in parallel. Light loads are carried by the machine driven by variable speed motor, the synchronous motor-driven machines being cut in as the load increases.

Famous-Barr Department Store

—water chilling

—manufacturing nylon

Nylon, the new synthetic substance, is another development of the chemical industry of the United States, manufactured with the aid of Carrier Centrifugal Refrigeration. This installation has a total refrigerating capacity of 3,300 tons. The plant is made up of four units; two rated at 650 tons each and two rated at 1000 tons each. All four units are driven by steam turbines and are under complete automatic control.

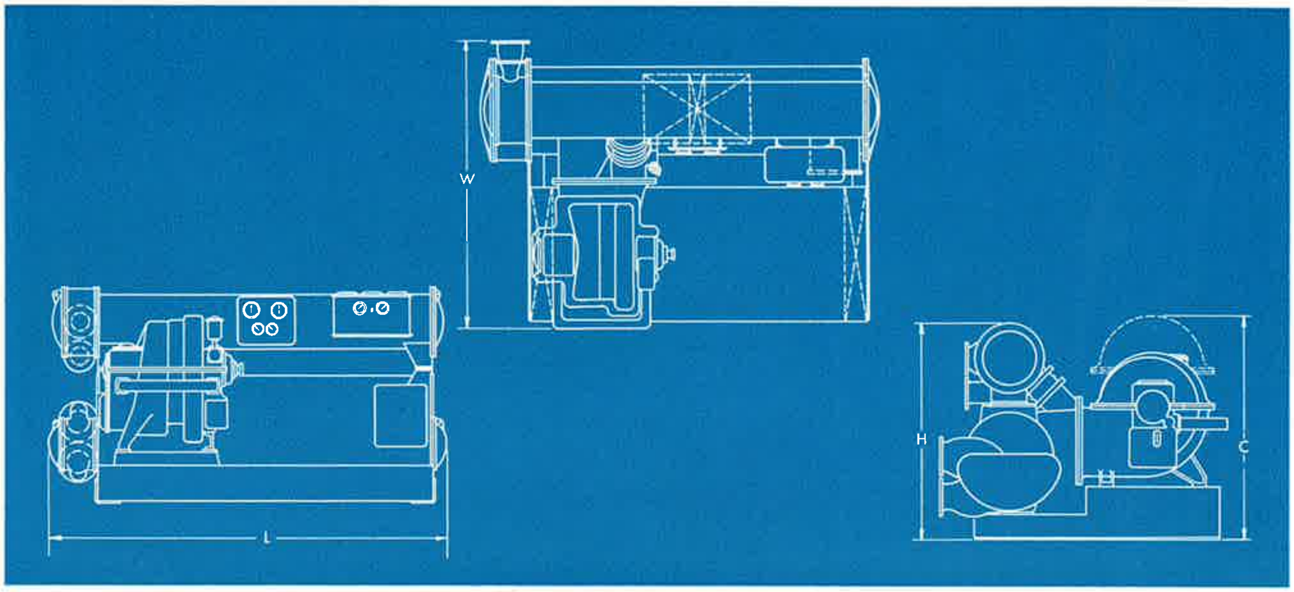
Carrier Centrifugal Refrigeration is used also to chill water for maintaining low dewpoints in air conditioning nylon knitting rooms. The new product introduced a new low temperature, low humidity requirement in textile mills. The Carrier Centrifugal Refrigerating Machine in the Archer Hosiery Mills was the first to be installed to meet the new requirement.

Installation of refrigeration on ships must meet many limiting demands, such as small space requirements, and safety, that are more exacting than land applications. The Carrier Centrifugal Refrigerating Machine meets these demands. The machine shown in the illustration has a capacity of 300 tons and chills water for the largest air conditioning system afloat.

Other well known ships equipped with Carrier Centrifugal Refrigeration are the ocean liners "Normandie," "Koan Maru," and the S.S. "Admiral" which sails the Mississippi.

