

Household Refrigeration

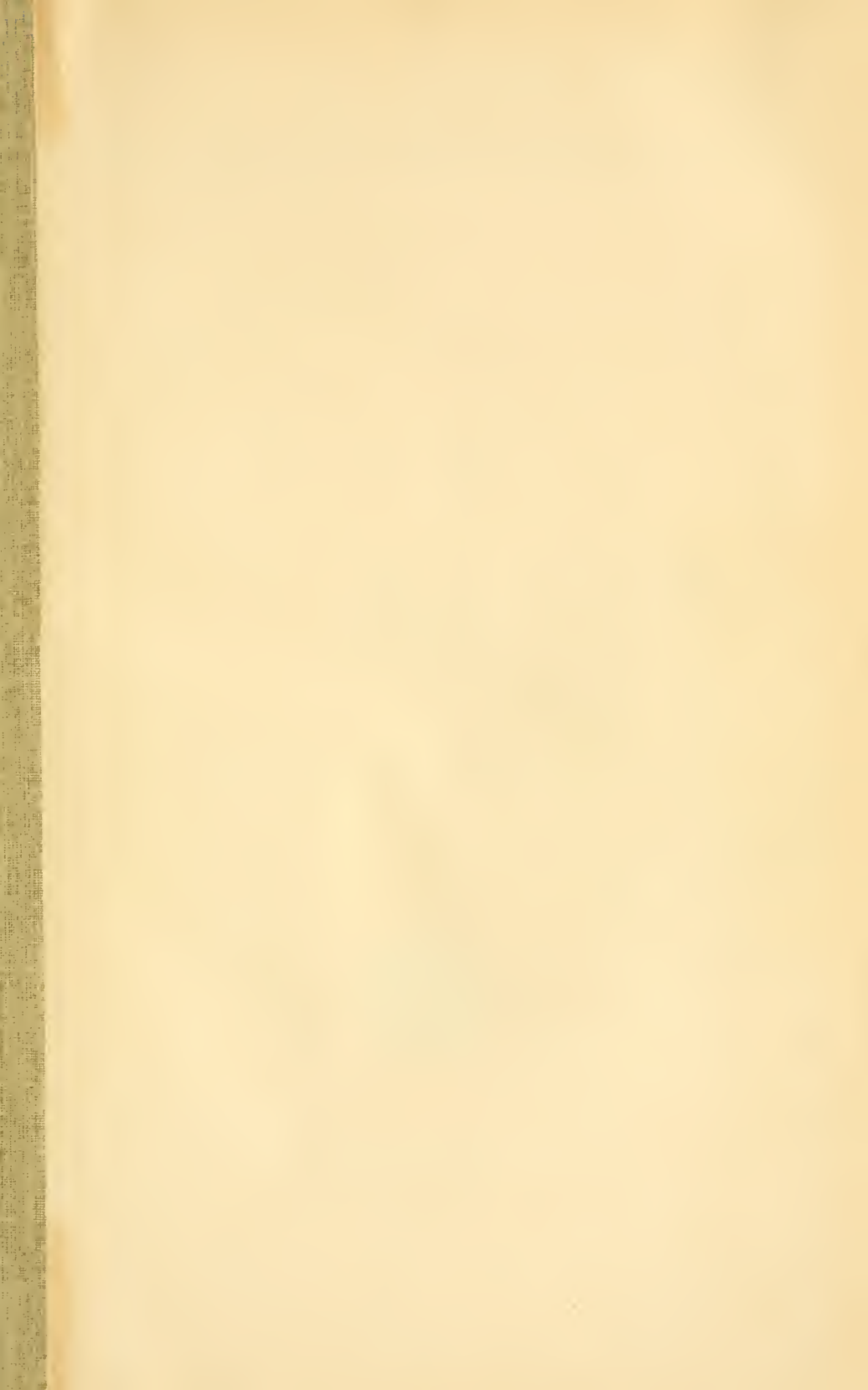


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Household Refrigeration

A COMPLETE TREATISE ON THE PRINCIPLES, TYPES,
CONSTRUCTION, AND OPERATION OF BOTH ICE
AND MECHANICALLY COOLED DOMESTIC
REFRIGERATORS, AND THE USE OF
ICE AND REFRIGERATION
IN THE HOME

BY
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Refrigeration Engineer

Third Edition, Revised and Enlarged



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PREFACE TO THE FIRST EDITION

In developing this work on "Household Refrigeration," the first of the kind published, the author has endeavored to present a subject in its broadest sense.

Attention has been given to the production of refrigeration for any household or domestic purpose by both ice and mechanically cooled refrigerators. The work consists of a treatise on the principles, types, construction and operation of both ice and mechanically cooled refrigerators, including therein certain considerations on the use of ice and refrigeration in the home.

It is believed that this work will not only be found to be interesting and instructive to designers, manufacturers, dealers, and distributors, of both ice and mechanically cooled refrigerators, but also will be of interest to the householder, who employs refrigeration in either of the aforementioned systems.

The author has drawn extensively on his experience as a refrigeration engineer for material for this work. However, in the many instances, he has made use of the work of others, for which proper credit has been given. The author desires to gratefully acknowledge the assistance which has been extended to him by various associations, publishers, manufacturers, and others, during the preparation of the subject matter of this book.

H. B. HULL.

PREFACE TO THE THIRD EDITION

The industry of Household Refrigeration has made great strides in the interim since the preparation of the first and second editions of this work.

The use of the small refrigerating machine in homes is rapidly increasing each year.

The use of ice in the home is also gradually increasing.

18855

Q. T. P. of. Col. J. Ferrelle

The seasonal character of sales of both household refrigerating machines and ice is gradually becoming less marked.

Many countries in Europe are demanding ice and household refrigerating machines to assure proper food preservation in the home.

This edition contains descriptions of the latest models of both compression and absorption type household refrigerating machines and also includes recent improvements in refrigerator construction.

October, 1927.

H. B. HULL,
Dayton, Ohio.

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FOREWORD.

The problem of preserving food collected during times of plenty, for use when the source of supply fails, has been practiced by man from even the remotest ages. Among primitive races, food preservation was essential to avoid famine. In the modern civilized countries, the preservation of food is an important factor in maintaining a balance between the demand and supply for perishable foods. There is a special need of preservation in order to transport food to the large cities.

Chemical processes of animal and vegetable tissue actively continue in these foods even after the more obvious evidences of life has gone. Fruits ripen, grains mature, starches become sugars, flavors develop, and meat becomes tender. These changes are desirable and nutritively beneficial.

There are numerous artificial methods employed to restrain the activity of these processes in foods. The most important is by refrigeration or cooling. Some other methods are by drying, dehydrating, smoking, pickling, curing, preserving, and cooking.

Refrigeration is the method of food preservation which causes a minimum of alteration of the desirable food properties. The natural freshness and flavors are retained without abstracting moisture, and there is a minimum change in the physical, chemical, or nutritive qualities of the food.

Refrigeration was first used by the Egyptians, Greeks, and Romans, who cooled their wines and water in crude vessels which extracted some of the heat from the liquids through evaporation.

The first methods of preserving food by cooling were very crude—a hole in the ground or a stream of water served this purpose.

In the early part of the nineteenth century, the ice box came into use. Natural ice was placed in the ice compartment. The melting of the ice produced a circulation of cold air which cooled the foods. This was a great improvement over previous methods of storing perishable foods.

Ice of the winter months was stored for this use in specially constructed buildings, located near the pond or lake supplying it.

The supply of natural ice was very uncertain. Transportation was difficult and ice was only available to limited localities.

The next important step in household refrigeration was the use of manufactured ice. Active work in the development of machines for producing ice in a commercial way was carried on from 1830-1870. The success of these machines permitted their use in even the warmest climates. In addition there were difficulties in transporting natural ice any great distance from its source. In regard to manufactured ice, the large loss in melting during months of storage and the time of transportation could be saved. The quality of the water used for making ice could be better controlled. The supply was more certain and could be regulated to meet the demand.

In addition to the increased use of manufactured ice, some improvement in the construction of household refrigerators was made. Better insulation was used, more sanitary linings and better air circulating systems designed. The temperature in the food compartments could be maintained from 20° to 30° lower than the room temperature.

During the last twenty years, the household refrigerating machine has been under active development. It is only within the last five years, however, that machines have been manufactured in quantities and proven a commercial success.

Mechanical household refrigeration is having an important influence on refrigerator cabinet construction. It is necessary to have better constructed and insulated refrigerators

to operate satisfactorily, with the lower food compartment temperatures produced by the mechanical unit.

The cost of operation of the household machine is about the same as the cost of ice. When the interest of the investment and depreciation are considered they will usually cost more than ice. The increased sale of machines indicate that the advantages compensate for this difference in cost.

There are about 15,000,000 wired homes in the United States supplied with electric current. Less than 3 per cent of these have electrical refrigerating machines so there is a large potential market for this product. About 12,000,000 iced refrigerators are in use in the United States at the present time. There are about 9,000,000 wired homes in Europe.

The production of household refrigerating machines during recent years has been approximately as follows:

| | | |
|------------------------|-----------|--------------------|
| Previous to..... | 1923..... | 20,000 |
| Year | 1923..... | 20,000 |
| Year | 1924..... | 24,000 |
| Year | 1925..... | 75,000 |
| Year | 1926..... | 260,000 |
| Estimate for year..... | 1927..... | 600,000 to 800,000 |

The gas fired absorption type household refrigerating machine is being rapidly developed at the present time. The cost of operation of this type machine can be considerably less than the cost of the equivalent amount of refrigeration with ice. There are about 17,000,000 gas meters in use in the United States.

It is predicted that, in the near future, the automatic household machine will compete with ice, even on a cost basis in homes having electric current or gas service.

CHAPTER I

REFRIGERATION UNITS AND THEORY

Heat Unit—A heat unit is an arbitrary standard or unit of measurement which expresses the capacity of a given body to absorb and retain heat energy under a given increase of its sensible heat. Water has a greater heat capacity than almost any other common substance and it has been used in framing the definition of a heat unit.

British Thermal Unit.—A British thermal unit (B.t.u.) is the quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit at or near its temperature of maximum density, 39.1° F. For practical work it may be considered as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Sensible Heat.—Sensible heat is the heat which goes to increase the temperature of a body without affecting its state, whether it be that of a solid, liquid or gas. Thus the addition of sensible heat to a body may be felt by the hand or be indicated by a thermometer.

Latent Heat.—Latent heat is the amount of heat that must be supplied to a body to change its state from a solid to a liquid, or from a liquid to change it to a gas. This heat separates the molecules of the substance and cannot be indicated by a thermometer since it produces no change in temperature. Every substance has a latent heat of fusion, required to convert it from a solid to a liquid, and another, a latent heat of vaporization required to convert it from a liquid to a gas or vapor. Experiments have shown that it requires 144 B.t.u.

to melt one pound of ice at 32° F. into one pound of water at 32° F.; thus we have 144 B.t.u. as the latent heat of fusion of ice.

If heat is applied to one pound of water at 212° F. the water will remain at this temperature under atmospheric pressure until all of it has been evaporated into steam at 212° F. This has been found to require 970.4 B.t.u.; therefore, the latent heat of vaporization of steam at atmospheric pressure is said to be 970.4 B.t.u.

Specific Heat.—The specific heat of a substance is the ratio of its heat capacity to that of water. One pound of water requires one B.t.u. to raise its temperature one degree F. One pound of cast iron requires only 0.13 B.t.u. Therefore, the specific heat of cast iron is 0.13. The specific heat of ice is 0.504; of air, 0.240, of anhydrous ammonia, 1.10. The specific heat of materials usually stored in a refrigerator averages about 0.80.

Refrigeration.—Refrigeration is a term used to represent the cold produced or rather the amount of heat removed. It is measured by the latent heat of fusion of ice. The capacity of a machine in tons of "ice melting" or "refrigeration" does not mean that the machine would make that amount of ice, but that the cold produced is equivalent to the melting of the weight of ice at 32° F. into water at the same temperature.

One ton of refrigeration is equal to 144x2,000 or 288,000 B.t.u. per 24 hours, or 12,000 B.t.u. per hour or 200 B.t.u. per minute.

Absolute Pressure.—Absolute pressure is the pressure reckoned from a complete vacuum. Gauges in common use indicate the pressure, in pounds per square inch, above atmospheric which is 14.7 at sea level; this reading is called gauge pressure. To convert gauge pressure to absolute pressure, 14.7 pounds, per square inch, must be added to the gauge reading.

Absolute Zero.—Absolute zero is the point at which molecules lose all motion; in other words, the temperature at which

there is an absence of all heat. This temperature has not been reached but is assumed to be 460 degrees below 0° F.

Mechanical Equivalent of Heat.—The mechanical equivalent of heat has been determined by accurate experiment. If the heat energy represented by one B.t.u. be changed into mechanical energy without loss, it would accomplish 778 foot-pounds of work. One hp. represents 42,416 B.t.u. per minute.

Refrigerating Machine Capacity Rating.—In December 1920, the A. S. R. E. and A. S. M. E. adopted a standard method for rating the capacity of any refrigerating machine which is concisely as follows:

"The capacity of any refrigerating machine shall be expressed in terms of 2,000 lbs. ice melting effect for 24 hours (288,000 B.t.u.) with 5° F. saturation temperature in the suction side and 86° F. saturation temperature at the discharge side."

Heat and Temperature.—Heat is a form of molecular energy. All bodies are composed of large numbers of extremely minute particles, known as molecules. These molecules have an attraction for each other, which is greater in solids than in liquids and greater in liquids than in gases. These molecules are in a state of continuous and irregular motion, the rate of which depends upon the temperature, being more rapid at higher temperatures. Absolute zero is supposed to represent the condition of matter where there is no kinetic energy of the molecules, and therefore no temperature. Absolute zero is -460° F., or -273° C.

Heat, being a form of energy, may be converted into electrical, chemical or mechanical energy. The two terms, heat and temperature, are frequently confused. Heat is a measure of quantity. Two pieces of iron may have the same temperature, however if one piece is larger than the other it will contain a larger quantity of heat. A cake of ice may contain more heat than a smaller quantity of boiling water. Heat is constantly passing from warmer objects to colder ones, just as water always tends to flow down hill. There is no natural process in which heat passes from a colder to a warmer object without the expenditure of outside work.

Temperature is a term used to denote the degree of hotness or coldness of a body and as explained above, it depends upon the amount of sensible heat contained in the body. Since our sensation of warmth and cold is not sufficiently accurate and trustworthy for technical purposes the physical change of expansion of a mercury, for example, accompanying its change in temperature has been agreed upon as a method of measuring temperature.

Theory of Refrigeration.—Refrigeration implies the reduction of the temperature of a body below the surrounding environment temperature. It further implies the maintaining of this temperature difference. This requires the constant extraction of heat from the space in which the temperature is already lower than the surrounding environment temperature.

Example.—The food compartment of a refrigerator is being maintained at a temperature of 45° F., and the room temperature is 70°. The refrigerator will continually absorb heat from the room. It is therefore necessary to “pump” this heat out of the refrigerator, as well as the heat supplied by placing relatively warm food or containers inside the refrigerator. To extract this heat from the 45° F. food compartment, it is necessary to have a still colder object such as a cake of ice, a brine tank, or cooling coil to continually absorb heat. The ice melts and the heat in the refrigerator is used to supply the latent heat necessary to change ice into water. With a brine tank in which are immersed the evaporator coils, the heat in the refrigerator is used to vaporize the liquid refrigerant in the coils, and a small amount to superheat the gaseous refrigerant, after being vaporized. The refrigerant is then compressed, and this heat passes into the condensing medium which is usually water or air.

Refrigeration Constants.—A number of the commonly used refrigeration constants are shown in Tables I to IX inclusive. Table I contains the interrelation of tons of refrigeration, pounds of refrigeration, and heat units (B.t.u.).

Table II gives the units of refrigeration, tons of refrigeration, and pounds of refrigeration expressed in B.t.u. per day, hour, minute and second. Due to the fact that the British

ton is 2,240 pounds, the corresponding British ton of refrigeration is therefore equal to $2,240 \times 144 = 318,080$ B.t.u. The corresponding American ton of refrigeration, $2,000 \times 144 = 288,000$ B.t.u.

Table III gives the tons of refrigeration required per ton of ice made when approximately 20 per cent is allowed for the losses occurring in the ice freezing process. Some of the common properties of ice are given in Table IV, while the weights of water per cubic foot and per gallon are given in Table V. Table VI contains some useful hp. equivalents. Some of the useful atmospheric pressure equivalents are given in Table VII. Some average weights of cork insulation are given in Table VIII. The heat transmission through one square foot of surface is found by dividing the total heat in B.t.u. transmitted per hour by the production of the mean temperature difference, and the heat transfer rate expressed in B.t.u. per square foot per degree of temperature difference per hour. Some of the fixed points in thermometry and other temperatures are given in Table IX.

TABLE I.—CONVERSION FACTORS

| | Tons | Pounds | B.t.u. |
|-----------------------------|---------|--------|-------------|
| Ton of Refrigeration..... | 1 | 0.0005 | 0.000003507 |
| Pound of Refrigeration..... | 2,000 | 1 | 0.007014 |
| B.t.u. | 288,000 | 144 | 1 |

TABLE II.—TONS AND POUNDS OF REFRIGERATION

| | |
|-------------------------|-------------------------------------|
| 1 Ton Refrigeration = | 288000 B.t.u. per day |
| 1 Ton Refrigeration = | 12000 B.t.u. per hour |
| 1 Ton Refrigeration = | 200 B.t.u. per minute |
| 1 Ton Refrigeration = | $3\frac{1}{3}$ B.t.u. per second |
| 1 Pound Refrigeration = | 144 B.t.u. per day |
| 1 Pound Refrigeration = | 6 B.t.u. per hour |
| 1 Pound Refrigeration = | 0.1 B.t.u. per minute |
| 1 Pound Refrigeration = | $.001\frac{2}{3}$ B.t.u. per second |

TABLE III.—RELATION OF REFRIGERATION TONNAGE TO ICE MAKING

| Temperature of Condensing | Tons Refrigeration |
|---------------------------|--------------------|
| Water degrees F. | Per ton ice making |
| 50 | 1.46 |
| 60 | 1.53 |
| 70 | 1.60 |
| 80 | 1.67 |
| 90 | 1.74 |

HOUSEHOLD REFRIGERATION

TABLE IV.—PROPERTIES OF ICE

| | | |
|----------------------------|-------|--------|
| Weight per cubic foot..... | 57.5 | pounds |
| Specific Heat..... | 0.504 | B.t.u. |
| Latent Heat..... | 144 | B.t.u. |

TABLE V.—WEIGHT OF WATER

| | | |
|----------------------------|------|--------|
| Weight per cubic foot..... | 62.5 | pounds |
| Weight per gallon..... | 8.35 | pounds |

TABLE VI.—HORSEPOWER EQUIVALENTS

| | | |
|-----------------------------|--------|------------------------|
| One mechanical horsepower = | 33,000 | foot pounds per minute |
| One mechanical horsepower = | 2545. | B.t.u. per hour |
| One mechanical horsepower = | 746. | watts |

TABLE VII.—ATMOSPHERIC PRESSURE EQUIVALENTS

| | | |
|------------------|-------|--------------------|
| One Atmosphere = | 14.67 | pounds per sq. in. |
| One Atmosphere = | 33.9 | feet of water |
| One Atmosphere = | 29.92 | inches of mercury |

TABLE VIII.—CORK INSULATION DATA

| | | |
|--|------------------------|---------------------|
| Weight per cubic foot, granulated = | 6.5 | pounds |
| Weight per cubic foot, regranulated = | 8.0 | pounds |
| Weight per cubic foot, corkboard = | 12.0 | pounds |
| B.t.u. heat leakage of one square foot corkboard | 6.5 x temp. difference | |
| per 24 hours = | | Thickness in inches |

TABLE IX.—FIXED POINTS IN THERMOMETRY

| | Fahrenheit Degrees |
|---|-----------------------|
| Absolute zero (theoretical)..... | -460° |
| Mercury freezes..... | -38° |
| Water freezes..... | +32° |
| Household refrigerator (ideal temperature)..... | 40° to 50° |
| Room temperature..... | 68° to 70° |
| Pasteurizing milk..... | 145° |
| Water boils..... | 212° |

CHAPTER II

ICE FOR REFRIGERATION PURPOSES

Historical Data.—The practice of cooling bodies below the temperature of the atmosphere by the use of ice, has been followed for centuries. In the earlier times, the ice used for refrigeration purposes was natural ice, which formed on the rivers, lakes and ponds, during the cold winter months. The ice, after being harvested in the winter, was stored in caves in the ground, so that perishable foods could be preserved during the hot summer months. Coming up to modern times, we find, in the last half of the nineteenth century, due to improved methods of storing, harvesting, and distribution, that the use of natural ice for refrigeration purposes assumed a large proportion in the United States. Later, practically within the time of the present generation, means were devised whereby ice for refrigeration purposes could be procured by mechanical means in commercial quantities. Still later, within the last decade, attention has been directed to ways and means of producing refrigeration in the home by mechanical means directly.

At present this subject is receiving the attention of many inventors, engineers, manufacturers, and others. New and improved devices and processes are being developed constantly.

The National Association of Ice Industries has recently published a bulletin, entitled "The Romance of Ice," which contains an interesting review of the historical data on this subject. The following has been extracted from this bulletin:

THE ROMANCE OF ICE

Prologue.—Every product, every industry, every modern development has its "story." Perhaps the pages have not been turned back to that he who runs may read and be interested, but the story is there. Some of our greatest untold romances concern those taken-for-granted commodities which the public sees, uses, enjoys, without giving a thought to their interesting origin or the struggles of men in their development.

For example, ice is a necessity without which the public would really suffer. True the blasts of winter turn the waters of river, lake, and pond into ice; one long puff from Boreas' cheeks provides thousands of tons of ice each year, but twenty-six million American families cannot be supplied by Nature's manufactory alone.

Let's turn back the pages of history for a moment and see what happened in the world of yesterday to make ice now as readily accessible as coal or wood. These pages reveal real romance.

History.—The early Greek poet, Simonides, while at a banquet, observed that the liquor served to the other guests was cooled by snow. Whereupon he expressed his dissatisfaction in the following ode:

"The cloak with which fierce Boreas clothed the brow
Of high Olympus, pierced ill-clothed man
While in its native Thrace; 'tis gentler now,
Caught by the breeze of the Pierian plain.
Let it be mine: for no one will commend
The man who gives hot water to a friend."

History's pages also show that the ancient Egyptians knew the secret of cooling by evaporation, as practiced by the native of India today—filling with water shallow trays of porous material placed on beds of straw, and leaving them exposed to the night winds, with the result that dawn finds a thin film of ice formed on the surface.

On a very early page we find that the Emperor Nero had slaves bring snow down from the mountains to cool his wines. Alexander the Great had trenches dug for storing snow. Hundreds of kegs of wine were cooled there, with the result that his phalanxes entering battle the next day didn't care much what became of them, just so it was a good battle.

Marco Polo, the great Italian navigator, brought recipes for water and milk ices from Japan and China in the thirteenth century.

When Catherine d'Medici left Florence, Italy, to go to France, in the sixteenth century, she took with her the best of the chefs to make sure that she would be supplied with frozen creams and ices every day.

Sir Walter Scott told how Saladin, leader of the Mohammedan armies, sent a frozen sherbet to Richard the Lion Hearted, much to the amazement of that doughty monarch.

During the seventeenth century the French government made an unsuccessful attempt at government ownership when it licensed the business of farming snow and ice. The farmers who received government favor thereupon raised prices with such studious regularity that the people refused to buy and the Government was forced to relinquish its control of this commodity. Immediately thereafter supply and demand got into its stride and the business settled back into sanity.

As Lord Bacon commented in his *Sylva Sylvarum*:

"Heat and cold are Nature's two hands whereby she chiefly worketh, and heat we have in readiness in respect of the fire, but for cold we must stay till it cometh or seek it in deep caves or mountains, and when all is done, we cannot obtain it in any great degree, for furnaces of fire are far hotter than a summer's sun, but vaults and hills are not much colder than a winter's frost."

Bacon knew what a useful thing it would be if man could have the same command of cold as of heat. Scientist that he was, he undertook experiments into its possibilities. This led to unfortunate results, as he caught his death of cold by alighting from his carriage one winter day and stuffing snow into a chicken to see if it would keep.

The Italians, Spaniards, and Frenchmen have always been devotees of better living, and history is filled with interesting side lights on their uses of snow and natural ice.

Then we have the picture of the early fishmonger in England selling ice from his wagon, a practice which is continued to the present day.

The first record of American delivery of ice to the home is in 1802. The first commercial shipment of natural ice from America was exported from Boston by Frederick Tudor in 1805 when a shipload was sent to Martinique in the West Indies to help stay the ravages of yellow fever.

During this time all of the ice used was produced by Nature.

Natural and Manufactured Ice.—One of the most interesting phenomena of Nature is the formation of ice. We all know that cold is the absence of heat and that the freezing point of water is 32° F. When the air above a pond, lake, or river is below 32° F., the top layer of water is cooled and will sink because it is heavier than the warmer layers underneath. This continues until all the water is cooled to 39.1° F., at which point water reaches its greatest density. The top layer will then be cooled still further but remains on top and eventually will be reduced to the freezing point and ice will form.

If the water underneath the ice is not in motion, opaque ice will form. On moving bodies of water, as rivers and large lakes, clear ice forms. This is because each drop of water in freezing sets free the air it contains. The bubbles of air adhere to the surface of the newly frozen ice crystal. As more ice encloses the bubbles, the product becomes opaque. But where the water is in motion, the bubble is washed off the surface of the newly formed ice crystal and thus the ice forms, clear and hard.

But how about the actual manufacture of ice?

As Edwin F. Slosson of the Science Service, Washington, D. C., explains in his article, "Science Remaking Everyday Life:"

"The chronicle of the century of effort to approach the farthest north of temperature, absolute zero, is as fascinating as the contemporary struggle to reach the geographic pole and unlike the latter has proved profitable at every stage. When Fahrenheit in 1724 stuck his mercury thermometer into a mixture of salt and snow, he thought he had reached the lowest point possible and boldly scratched zero on the tube. But it was not long before scientists began to climb down the minus steps. In 1769 a Russian professor, taking advantage of a cold spell, froze mercury itself in a mixture of snow and nitric acid."

A hundred years ago, Faraday, working in the Royal Institution of London, succeeded in condensing ammonia gas to a liquid by applying pressure and then cooling it. When the pressure was removed, the liquid of course boiled off rapidly as a gas, absorbing heat in doing so. Any liquid absorbs heat when it turns into a gas.

This discovery proved of the greatest importance, both practically and theoretically. A solution of ammonia and water was used by Carre in 1858 in his ice making machine. The first Carre machine to reach the United States was shipped through the blockade of New Orleans in 1863.

In 1755 Dr. William Cullen invented the first machine which produced ice by purely mechanical means, his achievement being followed by those of Vallance of France (1824) and Jacob Perkins, an American then residing in England, who is given credit for the forerunner of the modern compression apparatus, his model being patented in England in 1834, with ether as the refrigerant employed. Other early workers in this field of science were Prof. A. C. Twining, of New Haven, Connecticut, and Dr. John Gorrie, of Apalachicola, Florida.

In the rotunda of the capitol at Washington, where each of the states has set statues of its most distinguished citizens, Florida has chosen this same Dr. Gorrie instead of any of its pioneer politicians or military geniuses. Too many men of various countries have con-

tributed to the gradual development of mechanical refrigeration for any one person to be entitled to exclusive credit for the invention, but Dr. Gorrie certainly deserves this place in our National Hall of Fame for the service rendered to the country when he took out the first American patent in 1850 for a practical process of manufacturing ice.

In the years of 1873-75 the first successful ammonia compression machines were introduced by C. P. G. Linde of Germany, and David Boyle of the United States. From 1875 to 1890 many new forms of apparatus were produced and certain improvements were made.

Until the year 1890 the practical utilization of the art of ice making and refrigeration had seemed to come to a standstill. But there occurred in the year 1890 an incident that awakened the general public to the possibilities of the use of mechanical refrigeration. This incident was the greatest shortage in the crop of natural ice that has ever occurred in the United States. To this unusual shortage may be accredited the impetus that started the rapid development and utilization of mechanical refrigeration. Since 1890 the ice making and refrigerating industry has grown by leaps and bounds.

Thanks to the manufacturers of the refrigerating machine, ice can be had at any time and anywhere that power can be obtained. The ice machines give us ice in any quantity at any time.

Manufactured ice is made in cans holding 300 to 400 pounds. The can is filled with pure water and is let down into a tank which is filled with brine. The brine is made of sufficient density to permit its freezing point to fall to zero Fahrenheit or below. The cans are arranged in regular order, in rows; between these rows of cans are continuous coils of closed pipe through which passes the ammonia, it being the most commonly used refrigerant. The ammonia starts out as a liquid and expands, turning into a vapor and finally into a gas as it absorbs heat from the brine which surrounds the coils

As the ammonia circulates through the pipes in the brine tank, it absorbs the heat from the brine and lowers its temperature to a point below the freezing point of water. As heat always travels from the higher to the lower temperature, the brine, in turn, absorbs heat from the water in the cans. When the temperature reaches a point low enough, the water begins to freeze and ice forms on the inside of the cans. As the freezing continues, the ice thickens until it finally closes to the center of the can and is a solid block. As the ice forms, any foreign matter in the water is forced to the center of the block. In order to manufacture clear ice, it must be made from distilled water or from "raw water," which is low in mineral content. The water must also be kept in motion just as Nature keeps the river water moving. By so doing, the particles of air and gases are liberated and

come to the top, thus allowing clear ice to be frozen. This is accomplished by conducting a stream of cold air into the can which keeps the water in motion. Frequently, in order to get a cake that is clear and clean all the way through, avoiding what is called a "core," the water is drawn from the center of the can before it is completely frozen and this cavity is refilled with distilled water.

What Ice Can Do.—When ice melts, it absorbs heat. Each pound changing from solid ice to liquid water absorbs as much heat as would be required to raise the temperature of one pound of water 144 degrees Fahrenheit. Indeed, the heat absorbing capacity of ice is so great that it has been made the standard of comparison and the units in which we measure this power are called British thermal units.

Ice is greedy to absorb heat. Therefore, if it is to do specific work, it must be protected from those warm objects which we do not desire cooled. For instance, in our home refrigerators ice is placed inside of what we term insulated walls.

A material which does not allow heat to pass through it is called an "insulator." To keep the ice from melting too rapidly, we build into the walls of the container some insulator which keeps away the atmospheric heat. The articles to be preserved for cooking or to be kept cold are put into the insulated space with the ice. Then the ice can absorb their heat, thereby cooling them, but turning into water in doing so. This is the principle of all ice refrigerators.

The better the insulation, the less heat can get into the refrigerator or ice box, and therefore, the less the ice meltage due to heat leakage. The warmer the articles put into the box, the more ice they will melt before they reach the same temperature as the ice box itself.

The temperature of ice is 32° F. If we had a perfect insulator—one which would not allow any heat from outside to go through the refrigerator walls, the temperature of the inside of the refrigerator would be 32° F. also. However, all insulators allow some heat to pass; the best ones permit little, while the poor ones let much heat pass through. The poorer the insulation in the refrigerator, the higher will be its temperature and the more ice will be melted when the air outside is warm.

The question of proper air circulation in a refrigerator is one of vital importance. The heat enters the refrigerator in two ways; some through the walls of the box and some with the food to be cooled. The warm air travels to the ice, is cooled, drops down to the section directly under the ice and thence over the food, absorbing heat, moisture, and odors. The warmed air, being lighter, rises through the food chamber and again reaches the ice. Here the air is cooled, drops moisture because of its lowered temperature, and whatever odors may have been absorbed during its passage over the food are dissolved in

the film of water on the surface of the melting ice and pass off in the meltage. Then the cooled, dried, and cleaned air is ready to make another trip through the food compartment.

The intelligent housewife utilizes these facts to the advantage of her family and her pocketbook. She sees that the ice compartment of the refrigerator is ready to receive the ice when the ice man brings it. Every minute it stays outside the insulated space it is absorbing heat from the air and melting.

Refrigeration is the ideal preservative and the housewife who really wants to economize on both food and ice keeps her refrigerator well filled at all times. This is a simple matter of household efficiency. When the ice gets low in the refrigerator, the walls naturally grow warm and just that much more ice is required to bring the temperature down again to a safe point where the constant circulation of cold air across the top of the ice, down its sides, down the side of the small food compartment, across the floor of the refrigerator, up through the food compartment and over the ice again purifies, and preserves through every inch of its journey.

Ice in Daily Living.—In a multitude of ways ice has entered into the daily life of the American people. It tinkles in the glass of water with which the master of the house quenches his thirst; it furnishes soft, clean water to shampoo milady's hair; and a small piece rubbed on her satiny cheek brings the blush of youth. In the laboratory the scientist depends upon it to chill his mixtures, and, in the hospital the physician prescribes it to cure and to comfort. But most important of all is the use of ice to maintain freshness, wholesomeness, and high quality in foods, and, directly or indirectly, most of the ice produced is utilized for this purpose.

We are apt to think that the piece of ice in the home refrigerator is the ice which is doing the work of food preservation, which is true. But far behind the household refrigerator there is a long refrigerated channel through which foods travel from producer to consumer. For example, each refrigerator car holds from three to five tons of ice. We have a fleet of about 150,000 such cars. One filling of ice is seldom enough to protect the lading for the entire haul and, for long hauls such as from the Pacific to the Atlantic coast as much as ten tons of ice per car may be required. This means that millions of tons of ice each year are used to protect our foods while in transit.

And then, just think of the hundreds of thousands of butcher boxes, large and small, in which ice is the refrigerant.

How insignificant would appear the few ices and sherbets made by Catherine d'Medici's chef when compared with the great ice cream industry of this country. Though much of the ice cream manufactured in this country is frozen by mechanical means, yet millions of pounds

of ice are required each year in the packing and handling of the product. Over 300,000,000 gallons of ice cream are manufactured each year, to say nothing of the large quantities made in homes where ice must be used in the freezing process.

Of all the foodstuffs kept from spoiling by means of ice none is of such importance as milk. Neither is there any food which depends to such an extent upon ice to maintain its purity. From the cooling of the milk with ice on the farm to the cracked ice in the container for the bottles on the milkman's wagon, milk is never for one moment from the cow to the consumer unaccompanied by its guardian and caretaker—ICE.

What the Ice Industry Is Doing.—More than 6,000 factories supply America today with over 42,000,000 tons of ice each year. In addition to this the harvesters of natural ice supply about 15,000,000 tons per annum. It is the duty of the industry to see that the American public is supplied with enough ice for all needs the year 'round. To fulfill this responsibility requires a large investment in money and men as well as sound business policy to serve the public economically and produce that reasonable profit which must accrue to every successful industry. For example, the city of New York uses each year 3,750,000 tons of ice. That the supply may not fail when warm weather comes and the demand increases manyfold, ice is manufactured and stored for months or until there is an accumulation of 200,000 tons which is not considered excessive as a margin of safety for the consumer. This is in addition to an average daily capacity for production in the ice plants of greater New York City of 23,000 to 24,000 tons. Similar precautions are taken the country over.

Not only the large city but the small town and the country side must find ice available should the need or the desire arise. Accordingly, we find small ice plants dotting the country from Canada to Mexico and from Coast to Coast. Longer and longer are the delivery routes and more and more frequent the supply stations. Into the depths of the Grand Canyon where it is eternally summer, ice is brought by burro back. On the banks of northern waters great houses store Nature's product that even in the North food may be preserved in warm weather.

To give an idea of the amount of equipment necessary and the volume of business carried on, it is interesting to note that manufacturers of ice in large cities such as New York may have as many as five hundred trucks and wagons in service, employ as many as one thousand men and manufacture as much as one million and a half tons of ice per year.

Such is the story of ice and the part it has played as the centuries have rolled on and man has become more and more the master

of the elements about him. That he now holds the key which regulates temperature, has been a development successful only after toil and struggle.

But the benefits are available to all of us.

Properties of Ice.—Most substances on being cooled become denser, changing from vapor to liquid and then to solid form, each more compact than the preceding form. Water is an exception to this general law. Water upon being cooled behaves normally and becomes denser until cooled at 39° . Further cooling expands the water until 32° is reached, when it freezes. Ice forms with an expansion. If this were not so, lakes would freeze from the bottom up. One can skate on ice because the pressure melts the ice, making a thin film of water. It requires energy to change from a solid to a liquid as this is a property common to crystalline substances.

Ice freezes in crystals, hexagonal in shape. When ice is frozen in the ordinary can method, these prisms have the hexagonal side on the surface of the cake of ice. If there is no agitation of the water during the freezing process, these prisms will continue in straight surfaces from the outside of the cake to the center. When there is agitation of the water during the freezing, the crystals break and pile up, forming irregular lines and surfaces. This is the reason a sun test will melt a 300 lb. cake of ice frozen without agitation, from four to five hours sooner than it will melt a similar cake of ice frozen with water agitation. The light, air, and heat enter the cake frozen without agitation with much less resistance.

A cake of ice frozen with agitation has about one per cent greater density than a cake of the same size frozen without agitation.

One cubic foot of ice at 32° F. weighs 57.50 pounds.

One pound of ice at 32° F. has a volume of 0.0174 cubic feet or 30.067 cubic inches. The relative volume of ice to water at 32° F. is 1.0855. The specific gravity of ice is 0.922. The specific heat of ice is 0.504.

Quantity of Ice Required for a Dairy Farm.—The United States Department of Agriculture in Farmers' Bulletin No.

1078 gives the following information in reference to the quantity of ice required for a dairy farm:

The quantity of ice needed for a dairy farm depends on its location, number of cows milked, and methods of handling the product. In the Northern States, it has been found that with a moderately good ice house, where the shrinkage from melting is not more than 30 per cent, half a ton of ice per cow is sufficient to cool the cream and hold it at a low temperature for delivery two or three times a week. It must be understood, however, that suitable cooling tanks are necessary under this estimate. The half-ton-per-cow estimate for ice to be stored allows for a reasonable waste and also for ordinary household use. If whole milk is to be cooled the quantity of ice stored must be increased to one and a half tons per cow in the North and two tons per cow in the South. To meet the needs of the average family on a general farm, it will be necessary to store about five tons.

Cost of Harvesting Ice.—The United States Department of Agriculture in Farmers' Bulletin No. 1078 gives the following data on the cost per ton for harvesting ice:

The cost of harvesting ice also varies with local conditions. It is impossible, therefore, to give an estimated cost that will cover all cases. The ice-harvesting season fortunately comes at a time when there is the least work on the farm for men and teams, and consequently the actual money cost is usually not very great. Investigations have indicated that counting the full value of the men's time, the average cost of cutting ice is about 27 cents a ton. Add to this the cost of packing and hauling, and the average cost of a ton of ice is about \$1.50, when the ice house is near the source of supply. If the ice house is at a considerable distance the cost of hauling, of course, is increased, and the total cost of storing ice in some instances has amounted to \$3.00 or more a ton.

Refrigeration Required for Making Ice.—The refrigeration required to make a pound of ice may be calculated as follows, when the initial temperature of the water is 75° F.:

| | |
|--|------------|
| To cool water (75° F.—32° F.)..... | 43 B.t.u. |
| To freeze water (latent heat=144)..... | 144 B.t.u. |
| To cool ice from 32° F. to 18° F. (0.504x14) | 7 B.t.u. |
| Total | 194 B.t.u. |

These quantities are shown graphically by Fig I. An additional amount of refrigeration, equivalent to from 15 per cent to 20 per cent of the foregoing, must be allowed to cover the unavoidable losses during the freezing of the ice. The foregoing methods, together with an allowance of approximately 20 per cent for losses, were used for the calculation of the data given in Table III of Chapter 1.

Size of Ice Cans.—Recent survey of the different sizes of ice cans indicated there were being manufactured at present about fifty different sizes. Of course, a great portion of the ice manufactured in the United States is frozen in 300 lb. and 400 lb. cans. Table X gives the sizes of the so-called standard ice cans. These particular sizes are used in a great majority of the plants.

TABLE X.—STANDARD SIZES OF ICE CANS

| Size of cake, in pounds | Size of top, inches | Size of bottom, inches | Inside depth, inches | Outside depth, inches | Size of band, inches |
|-------------------------|---------------------|------------------------|----------------------|-----------------------|----------------------|
| 50 | 8x 8 | 7½x7½ | 31 | 32 | ¼x1½ |
| 100 | 8x16 | 7¼x15¼ | 31 | 32 | ¼x1½ |
| 200 | 11½x22½ | 10½x21½ | 31 | 32 | ¼x2 |
| 300 | 11½x22½ | 10½x21½ | 44 | 45 | ¼x2 |
| 400 | 11½x22½ | 10½x21½ | 57 | 58 | ¼x2 |

Cutting of Ice Into Blocks.—The cutting of ice into blocks suitable for household refrigerators should be given special attention. The 25 pound unit system of cuts is in general use. The larger or 100 pound blocks are cut from the ends of the cake and the 50 pounds cuts are made by splitting the middle 100 pounds blocks. The 300 and 400 pound ice cakes usually have from five to ten per cent overweight to allow for loss in melting during storage and delivery.

Ice scoring machines are being used by the more progressive manufacturers. Some of the advantages of the ice scoring machines are: Insures customer of full weight, saves time in delivery, and gives blocks of suitable dimensions for standard ice compartment. The ice scoring machine has a series of saws which score the two largest faces at the same time. The scoring for a 300 pound block requires one horizontal and five vertical cuts.

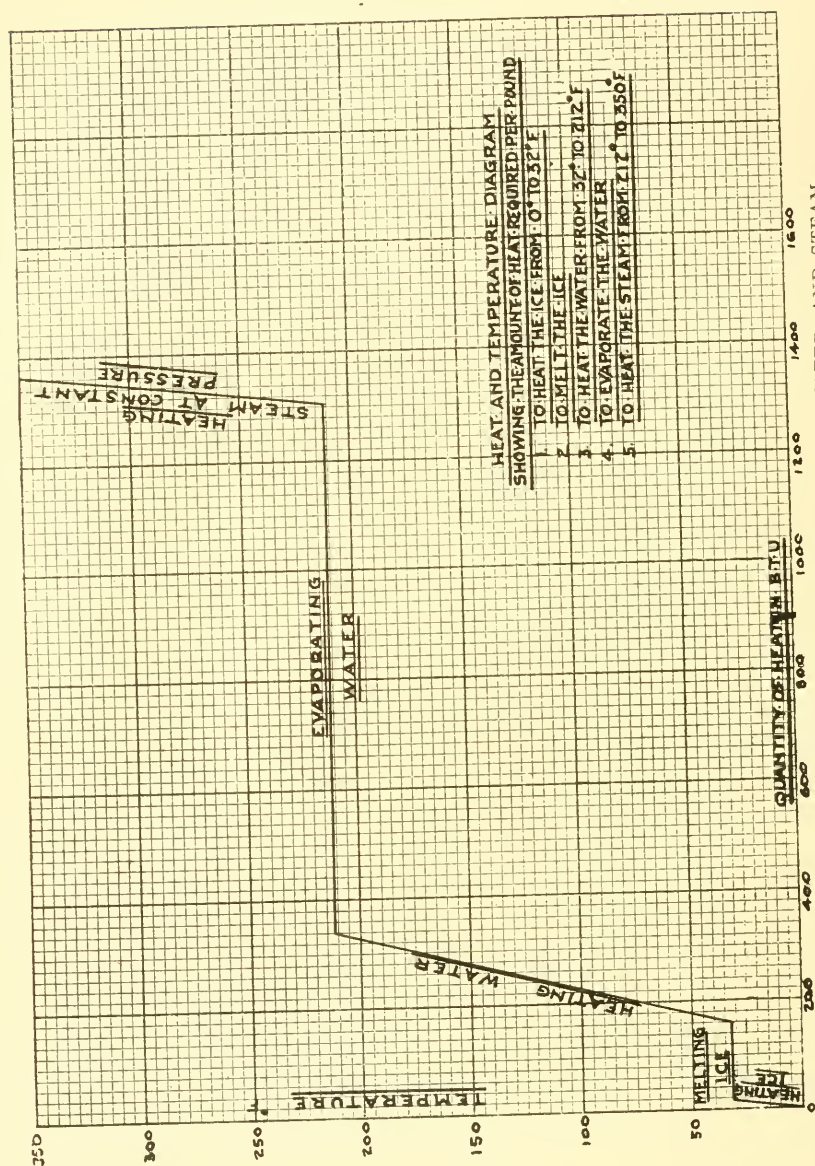


FIG. 1. HEAT TEMPERATURE DIAGRAM FOR ICE, WATER AND STEAM.

Water.—Some of the dissolved solids found in ordinary tap water are as follows:

| | |
|------------------------|-----------------------|
| Silica, | Sulphate of soda, |
| Carbonate of iron, | Chloride of soda, |
| Alumina, | Carbonate of soda, |
| Carbonate of lime, | Chloride of lime, |
| Sulphate of lime, | Chloride of magnesia. |
| Carbonate of magnesia, | |

The first six of this list are scale forming solids.

CHAPTER III

REFRIGERANTS

General Requisites.—The most desirable refrigerant should possess the following properties:

1. A high latent heat as well as a high ratio of the latent heat to the specific heat of the liquid, in order to produce a large refrigerating effect per cycle of operation.
2. A boiling point at ordinary atmospheric pressure low enough to obtain the temperature desired.
3. A condensing temperature at a relatively low pressure.
4. A low specific volume of vapor.
5. A high critical temperature.
6. A low ratio of compression.
7. A non-corrosive action on metals.
8. A chemical composition which is stable under working conditions and inert on lubricants and gaskets.
9. A non-inflammable and non-explosive nature even when mixed with air.
10. An inoffensive odor, non-injurious to health.
11. A behavior whereby its presence in small quantities may be visibly detected by a simple test.
12. A low cost of production for a product of necessary chemical purity for commercial use.
13. No affinity for constituents of the atmosphere whereby leaks might form gases or acids effecting the normal operation of the system.
14. A non-corrosive action on desirable bearing materials.

Refrigerants for Household Systems.—There are approximately 500,000 household refrigerating machines in operation

in the United States. Sulphur dioxide is the refrigerant used in more than 75 per cent of these systems. Some of the other mediums employed are: methyl chloride, ethyl chloride, butane, isobutane, ammonia, propane, carbon dioxide, ether, air and water vapor.

Ammonia is used in more than 90 per cent of the larger or commercial refrigerating plants.

Carbon dioxide is now used extensively for refrigerating systems in boats where formerly ethyl chloride and air machines were favored. Carbon dioxide and air machines are considered safer than machines with other refrigerants, in case of accident or fire. Carbon dioxide is used rather extensively in Europe for small household machines and its use in cooling theatres and public buildings is increasing in the United States.

Ether has some use in small hand operated machines which are manufactured in Europe and sold in the tropics.

Nitrous oxide has a limited use in the chemical industries when very low temperatures are desired.

Pressure of Condensation.—The condensing pressure should be comparatively low. Assuming 86° F. as the condensing temperature, the following pressures are obtained with the refrigerants in common use:

| | | |
|----------------------|--------|------------|
| Ether | 2.4 | Lbs. Gauge |
| Ethyl Chloride..... | 12.40 | Lbs. Gauge |
| Sulphur Dioxide..... | 51.75 | Lbs. Gauge |
| Methyl Chloride..... | 80.83 | Lbs. Gauge |
| Propane | 143.0 | Lbs. Gauge |
| Ammonia | 154.5 | Lbs. Gauge |
| Ethane | 666.0 | Lbs. Gauge |
| Nitrous Oxide..... | 915.3 | Lbs. Gauge |
| Carbon Dioxide..... | 1024.3 | Lbs. Gauge |

The high condensing pressure reached with carbon dioxide and even ammonia, necessitates very strong and well made apparatus. The carbon dioxide machines in use today are water cooled. The ammonia machines are also water cooled. Air cooled ammonia machines have been built but have not been used commercially. Sulphur dioxide machines have been placed on the market, both as water cooled and air cooled. The air cooled operate at a condensing pressure of 10 to 20 pounds higher than the water cooled type. Air cooling lowers

the efficiency, but increases the simplicity of the refrigerating system. A study of the development of household machines indicates that it is very desirable to use air cooled condensers to obtain simplicity, lower initial cost, and lower installation costs. Air cooled condensers are now used almost universally in household machines of the compression type.

It has not proven practical to use air cooling for refrigerants operating at a condensing pressure of more than 150 lbs. gauge. It is usually necessary to centralize the piping with refrigerants having a condensing pressure of over 150 lbs. gauge and distribute the refrigeration by means of a brine system.

Pressure of Vaporization.—The following evaporating pressures are obtained with the refrigerants in common use at 5° F., evaporating temperature.

| | | |
|-----------------------|--------|------------|
| Ether | —13.19 | Lbs. Gauge |
| Ethyl Chloride | —10.05 | Lbs. Gauge |
| Sulphur Dioxide | —2.88 | Lbs. Gauge |
| Methyl Chloride..... | 6.19 | Lbs. Gauge |
| Ammonia | 19.57 | Lbs. Gauge |
| Propane | 30.5 | Lbs. Gauge |
| Ethane | 221.0 | Lbs. Gauge |
| Nitrous Oxide..... | 318.3 | Lbs. Gauge |
| Carbon Dioxide..... | 319.7 | Lbs. Gauge |

The evaporating pressure has an important influence on the stuffing box. The packing is usually made to take up wear automatically. It is advantageous to have nearly the same pressure on both sides of the packing.

Sulphur dioxide operates at an evaporating pressure very close to atmospheric pressure, thus favoring this condition better than any of the other refrigerants in common use.

With a refrigerant such as ethyl chloride, which normally operates with a partial vacuum on the evaporator, it is very difficult to locate a leak as air could enter the system unnoticed, and would greatly reduce the efficiency of the apparatus.

Some household machines have all moving parts entirely enclosed, thus eliminating this packing gland difficulty. The compressors so far designed with a method of eliminating the packing gland include the design features which have not as yet proven practical in large quantity production. Other

machines have an oil reservoir on both sides of the stuffing box, so that any small leak would be of oil either into or out of the compressor crank case. This would depend upon the pressure inside the crank case being above or below atmospheric pressure.

Latent Heat of Vaporization.—The latent heat of vaporization should be carefully considered in selecting a refrigerant for a household machine. One of the most difficult problems is the expansion valve, float valve, or liquid restriction device, which controls the rate of flow of liquid from the condensing to the evaporating side of the system. With a high latent heat of vaporization, this problem is more difficult, as it is then necessary to control through a more sensitive valve (the amount of liquid circulating per minute being less). In making this comparison it is also necessary to consider the condensing and evaporating pressures. These determine the pressure differential trying to force the liquid through the expansion valve.

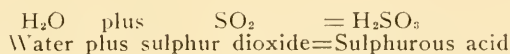
This problem is more difficult with ammonia than with sulphur dioxide, as it is necessary to circulate three to four times more refrigerant in the sulphur dioxide system, because of its lower latent heat of vaporization, while the pressure differential between the condensing and evaporating sides are less than in an ammonia system. On larger refrigerating systems, the liquid control problem is less difficult; therefore, a refrigerant with a high latent heat of vaporization is preferred.

Carbon dioxide has a very low latent heat of vaporization, about half that of sulphur dioxide. However, the pressure differential is so great as to more than offset the advantage of having a lower latent heat.

The latent heat of vaporization of the household refrigerants in common use at 5° F. is:

| | | | | |
|----------------------|--------|--------|-----|-----|
| Carbon Dioxide..... | 115.30 | B.t.u. | per | Lb. |
| Nitrous Oxide..... | 121.4 | B.t.u. | per | Lb. |
| Sulphur Dioxide..... | 169.38 | B.t.u. | per | Lb. |
| Propane | 169.5 | B.t.u. | per | Lb. |
| Ethane | 176.0 | B.t.u. | per | Lb. |
| Ethyl Chloride..... | 177.0 | B.t.u. | per | Lb. |
| Methyl Chloride..... | 178.5 | B.t.u. | per | Lb. |
| Ammonia | 565.0 | B.t.u. | per | Lb. |

Corrosion of Metals.—An important factor in choosing a refrigerant is the corrosive action on metals. Sulphur dioxide has no corrosive action on iron or steel, unless there is water present. Water and sulphur dioxide combine chemically as follows:



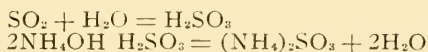
Sulphurous acid is formed, which will attack iron. This condition sometimes occurs, resulting in a so-called "frozen" compressor. The pistons will "freeze" to the cylinders so tightly that it is necessary to take the compressor apart and remove such material before operating again.

Sulphur dioxide has no chemical or corrosive action on copper or copper alloys, thus permitting the use of copper tubes for the condensing and cooling elements. This is an advantage, as the thermal conductivity of copper is seven or eight times greater than that of steel or iron. Copper or copper alloys cannot be used with ammonia when there is water present. Copper can be used with anhydrous ammonia. Copper lines are used on some absorption machines using a solid absorbent and charged with anhydrous ammonia.

Methyl chloride, ethyl chloride, butane, and carbon dioxide have no chemical or corrosive action on copper, copper alloys, iron or steel; therefore, these refrigerants may be used with any of these metals.

Testing for Gas Leaks.—Sulphur dioxide is one of the two refrigerants, ammonia being the other, with which it is possible to find leaks by means of a visible method called the "smoke" test.

The smoke test consists of placing aqua ammonia near the sulphur dioxide leak. A chemical reaction occurs and dense white smoke apparently issues from the opening.



$(\text{NH}_4)_2\text{SO}_3$ is a white solid ammonium sulphite. A burning sulphur stick is used in testing for an ammonia leak.

A small alcohol flame is sometimes used in testing for an appreciable leak of methyl chloride. The flame is passed near the connections to be tested. A leak of methyl chloride will

impart a green color to the nearly colorless alcohol flame. There is no danger of igniting an explosive mixture of methyl chloride and air in making this test. It is necessary to have at least 10 per cent and not more than 15 per cent of methyl chloride present by volume to form an explosive mixture with air. It is impossible to remain in a room for more than a minute or two with this concentration present because of the physiological effect upon breathing.

Another method used to find leaks of methyl chloride is to use a small electrically heated wire. The wire is heated to a dull red temperature. While the wire is being applied, the fumes of ammonia are brought near. If methyl chloride is present a fume will result, due to the decomposition of the methyl chloride to hydrochloric acid and carbon and the reconstruction of the hydrochloric acid set free with the ammonia.

Comparisons of Refrigerants for Household Machines.—From foregoing considerations it will be observed that the operating pressures, latent heat of vaporization, facility for testing for gas leakage, inflammability, corrosive action on

TABLE XI.—REFRIGERANTS FOR HOUSEHOLD MACHINES.
Relative Advantage for Use in Household Machines.
Listed in order of preference under each heading.

| Operating Pressures | Latent Heat of Vaporization | Testing for Gas Leaks | Inflammability | Corrosive Action on Metals | Danger of Breathing Small Concentration of Gas in Air | Lubrication |
|---------------------|-----------------------------|-----------------------|-----------------|----------------------------|---|-----------------|
| Sulphur dioxide | Carbon dioxide | Ammonia | Carbon dioxide | Methyl chloride | Carbon dioxide | Sulphur dioxide |
| Methyl chloride | Sulphur dioxide | Sulphur dioxide | Sulphur dioxide | Ethyl chloride | Ethyl chloride | Ammonia |
| Ammonia | Ethyl chloride | Methyl chloride | Ammonia | Ether | Methyl chloride | Methyl chloride |
| Ethyl chloride | Methyl chloride | Ether | Methyl chloride | Carbon dioxide | Ether | Ether |
| Ether | Ether | Ethyl chloride | Ethyl chloride | Sulphur dioxide | Ammonia | Carbon dioxide |
| Carbon dioxide | Ammonia | Carbon dioxide | Ether | Ammonia | Sulphur dioxide | Ethyl chloride |

metals, danger of breathing, and lubrication, are the principle factors to be considered in the selection of a suitable refrigerant for household refrigerating machines. With these factors

in mind, the author has prepared Table XI, to show the relative advantages of various refrigerants in household machines. These are listed in order of preference, under each of the headings for sulphur dioxide, ethyl chloride, ammonia, methyl chloride, ether, and carbon dioxide.

Characteristics Influencing Selections.—The following are some of the general characteristics influencing the selection of refrigerants:

1. The condensing pressure should be reasonably low at tap water or atmospheric air temperatures, depending upon the cooling medium used. The evaporating pressure necessary to freeze ice in a reasonable length of time should be close to atmospheric pressure, preferably above, to prevent gas leaks when a stuffing box is used. The ratio of compression between the condensing pressure and pressure of vaporization should be small in order to facilitate the functioning of the expansion valve.

2. A low latent heat of vaporization is preferred so that a larger amount of liquid refrigerant circulates to do the same amount of cooling. This makes the expansion valve or liquid control restriction less sensitive and permits the valve to leak more without affecting normal operation.

3. A refrigerant having a visible or "smoke" test for leaks is preferable as it is then not necessary to test every joint with oil or soap water. It is extremely difficult to find leaks if a refrigerant operates at a pressure less than atmospheric as air can leak into the apparatus affecting normal operation before the leak is detected.

4. A non-inflammable refrigerant is preferred in order to prevent danger in case of a gas leak in the refrigerating system in a home and also to prevent danger in case of fire.

5. A refrigerant is favored which does not have a corrosive or chemical action on metals. It is advantageous to be able to use copper and copper alloys for heat interchange apparatus on account of the higher rate of heat conductivity. Some refrigerants have a corrosive effect on metals when water or gases from the atmosphere are allowed to enter the refrigerating system.

6. Preference is given to the different refrigerants in accordance with the percentage of gas, which, when mixed with air, will not give discomfort when breathed for a considerable length of time.

7. It is preferable to use oil as a lubricant. It is desirable to eliminate the oil trap. The lubricant problem is more difficult when larger volumes of gas must be compressed, often necessitating a rotary compressor.

Amount of Refrigerant to Be Evaporated.—The relative amount of the liquid refrigerant to be evaporated to produce refrigeration at a given rate depends upon the relative latent heat of vaporization and sensible heat of the respective refrigerant. Generally, those refrigerants which have high latent heat of evaporation require a small amount of liquid to be evaporated to produce a given refrigerating effect. This is illustrated by ammonia, which has a fairly large latent heat of evaporation. On the other hand, certain refrigerants have

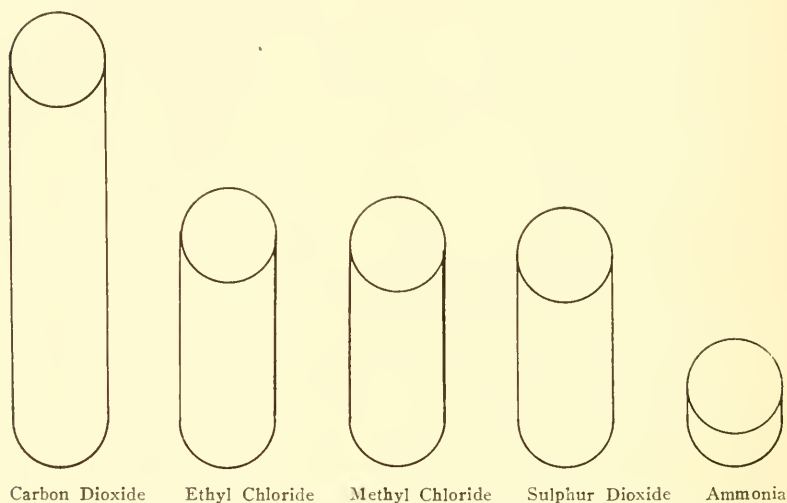


FIG. 2—AMOUNT OF LIQUID REFRIGERANT TO BE EVAPORATED

low latent heats of evaporation, in which case, the sensible heat of the liquid corresponds to a large proportion of the available latent heat of evaporation. By sensible heat of liquid is meant the heat required to cool the liquid refrigerant from the temperature at the exit from the condenser, or at a point just before the expansion valve to the temperature existing in the evaporator. Carbon dioxide is one of the representative refrigerants which has a fairly small latent heat of evaporation. Fig. 2 shows graphically the amount of refrigerant which must be evaporated per minute to produce one pound of ice melting effect per 24 hours for carbon dioxide, ethyl chloride, methyl chloride, sulphur dioxide, and ammonia.

Use of Refrigerants in the United States.—The various types of refrigerating plants using different refrigerants in the United States may be classified into large commercial plants, small commercial plants, marine installations, and household refrigerating machines. In a large commercial plant, it will be found that ammonia is used extensively; in small commercial plants ammonia is used extensively also; in marine installations, carbon dioxide is used extensively, and in the household machines, sulphur dioxide is used extensively. Table XII shows the use of the different refrigerants in the United States at present.

TABLE XII.—USE OF REFRIGERANTS IN UNITED STATES
Table Showing Present Usage in U. S. for Various Types of Refrigerating Plants.

| | Large Commercial Plants | Small Commercial Plants | Marine Installations | Household Machines |
|--------------------------|-------------------------------|-------------------------------|-------------------------|-----------------------|
| Ammonia (Compression) | Extensive | Extensive | Limited | Very Limited |
| Sulphur Dioxide | None | None | Very Limited | Extensive |
| Methyl Chloride | None | None | Very Limited | Limited |
| Ethyl Chloride | None | None | Very Limited | Limited |
| Carbon Dioxide | Limited | Limited | Extensive | Very Limited |
| Air | None | None | Very Limited | Very Limited |
| Ammonia (Absorption) | Limited | Limited | None | Limited |
| Isobutane | None | None | None | Limited |

Comparative Cylinder Displacements.—On account of the fact that the different refrigerants have different latent heats of evaporation and sensible heats of liquid, as well as specific volumes of vapors, it is evident that the cylinder displacements will be individual with each kind of refrigerant. Those refrigerants which have high refrigerating effects with corresponding low specific volumes of vapor, will require the minimum cylinder displacements, while those which have low refrigerating effects, and correspondingly large specific volumes of vapor, will require the maximum cylinder displacements. The converse of this may be stated by giving the refrigerating effect per cubic foot of cylinder displacement. Table XIII has been prepared to show the relative refrigeration per cubic foot of cylinder displacement for an evaporating temperature of 5° F., and a condensing temperature of 86° F. for some of the common refrigerants. From this table, it will be noted

that ethyl chloride has a very small refrigerating effect per cubic foot of cylinder displacement, that carbon dioxide has a high refrigerating effect per cubic foot, and that sulphur dioxide, methyl chloride, and ammonia, have a medium refrigerating effect per cubic foot of cylinder displacement.

TABLE XIII—COMPARATIVE REFRIGERATION PER CU. FT. OF CYLINDER DISPLACEMENT

For 5° F. Suction Temperature and 86° F. Condensing Temperature

| | Sulphur Dioxide | Ammonia | Methyl Chloride | Carbon Dioxide | Ethyl Chloride |
|---|--------------------|-----------------|--------------------|-------------------|----------------------------------|
| Chemical Symbol, | SO ₂ | NH ₃ | CH ₃ CL | CO ₂ | C ₂ H ₅ CL |
| Latent Heat at 5° F. | 169.38 | 565.0 | 178.56 | 115.3 | 177.0 |
| Heat to Cool Liquid. | 28.01 | 90.55 | 38.15 | 58.61 | 34.7 |
| Refrigerating Effect per lb. . | 141.37 | 474.45 | 140.41 | 56.69 | 142.3 |
| Specific Volume Vapor at 5° F. (cu. ft. per lb.) . . . | 6.421 | 8.15 | 4.53 | 0.2673 | 17.06 |
| