SELECTION OF LUBRICANTS IN MECHANICAL REFRIGERATION

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Mechanical refrigeration has become a vast industry essential to our well being in modern civilization. Without the aid of mechanical refrigeration for the preservation of foodstuffs, the development of large population centers would have been impossible and our mode of living would be much the same as that of fifty years ago. Even the farmer, who used to be self-supporting, finds it advantageous today to depend on others and not to attempt the production of his entire needs. Foodstuffs can be produced in abundance in localities favored by soil or climatic conditions, but only with the aid of mechanical refrigeration is it possible to preserve these primary food products during transportation to markets for final preparation and distribution to the public.

Advanced civilization is dependent on team work; refrigeration, cold storage and air conditioning represent team work in the highest degree. In fact, the preparation, transportation and storage of meats, fruits, dairy and poultry products would be quite impossible without mechanical refrigeration, even with faster express freight service than now appears probable or possible unless air handling is adopted.

While its advantages are most obvious in the food and fur storage industries, mechanical refrigeration finds indispensable application in many other industries. Certain chemical operations, for example, can only be perfected at temperatures lower than atmospheric; the same holds true for the separation of wax in petroleum refining.

DEFINITIONS AND GENERAL METHODS

Broadly defined, refrigeration is the art of producing cold, with particular reference to cooling below prevailing atmospheric temperatures. Thus, cooling may be effected by the melting of ice, or by evaporation of any volatile liquid. In the broadest sense any medium used for abstracting heat is a refrigerant. As more commonly interpreted, however, the term refrigerant refers to any material used in mechanical refrigeration, by which process the refrigerant is recovered and recirculated, as distinguished from those processes in which the spent refrigerating medium is wasted, such as in the melting of ice.

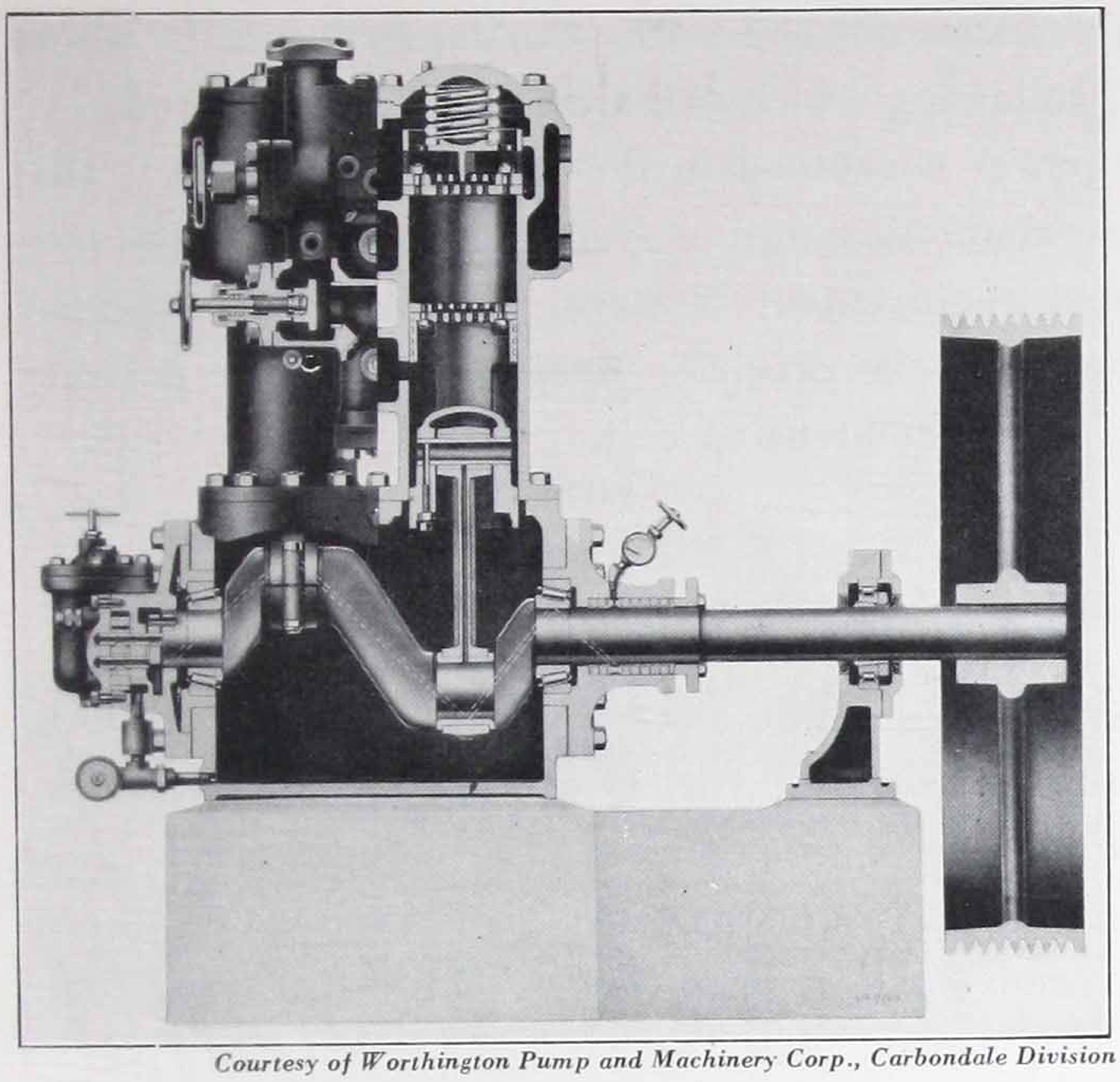
Refrigeration can be direct or indirect. In the former the refrigerant is caused to evaporate inside of coils located directly in the compartment, tank or material which it is to cool. An example of indirect refrigeration is the cooling of air by its circulation over coils in which the refrigerant is being evaporated, from which it passes to the storage rooms containing the material which it is desired to cool. The better known and more commonly used method of indirect refrigeration deals with concentrated salt solutions (brines) which can be cooled to the desired temperatures and then circulated within the space to be refrigerated. Generally direct refrigeration is the more economical in that it involves less equipment to install, maintain and operate. It is often inapplicable, however, due to the hazards involved in leakage of the refrigerant into surroundings where damage to property or injury to human beings would be serious.

PRINCIPLES OF MECHANICAL REFRIGERATION

It is known to all that when some liquid such as water, alcohol or a volatile gasoline is allowed to evaporate rapidly in the hand, a feeling of cold is experienced. It is obvious that this phenomenon can be used to obtain refrigeration provided a suitable liquid is selected and provision made for allowing evaporation to proceed under controlled conditions, to absorb heat from the surroundings to be refrigerated at the desired rate. For the process to be economical the refrigerant must, of course, be collected and brought back to its original liquid state and the process repeated. The evaporation which is necessary for cooling is done at a relatively low pressure. By subjection of the vaporized refrigerant to a considerably higher pressure within suitable cooling coils it can be made to condense at temperatures which can be readily maintained with cooling water. The basic principles involve:

1. Evaporation and expansion of the refrigerant, whereby heat is absorbed.

2. Compression and condensation whereby heat is in turn abstracted from the refrigerant.



Sectional view of a Carbondale vertical 2-cylinder compressor. This machine is designed for positive and automatic circulation of oil. Note tapered roller bearings on crankshaft and design of the stuffing box.

Courtesy of Worthington Pump and Machinery Corp., Carbondale Division

SYSTEMS OF REFRIGERATION

In the compression system a compressor is used which may be of the positive displacement type (reciprocating or rotary compressor), or the impeller type (centrifugal compressor). The compressor takes suction from the low pressure refrigerating coils in which evaporation takes place, discharging to the condensing coils in which heat is abstracted usually by cooling with water. The desired pressure is maintained in the condensing coil by an expansion valve which releases the liquid refrigerant into the refrigerating or expansion coils where evaporation takes place.

Absorption refrigeration, in turn, employing ammonia, provides for drawing this latter from expansion coils into an absorber where it is contacted and dissolved in the absorbing medium, usually water, or a weak solution of ammonia in water known as aqua-ammonia. Following absorption the concentrated liquid solution is pumped into a generator where heat is applied and the ammonia is driven off as a vapor. At this stage, since the ammonia is not sufficiently pure, it is passed through a rectifier which removes the entrained water, for return to the generator. From the rectifier the ammonia vapor is passed to the condensing coils where it is liquefied by cooling with water. The liquefied ammonia under high pressure is released through an expansion valve into the expansion coils, where refrigeration is effected, following which the above cycle is repeated.

The only mechanical power consumed in the absorption system is that required for pumping the ammonia solution from the absorber to the generator. However, the heat requirement is large, particularly where the operation is not controlled with the precision necessary to insure delivery of nearly pure ammonia to the condensing coil.

REFRIGERANTS USED IN VAPOR COMPRESSION SYSTEMS

The choice of a refrigerant will be influenced by the specific conditions to be met. These may be quite varied in the variety of applications as encountered today. In applications where the reciprocating compressor is most advantageous, refrigerants of high vapor pressure give best results, due to low piston displacement and small friction losses. With the centrifugal compressor, in turn, it is necessary that the refrigerant have low vapor pressure to reduce the number of stages. A heavy density of the vapor is desirable, however, in order to reduce the peripheral speed.

The proper correlation and adaptation of machine and refrigerant to the specific application consequently becomes a complicated problem, worthy of the best thought of the refrigerating engineer. Being responsible for the safety and economical operation of refrigerating equipment it is demanded of the refrigerating engineer that he have more than a casual knowledge of the important properties of refrigerants in respect to chemical stability, inertness to the various metals which they may contact, ease of detection of leaks, and their tendency to react with lubricating oils.

Under certain conditions a very large number of liquids might serve as refrigerants, but of the thousands of liquids which have been proposed for this purpose only a few are in common use, due to the many controlling factors. The following are characteristics of major importance:

1. Liquefying and solidifying temperatures; pressure relationship.
2. Toxicity.
3. Odor and ease of detection of leaks.
4. Stability in service.

5. Inertness to materials, and type of construction used in mechanical refrigerating systems.
6. Vapor density.
7. Latent heat.
8. Behavior toward lubricants.

AMMONIA

Ammonia enjoys the distinction of being the oldest refrigerant, having been used by Linde in Germany, and Boyle in the United States, both of whom pioneered mechanical refrigeration in 1871-1873. Ammonia is still the leading refrigerant in commercial service, due largely to the fact that its thermodynamic properties are such that the volume of refrigerant circulated per ton of refrigeration is low. It may be used for temperatures as low as—50°F. Iron and steel are not affected by ammonia; brass or bronze on the other hand can be used in contact with ammonia only if water is absolutely excluded. Its pungent irritating odor and toxicity exclude it in many applications, such as some types of marine refrigeration or air conditioning, due to the ever-present possibility of leakage. Its solubility in oil is comparatively low.

CARBON DIOXIDE

Carbon dioxide, being a colorless, odorless, non-explosive, non-toxic gas, finds extensive application in the refrigeration of foodstuffs, and the allied industries, due to impossibility of contaminating the product with the refrigerant. In marine refrigeration and air conditioning the possibility of leakage of the refrigerant may also demand the use of carbon dioxide, on account of its unusual properties.

The high operating pressures (usually around 250 pounds suction and 900 pounds on discharge) require heavier construction than for other refrigerants. This has tended to limit the use of carbon dioxide, but with proper design leakage can be kept very low and the cost of construction will not be so much higher than for other refrigerants as to be a determining factor in its selection.

Carbon dioxide has the unique property of not existing as a liquid at atmospheric pressure. Solid carbon dioxide (dry ice) is used to advantage commercially in the handling of ice cream and other applications where water formed by melting ice is very objectionable. The much lower temperature and the smaller weight of dry ice is another important advantage. The manufacture of dry ice is accomplished by the compression and liquefaction of carbon dioxide and expansion at atmospheric pressure with the resultant formation of the solid.

Carbon dioxide is entirely inert to metals except in the presence of water. The solubility of lubricating oils in carbon dioxide is very low and only the simplest methods are required for satisfactory lubrication.

SULFUR DIOXIDE

In comparison with the older and more common refrigerants, sulfur dioxide condenses at rather high temperatures, with low pressures, which largely explains its wide usage in household refrigerating machines, where light construction and air cooling is desirable. The volume of vapor compressed per unit of refrigeration is 2.5 to 3.0 times as great with sulfur dioxide as with ammonia, but this is not objectionable in the household machines where, due to the small capacity, compressor sizes with sulfur dioxide can be kept within reasonable limits.

Sulfur dioxide has a very pungent odor and is so highly irritating in extremely low concentrations that ample warning is given in case of leaks. The most noticeable effect of exposure is irritation of the mucous membranes. When completely dry it is non-corrosive, but traces of water render it acidic and highly corrosive. A maximum of 20 parts per million of water is specified for the refrigerant grade of sulfur dioxide.

Lubricating oils must be specially refined for sulfur dioxide service. They are soluble in sulfur dioxide only to a small extent. Sulfur dioxide, being heavier than oil, any oil passing out of the machine must be separated as a top layer.

FREON, ETC.

As a result of the activity in promoting air conditioning, intensive study has been made of the properties of halogen derivatives of certain aliphatic hydrocarbons, with the result that a number of new refrigerants having very interesting properties have been introduced within recent years. Outstanding among these is Freon (dichlorodifluoromethane—CCl_2F_2) which is odorless, non-toxic and practically non-inflammable. It has been shown that this chemical has no ill effect on animals in concentrations up to the point where suffocation results.

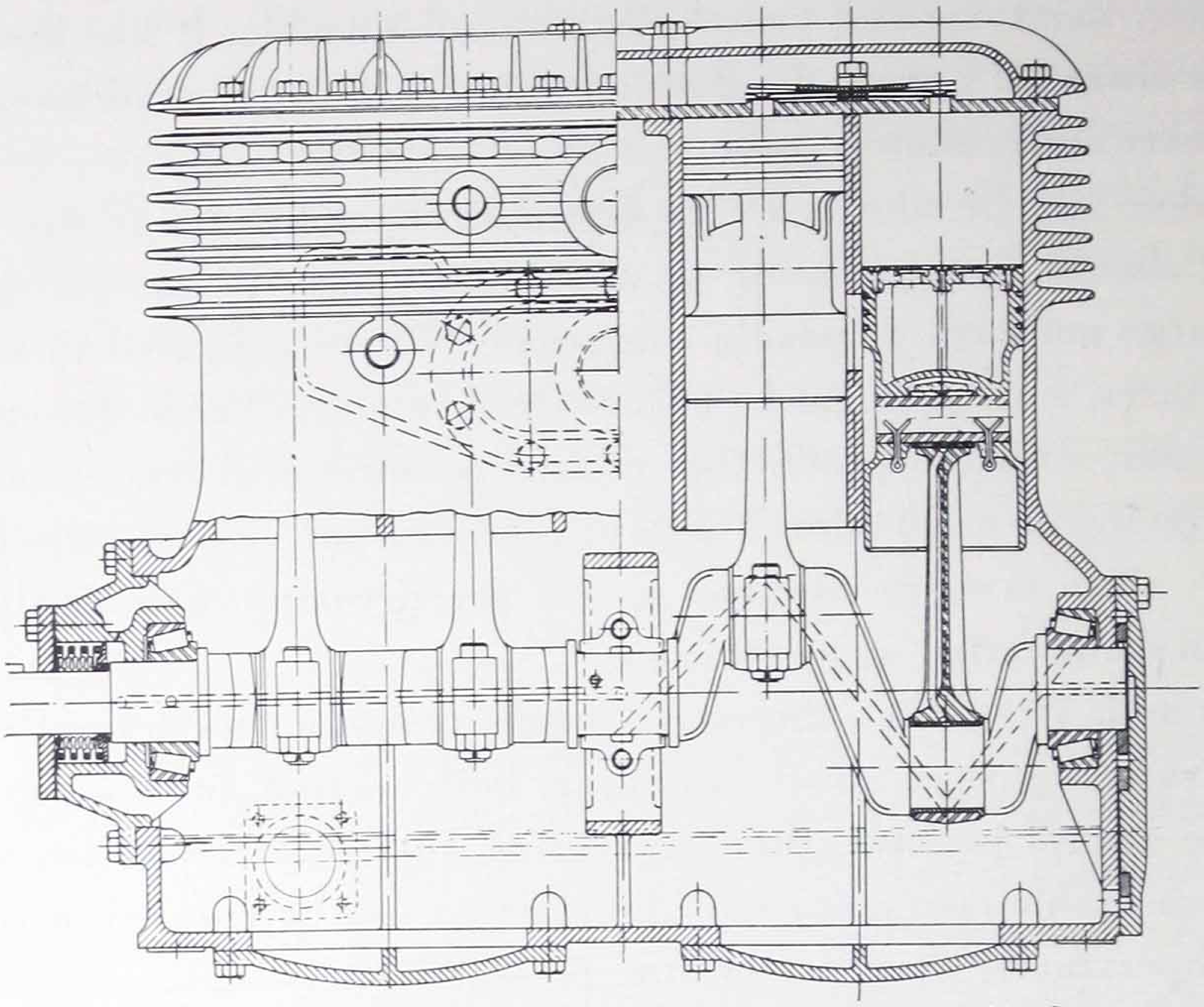
Complete lack of odor is a very desirable characteristic, in that panic is avoided should leakage occur in air conditioning systems for buildings where large numbers of people congregate. Where subjected to very high temperatures, such as might be encountered in a fire, Freon decomposes to some extent, with the production of hydrochloric acid among other substances, giving an acrid odor. This will rarely be particularly objectionable, however, since even in confined spaces the decomposition products will not build up to lethal concentration.

Freon boils at —21°F., therefore, for the temperatures desired in household refrigeration and air conditioning, both suction and discharge pressures are always positive, thus preventing any filtration of air, water or other undesirable contaminants. Liquefaction can be effected at relatively high temperatures, even under low pressures, thus making possible the use of very light materials in construction. While the thermodynamic properties are such that for average conditions the amount of refrigerant circulated is 1.6 to 1.7 times as much as for ammonia, this is considerably less than for sulfur dioxide, and approximately the circulation required for methyl chloride. It is particularly adapted to reciprocating compressors.

Freon is miscible with water to only a very slight extent. Where temperatures below 32°F. are used it is essential, of course, to have complete absence of water. Freon, however, is miscible with lubricating oil in all proportions, therefore, in unit type machines provision must be made for the return of the oil with the Freon gas to the compressor crankcase.

METHYL CHLORIDE

Methyl chloride has found application in installations of medium capacity adaptable to commercial and household refrigeration. For a given refrigerating effect the amount of methyl chloride required is 1.8 times that of ammonia, but only 70% of the amount of sulfur dioxide. Compression pressures, while slightly higher than for sulfur dioxide, are sufficiently low to permit use of light weight materials with air cooling in temperate climates. Methyl chloride is especially advantageous in that the lowest temperatures required for preservation of foodstuffs can always be attained with positive pressure on the suction side of the compressor.



Courtesy of Baker Ice Machine Company

Details of a Baker reciprocating compressor. All bearings in this unit are under full force feed lubrication which is maintained by a built-in positive drive high pressure gear type oil pump.

Since it is slightly toxic and mildly inflammable, the use of methyl chloride has met with objections which would seem to have been overemphasized in the case of household refrigeration, where the quantities are probably too small to cause trouble. The addition of odorants to methyl chloride to serve as a warning in case of leakage has been practiced to some extent; however, their use has not been uniformly advocated.

Methyl chloride is miscible with oil in all proportions, therefore, the evaporator must be designed to permit return of the lubricating oil to the compressor via a suitable separating medium.

F-11

In general the chemical characteristics of F-11 (trichloromonofluoromethane) is quite similar to Freon (F-12), or (dichlorodifluoromethane). The thermodynamic properties of importance in the selection of refrigerants, however, are quite different. The boiling point of F-11 is 74.7°F., therefore, in order to obtain effective refrigeration temperatures quite high vacua must be employed in the evaporator, which results in large vapor volumes to be handled. Centrifugal compressors are, therefore, necessary for satisfactory economy. The use of vacuum results in air infiltration which necessitates some provision for its continuous removal. For this reason the lubricant must serve both as a seal as well as a lubricant.

In general, F-11 is limited to air conditioning installations where the minimum temperatures are quite high in comparison with those required in other refrigeration applications. The toxicity, inflammability, inertness to materials of construction, and other properties are quite similar to those of Freon, mentioned above.

METHYLENE CHLORIDE (CARRENE)

The desire for safety beyond question has led to the development of a system employing a relatively high boiling liquid as the refrigerant, so that vacuum may be used on both sides of the compressor. Therefore, in case of a leak, flow is inward, with no possibility of leakage of the refrigerant. The most widely used refrigerant for this purpose is methylene chloride, which boils under atmospheric pressure at 105°F. Operation under vacuum necessitates handling of large volumes of vapor, for which reciprocating compressors are unsuitable. As a result, centrifugal compressors of special design have been developed which operate with a differential pressure of about 10 pounds per square inch.

Methylene chloride is a water white liquid, non-inflammable and non-corrosive. With centrifugal compression the lubricant is not in direct contact with the refrigerant, consequently there is no lubricating problem involving the effect of the refrigerant on the lubricating oil.

HYDROCARBONS

There are a number of hydrocarbons, notably propane, iso-butane and butane, which from the standpoint of thermodynamic properties alone might be considered excellent refrigerants for many purposes. However, due to their high degree of inflammability and the explosion hazard involved, hydrocarbons of this nature have been used to a very limited extent in refrigeration. Of course, in the petroleum industry, where such materials are being handled constantly the technique necessary for safety has been developed to a point where the refrigerating properties are utilized to most complete advantage in the recovery of condensibles from gases.

SELECTION OF LUBRICANTS FOR AMMONIA SYSTEMS

In the selection of lubricants for cold storage and refrigeration machinery, due regard must always be given to the service involved and the operating conditions that will probably be encountered.

Lubrication of refrigerating machinery is exceptional in that we must consider the action and effects of the lubricants upon parts not requiring lubrication as well as upon the actual wearing surfaces. As a result, considerable care and judgment must be used in selecting the lubricants.

Oil in any part of a cooling system will tend to reduce refrigerating efficiency due to its becoming so sluggish under the low temperatures involved as to form an interior lining in the expansion coils and materially affect the heat transfer.

To overlook or disregard the importance of such factors as the method of lubrication involved, the temperature in the expansion or refrigerating coils, the mechanical condition of the compressor, etc., and the location, type and efficiency of the oil separator may frequently lead to marked increase in maintenance costs and reduction in capacity.

IMPORTANCE OF THE POUR TEST

The most important characteristic of an oil for refrigerating machinery lubrication is that it shall remain fluid at the lowest temperatures to which it may be subjected during operation. These temperatures will be encountered in the expansion or refrigerating side of the system, or, in other words, beyond the expansion valve.

There are many oils, of course, which, by virtue of their base and degree of refinement, will not be able to withstand lower temperatures without congealing to a certain extent, depending upon the amount of wax that may be contained.

CONGEALMENT WILL INVOLVE DEPOSITS

Congealment will mean that a film of oil will be deposited on the inner surfaces of the refrigerating piping to form more or less of an insulating medium which will prevent proper abstraction of heat from the compartment or medium which is to be cooled. If this is allowed to continue it is evident that the refrigerating capacity of the system will be reduced and ultimately it will be necessary to clean out these congealed oil deposits.

WATER AN OBJECTION

In connection with this matter of possible congealment, consideration must also be given to water. It is essential that the oil at all times be practically free from water, otherwise this will freeze if carried over to the refrigerator coils, in which case it would probably remain in the system and result in a certain decrease in evaporative efficiency.

FILTERED MINERAL OILS MOST SUITABLE

For such service a straight mineral filtered oil having a viscosity of around 150 seconds Saybolt at 100 degrees Fahr., such as Texaco Capella Oil B, will be necessary where the temperature in the refrigerating coil is below 5 degrees Fahr. Above this temperature, however, an oil of somewhat higher viscosity, i.e., 200 to 300 seconds Saybolt, will give more satisfactory results, such as Texaco Capella Oil C or Texaco Capella Oil D.

The finest grade of straight distilled mineral oil obtainable is always advisable in order that the above requirements will be adequately met. Oils of this nature will have a sufficient range of physical properties to lubricate the standard type of ammonia compressor effectively under all normal operating conditions.

Mineral oils are more suitable than compounded lubricants inasmuch as animal and vegetable oils will not only have a tendency to congeal at low temperatures and gum at higher temperatures, but will also react to a certain extent with ammonia. In addition, they may tend to cause the formation of sludge by reaction with ammonia gas.

VAPORIZATION ALSO A FACTOR

Low pour test is not the only important characteristic. It is also essential, at the same time, that the oil shall not vaporize excessively at the pressure involved, to insure against being carried over too rapidly at the discharge temperature, otherwise objectionable accumulations may develop.

In a wet compression system vaporization is of less concern, inasmuch as discharge temperatures are usually considerably below those encountered in dry compression. Normally, such temperatures will range below the flash point of the usually accepted oil designed for ammonia compressor lubrication.

WHEN VISCOSITY MUST BE CONSIDERED

Viscosity is a factor where enclosed crankcase, high speed machines are used in connection with evaporating systems which may allow liquid refrigerant to return to the compressor. As a rule, oils should be used which will stand considerable churning in the presence of the refrigerant and a certain amount of water vapor.

The one oil lubricates the entire machine. As a result, it must be capable of serving both the cylinders and the bearings. It should not emulsify to any great extent, for this might result in clogging of the lubricating system or impairment of refrigeration should it work past the piston rings and over to the refrigerating side.

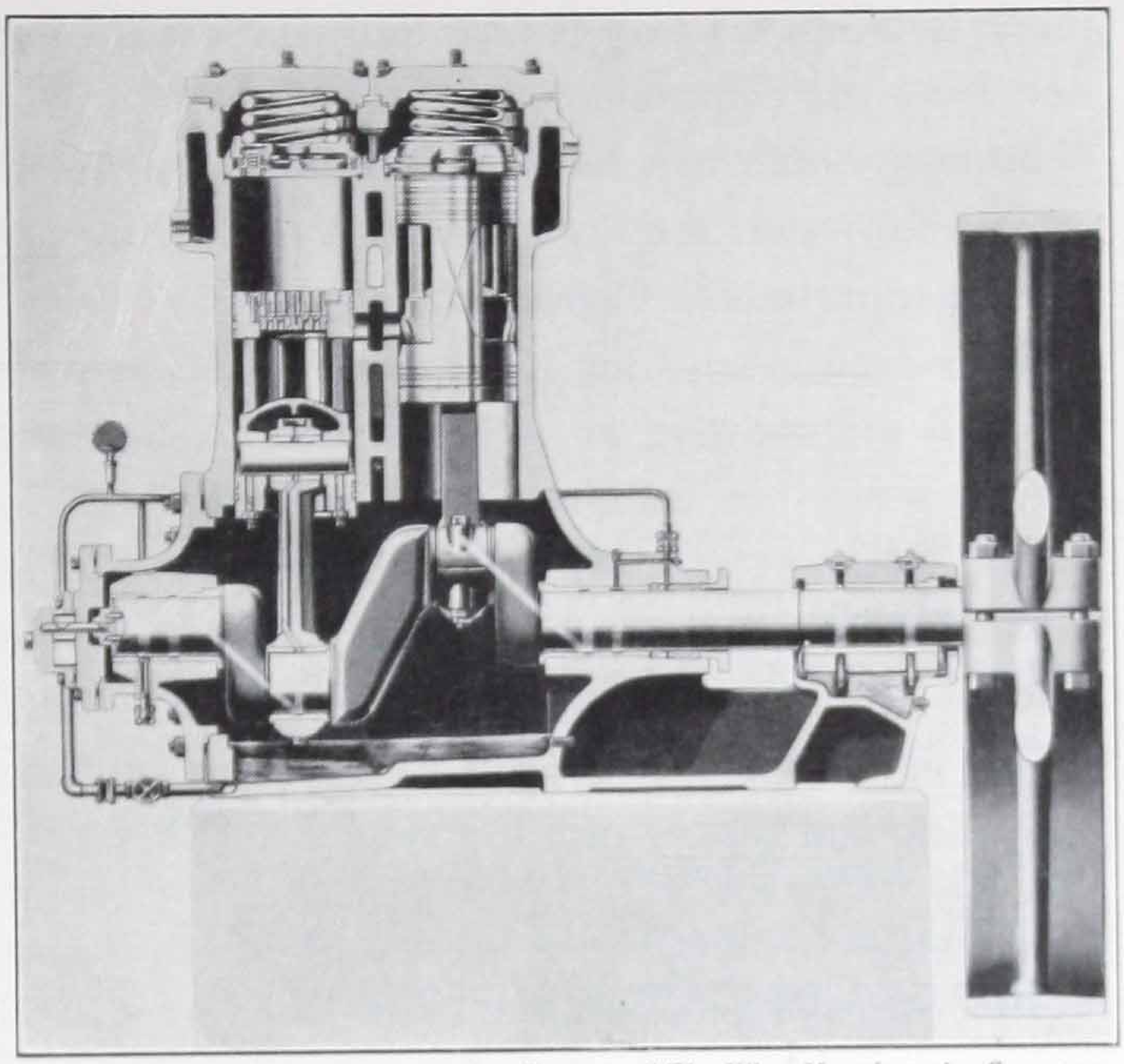
The physical condition of the valves, piston rings and stuffing boxes must always be considered in deciding upon the viscosity of oil to use.

Practically as important as its lubricating properties will be the seal and compression-forming ability. If the cylinder wall and moving parts are in first-class condition, a straight mineral oil of approximately 200 seconds Saybolt viscosity at 100 degrees Fahr. will serve the purpose admirably, i.e., Texaco Capella Oil C.

The more worn and scored the cylinder walls and rings, naturally the higher must be the viscosity (within practical limits) to maintain the requisite seal and degree of compression. Usually an oil having a viscosity of 300 seconds Saybolt at 100 degrees Fahr., such as Texaco Capella Oil D, will be satisfactory in this event.

Horizontal compressor cylinders will have a greater tendency to wear out of round than those of vertical machines due to the weight of the piston which must be carried on the under wall. Therefore, such compressors will, in general, require a somewhat heavier lubricant. It is not advisable, however, to attempt to compensate for wear by increasing the viscosity too much, due to power losses, the possibility of emulsification, and contamination of the refrigerant as already mentioned above.

The Vilter Enclosed Vertical Ammonia Compressor. This unit is designed for force feed lubrication to all operating parts, the piping essential thereto being plainly shown.



Courtesy of The Vilter Manufacturing Company

CARBON DIOXIDE COMPRESSORS

From an operating and constructional point of view there is a decided similarity between both ammonia and carbon dioxide compressors. The marked difference in pressures, however, often requires separate consideration in regard to lubrication.

For such machinery the lubricant should be a straight mineral oil having essentially the same characteristics as for a dry ammonia compression system; such as low pour test, a flash point sufficiently above the discharge temperature to insure against excessive vaporization, and a viscosity in the neighborhood of 100 to 200 seconds Saybolt at 100 degrees Fahr., dependent upon operating conditions and the pressures involved, i.e., Texaco Capella Oils A, B, or C.

Cylinder temperatures in a carbon dioxide compressor are comparatively high due to the pressures which will prevail. It is interesting to know that mineral oil has no affinity for carbon dioxide, hence there is little or no possibility of its being carried over into the condenser unless it is vaporized. This is not likely to occur, however, when an oil which is suited to the requirements is used.

On the other hand, to insure against any oil whatsoever passing over into the system, an oil trap is usually installed at some point in the discharge line from the compressor.

Stuffing boxes are built similar to those on a double-acting ammonia compressor, with the exception that the higher pressures involved require more compartments to prevent leakage.

Force-feed lubrication is the usual means provided for serving the piston rod and maintaining an adequate stuffing box seal. The same lubricator usually serves the compressor valves and piston as well. The feeding of a suitable amount of lubricant to the stuffing box prevents loss of gas.

The lubricator must be very carefully adjusted at all times, however, the same as for an ammonia compressor, since the feeding of an excessive supply of oil will often result in a certain amount of it passing to the gas relief line and thence into the system.

MEANS OF LUBRICATION EMPLOYED

Splash and pressure lubrication predominate in the heavy duty, industrial refrigerating compressor. The latter is suited for the lubrication of both vertical and horizontal machines. The former, however, is more adapted to the vertical compressor.

The system involved for the lubrication of compressor cylinders, stuffing boxes and enclosed bearings will have a decided influence upon the grade of the oil that should be used.

It will, therefore, be of interest to study the principles involved in these methods of lubrication.

SPLASH SYSTEMS

Splash lubrication constitutes distribution of the oil at each revolution of the crank, the level in the crankcase being maintained just high enough to permit the crank to dip and splash the necessary amount of oil to the cylinder walls, etc.

Continued operation will result in the crankcase being filled with a lubricating vapor above the main body of oil, which will insure adequate lubrication of main, wrist pin and crank pin bearings.

Careful attention is necessary, especially when re-charging the case with oil, to see that the level is not raised too high. The result would be churning by the crank, bringing about such violent agitation in the main body of oil as to oftentimes preclude effective precipitation of any solid impurities that may have gained entry. There would also be possibility of loss of lubricant past the piston rings, with subsequent entry of an excess of oil into the condensing and evaporating parts of the system.

PISTON RINGS MUST BE PROPERLY ADJUSTED

Another point to remember in this regard is that where piston rings are not sufficiently tight, if the crankcase contains too much oil or agitation is too violent, the excess which naturally will reach the cylinder walls will tend to work past the rings, just as so frequently occurs in the automotive type of internal combustion engine.

This is often termed oil pumping. Not only is it wasteful, but especially in an ammonia compression system will it be a detriment, for oil in the refrigerating lines will impose an added load on the oil separator. Furthermore, if by chance the oil is not of sufficiently low pour test there will be possibility of its congealment within the system, reducing refrigeration to a marked degree.

EXCESS OIL A DETRIMENT

Use of excess oil in a splash lubricated system will also involve the possibility of difficulty when draining and cleaning, especially where sludging has taken place.

Churning of certain oils will give rise to sludge formation if they have not been very highly refined. In part this is due to oxidation; it will be most probable where water is present or the oil is laden with very much foreign matter, such as dirt, metallic particles, or carbon.

It is, therefore, important to observe regular periods for cleaning, and to look carefully into the condition of the used oil, for this will very often indicate both the approximate suitability of the latter and the extent to which effective lubrication is being attained.

PRESSURE LUBRICATION

Where larger types of vertical or horizontal refrigerating machines are involved, pressure lubrication is used with marked success. With such a system, more accurate control of the amount of oil delivered to cylinder walls and compressor bearings is made possible. On the other hand, it requires more equipment, piping, etc., and entails frequent filling of the reservoir and more attention from the operator than where splash lubrication is involved.

One of the chief advantages of pressure lubrication, however, is the possibility of effective filtration or purification of the oil where there is provision for circulation.

MECHANICAL FORCE FEED OILERS ADAPTABLE

Mechanical force feed lubricators are extensively used where compressor cylinders are to be pressure oiled. Excellent economy will be attained by regulating such lubricators so that just enough oil is delivered to maintain the requisite lubricating films, with the least amount of excess to drain off.

On many types of machines, it is good practice to lubricate internal and external parts individually. In other words, using the mechanical lubricator with perhaps three outlets for cylinder and stuffing box service, and an independent gravity or mechanical pressure circulating system for all external bearings.

For these latter a high grade engine or machine oil, such as Texaco Nabob or Texaco Aleph Oil, will suffice. Low pour test for this type of work is relatively immaterial; it is only essential that the viscosity be sufficient to carry the prevailing bearing loads, and that the oil is conducive to ready separation from foreign matter and impurities.

Mechanical force feed lubricators are especially adapted to cylinder and rod lubrication via the oil lantern, or oil recess within the piston rod stuffing box. By properly constructing a stuffing box with a lead to come from the lubricator, it is possible to operate the piston rod continually through a ring of oil. In this way, effective rod lubrication, as well as sealing against pressure, are maintained.

To lubricate the cylinder in addition, it is only necessary to deliver a certain excess of oil to the stuffing box lantern and provide a so-called overflow pipe to carry this to the refrigerant suction line adjacent to the cylinder. In effect, this is similar to the principles of steam cylinder lubrication, the refrigerating gas being impregnated with vaporized lubricant prior to its passage through the compressor.

Hand pump oilers can also be used for this purpose, but mechanical force feed lubricators are more positive and require less attention on the part of the operator.

OIL SUPPLY MUST BE CONTROLLED

Wherever an excess of oil may find its way to the evaporating or cooling side of a refrigerating system, certain detriments will be involved, as have already been mentioned.

In this connection, it is interesting to discuss the means whereby this is normally prevented by use of an oil separator.

HOW THE SEPARATOR FUNCTIONS

The actual function of the oil separator is to remove any particles of oil from the refrigerant while it is in gaseous form, after it has left the compressor. The larger the oil particles, of cousre, the more effective will be the separator. It should, therefore, be located at a sufficient distance away from the compressor to permit of adequate precipitation of the oil within the ammonia or carbon dioxide gas.

The capacity of any separator should be ample so that the velocity of the gas passing through will not be too high. But we must realize that any excessive lubricant fed to the compressor will tend to impose a heavy load upon the oil separator.

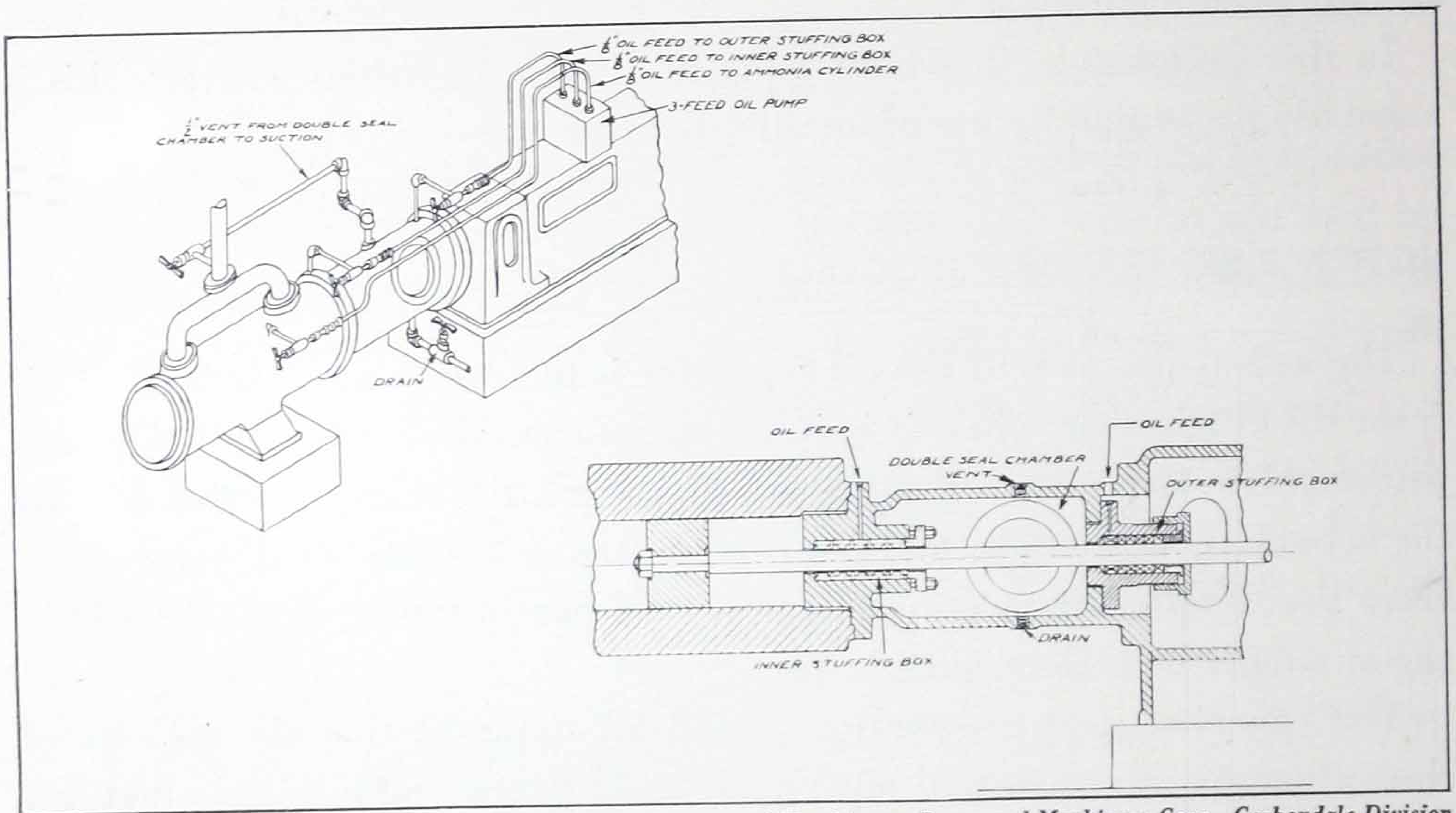
LOCATION AND INSTALLATION

The manner of location of the oil separator or trap is, therefore, decidedly important. In general, it should be placed between the discharge of the compressor and the point of entry of the gas into the condenser.

In certain machines, a drain valve may be installed under the condenser to enable removal of any oil that may have passed the separator. Where the oil separator fails to function properly, the reason is often because it is set too near the compressor, the rush of hot gas preventing proper condensation and collection of the oil.

Oil will practically always be atomized to a certain extent by virtue of the heat of compression which is prevalent, regardless of how high the flash point may be. This oil vapor will naturally tend to pass into the system with the refrigerant, to condense and remain in the colder parts, unless it is effectively removed before it enters the condenser.

In consequence, the separator should be located as close to the condenser and as far away from the compressor as possible. It is always advisable that it should be of sufficient size to allow of ample reduction in the velocity of the gas in order to permit of effective separation.



Courtesy of Worthington Pump and Machinery Corp., Carbondale Division

Oil piping for double cylinder stuffing box of the Carbondale type.

A smaller separator located some distance from the compressor may often prove more effective than a large separator located nearby.

Where it is impossible to locate the main oil separator elsewhere than adjacent to the compressor, it is well to use an oil of as low an atomizing tendency as possible. Low atomization tendency will usually accompany high viscosity. The choice of a heavier oil would, therefore, solve the problem to some extent. In general, an oil of a viscosity of about 200 seconds Saybolt at 100 degrees Fahr., will meet these conditions easily, i.e., Texaco Cappella Oil C.

The efficiency of an oil separator can be readily checked by comparing the amount of oil removed from it with the amount fed to the compressor. Any extensive difference would indicate that the oil is not being entirely removed or trapped. Allowance, of course, should be made for oil leakage around the stuffing box, although to just what extent this may occur will depend on the individual installation, the care given to lubrication, and the original viscosity of the oil.

SEALING THE STUFFING BOX

With compressors using either ammonia or carbon dioxide, one of the most important factors is to maintain suitable stuffing box seals and properly lubricated piston rods.

Where ammonia is involved, it is necessary to remember that this chemical has a certain corrosive action upon copper and bronze. Stuffing boxes, for such service, are therefore, usually built of cast iron or steel (as are other parts of the compressor) and metallic (babbitt metal), asbestos, or rubber packing is used.

HOW THE OIL LANTERN FUNCTIONS

In some types of machines a hollow space or "oil lantern" is located between two separate sets of packing. This space surrounds the rod and is filled with oil. It not only serves as a seal to prevent loss or leakage of ammonia or carbon dioxide, but also as an effective means for piston rod protection by means of lubrication.

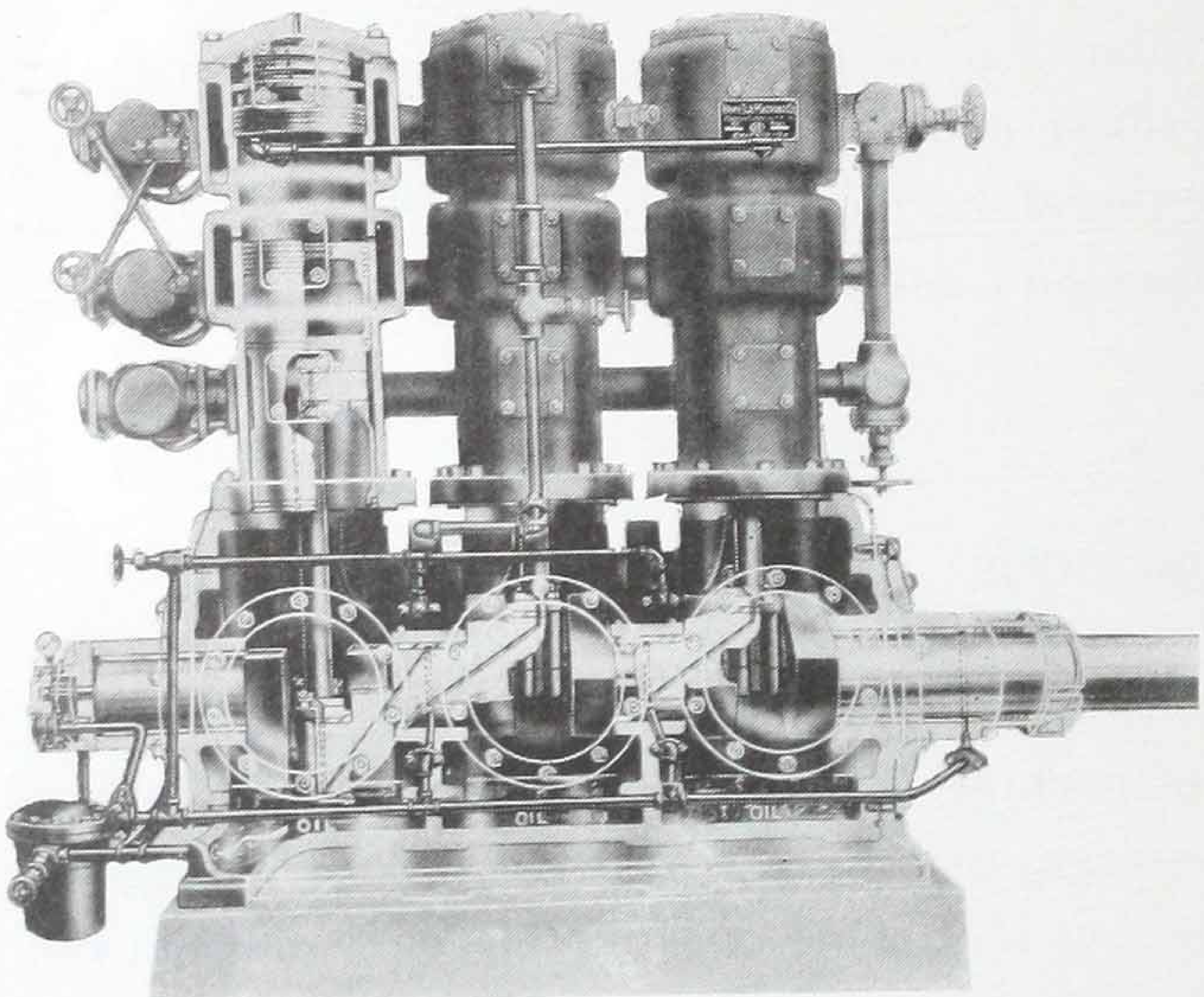
Lubricant is usually fed to the "oil lantern" by means of a hand or automatic pressure oil pump.

Where the piston rod is efficiently lubricated, its surface will have a smooth gloss and be covered with a light film of oil; there will be no indication of overheating, and a relatively perfect seal will be maintained with a minimum of leakage.

In some types of double-acting machines, the "oil lantern" serves also as a means of introducing the lubricant to the compressor cylinder by allowing it to work past the piston rod packing. There is an added advantage to this method in that certain grades of packing, which might be reacted upon by ammonia gas, will be protected by the lubricant.

More usual practice in cylinder lubrication, however, is to design compressors for pressure lubrication, using a positive oil pump or force feed lubricator which is driven from the reciprocating mechanism through suitable connecting links or gearing.

Force feed lubrication is advantageous in that the amount of lubricant supplied to the compressor is dependent upon the speed of operation. It is, therefore, dependable, economical and requisite of little attention on the part of the engineer, excepting when it is necessary to refill the lubricator. Thus, by careful adjustment and correction, it is possible to feed a definite quantity of lubricant at each stroke and at just the right time to afford the most positive protection.



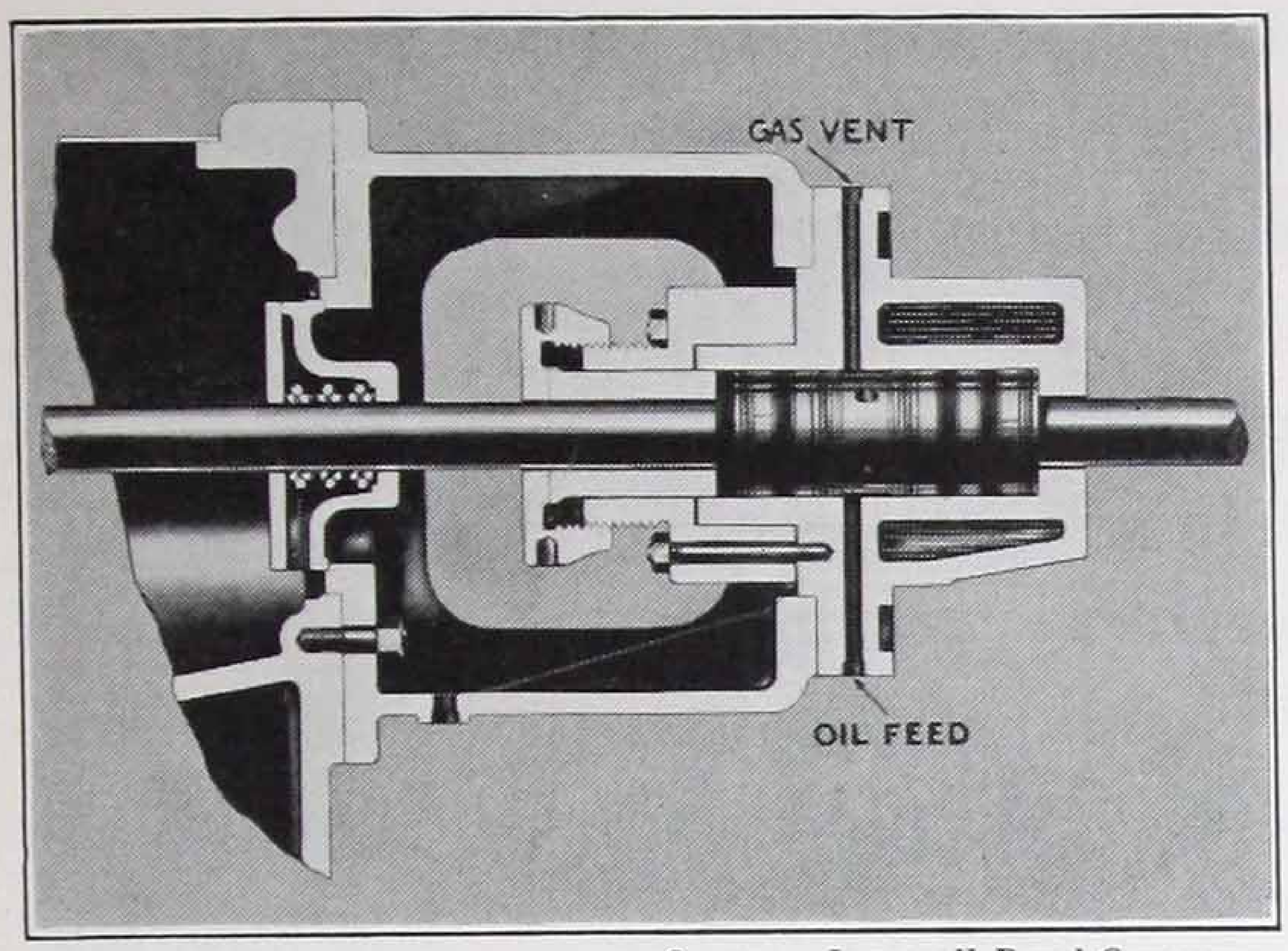
Courtesy Howe Ice Machinery Company

The Howe compressor showing the entire oiling system. In this an oil pressure of from 15 to 30 lbs. is carried on the main bearings. It is regulated by a valve located on the stuffing box bearing, which is designed to by-pass part of the oil from the main oil header.

RECLAIMING COMPRESSOR OILS

It is practicable to reclaim oil from an ammonia compression system by installing an ammonia distilling apparatus. This device has the dual advantage of both recovering the oil and purifying the charge of ammonia to keep same in a pure anhydrous condition without interfering with the continuous operation of the plant.

Such equipment can be connected to the discharge line oil separator and the bottom of the liquid ammonia receiver, from which oil and other impurities may be drawn, for subsequent distillation of ammonia.



Courtesy Ingersoll-Rand Company

Showing a type of ammonia stuffing box as applied to an Ingersoll-Rand ammonia compressor. This design includes special metallic packing, water jacketing, force feed lubrication and venting to the intake to reduce ammonia loss.

After all the liquid ammonia has been evaporated and returned to the suction line of the system, the oil can then be drawn from the bottom of the still using suction pressure for this purpose. Such oil as is drawn off will contain a certain amount of gas. It should, therefore, be set aside until the gases have freed themselves. The application of a little heat will assist this operation materially.

Care should, of course, be taken in handling the distillation to prevent too rapid evaporation, which will cause a boiling-over effect and the loss of a large proportion of oil through passage back to the suction line.

After removal of the oil from the distilling system it is ready to be filtered. A separate filter should be used for this work. The size and type of filter to be used will depend upon the size of the plant and the amount of oil to be handled. Providing the original oil has been chosen with a view to giving most effective lubrication the oil recovered from the distiller, after careful filtration, can again be used for compressor lubrication.

In many plants where oil is reclaimed, however, it is used for external lubrication, and only new oil is employed for the lubrication of cylinders and other internal parts. This is safe practice, and an assurance that the oil used where service is most severe is perfectly clean and up to the usually accepted specifications.

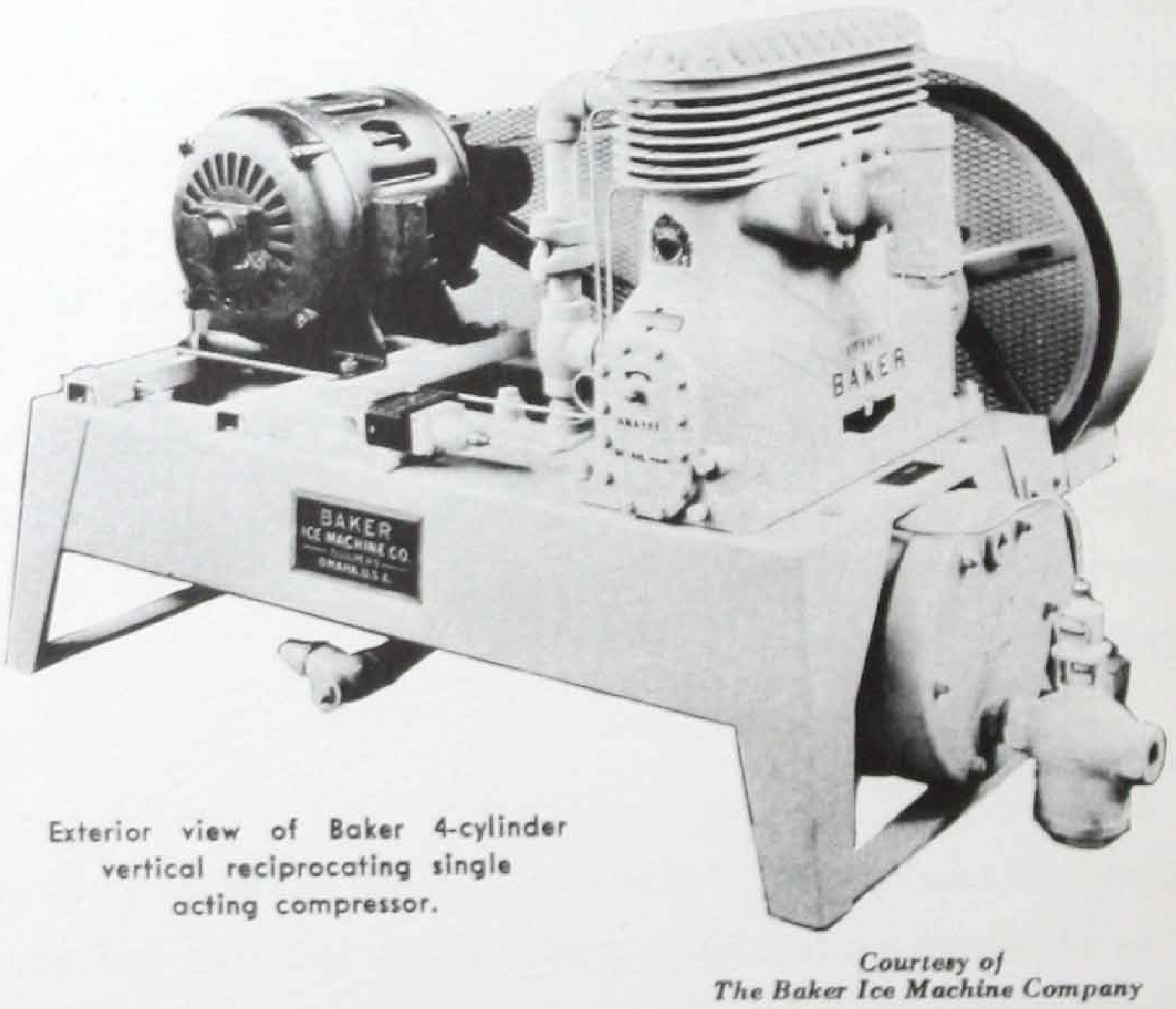
EXTERNAL LUBRICATION

The so-called external parts of the average ice plant or cold storage compressor such as crank pins, bearings and guides, involve but few difficulties as a rule in their lubrication. In general, this is automatic, it being customary to employ splash or force feed lubrication on most machinery.

In many types of vertical compressors, splash lubrication is prevalent; the one oil frequently serving both the compressor cylinder and the bearings in much the same manner as in an automobile engine.

Outboard bearings of vertical compressors can be efficiently lubricated by ring or chain oilers, where necessary using the same oil as in the compressor itself. If there is no danger of contaminating the refrigerant with oil a medium viscosity machine oil, such as Texaco Nabob or Texaco Aleph Oil, will also serve the same purpose.

Horizontal compressors and certain larger types of vertical machines are usually equipped with a gravity or force feed lubricating system, which furnishes a continuous stream of oil to all bearings beyond the compressor. Such systems generally include a suitable oil filter, over-head storage tank (which allows for gravity feed), water separator and geared pump. This latter is installed in the base of the crankcase, being driven from the compressor itself. It is advisable to filter the oil prior to each circulation, to insure most efficient lubricating service.



Exterior view of Baker 4-cylinder vertical reciprocating single acting compressor.

Courtesy of
The Baker Ice Machine Company

ELECTRIC REFRIGERATION

THE PRINCIPLES OF REFRIGERATION

"How it works" is often a point of interest to any owner of an electric refrigerator. Even the technician or practical engineer must sometimes stop to think out the refrigerating cycle. So a word as to what goes on when one plugs the connection into the electric socket will be in order. Obviously, an electric motor is essential to run the unit, and electric current runs the motor to bring about rotary motion. Through a suitable connection to the compressor this rotary action is transformed into reciprocating motion in the cylinder type of unit or it rotates the rolling element in the rotary machine. The compressor is one of the most important parts of a refrigerating machine; its function is to reclaim and compress the chemical vapor or gas — a procedure which is necessary continuously to thoroughly complete the refrigerating cycle.

This process of refrigeration involves the transfer of heat from any given article or space which is to be cooled. In the conventional ice box, ice serves as the cooling medium. Being of much lower temperature than the contents or interior of the box, it tends to absorb heat from the latter. As this occurs, the temperature of the box is lowered, but at the same time the temperature at the surface of the ice is raised above the freezing point, hence melting takes place. The extent to which a cake of ice can properly cool an ice box will, of course, depend upon the total area of its exposed surfaces. Where this area can be kept constant, uniform cooling will be accomplished. Otherwise, the temperature of the box will rise gradually due to outside influences, as the cake of ice becomes smaller.

The electric refrigerator replaces ice through the cooling effect of some liquid chemical of comparatively low boiling point. By proper circulation of this chemical through a suitable heat exchanger or cooling unit, a constant and uniform rate of heat transfer to this element from the space to be cooled is continually maintained.

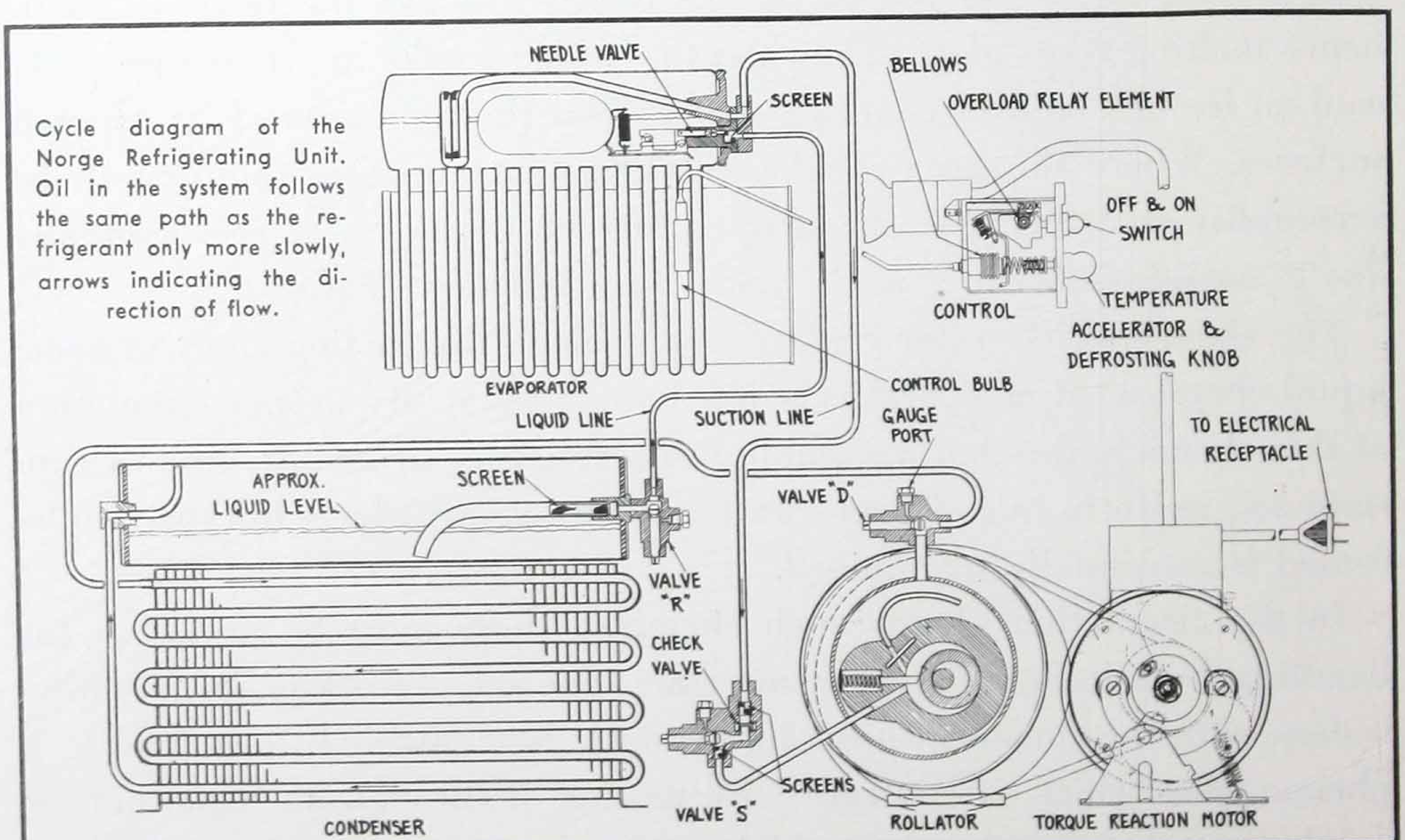
In the circulation of any such chemical, there must be provision for handling, both in liquid and gaseous state. The actual work of refrigeration is done with the chemical in the liquid state; by allowing it to evaporate, a phenomenon which is controlled by passing it through an expansion or regulating valve. Evaporation, which is a result of boiling of the refrigerant, is effected by the drop in pressure which occurs as the refrigerant passes through the expansion valve.

In physics the latent heat of the refrigerating medium is discussed in connection with refrigeration and heat transfer. In this connection it means the amount of heat necessary to change a product from liquid to gaseous state at its boiling point. So, according to the rate at which liquid refrigerant is passed through the expansion valve, converted into gas and passed into the evaporator, heat is taken up and the temperature of the space surrounding the evaporator is lowered. This space is the interior of the refrigerator cabinet. To complete the cycle this gaseous refrigerant must then be again converted to liquid form, a procedure which necessitates a compressor and condensing unit.

The equipment essential to a complete electric refrigeration installation therefore requires an electric motor, a compressor, condenser, the refrigerant receiver, an expansion valve (an oil trap or separator in some types of design) and the cooler or evaporator.

OPERATION OF THE COMPRESSOR

From the viewpoint of lubrication, the compressor is the most important part of the system. For the information of the layman, this machine func-



Cycle diagram of the Norge Refrigerating Unit. Oil in the system follows the same path as the refrigerant only more slowly, arrows indicating the direction of flow.

Courtesy of Norge Division, Borg-Warner Corporation tions somewhat as a pump, being designed to compress the gas from a comparatively low pressure to a higher pressure.

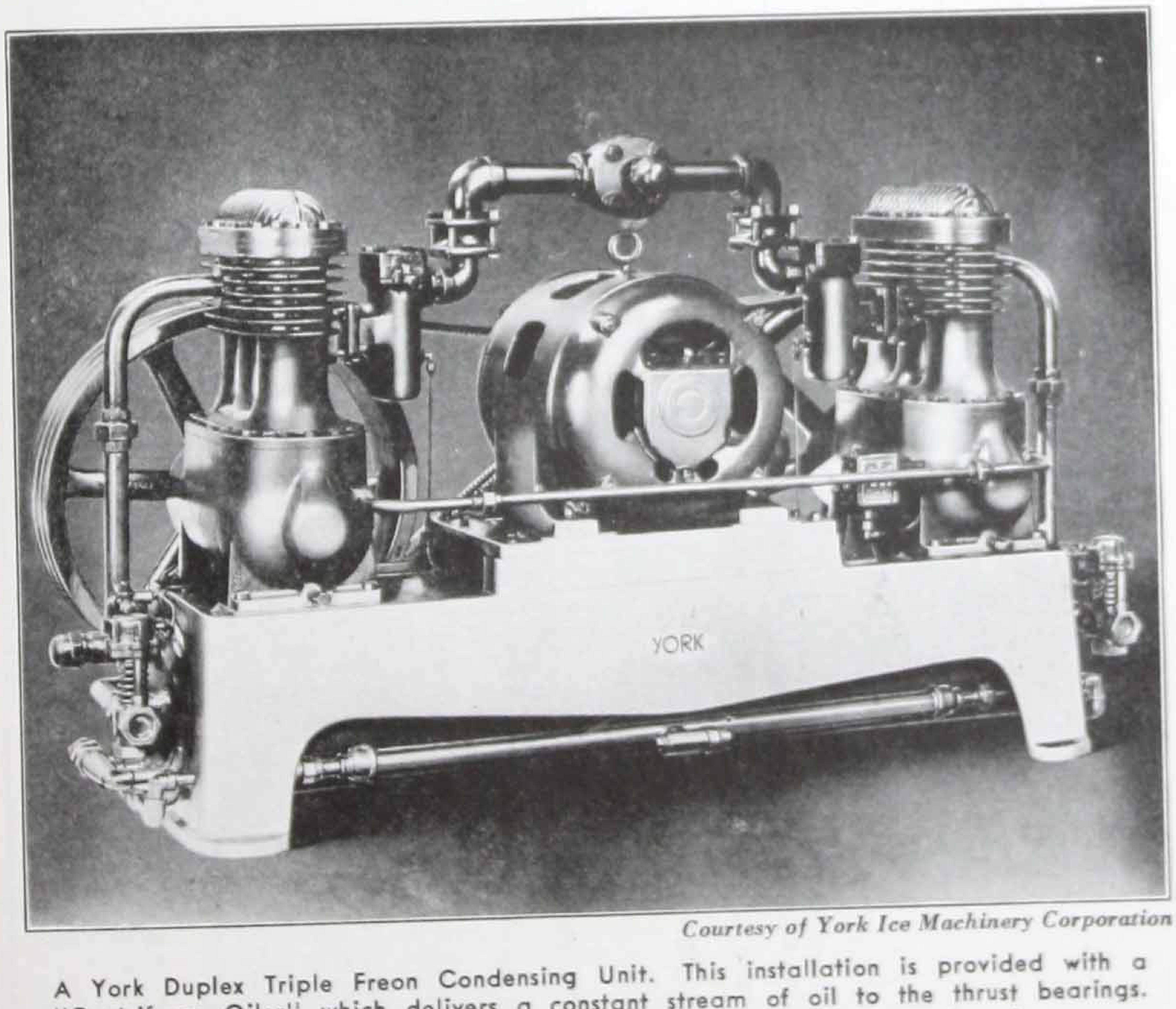
RECIPROCATING UNITS

The recripocating type of compressor resembles in principle the automotive engine in design with the exception of the number of cylinders. Normally, the electric refrigeration compressor will have only one or two cylinders. In these cylinders are fitted the pistons with suitable connecting rods, wrist pins and crank connections.

The compressor crankshaft may be directly connected to the driving motor through a yoke connection or some other type of fixed coupling, or a belt connection may be used.

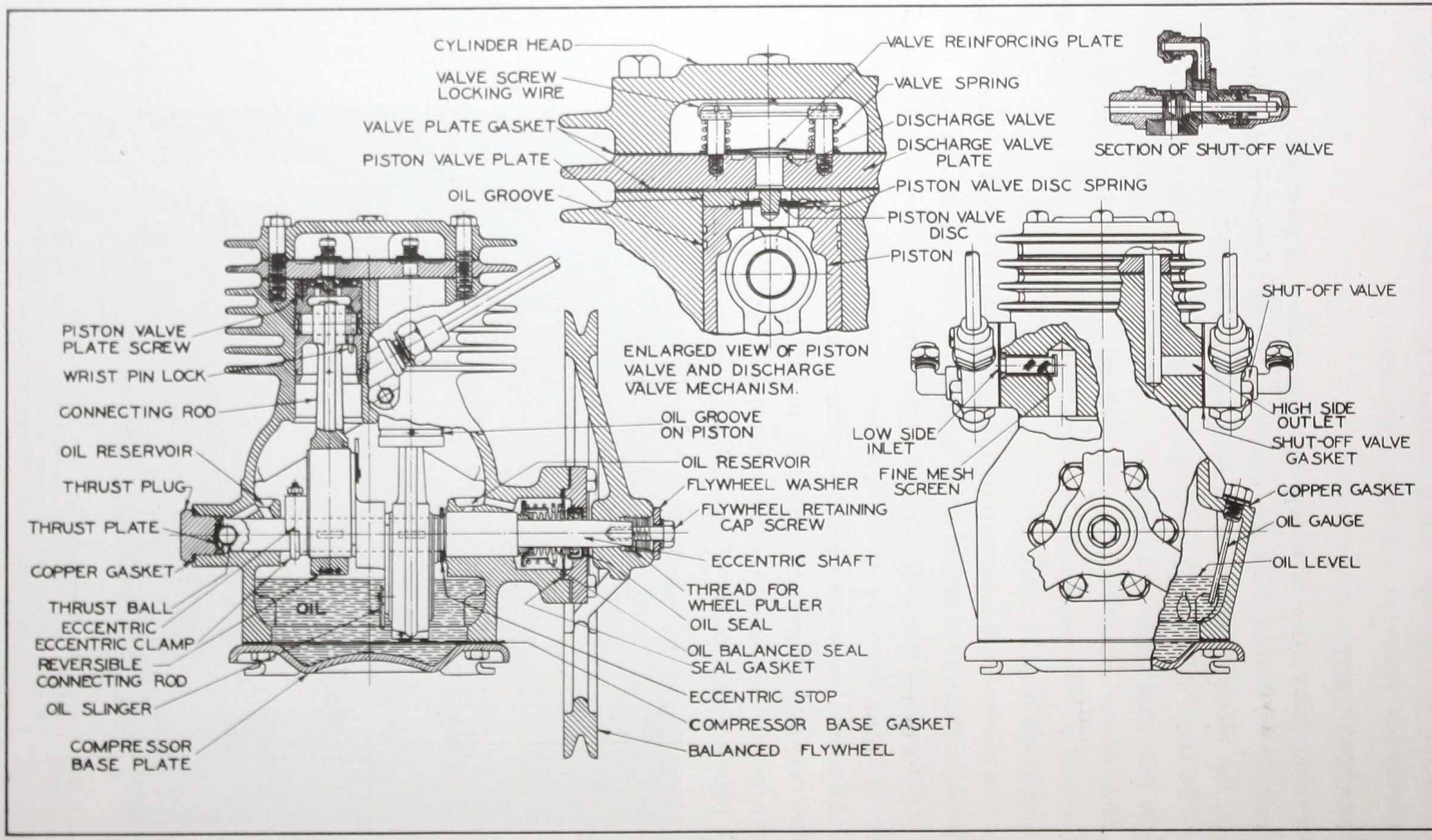
There is a marked difference in piston and cylinder design of the household type refrigerating compressor as compared with practically any other type of reciprocating machine, in that piston rings are rarely used. Instead the designers plan for very close clearances between pistons and cylinder walls, and depend upon the lubricating film to maintain the necessary seal.

Another marked difference pertinent to this machine is the manner in which the gas to be compressed is drawn into the cylinders. In contrast with the conventional mode of handling the gas in any other type of com-



Courtesy of York Ice Machinery Corporation

A York Duplex Triple Freon Condensing Unit. This installation is provided with a "Centriforce Oiler" which delivers a constant stream of oil to the thrust bearings. The main bearings are submerged in oil and a splash system is provided for the wrist pin bearing and cylinder walls.



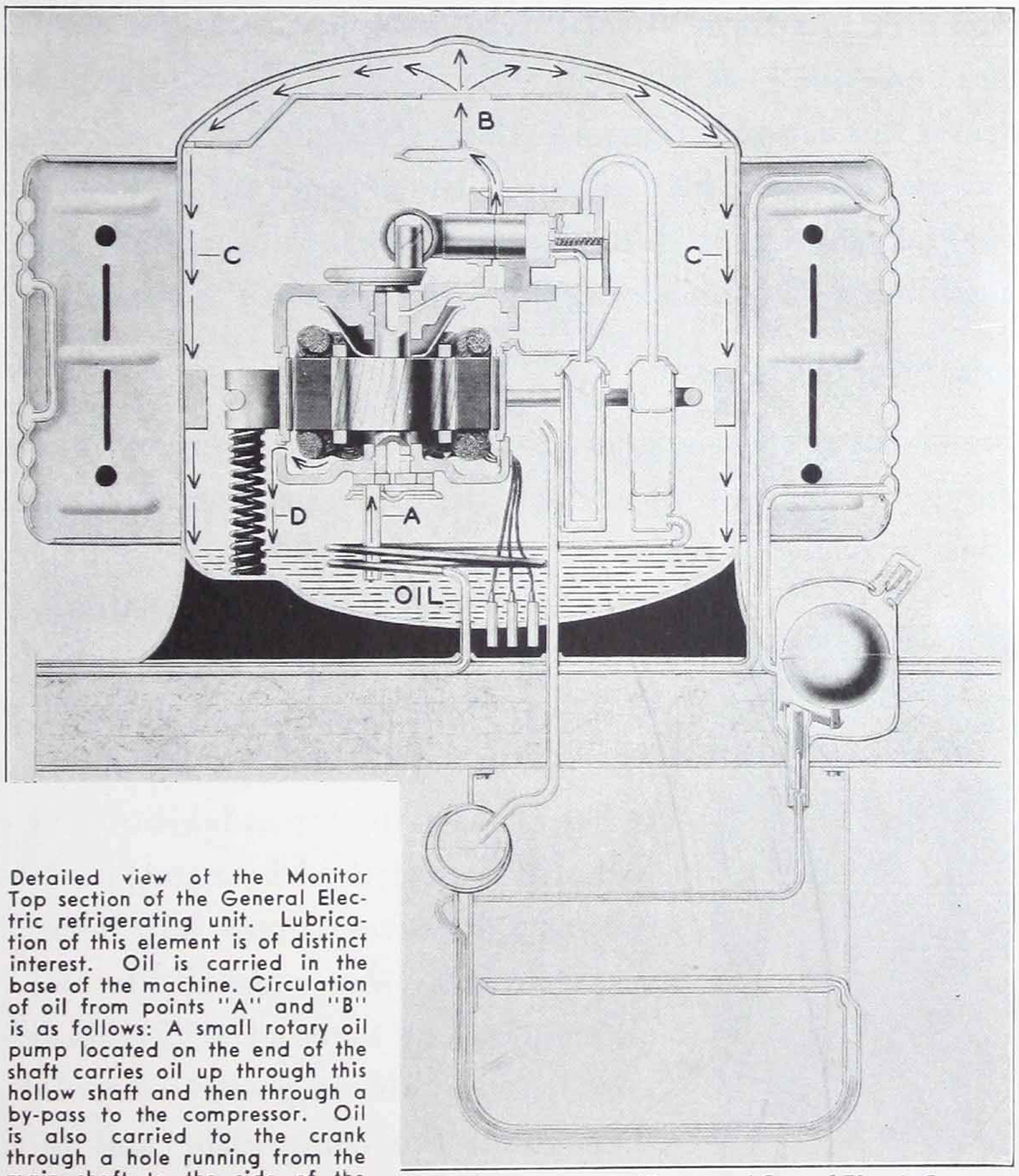
Courtesy of Stewart-Warner Corporation

Constructional details of the Stewart-Warner compressor showing essentials of the lubricating system. Special oil slinger paddles attached to the eccentric, splash oil onto the cylinder walls and into the reservoirs which lead to the bearings. Oil grooves cut in the sides of the pistons in turn assure a source of lubricant for the cylinder walls.

pressor or engine, i.e., taking the charge from the topside as is customary in the automotive engine or air compressor, the electric refrigerating compressor has provision for drawing in the low pressure gaseous refrigerant through the crankcase, using valve mechanisms which are located adjacent to or a part of the piston.

THE ROTARY TYPE

The rotary positive displacement type compressor brings about compression through the rotation of an eccentrically driven roller which moves in a gyratory manner in a closed cylinder. The inlet and discharge passages are separated by a suitable blade which is held in contact with the



Courtesy of General Electric Company

Detailed view of the Monitor Top section of the General Electric refrigerating unit. Lubrication of this element is of distinct interest. Oil is carried in the base of the machine. Circulation of oil from points "A" and "B" is as follows: A small rotary oil pump located on the end of the shaft carries oil up through this hollow shaft and then through a by-pass to the compressor. Oil is also carried to the crank through a hole running from the main shaft to the side of the crankpin. When the oil leaves the compressor, part of it is discharged vertically at a point marked "B" flowing upward and outward as indicated by arrows and following along the walls of the housing to return to the base. The remainder of the oil from the compressor flows out of another opening over the end of this part of the machine. This oil serves to cool the compressor and particularly the valves. The overflow spills into a cup which carries it to the motor compartment to flood and cool the windings. Small holes in the stator allow the oil to drain to the lower winding compartment, from which it spills through an overflow hole and returns to the sump as indicated at "D."

roller surface by springs or oil pressure. Oil also serves to maintain the necessary seal between the surfaces of the roller and housing. Submersion of all the moving parts in oil under pressure, therefore, protects them adequately against wear and enables manufacture to very close clearances.

FUNCTION OF THE CONDENSER

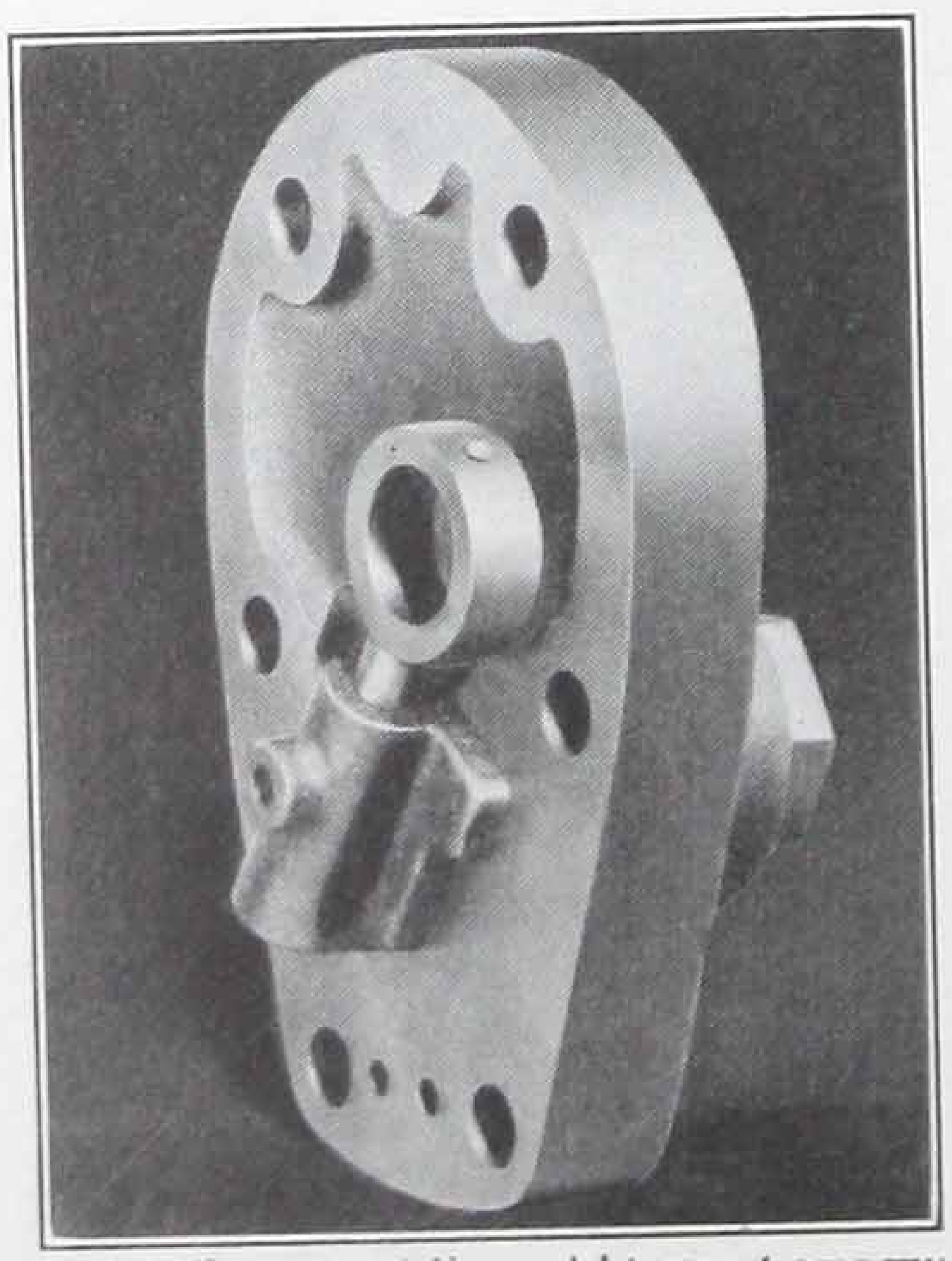
Irrespective of the type of compressor, the condenser performs the same function in a refrigerating system in that it brings the gaseous compressed refrigerant to a liquid state. This requires cooling of the condenser surfaces, which is accomplished by natural or forced circulation of room air in the electric household unit, or by cooling water in some types of commercial installations.

The condenser is a form of heat exchanger just as is the evaporator. In the former, however, heat is taken away from the refrigerant, whereas in the evaporator this action is reversed; the refrigerant serving to take up heat.

After passage through the condenser, the refrigerant is, therefore, ready to do work and perform its intended function in absorbing heat from the air in the cabinet and from the water in the ice trays to make ice cubes.

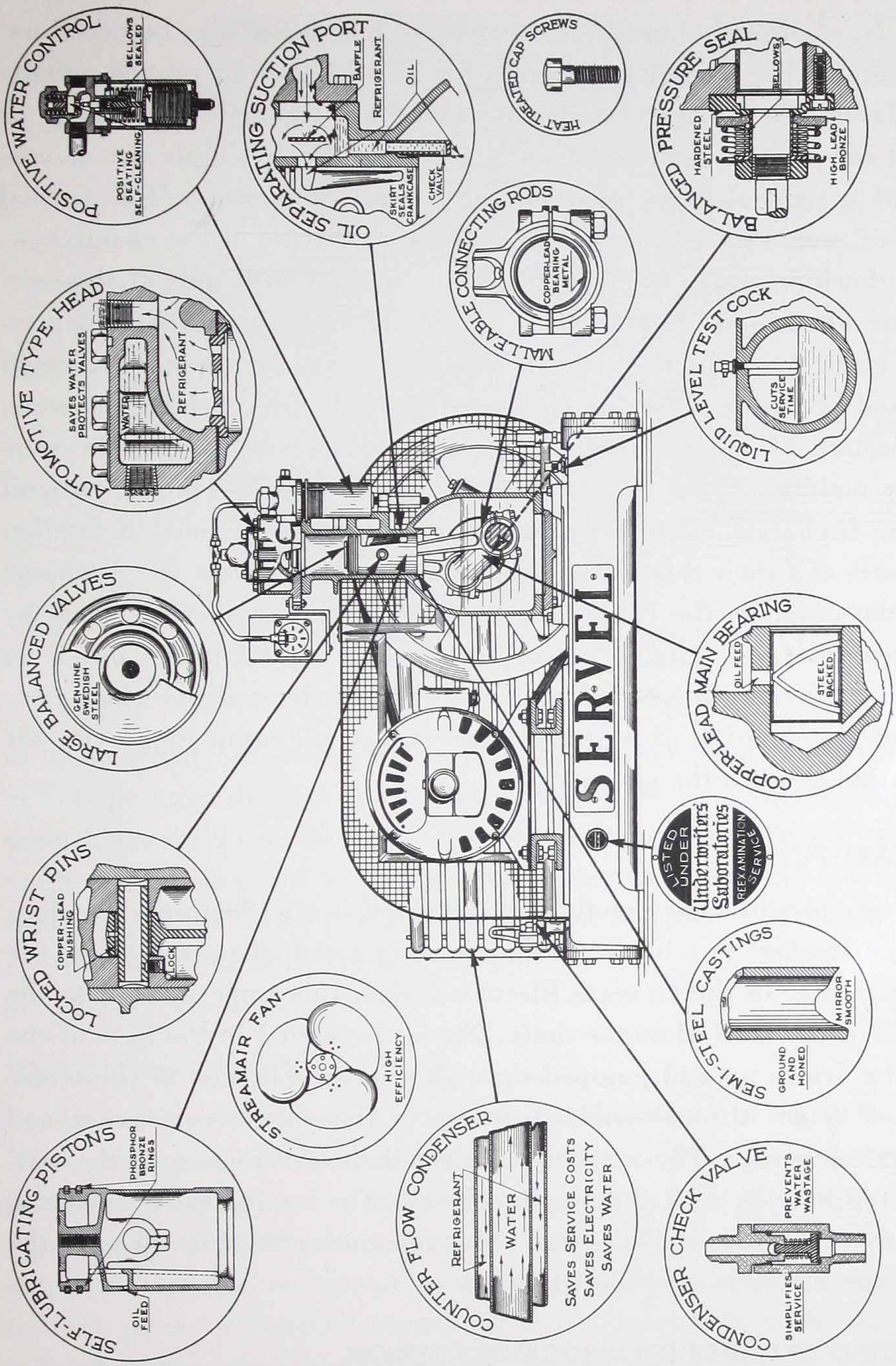
SYSTEMS OF LUBRICATION

There has been much consideration given to methods of lubrication in the development of the unit refrigerating compressor. With automotive experience as a background and the comparatively successful results obtainable from splash lubrication, as it was used when the electric refrigeration industry first came into prominence, it was logical that this means of lubrication should be favored. It has proved its dependability and economy and still is preferred by many builders. More recently, however, there has been extensive research into the adaptability of pressure, either alone or together with splash, the purpose being to obtain positive circulation of oil throughout the compressor and to eliminate foaming as far as possible. Obviously, in a splash lubricated reciprocating compressor, foaming will always be present. The extent to which it may be objectionable will depend



Courtesy of General Electric Company

The oil pump for the General Electric type CM condensing unit. This device is an oscillating cylinder type of reciprocating pump operating from an eccentric on the end of the crankshaft.



Courtesy of Servel, Inc.

The Servel electric refrigeration condensing unit with essential parts shown in detail. Inasmuch as all refrigerating machines using methyl chloride, Freon or other similar refrigerants circulate some oil with the refrigerant, provision is made for returning this to the crank-case through special check valves connected to the suction port.

upon the oil level and the location of the suction valves. Inasmuch as the unit type of compressor takes its suction through the crankcase, if the foam level rises to a sufficient degree foam may be carried over to the high side with the refrigerant to cause serious retardation of heat transfer.

Ultimately, if allowed to continue, cleaning of the system may be necessary.

The automotive type of gear pump for oil distribution proved equally adaptable to the refrigerating compressor. The typical gear pump as designed for positive delivery of oil is a comparatively simple device consisting of a pair of gears mounted in a suitable housing. The normal location of such a pump is in the base of the crankcase of the compressor. Some authorities prefer to place this pump at the lowest part of the case. Others are of the opinion that the pump should be set just above a depression or catch basin in the case to provide means for trapping foreign matter and preventing it being circulated through the lubricating system.

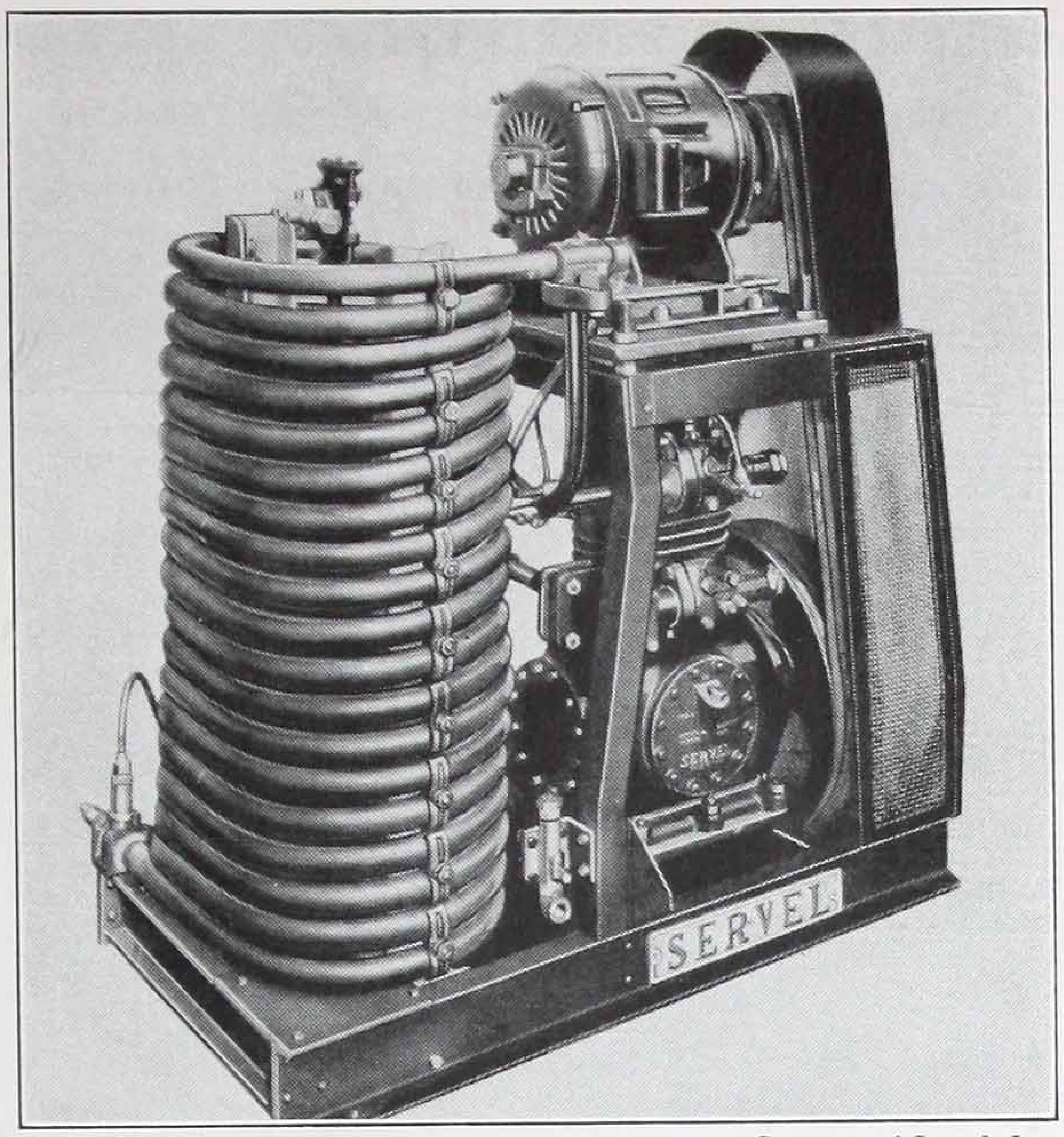
Irrespective of the location of the pump, however, suction is automatically maintained by gravity since the pump is below the normal oil level. The discharged oil, under pressure, according to the speed of rotation of the gears and their relative tooth dimensions, is led from the discharge side of the pump to the connecting rod bearings and other elements by drilled passages and suitable piping connections. As oil passes out from the bearing clearance spaces or drips from the cylinder walls or other parts of the interior housing, it returns to the case or oil sump by gravity for recirculation through the system.

THE ROTARY PUMP

The principles of rotary motion are involved in the floating blade type of rotary oil pump. Two blades free to move in a slotted rotor serve as the pumping media. In the General Electric design, this rotor is fixed to the lower end of the vertical motor shaft. The oil is carried in the base of the unit, being drawn up and pumped through a passage drilled in the motor shaft, and thence through other passages to the yoke arrangement and lower shaft bearings. The majority of the oil, however, goes to the self-aligning top bearing and to the cylinder wall. On leaving these elements, part of this oil returns to the base, the remainder flowing through the stator of the motor to cool the windings.

OSCILLATING CYLINDER RECIPROCATING DESIGN

Most recent studies in connection with commercial refrigerating units, have been directed towards the adaptability of the oscillating cylinder type of reciprocating pump. This is of single cylinder design, operated from an eccentric on the end of the crankshaft. The entire assembly is located so



Courtesy of Servel, Inc.

Exterior view of the Servel Model WAG-1000 Condensing Unit.

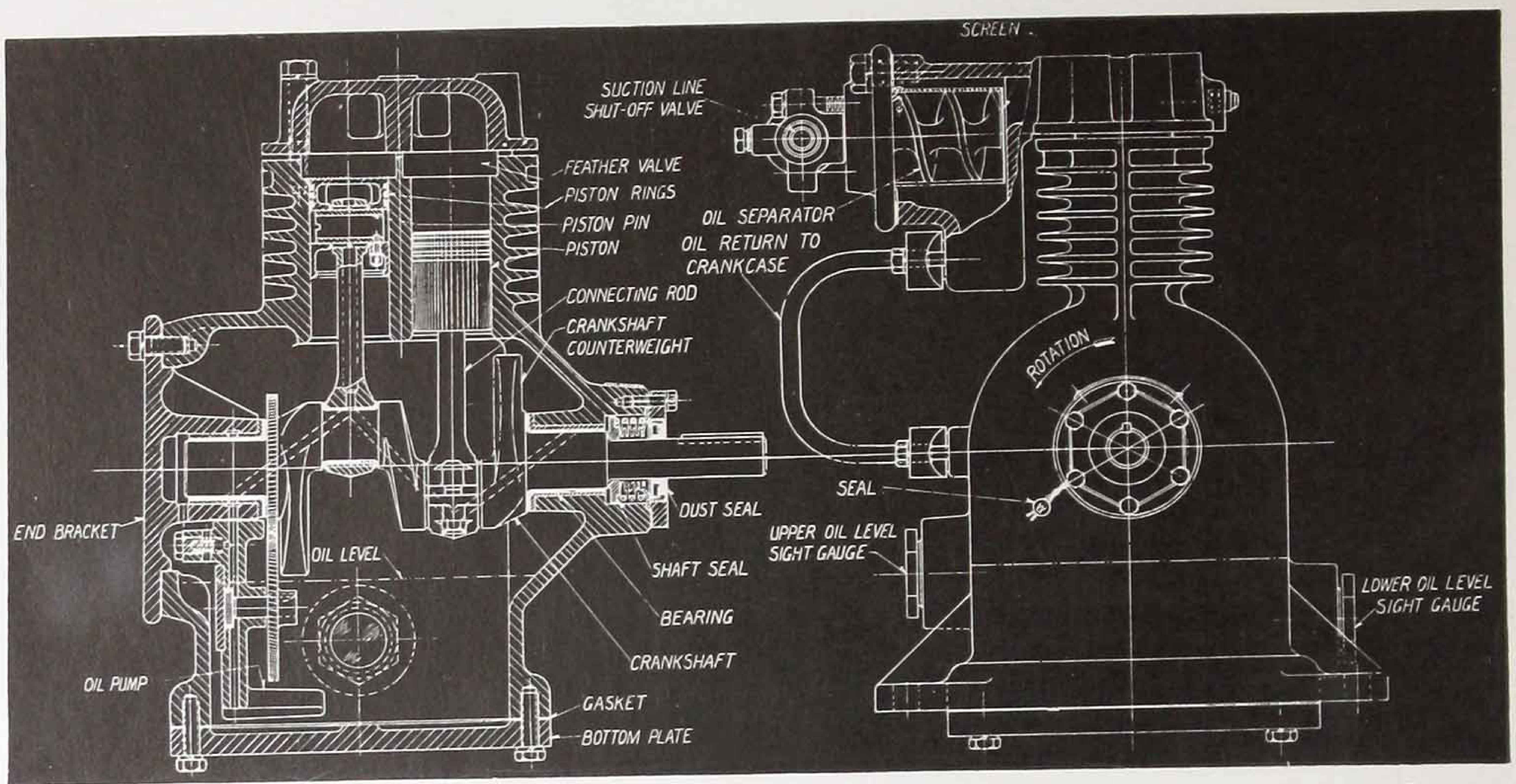
as to be readily accessible for inspection without removal of other parts.

This pump is designed to supply oil under pressure directly to the two main bearings. From here, oil is passed through holes in the crankshaft to the connecting rod bearings, center bearing and shaft seal. Through tubes, a part of this oil is also pumped to the piston pin bearings. The cylinder walls, however, in any machine equipped with this type of pump are splash lubricated.

LUBRICATION PRACTICE

The owner of the electric refrigerating compressor is normally relieved of the responsibility of lubrication; instead, this is taken over by the builders. In other words, all machines as they leave the manufacturer's plant are lubricated with an adequate charge of oil, which, barring unforseen development, is capable of maintaining lubrication for a period of several years or longer, according to the operating conditions. When re-lubrication is necessary, it is customary for this to become a part of the service procedure. Uniformity in lubrication is thereby assured and the possibility of use of an unsuitable oil by any machine owner is entirely eliminated. Texaco Capella oils have been specially designed for this type of service where the most carefully refined lubricants are desirable.

It has been essential for the builders to follow such a procedure due to the properties of the various chemicals used for refrigeration, as already described. Another factor which imposes a comparatively severe require-



Courtesy of Westinghouse Electric and Manufacturing Company

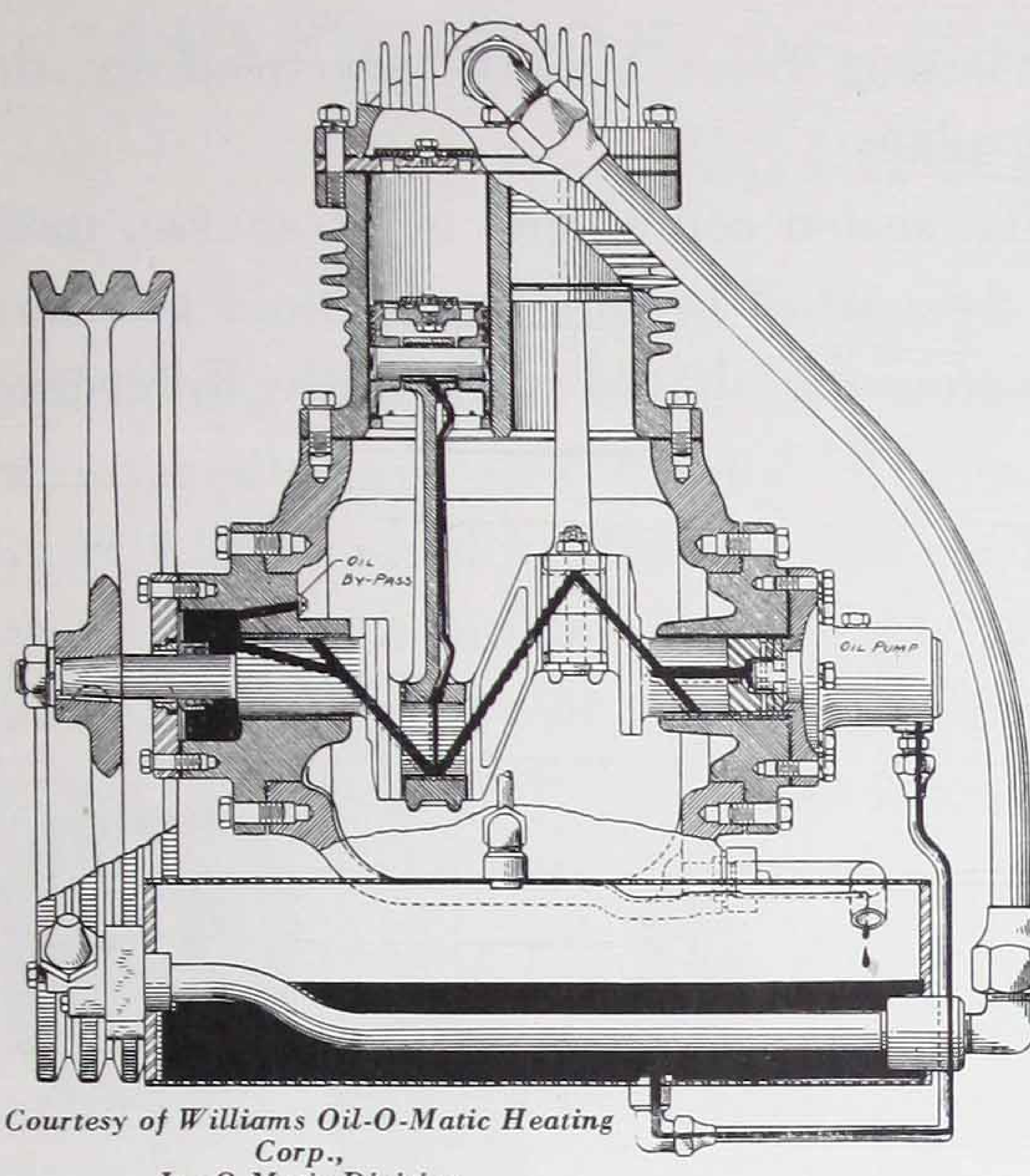
Detailed view of a Westinghouse compressor, showing oil level in the crankcase and means of circulation. Note in particular the location of the oil separator and oil return to the crankcase.

ment upon any oil used for electric refrigeration service is that, in addition to lubricating the compressor and motor bearings, it must also serve as a cooling medium for the stator windings in some types of machines.

HANDLING OF LUBRICANTS

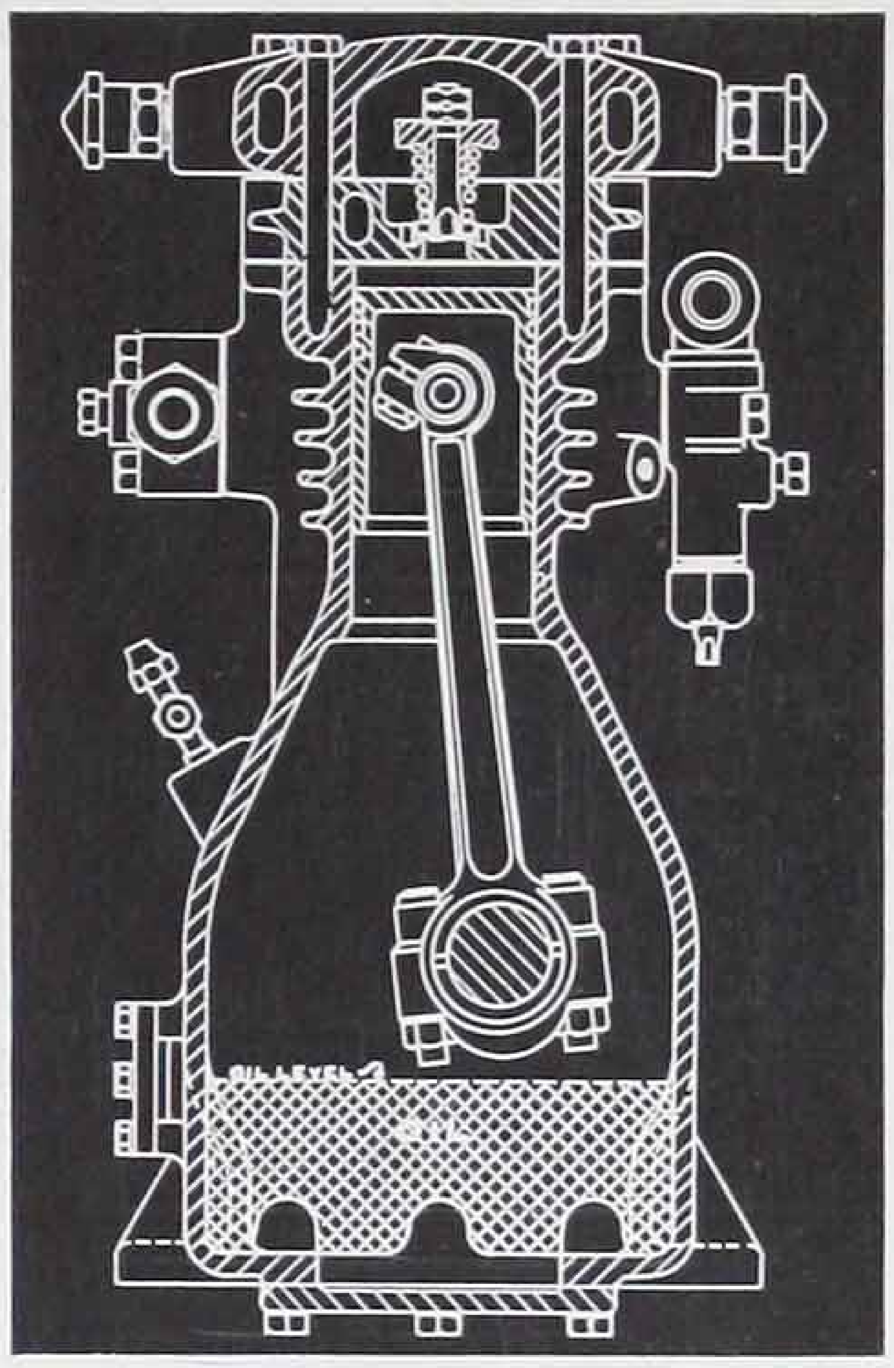
The methods employed in handling lubricating oils for condensing units should always be given careful consideration. It is essential at all times that every precaution be taken to keep the oil virtually free from water, and the system free from air. In the original assembly, drying and lubrication procedure at the manufacturer's plant, the utmost care is observed in this regard. In servicing, especially where re-lubrication is necessary, it is not always practicable to furnish the service engineer with plant facilities. Hence the practice among many builders of bringing units into a headquarters' service plant or even to their main plant for overhaul.

Where field service must be carried out, Texaco Capella oils should preferably be handled in one gallon sealed cans, obtained directly from the refinery. This will assure of the necessary dielectric strength which is an indication of freedom from water; it will also assure that the oils have not been exposed to sunlight, air or foreign non-lubricating impurities, as



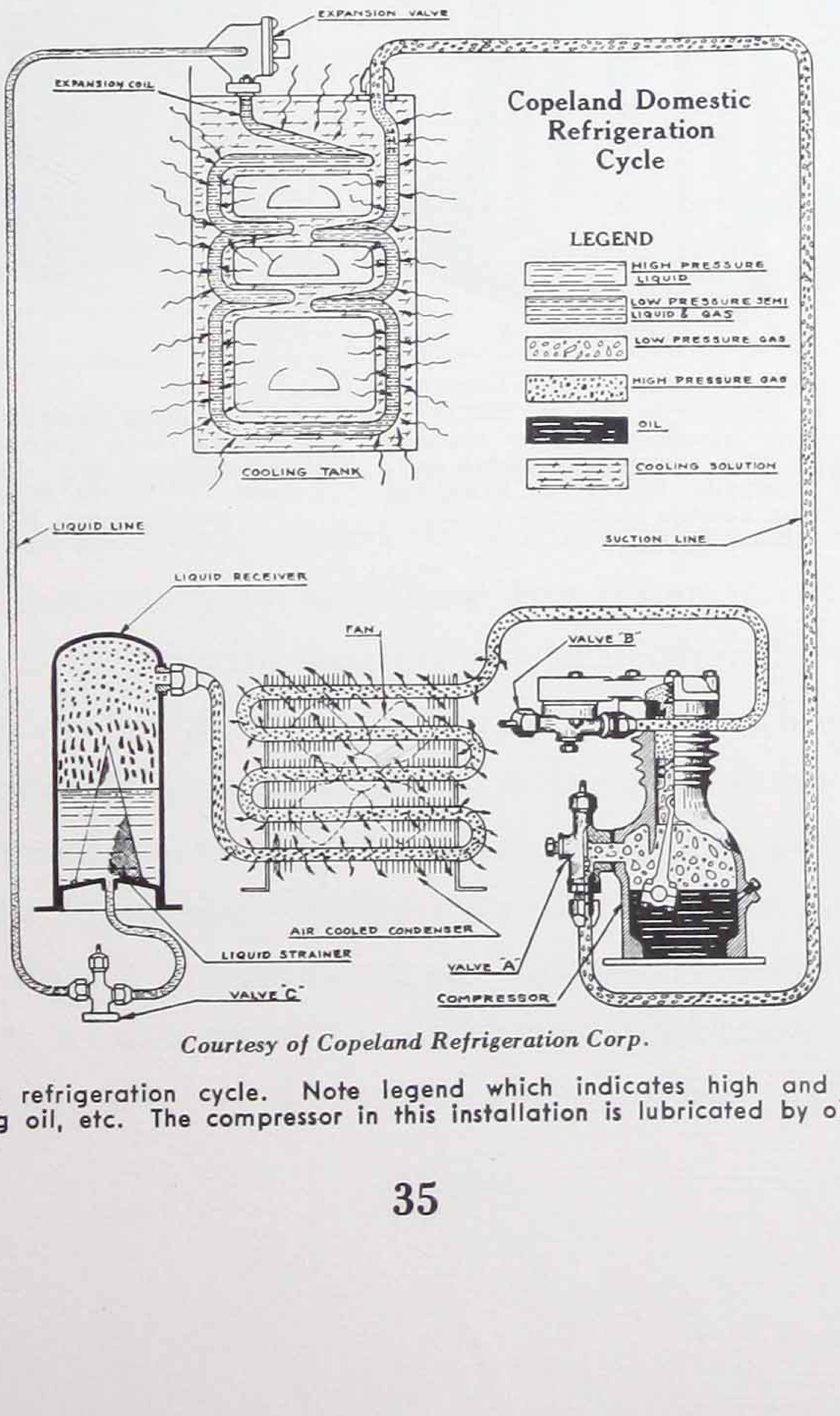
Courtesy of Williams Oil-O-Matic Heating Corp., Ice-O-Matic Division

The compressor body of a Williams Ice-O-Matic refrigerating unit, showing the pressure lubrication system. The oil pump is of the rotary gear type and is driven from the crankshaft. Note that the oil supply is removed from the crankcase to an auxiliary oil tank, thereby giving a "dry" crankcase. Oil in the system is indicated by heavy black.



Courtesy of Universal Cooler Corporation

Sectional view of a Universal Cooler condensing unit, showing relative location of essential parts and the oil level in the base of the compressor. All refrigerant gases and vapor are excluded from the crankcase which holds only the lubricating oil and the oil mist from crank splash.

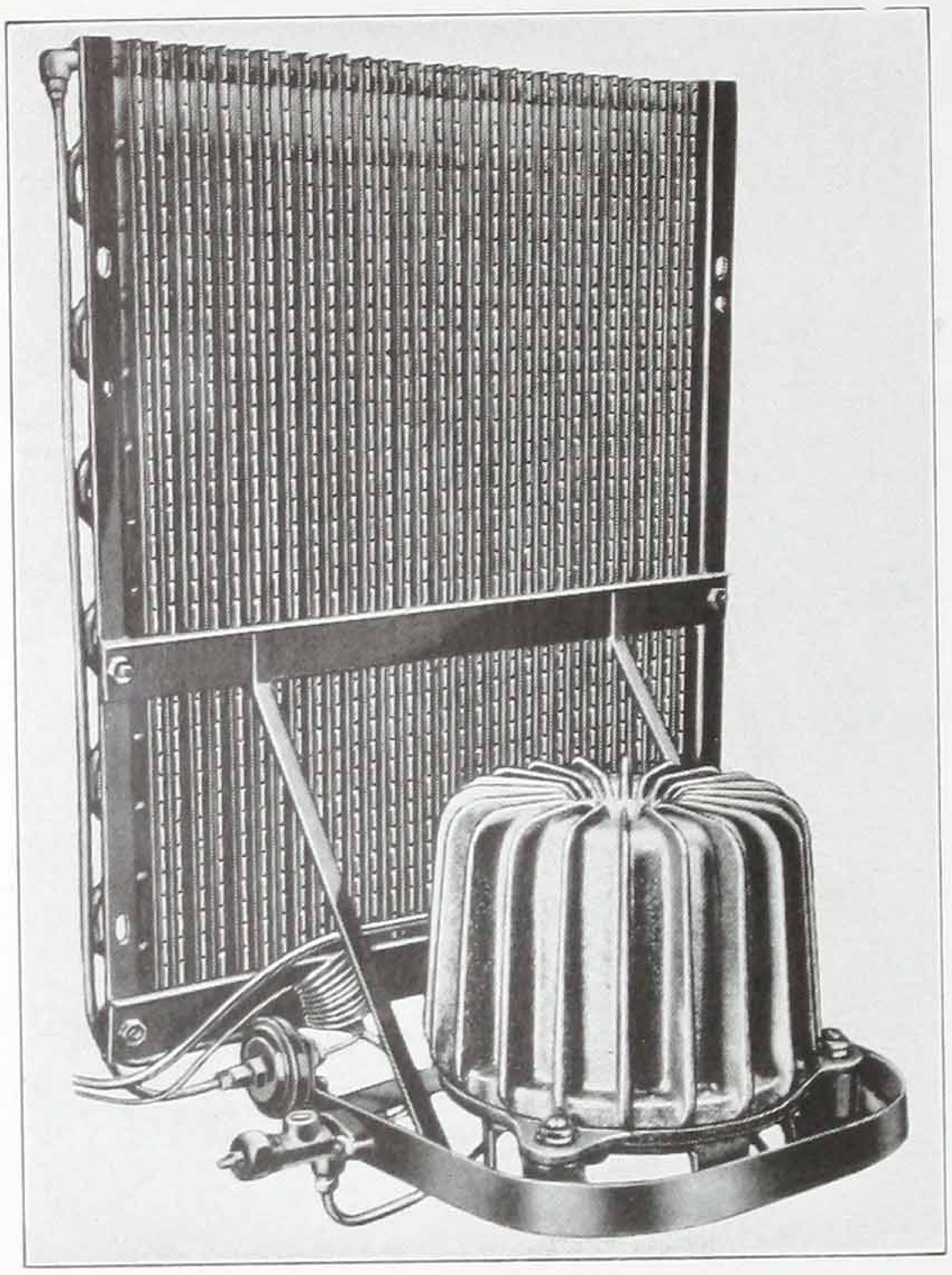


Courtesy of Copeland Refrigeration Corp.

The Copeland domestic refrigeration cycle. Note legend which indicates high and low pressure gas, the lubricating oil, etc. The compressor in this installation is lubricated by oil splash.

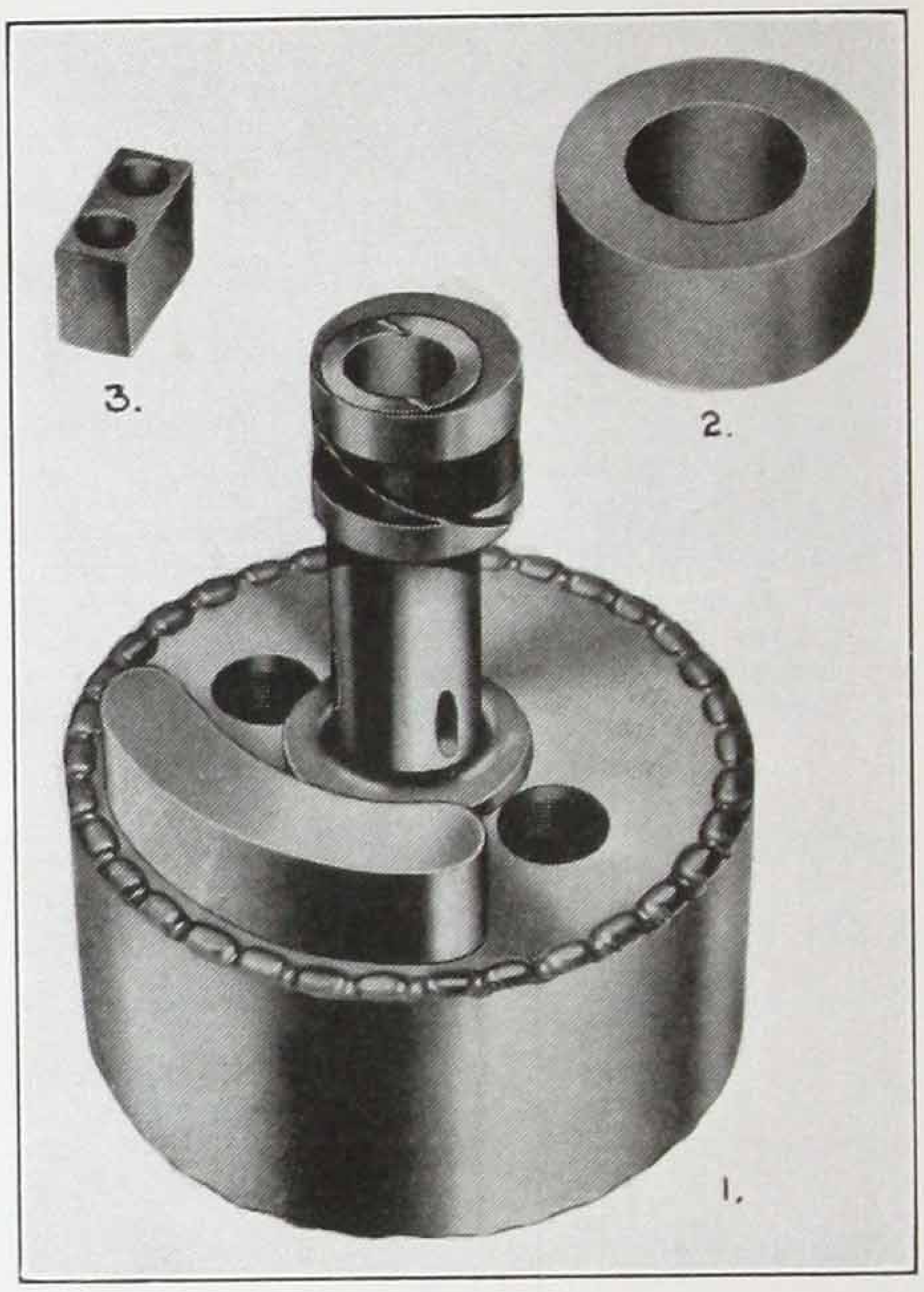
might occur so readily if re-packaging from bulk is practiced by the machine manufacturer in his own plant.

Purchase of oil in small capacity, sealed containers, is, of course, more costly but when balanced against the cost of re-handling of bulk oils by a machine manufacturer, the ultimate costs should show little difference.



Courtesy of The Crosley Radio Corporation

Showing the Crosley rotary compressor. This machine possesses all the advantages of a hermetically sealed unit; the rotor with the eccentric impeller and blade being the only moving parts. These operate constantly in a bath of lubricating oil.



Courtesy of The Crosley Radio Corporation

Showing the three working elements of the Crosley rotary compressor. "1" indicates the eccentric or rotor shaft, "2" is the impeller and "3" is the blade which separates the high pressure from the low pressure side within the unit.

LUBRICATION OF AIR CONDITIONING EQUIPMENT

Study of the lubrication of refrigeration machinery as applied to air conditioning operations has been actively extended over recent years with the markedly increased popularity of comfort cooling. It has been particularly accelerated by the necessity for lubricating oils employed in compressor service to function dependably over extended periods of time, and under a wide variety of operating conditions. The function of the compressor is especially important, as it must recover the refrigerant or cooling agent after the latter has been evaporated in the cooling side of the system, and then bring it into such a form as to render it again capable of cooling. This cycle must be continuous and positive.

Advances in the study of compressor design, in turn, have led to the adoption of two distinct types of compressors, viz.:

1. The reciprocating machine, either single or double acting, of one or more cylinders, according to the size of the job and the amount of refrigeration required, and

2. The centrifugal compressor. This latter is unique by reason of the constant pressures available, and the comparative simplicity of its lubricating system.

An air conditioning compression system will include a compressor, an oil trap, condenser, expansion valve and evaporating element. In air conditioning operation as already stated the compressor may be of either the centrifugal or reciprocating type. Where the latter is involved the principles of single or double acting operation will prevail. In the compression process, the refrigerant or cooling agent is recovered after each expansion by means of mechanical compression. To bring this about the compressor performs three functions in that it serves first as a pump to withdraw gaseous refrigerant from the cooling unit through the suction line, and then to compress this to a comparatively high pressure prior to discharge into the condenser. At this point the discharge control serves to divide the low and high pressure sides of the system and maintain maximum efficiency of operation by preventing leakage of the compressed vapor back into the low pressure side of the system.

In the process of refrigeration, the gaseous refrigerant which has left the compressor must be cooled to convert it to liquid form. Under compression alone it will still remain as a gas due to the fact that the application of pressure raised the temperature above the liquefaction point.

From the discharge end of the machine the refrigerant is, therefore, passed to the cooling coils of the condenser where the temperature is lowered by means of air in some smaller types of air conditioning units, or by cold circulating water in larger installations, to convert this gas into liquid form. It is then capable of serving as a cooling medium. This is brought about by passing it through an expansion or regulating valve on the expansion side of the system. Here, by virtue of a drop in pressure, it evaporates and returns to its gaseous state. In so doing, it gives up its latent heat of vaporization and as a result is capable of absorbing heat. After suitable circulation through the heat transfer element and air conditioning unit, the refrigerant is then ready for return to the compressor for repetition of this cycle.

TYPES OF INSTALLATIONS

Air conditioning installations as they are being planned today may be broadly divided into two classifications, viz.:

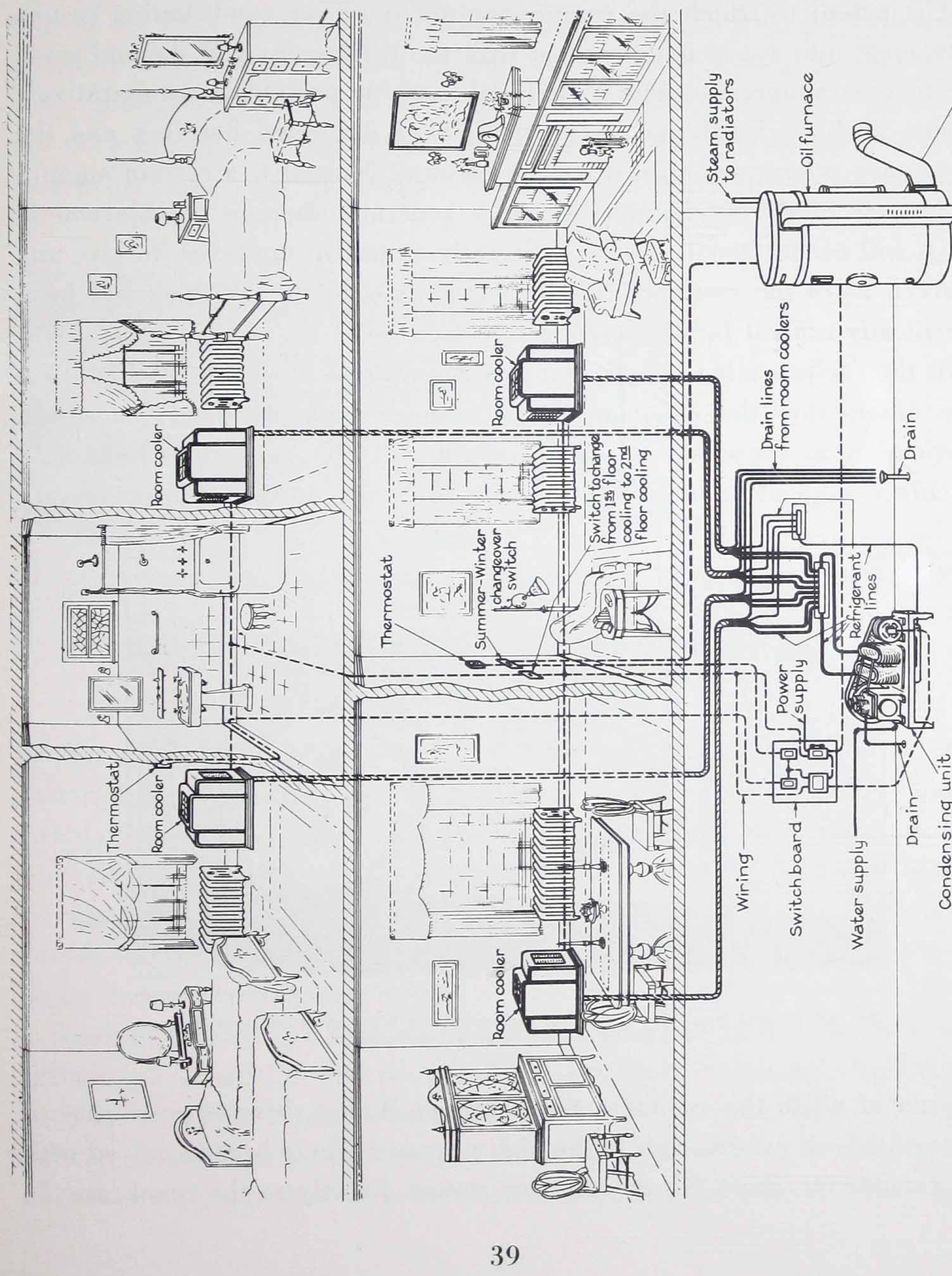
The Centralized, and

The Unit Type.

Centralized installations are normally designed to serve an extensive amount of space such as would be involved in theatres, restaurants, clubs, hospitals, office buildings and public halls. From one to an extensive number of rooms can be conditioned by such a system, dependent upon the feasibility of installing the necessary ducts for air circulation. The compactness of the compressor and other machinery renders location a very flexible matter, from a corner of the power plant or basement to any available space regardless of floor level.

Unit air conditioning, in turn, is generally applicable to homes, individual office rooms, dining cars and other railway equipment. Normally a unit installation involves a complete compressor and refrigerating system for each room or compartment to be served.

The centrifugal type of compressor has been widely adapted to central station applications along with the more conventional type of multi-cylinder reciprocating machine.



Courtesy of General Electric Company

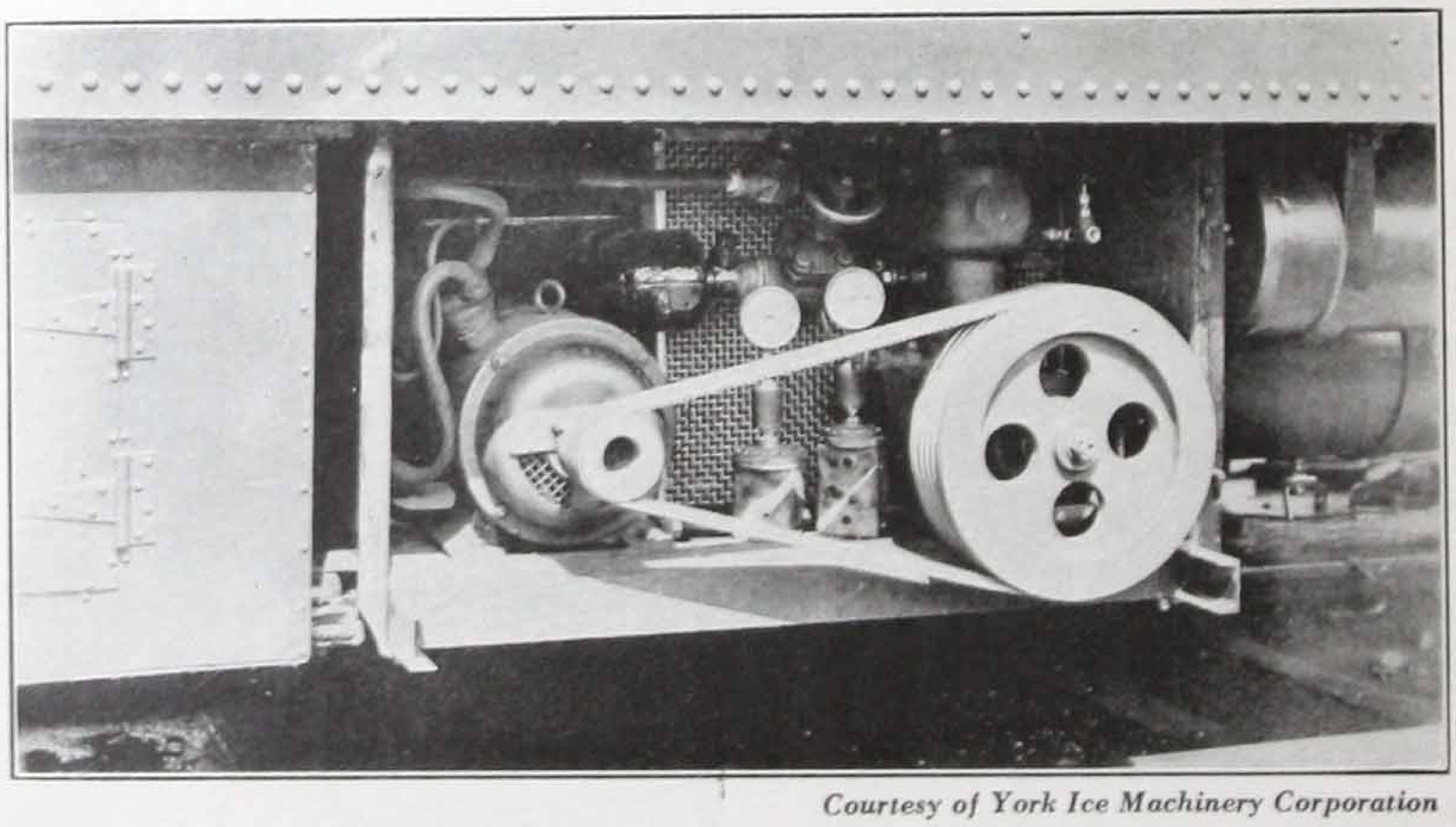
A General Electric air conditioning system for radiator equipped homes.

MISCIBILITY WITH LUBRICATING OILS

Certain refrigerants are completely miscible with petroleum lubricating oils. In air conditioning service, we are particularly concerned with Freon, carrene and methyl chloride, although there are a considerable number of other refrigerants of chlorinated hydrocarbon nature, or the halo-fluoro derivatives of aliphatic hydrocarbons which must also be considered in a study of this nature.

The extent to which the compressor oil in an air conditioning system may come into appreciable contact with the refrigerant will depend upon the type of compressor. The centrifugal machine presents a comparatively simple problem involving the lubrication of ring-oiled bearings and the maintenance of a seal against loss of vacuum. Normally, a certain amount of leakage of the refrigerant, which is generally carrene (dichloromethane), will occur; it will not be sufficiently extensive, however, to give any concern as to the resultant lubricating ability of an oil which has been specifically refined for this class of service.

In the reciprocating installation the question of the method of lubrication enters into the problem. Small tonnage units designed for splash lubrication, as are so many of the vertical unit type railway or household machines, depend upon oil thrown from the crank to splash the necessary

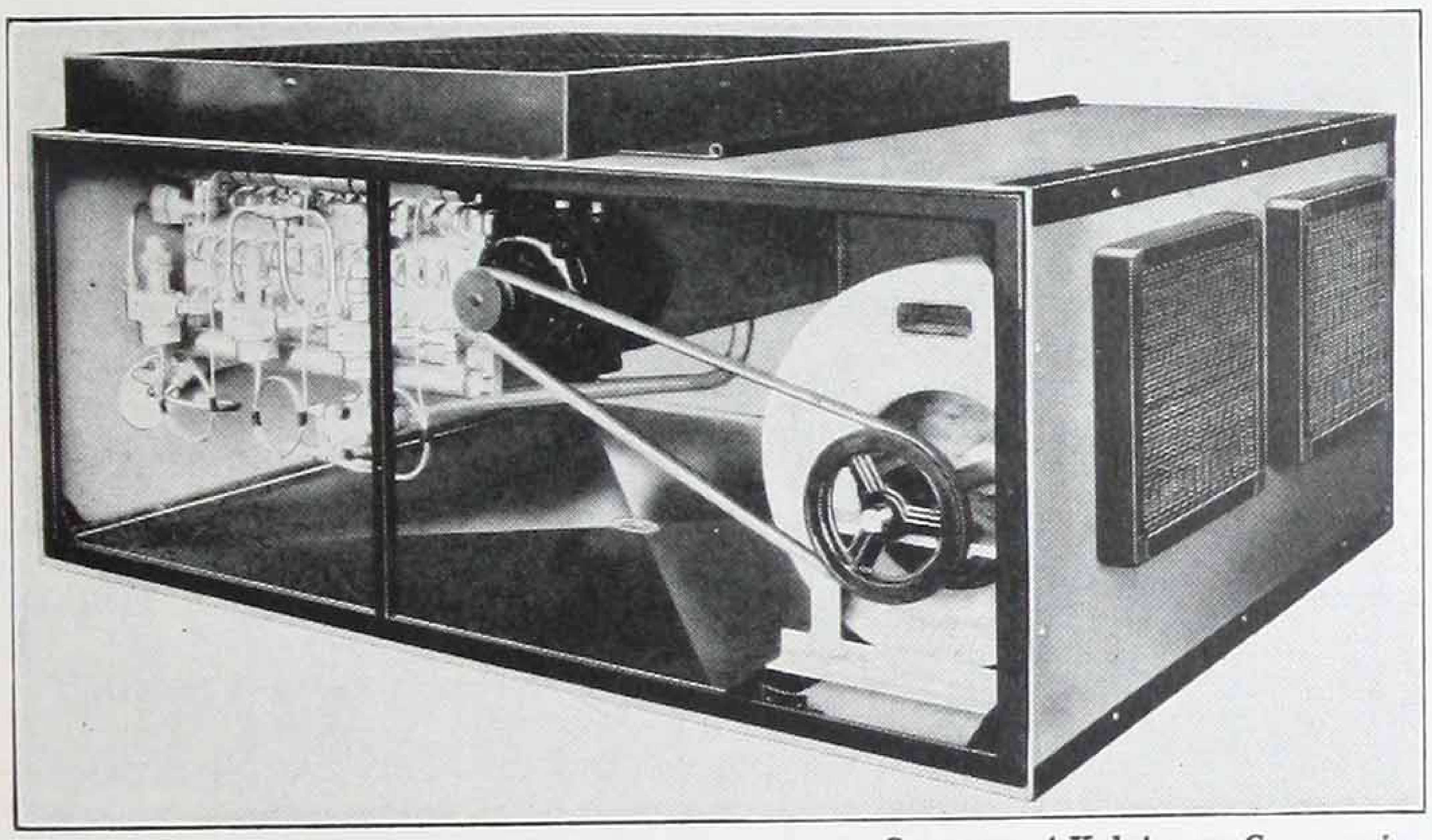


Courtesy of York Ice Machinery Corporation

The York railroad type Freon compressor and motor with V-belt drive and special mounting for installation under a passenger car.

amount of oil to the cylinders and bearings. Where there is possibility of some of this oil passing over to the high pressure side to become mixed with the refrigerant, there is provision for return directly to the crankcase. In such machines an oil level regulating device is, therefore, frequently installed, although if care is observed not to charge the compressor with too much oil to begin with, oil level regulation may not be necessary; it is, therefore, not always used on the small unit type of machine. In other designs oil is returned to the condensing unit by the velocity of the refrigerant vapor in its course through the system.

The reciprocating compressor can also be built so that the refrigerant vapors are kept entirely apart from the crankcase. In such machines, the possibility of mixture with oil, at least at this point, is largely eliminated. This enables the oil to maintain its original viscosity, or merely to follow the normal reduction in viscosity which would take place as the crankcase comes up to average operating temperature. This condition will prevail

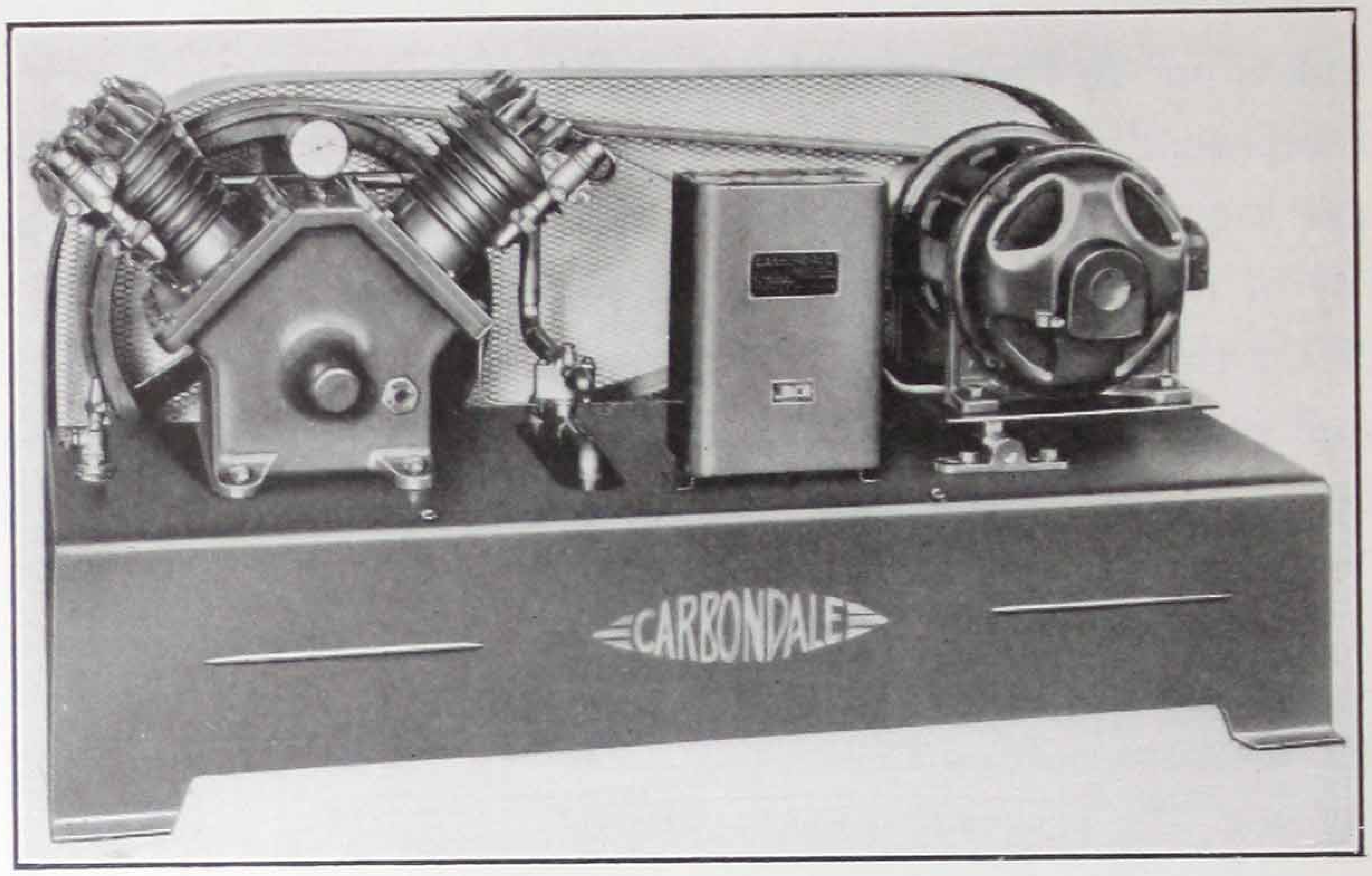


A Kelvinator air conditioning unit of the suspended type with side panel removed to show the interior.

Courtesy of Kelvinator Corporation

in the enclosed crankcase machine equipped with trunk-type pistons and designed for pressure lubrication. The oil pump maintains positive circulation of oil without excessive splash effect, therefore, foaming is markedly decreased. Reduction of oil splash in turn reduces the tendency of any refrigerant present to mix with the oil supply, especially as there is no circulation of refrigerant vapors within the crankcase. Location of the oil pump in such a machine must, of course, be carefully studied. Some authorities recommend that it be at the lowest point in the case to insure against loss of suction and the resultant reduction in volume of oil circulated which might readily lead to impaired lubrication; others feel that a settling chamber below the pump is an advantage.

The cross head type of vertical compressor, as well as the horizontal double-seal stuffing box machine, are also adaptable to large tonnage central station air conditioning service. In these units, the refrigerant vapors are also kept out of the base or crankcase of the machine; instead they are returned directly to the cylinder block. As a result, there is no possibility



Courtesy of Worthington Pump and Machinery Corp., Carbondale Division

Showing the Carbondale CBW unit designed for air conditioning service, to function with either methyl chloride or Freon. This unit is splash lubricated and can be built up to 25 H.P. capacity.

of the oil in the case becoming mixed with refrigerant, so here again foaming, especially with Freon, is eliminated along with reduction in viscosity. Since lubrication of the crankcase elements or external parts is maintained entirely independent from the cylinders, it is customary to provide for injection of a certain amount of oil into the refrigerant return line or directly to the cylinder and stuffing boxes to take care of piston and valve lubrication and protection of the cylinder walls against scoring.

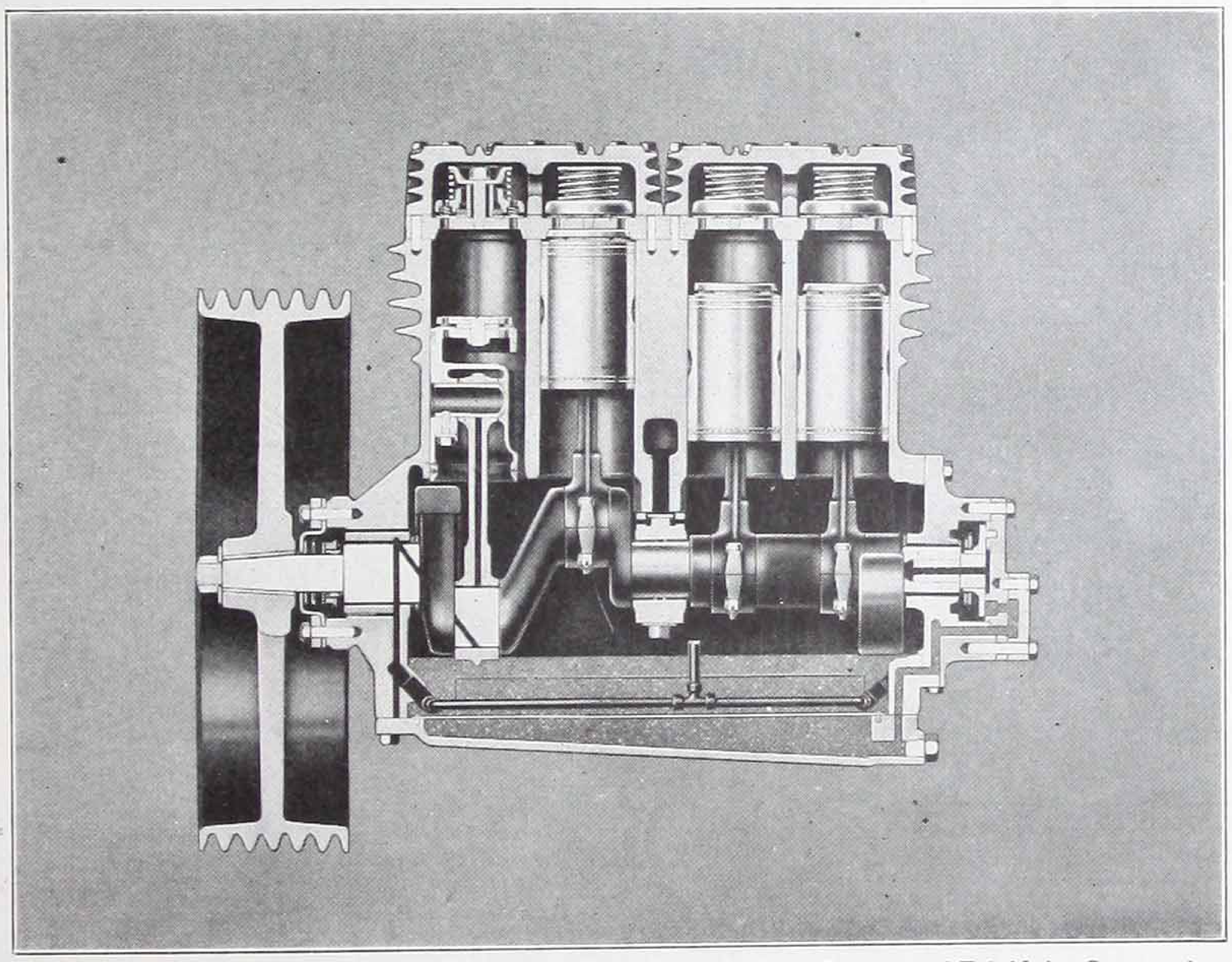
FACTORS GOVERNING ABSORPTION OF FREON BY LUBRICATING OIL

Apart from mechanical and constructional conditions, the amount of Freon which may be absorbed by any mineral oil will be dependent upon the viscosity of the oil at the temperature of contact and pour test of this oil; pressure also becomes a factor. In other words, larger amounts of Freon are absorbed by mineral oils at higher pressures and lower temperatures, just as smaller amounts of this refrigerant will be absorbed at lower pressures and higher temperatures. In addition, lower viscosity oils absorb less Freon for a given weight than will lubricants of higher viscosity.

LUBRICATING OIL REQUIREMENTS

VISCOSITY RANGE

This matter of mixture of petroleum lubricating oil with refrigerants of halogen combinations must of course influence the original selection of such lubricants from the viewpoint of viscosity. In other words, when dealing with lubrication of a compressor charged with Freon or methyl chloride, an oil of somewhat higher original viscosity must be used than would be necessary were the refrigerant to be non-miscible with such an oil. Theoretically, a wide range of operating and constructional conditions exist which should be given careful consideration. Unfortunately, however, these may occur in such a variety of combinations as to render it necessary to adopt a broad grouping of oil characteristics contingent upon the most influential factors such as speed, intake and discharge temperatures, means of cooling and the method of application of the lubricant.

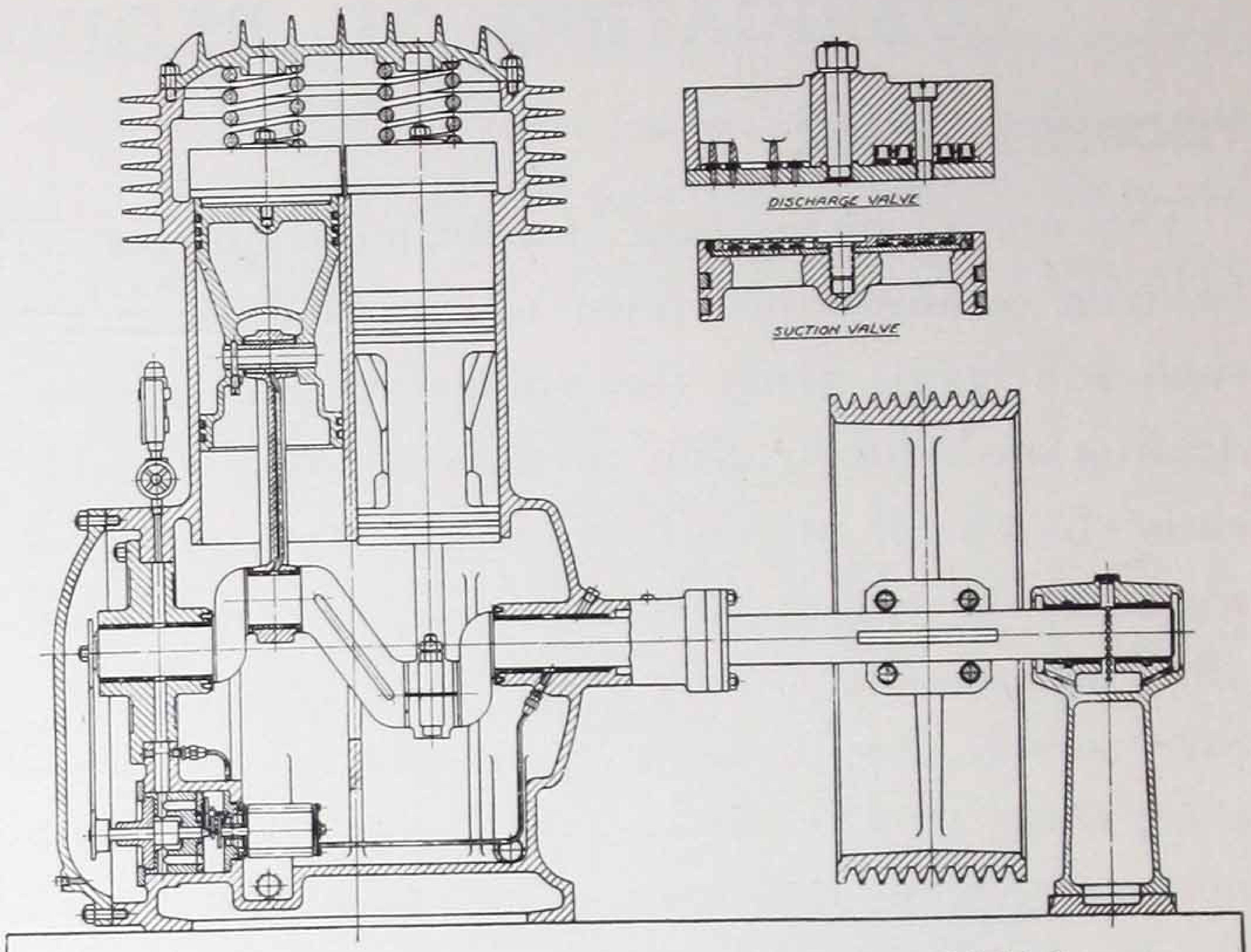


Courtesy of Frigidaire Corporation

Showing a cut-away view of the Frigidaire 4 cylinder air conditioning compressor. All parts of this machine are designed for very accurate precision and lubrication is entirely automatic.

For example, in a small capacity, enclosed type, slow speed machine operating from an evaporator temperature around zero degrees Fahrenheit, an oil of from 150 to 300 seconds Saybolt viscosity at 100 degrees Fahrenheit, such as Texaco Capella oil B, C, or D, will be advisable, the

Sectional view of the Frick type FR enclosed Freon Compressor. A unique feature of this machine is the force feed oil pump located in the base of the crankcase and operated by a chain connection from the main shaft. Internal piping carries oil to the main bearings and other elements, the oil flowing therefrom back to the case by gravity.



Courtesy of Frick Company

higher viscosity range being approached in accordance with positive information as to the normal content of refrigerant. Some interesting test data have been developed to indicate that this will be from 10 to 12 percent in average service.

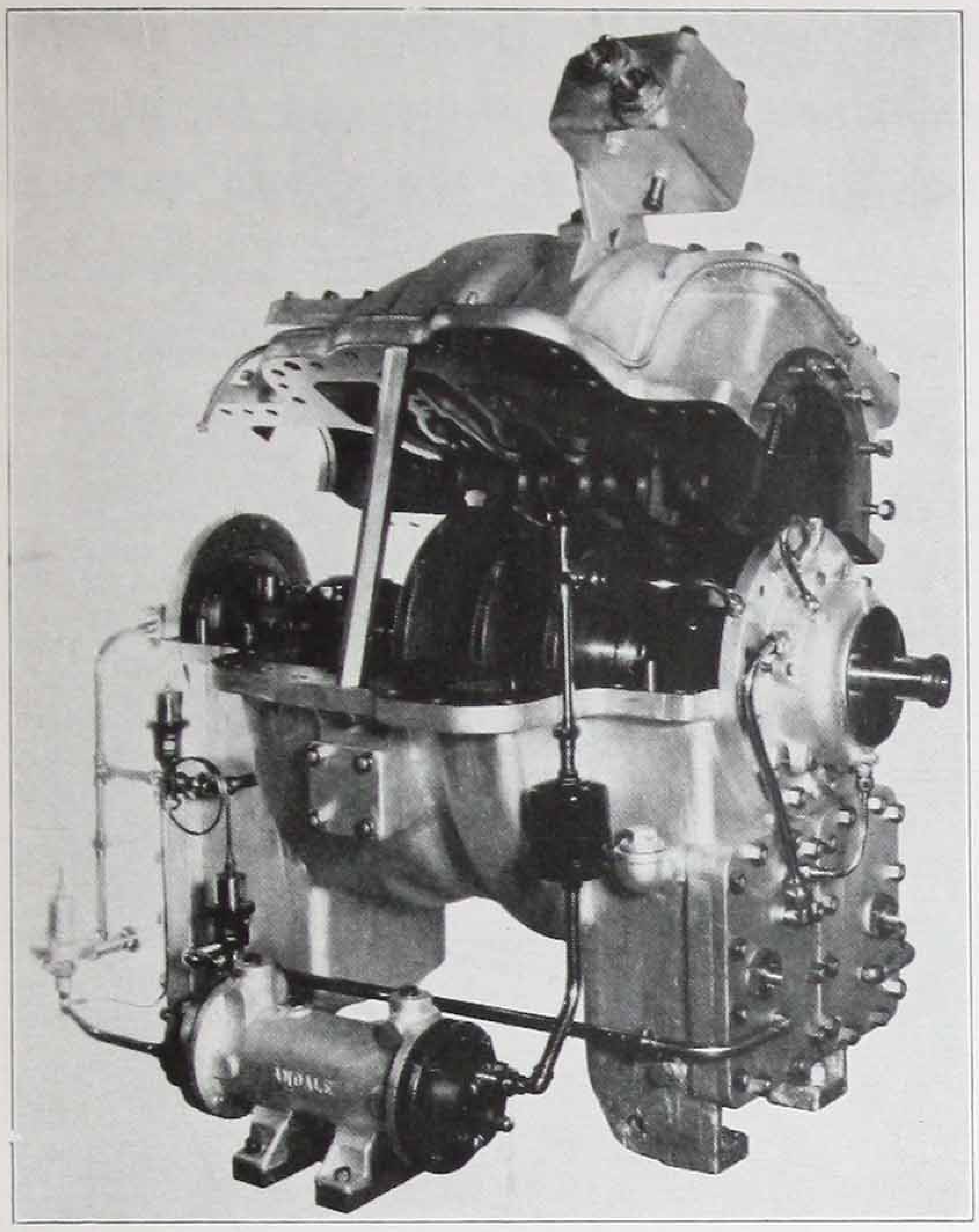
As one approaches higher speed, load or tonnage conditions, however, such as might prevail in the central station installation or on the relatively high speed railway compressor, an increase in viscosity is deemed advisable, with proportionately less stress being attached to the pour test of the oil due to the higher operating temperature range. In such installations the oil viscosity may have to range from 300 to 500 seconds Saybolt at 100 degrees Fahr., according to type and capacity of the compressor. Texaco Capella oils D and E meet these requirements.

VAPORIZATION

While the average air conditioning compressor will function at maximum temperatures considerably below 200 degrees Fahr., there will be times when an installation of the booster type may approach 250 degrees Fahr., on the discharge side. For this reason the relative vaporizing tendency of petroleum lubricating oil must be given consideration.

CORROSION AND RESISTANCE TO BREAKDOWN

The tendency which any petroleum lubricating oil will have to bring about the above reactions will be more or less a measure of the method of refinement. In the interest of reducing the corrosion tendency it is espe-



Courtesy of Carrier Engineering Corporation

Open view of a Carrier centrifugal refrigerating compressor showing the design of the interior and essential piping.

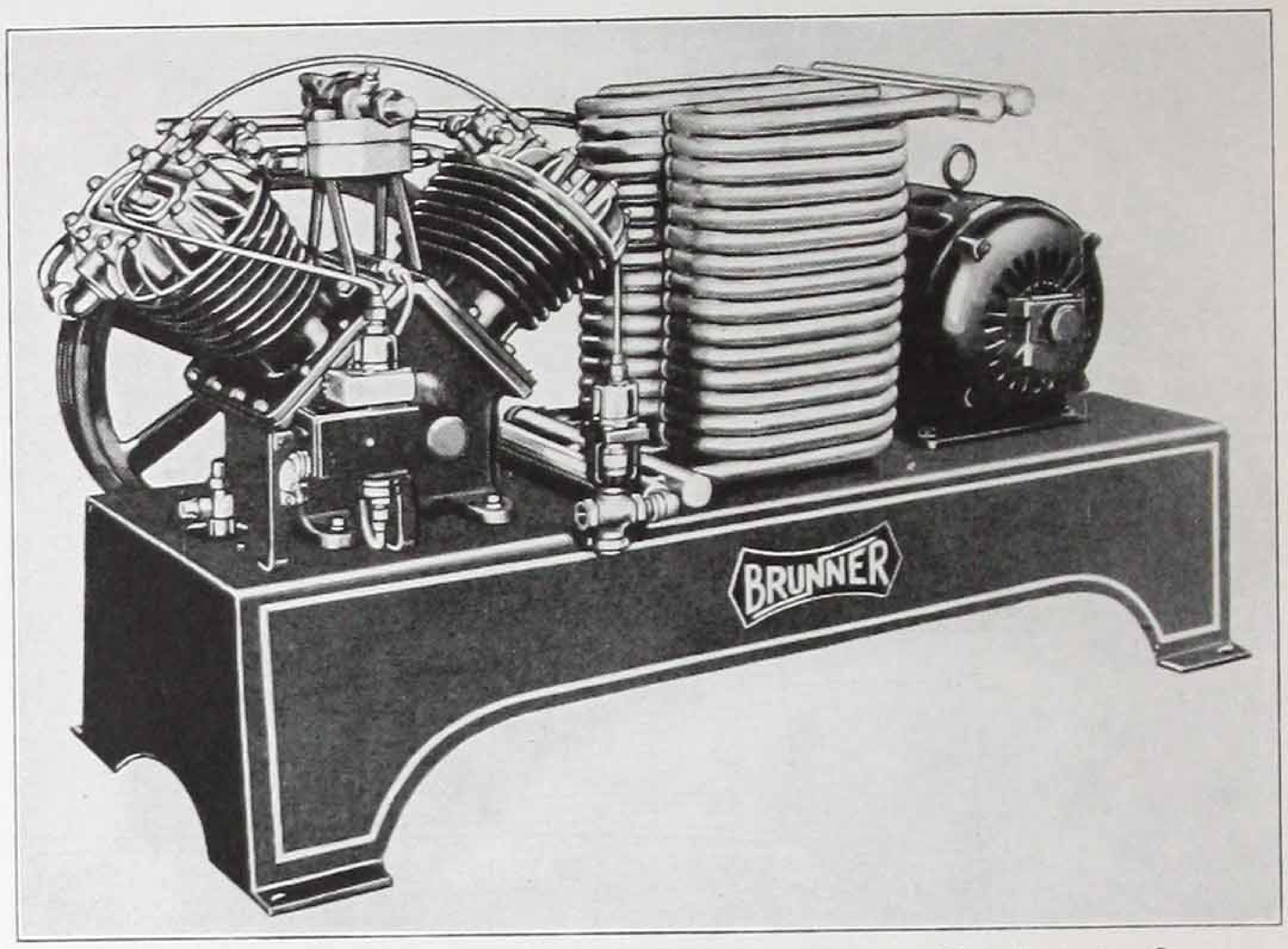
cially essential that the water content be practically nil; this is also necessary to prevent freezing at the regulating valve and possible restriction of flow of refrigerant. Water would also freeze in the cooling coils, to reduce evaporative efficiency. A dehydrated oil is also advisable to prevent possible chemical dissociation of Freon, which might lead to serious damage to the machine parts through acid formation.

The results which may accrue from chemical breakdown of the oil itself will be very disturbing in the average air conditioning installation regardless of the type of refrigerant used, for it will lead to gum formation and actual stopping of the unit. Resistance to breakdown is determined by the petroleum chemist in terms of resistance to oxidation. A variety of interesting tests have been developed to enable accurate prediction of this tendency and to guide him in development of refinery methods which will effectively remove those hydrocarbon constituents which may be unstable and thereby most readily susceptible to chemical dissociation. It is this latter which is regarded as being the basic cause of gum formation, and deposition of residual matter around piston rings, or in bearing oil grooves. Its formation is materially accelerated by heat in the presence of more or less moisture, or by the solvent action of certain types of chemicals.

PHYSICAL EFFECTS OF TEMPERATURE

The effect of cold upon petroleum lubricating oils is not the same as upon simple fluids such as water, alcohol, glycerine, etc. Such products have fixed and accurately ascertainable freezing points at which a complete change from the liquid to the solid phase takes place. Lubricating oils, however, which are complex mixtures of hydrocarbons of various melting points or freezing points, behave like solutions and frequently deposit some portion of their constituents before the whole mixture becomes solidified.

This fact must be thoroughly recognized when specifying and refining such oils for air conditioning compressor lubrication, in conjunction, of course, with the minimum operating temperatures to which any such oil may be subjected. Fortunately, in average air conditioning service, these temperatures will not be as low as in some types of refrigeration work. They will however, be sufficiently extreme to render the pour test one of the principal characteristics to be investigated in a study of lubricating oils for such service.



Courtesy of Brunner Manufacturing Company

Showing the Brunner Model W-500 unit, adaptable either for electric refrigeration or air conditioning service. When used for electric refrigeration, this unit normally operates on methyl chloride. Lubrication of all parts of the compressor is accomplished by splash.

The varied behavior of certain types of petroleum oils when subjected to low temperature conditions has led to exhaustive study of methods of test, to determine accurately when congealment begins and fluidity becomes retarded. Where we are concerned with lubrication of compressors applied to air conditioning installations this knowledge becomes of considerable value in the initial selection of lubricating oils which will possess adequate fluidity to enable ready handling by the conventional types of oil circulating systems, and maintain protective lubrication of the parts to be served. Obviously, the oil must also remain comparatively fluid at the lowest temperatures to which it may be subjected during operation. These temperatures will usually be encountered in the expansion or refrigerating side of the system after the refrigerant has passed the expansion valve. Should the refrigerant be carrying a high percentage of oil at this point, any tendency towards wax congealment might lead to faulty operation of this valve or insufficient heat transfer. The pour test is indicative of the extent to which this may be expected. In the terms of the American Society for Testing Materials—"the pour point of a petroleum oil is the lowest temperature at which the oil will pour or flow when it is chilled, without disturbance under definitely prescribed conditions."

The proviso in regard to disturbance is especially important. Extensive research has developed that any agitation or stirring of the oil while cooling in a pour test determination is contrary to good practice. When an oil is stirred it solidifies at a lower temperature than when held absolutely motionless. This is explained by the assumption that the movement of the oil destroys the formation of a fine network of microscopic particles of paraffinic bodies in the course of separation. This segregation is regarded as giving the oil a certain amount of support, to thereby facilitate solidification. The test procedure should, therefore, provide for absolutely motionless cooling during the time involved.

METHODS OF LUBRICATION

Splash, pressure or circulated lubrication by means of ring oilers, have proved the most adaptable methods of lubricating air conditioning compressors. Splash oiling is best adapted to the small tonnage, enclosed type, vertical reciprocating machine. Pressure lubrication in turn by means of an enclosed gear pump, and oscillating cylinder reciprocating pump, or an external force feed lubricator is applicable to the larger type vertical or horizontal unit; whereas the ring oiler in conjunction with force feed, for sealing purposes, has proved especially adaptable to the bearings of the typical centrifugal machine.

SPLASH OILING SYSTEMS

In a splash system, the oil is distributed at each revolution of the crank, the level in the crankcase being maintained just high enough to permit the crank to dip and splash the necessary amount of oil to the cylinder walls, etc. Continued operation will result in the crankcase being filled with a lubricating vapor above the main body of oil, which will also insure adequate lubrication of main, wrist pin and crank pin bearings.

When recharging the case with oil the level must never be raised too high. Otherwise, oil would be churned by the crank, bringing about such violent agitation as oftentimes to preclude effective precipitation of any impurities that may have gained entry. There would also be possibility of loss of lubricant past the piston with subsequent entry of an excess of oil into the condensing and evaporating parts of the system, or increase in the rate of mixture with the refrigerant.

This can be partly overcome by proper adjustment of the piston rings. Where the latter are not sufficiently tight, if the crankcase contains too much oil or agitation is too violent, the excess which naturally will reach the cylinder walls will tend to work past the rings. This is not only wasteful, but a detriment, for if the oil is not of sufficiently low pour test there will be a possibility also of its congealing within the system to act as an insulator and reduce refrigeration to a marked degree. The presence of oil in the system may also cause a higher condenser pressure by reason of the vapor pressure produced by the oil.

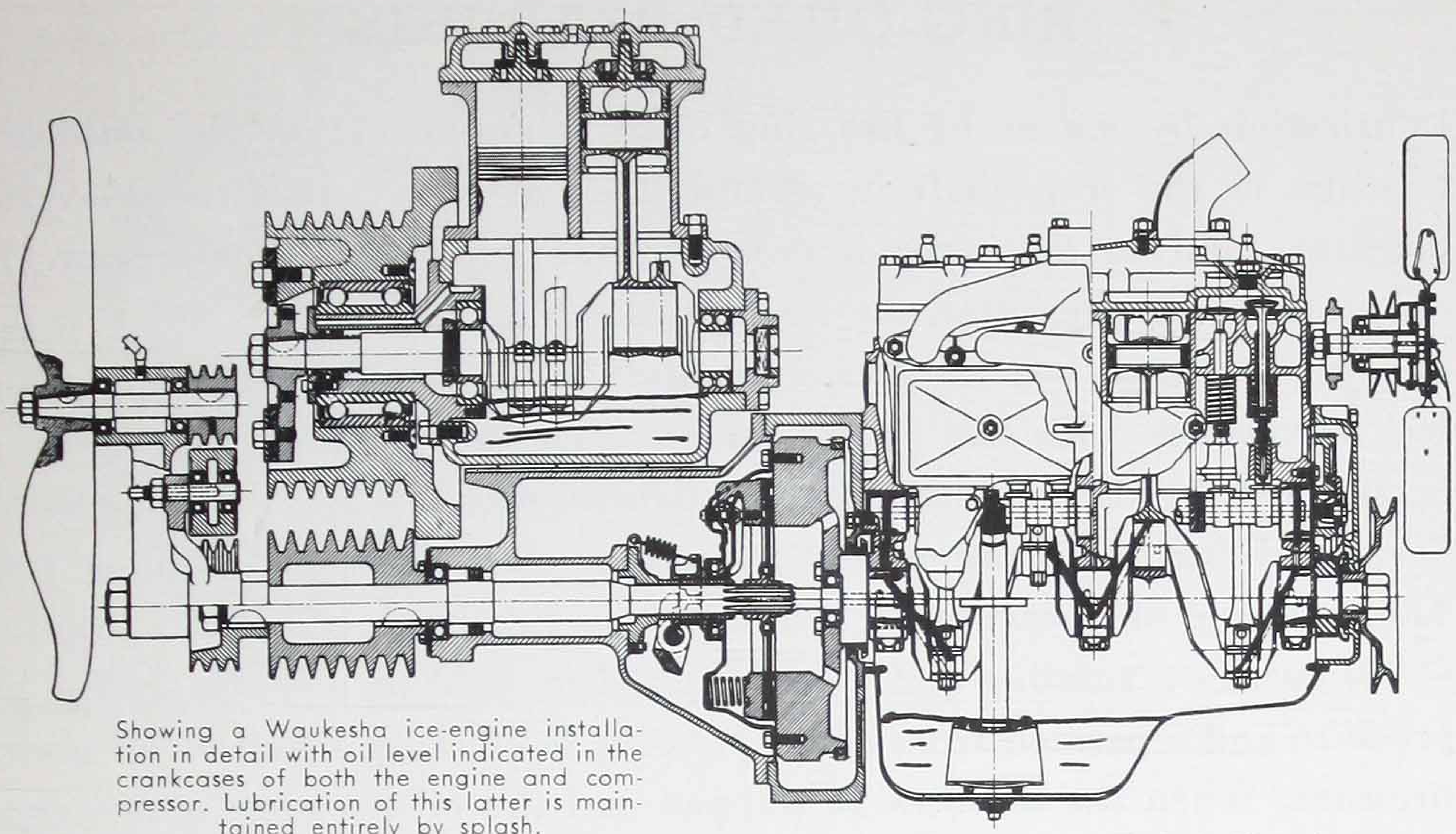
Use of excess oil in a splash lubricated system will also involve the possibility of difficulty when draining and cleaning, especially where sludging has taken place. Churning of certain oils in a crankcase will give rise to sludge formation if they have not been very highly refined. In part, this is due to chemical breakdown; it will be most probable where water is present or the oil is laden with foreign matter, such as dirt, metallic particles or carbon.

It is, therefore, important to follow regular periods for cleaning, and to look carefully into the condition of the used oil, for this will very often indicate both the approximate suitability of the latter and the extent to which effective lubrication is being attained.

PRESSURE LUBRICATION

With a pressure system, more accurate control of the amount of oil delivered to cylinder walls and compressor bearings is made possible. On the other hand, some types of design may require more equipment, piping, etc., frequent filling of the reservoir where a mechanical force feed lubricator is installed, and regular attention from the operator.

In the central station type of installation, pressure lubrication is especially adapted to cylinder and rod lubrication via the oil lantern, or oil recess within the piston rod stuffing box. By properly constructing a stuffing box with a lead to come from the lubricator, it is possible to operate the piston rod continually through a ring of oil. In this way



Showing a Waukesha ice-engine installation in detail with oil level indicated in the crankcases of both the engine and compressor. Lubrication of this latter is maintained entirely by splash.

Courtesy of Waukesha Motor Company

effective rod lubrication, as well as sealing against pressure, can be maintained with dependable consistency.

To lubricate the cylinder in addition, it is only necessary to deliver additional oil to the stuffing box lantern and provide a so-called overflow pipe to carry this to the refrigerant suction line adjacent to the cylinder. In effect, this is similar to the principles of steam cylinder lubrication, the refrigerating gas being impregnated with vaporized lubricant prior to its passage through the compressor.

Mechanical force feed lubricators can also be used where compressor cylinders are to be pressure oiled. Excellent economy will be attained by regulating such lubricators so that just enough oil is delivered to maintain the requisite lubricating films, with the least amount of excess to drain off.

ENCLOSED OIL PUMP DESIGN

In realization of the necessity for controlled lubrication, certain compressor builders have given some noteworthy study to the application of the enclosed type of force feed oil pump. One particular design has provision for location of this pump in the base of the crankcase, driving through sprockets by chain connections to the main shaft. By locating the pump also at the lowest part of the case the possibility of loss of suction is eliminated inasmuch as the oil is continually being returned by gravity. This assures positive delivery of oil to all reciprocating parts through the pipe connections provided for same.

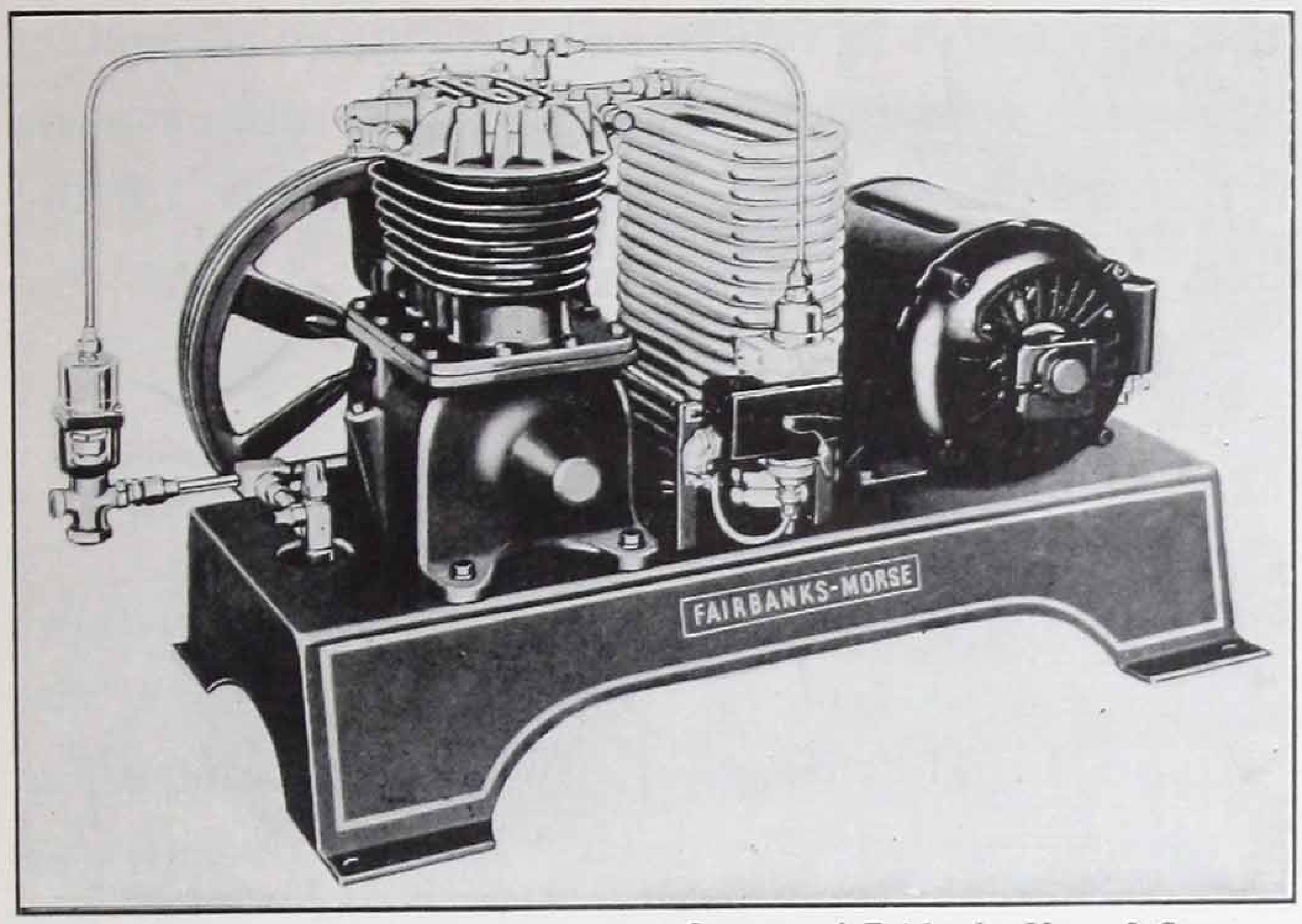
RING-OILED BEARINGS

Lubrication by means of the ring oiler is applicable to the outboard bearings of the crankshaft in certain types of heavy duty reciprocating machines and to the rotor bearings of the centrifugal compressor. In connection with the latter, the oil performs a dual function in that it not only lubricates the bearings but also maintains an automatic oil seal against loss of vacuum. This seal at the drive end of the centrifugal compressor is obtained through an automatic mechanism actuated by the oil pressure developed during operation, and by springs when the machine is at rest. The principle of operation, according to Carrier Engineering Corporation —"comprises a rotating and a stationary disc, held in position by the oil pressure and separated from actual wearing contact by a film of oil under pressure. When the machine is stopped and the oil pressure ceases compression springs are automatically released and these then effect an equally dependable and leak-proof seal while the machine is inoperative."

As a means of lubrication the ring oiler is simple, clean, entirely automatic, uniform in oil distribution and requiring but little attention. In construction it comprises a bearing housing which is built with a reservoir and a slot of sufficient width and depth in which revolve one or more rings suspended from the shaft, according to the length of the bearing; the turning of the shaft causes the rings to rotate. By this action a certain amount of oil is carried to the top of the shaft from whence it flows into the bearing oil grooves and clearance space to be ultimately distributed over the entire wearing surface. The oil after passing through the bearing flows out to the end or ends of the shaft and back to the reservoir to a return chamber which is part of the bearing housing.

A ring-oiled bearing is flood-lubricated with a considerable excess of oil over the amount necessary to furnish the requisite oil film. Bearings designed for this type of lubrication may be said to be doubly protected in that the oil serves not only as a lubricant, but also as a cooling medium to carry away part of the frictional heat developed, thereby reducing the temperature of operation. If the oil reservoir in the base of the bearing has been properly designed and is of sufficient capacity, this overheated oil in turn becomes sufficiently cooled after each circulation to enable it to perform this heat transfer function indefinitely.

Oil splash or churning is objectionable in the centrifugal compressor



Courtesy of Fairbanks, Morse & Company

The Fairbanks, Morse air conditioning condensing unit, showing compactness of the assembly and relative location of the parts.

due to the possibility of impairment of the seal. For this reason, oil which is carried to the top of the bearing on this machine must be returned to the reservoir as rapidly as it is delivered by the ring in order to avoid undue accumulation in the upper part of the housing. The same condition might arise if the oil is carried too high in the well, or if the ring is too small or rotates too rapidly.

PISTON RING INSTALLATION

The use of piston rings in the reciprocating type of air conditioning compressor will be dependent upon the size and design of the machine. Rings are always used in the horizontal compressor; in the smaller unit type of vertical machines, however, piston rings may be eliminated in favor of closer clearance of a tighter fit between the pistons and cylinders. This practice, on the other hand, requires very accurate machine work and thorough knowledge of materials and their susceptibility to wear.

In the interest of maintenance of a suitable seal, and preventing abnormal passage of lubricating oil from the crankcase into the refrigerating side of the system, some very interesting studies have been made in regard to ring design, materials and installation. It has been indicated that the conventional type of soft iron ring is not always dependable due to the tendency it may have to warp or bend, especially when being installed. Any deformation may, of course, lead to binding or even sticking in the ring grooves. Obviously, this may result in faulty lubrication, an imperfect seal, and passage of a considerable volume of oil over into the refrigerating or heat transfer side of the system to cause reduced efficiency of the entire unit during operation.

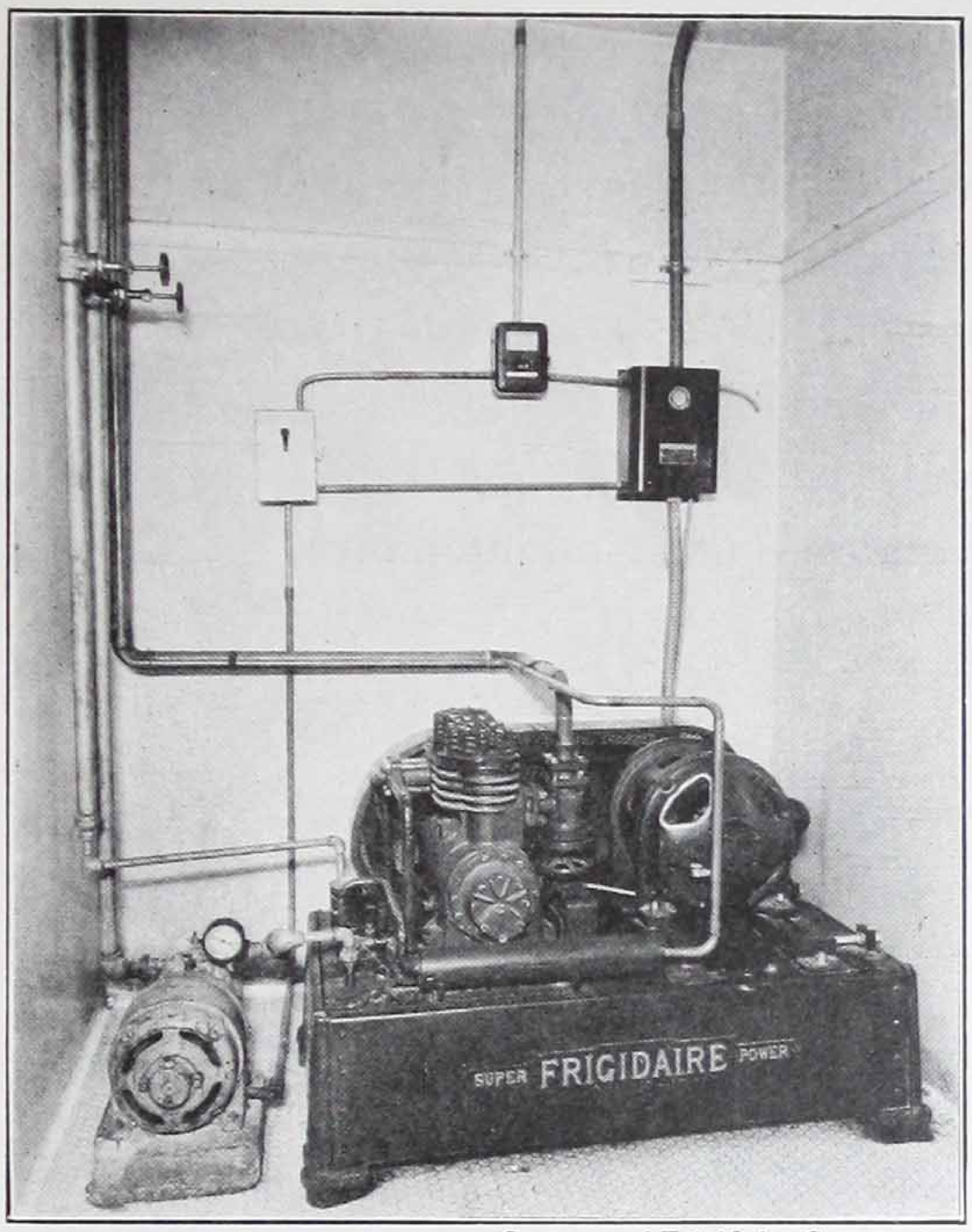
MOTOR AND FAN BEARING LUBRICATION

Electric motor bearings and the bearings of other accessories, such as fans, which are essential to a mechanical air conditioning system, are largely of the anti-friction type. In addition, the ball bearing hanger has been widely adopted in connection with railroad car air circulating systems. Lubrication of such bearings should differ but little from the lubrication of the industrial ball or roller bearing motor, with the exception that location in confined spaces might, in some cases, tend to cause higher average bearing temperatures in operation.

The first cost of such bearings may be somewhat higher than the conventional plain bearing. Positive protection to justify this cost is, therefore, essential. Such protection is assured by lubrication provided the proper lubricant is used. Normally, the design will call for a grease, the bearing seals being so designed as to enable such a lubricant to function at its best, apart from contamination from external sources. This will assure easy rolling of the bearing elements, with minimum friction and wear. Rolling motion must be maintained as perfectly as possible, however, for if it is impaired in the case of even but one ball or roller more or less sliding will occur to the detriment of the contact surfaces of itself as well as the raceways. Ultimately these will wear out-of-round.

Adequate sealing is highly important on any air conditioning installation, not only as a protection against contamination, but also in the interest of preventing leakage and necessity for frequent renewal of grease. It is obvious that positive protection of the bearing elements cannot be assured if the lubricant is prematurely lost, furthermore, leakage, especially in a railroad car installation where the fans and motors may be located overhead in a space above the doors, might cause considerable expense and discomfort to passengers should this leakage drip through and onto clothing.

While a tightly sealed bearing will, of course, permit the use of a lighter lubricant, which will lead to reduction in torque and power consumption, the matter of temperature must not be overlooked, for temperature will



Courtesy of Frigidaire Corporation

A Frigidaire hotel installation showing manner of arrangement of piping and controls.

affect the consistency of any grease. Research in grease manufacture has developed a type of lubricant which is possessed of certain highly desirable properties, in that it resists change in consistency and even at higher temperatures it will train with the bearing and not work out. Furthermore, it is remarkably low in torque characteristics. From a chemical angle, it is free from acid forming tendencies which assures protection against corrosion, and is resistant to oxidation or expansion through air entrainment. These properties, along with an ability of the lubricant to resist oil separation, should be most carefully considered in the purchase of grease for any ball or roller bearing.

Application or renewal of lubricant is also important. One should never force an excess of grease into any anti-friction bearing housing by either a compression grease cup or pressure gun. The latter must be handled especially carefully due to the potential pressures available. If pressure is not controlled the charging of too much grease may affect the tightness of the bearing seal. An excess of grease in the bearing may also lead to overheating as well as increase in power consumption. For these reasons, operators and maintenance mechanics should realize that any ball or roller bearing has a certain limited capacity for lubricants which should not be exceeded. Unfortunately there is no direct way of determining this, hence the advisability of removing the bearing caps, and inspecting at overhaul periods. Experience with bearings of various size, and knowledge of the effectiveness of their seals, along with the lubricating ability of certain greases, will soon enable an observant operator to develop a suitable lubrication schedule which will assure bearing protection, economy of lubricant and minimum cost of maintenance.

TEXACO PRODUCTS
FOR
REFRIGERATION MACHINERY
AIR CONDITIONING and ELECTRIC UNITS

COMPRESSORS

Refrigerant	*Type of Compressor*	*Texaco Recommendation*
Freon Group	Rotary	Capella Oil D
	Centrifugal	Capella Oil D
	Reciprocating	Capella Oil D or E
Sulfur Dioxide	Reciprocating (*according to design*)	Capella Oil AA, A, B, or C
Methyl Chloride	Reciprocating	Capella Oil C or D
Carrene	Centrifugal	Capella Oil D
Carbon Dioxide	Reciprocating	Capella Oil D or E

ELECTRIC MOTORS, FANS, ETC.

Bearings	*Oil lubricated*	
	According to installation	Canopus, Cetus, or Alcaid Oils
Bearings	*Grease lubricated*	
	Light to medium duty	Starfak No. 2
	Heavy duty	Marfak No. 2

ICE REFRIGERATION EQUIPMENT

SPLASH, FORCE-FEED OR GRAVITY CIRCULATING SYSTEMS ON COMPRESSORS

Where the oil may gain entry into the refrigeration system or compressor cylinder	TEXACO Capella Oils
Where there is no danger of this occuring	
In Force-Feed or Gravity Systems	TEXACO Alcaid Oil or Algol Oil
In Splash Systems	TEXACO Capella Oil C

STEAM CYLINDER LUBRICATION

Where separation of oil from condensate is not important	
Saturated Steam (Above 150 lbs. pressure)	TEXACO Leader Cylinder Oil or TEXACO Cavis Cylinder Oil or
Saturated Steam (Below 150 lbs. pressure)	TEXACO Pinnacle Cylinder Oil or TEXACO Draco Cylinder Oil
Where the condensate is used for ice making or core filling	
Saturated Steam (Above 150 lbs. pressure)	TEXACO Cavis Mineral Cylinder Oil or TEXACO 650 T Mineral Cylinder Oil
Saturated Steam (Below 150 lbs. pressure)	TEXACO Pinnacle Mineral Cylinder Oil

ELECTRIC MOTORS

Ring Oiled	
Normal Temperatures	TEXACO Capella Oil C or TEXACO Canopus Oil
Low Temperatures	TEXACO Capella Oil A or B
Ball and Roller Bearings	
Oil Lubricated	TEXACO Canopus, Cetus, or Alcaid Oils
Grease Lubricated	
Light to Medium Duty	TEXACO Starfak Grease No. 2
Heavy Duty	TEXACO Marfak No. 2
Wick or Wool Yarn Systems	
According to size	TEXACO Cetus Oil or TEXACO Alcaid Oil

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