S. S. Nieuw Amsterdam

—on the ocean



NOMINAL DIMENSIONS AND WEIGHTS

Machine	L Length	W Width	H Height	C Compressor Head Room	Approx. Shipping Weight in Pounds Without Drive
17M31-4-3 17P 31-4-3	14′6″ 14′6″	7′3″ 7′3″	6′4″ 6′4″	6′2″ 6′2″	17,580 17,980
17M32-4-4 17P 32-4-3	14′6″ 14′6″	7′3″ 7′3″	6′4″ 6′4″	6′2″ 6′2″	17,900 17,980
17M33-5-4 17P 33-4-3	14′6″ 14′6″	7′6″ 7′3″	6′4″ 6′4″	6′2″ 6′2″	18,950 17,980
17M41-6-5 17P 41-6-5	14′6″ 14′6″	8′8″ 8′8″	6′9″ 6′9″	7′0″ 7′0″	23,600 24,750
17M42-6-6 17P 42-6-5	14′8″ 14′8″	8′8″ 8′8″	6′11″ 6′9″	7′0″ 7′0″	24,200 24,750
17M43-7-6 17P 43-6-5	14′9″ 14′6″	9′2″ 8′8″	7′3″ 6′9″	7′0″ 7′0″	25,600 24,750
17M51-8-7 17P 51-8-7	14′10″ 14′10″	10′9″ 10′9″	8′1″ 8′1″	8′3½″ 8′3½″	34,400 37,250
17M52-8-8 17P 52-8-7	14′10″ 14′10″	10′9″ 10′9″	8′5″ 8′1″	8′3½″ 8′3½″	35,800 37,250
17M53-9-8 17P 53-8-7	15′0″ 14′10″	11′0″ 10′9″	8′9″ 8′1″	8′7½″ 8′7½″	38,400 37,250
17M61-10-9 17P 61-10-9	15′8″ 15′8″	12′8″ 12′8″	9′8″ 9′8″	10′6″ 10′6″	55,900 61,900
17M62-10-10 17P 62-10-9	15′8″ 15′8″	13′0″ 12′8″	10′0″ 9′8″	10′9½″ 10′9½″	57,400 61,900
17M63-11-10 17P 63-10-9	15′9″ 15′8″	14′0″ 12′8″	10′1″ 9′8″	10′9½″ 10′9½″	67,000 61,900

SPECIFICATIONS FOR CENTRIFUGAL REFRIGERATION EQUIPMENT WATER-COOLING MACHINE

(For the Guidance of Consulting Engineers and Architects)

1. **Centrifugal Refrigerating Machine**—Furnish and install where indicated on the plans, one Centrifugal Refrigeration Machine, complete with compressor, condenser, evaporator, and necessary auxiliaries as specified below.

2. **Compressor**—Compressor shall be of the multi-stage centrifugal type, provided with a rotor which shall be statically and dynamically balanced, and with impellers lead-coated to preserve this balance. A complete oiling system shall be provided with a submerged oil pump driven by a worm gear on the compressor shaft. An oil cooler shall be provided within the oil reservoir. Thermometers shall be supplied for each main shaft bearing. Compressor shall be furnished with replaceable bearings. Shaft seal of the bellows type shall be automatic in operation and be provided with oil seal reservoir to protect against inward leakage of air during shut-down. During operation, both bearing chambers and main oil reservoir shall be subject to low pressure only.

3. **Drive**—(a) If motor drive, specify type and current characteristics (Variable-speed motor preferred). Also specify a set of speed-increasing gears is to be furnished and mounted for interconnecting the motor and compressor. These gears are to be of the double helical type. Large babbitt bearings are to be provided on both gears and the pinions are to be pressure-lubricated. The gear teeth are to be continually flooded with oil, and a filter and pump are to be included with the gear.

   (b) If steam turbine, specify steam pressures and quality of steam.

4. **Condenser**—Condenser shall be of the tubular marine type with shell of welded steel construction. Water spaces shall be suitable for a working pressure (up to 250 pounds per square inch). Water boxes and covers shall be made of cast-iron, and heads shall be removable without dismantling piping. Tubes shall be of copper and the tube sheets of cupro-nickel.

5. **Cooler**—Cooler shall be of the tubular type with shell of welded steel construction. Water spaces shall be suitable for a working pressure (up to 250 pounds per square inch). Water boxes and covers shall be made of cast-iron, and heads shall be removable without dismantling piping.

   Tubes shall be of copper and the tube sheets of cupro-nickel.

   An economizer shall be provided, which shall be built into, and be an integral part of, the cooler. Cooler shall be provided with a thermometer to indicate the temperature of the refrigerant liquid, and with a rupture valve set at a pressure which is safely below the maximum pressure for which machine is designed.

6. **Purge-Recovery System**—The purge-recovery system shall consist of a reciprocating compressor with air-cooled condenser and accessories. It shall include an evacuating chamber provided with an automatic relief valve, and all other necessary devices for evacuating air and water vapor from the condenser and for condensing, separating and returning refrigerant to the system. The purge-recovery system shall include 0.5 horsepower, 110-220 volt, 60-cycle, single-phase motor and drive.

7. **Control Panel**—A complete control panel shall be furnished incorporating the following gauges and protective devices:

Evaporator Pressure Gauge
Combined Condenser Pressure Gauge and Air Indicator
Compressor Oil Pressure Gauges (2)
Refrigerant Temperature Cut-Out Switch
Condenser Pressure Limit Switch
Oil Pressure Low Limit Switch

8. **Base**—Provide all necessary information for building a concrete base under the complete machine. This base to be furnished by another contractor who will also provide suitable cork under base, designed to distribute the machine load at the necessary number of points.

9. **Refrigerant and Oil**—Furnish an initial charge of Carrene No. 2 refrigerant and an initial charge of oil.

10. **Condenser Water Control**—(Usually specified where economy in condenser water is important, not specified with cooling tower operation.) Furnish a condenser water control consisting of a reverse acting diaphragm valve in the condenser water line and a single duty regulator. Controls to be erected by others.

11. **Tools**—Furnish a complete set of wrenches and coupling pullers.

12. **Small Water Piping**—Furnish the piping for small water supply lines or branch connections from the small supply manifold to compressor oil cooler and to bearings to the open sight drain. Installation of these lines to be performed by piping contractor.

13. **Operating Instructions**—Furnish complete operating instructions.

14. **Erection**—This contractor shall furnish a competent erecting superintendent and all the necessary labor to install the equipment above specified.

15. **Operation and Instruction**—Furnish a competent engineer to supervise the operation of the machine by the owner and instruct the owner's operator during a two weeks' operating period.

16. **Guarantees—(a) Equipment:** Contractor shall guarantee the equipment furnished against defect in workmanship and material for a period of one year and shall repair or replace at point of manufacture any equipment found defective within that time.

(b) Performance: The equipment furnished by the contractor when supplied with adequate steam at ______pounds gauge pressure (or sufficient power at ______volts, ______cycles, ______phase) and ______gallons per minute of condenser water at a temperature not exceeding ______° F., and when operated in accordance with the written instructions of the contractor is guaranteed to be of sufficient capacity to cool ______gallons per minute of water from an entering temperature of ______° F. to a leaving temperature of ______° F., requiring ______Bhp. The above guarantee shall be based on an allowance for scale in both cooler and condenser.

17. **Related Equipment and Work**—The following additional material or services (items 19-25) are necessary for the installation and operation of the above machine, but are to be furnished by others than this contractor.

18. **Floor or Foundation**—Supporting floor and concrete base.

19. **Thermometers in Water Line**—One thermometer each in entering and leaving chilled water lines and entering and leaving condenser water lines.

20. **Electrical Wiring**—Electrical connections are required for:
    a. Main compressor drive (when electric)
    b. Purge-recovery unit
    c. Control panel board

21. **Insulation**—All insulation, including insulation on shell and tube cooler.

22. **Piping**—All piping and pipe covering, except that specifically included above.

23. **Cutting and Patching; Painting**—Suitable openings for entrance and installation of the equipment; cutting, patching, painting (except shop coats on equipment).

24. **Permits**—Permits and certificates of inspection.

25. **Defense Priorities**—May limit availability of certain materials specified as cupro-nickel, nickel steel, etc.

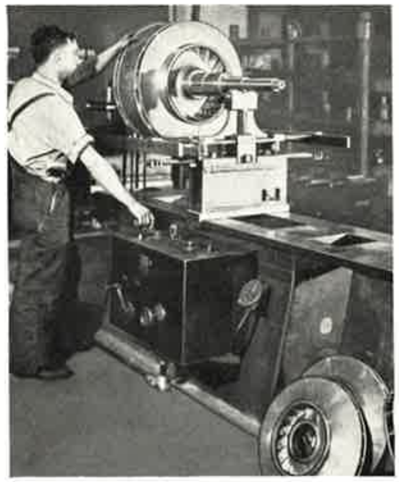
CARRIER SERVICES . . . Scope of Equipment — Engineering — Distribution

Carrier Corporation makes a complete range of equipment, from the window ventilator handling a few hundred cfm of air to heat diffusers delivering hundreds of thousands of Btu—from completely self-contained room conditioners to central station installations handling thousands of cfm—and from drinking water coolers employing 1/5 ton units to the Centrifugal Refrigerating Machines described in this booklet.

The self-contained units are manufactured completely in the Carrier factory and require only putting in place, and service connections. The central station systems for the conditioning of large spaces or complete buildings, and unitary equipment for spaces large or small, are available to meet economically all sizes and types of requirements.

Carrier markets the equipment which it manufactures, and for which it contracts, through its Direct Engineering and Sales Organization and through its authorized Distributors, Dealers and Agents—at home and abroad.

Carrier's objective is to achieve economy of distribution, to provide efficient service within easy reach of the consumer, and to make available to all its years of experience gained from $130,000,000.00 of refrigerating, industrial air conditioning, heating and air cleaning installations which are giving satisfaction in more than 200 industries in over 99 countries. Carrier's interests range, therefore, from the simple sale of packaged equipment to contracts for complete installations in co-operation with Architects, Engineers and the staffs of industrial organizations.



Behind the successful manufacture of the Carrier Centrifugal Refrigerating Machines are scores of skilled men. Some of the skilled workers who have served the company since, or shortly after it started, are still employed, earning 30- and 35-year service pins. Approximately 70% of the skilled workers are wearing 10-year service pins.

Precision machines are another reason for Carrier's success in producing faultless equipment. Finned tubes are produced on the extrusion machine illustrated in the photograph at the upper left on this page.

Large vertical boring and turning machines, with special attachments, are used to machine the gas passage guide vanes —shown in the lower left photograph.

Dynamic and static balancing, an essential in making a vibrationless machine, is accomplished on the apparatus depicted at center top. An entire year of constant practice and experience is the requirement of an operator before he is entrusted with this precision work.

The photograph at upper right shows the disassembly and inspection of a compressor after the run-in and load test.

A view of the erection floor with the refrigerating machines in various stages of completion is shown in lower right photograph.

CARRIER CORPORATION

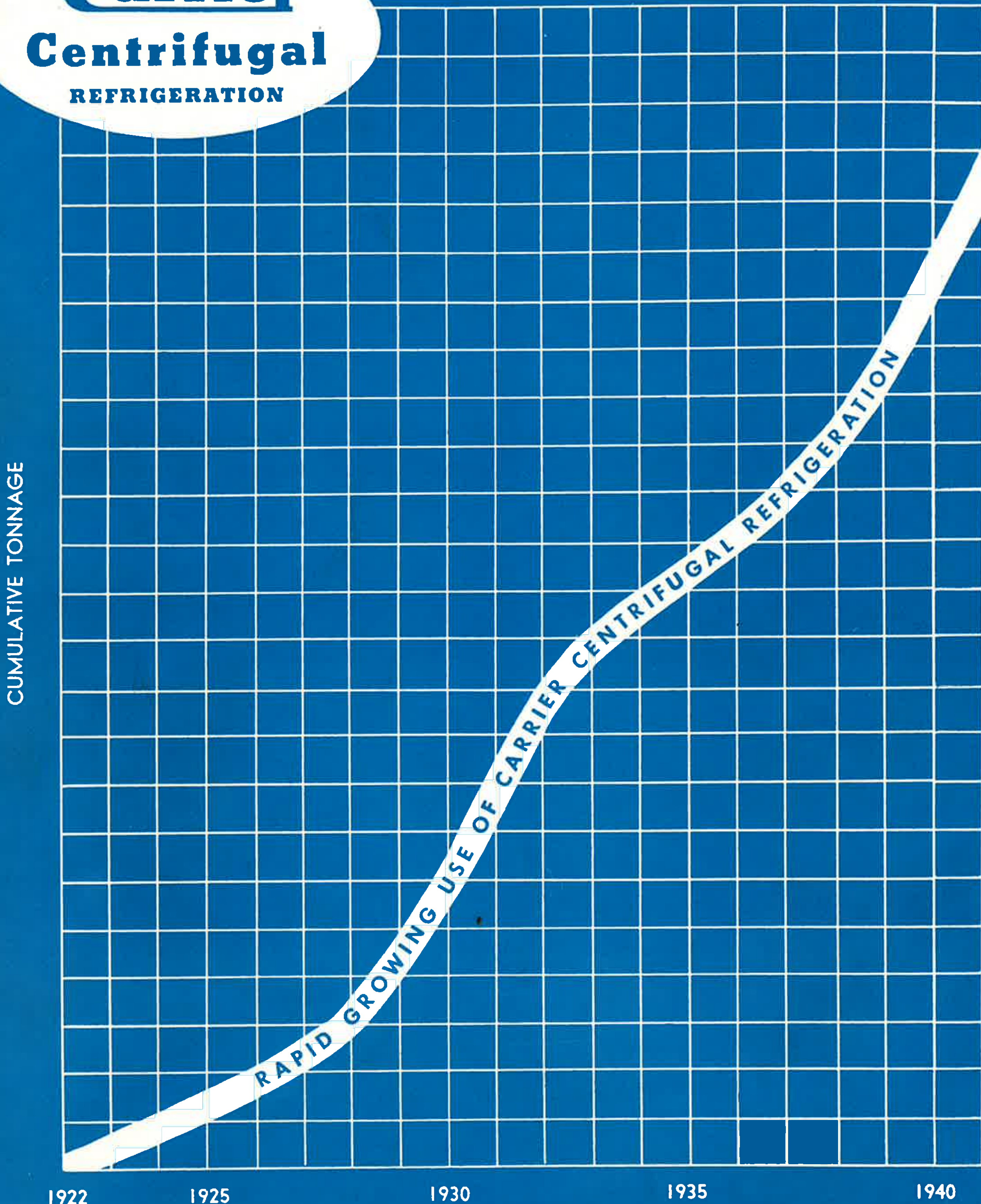
SYRACUSE, N. Y., U. S. A.

LIST OF OFFICES

ATLANTA, GEORGIA
BOSTON, MASS.
CHICAGO, ILLINOIS
CINCINNATI, OHIO
CLEVELAND, OHIO
DALLAS, TEXAS
DENVER, COLORADO
DETROIT, MICHIGAN
KANSAS CITY, MO.
LOS ANGELES, CALIF.
NEW ORLEANS, LA.
NEW YORK, N. Y.
PHILADELPHIA, PENNA.
ST. LOUIS, MO.
SAN FRANCISCO, CALIF.
WASHINGTON, D. C.

AND AFFILIATES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

Carrier
Centrifugal
REFRIGERATION



Carrier CENTRIFUGAL MACHINES THROUGH THE YEARS

PRINTED IN U. S. A.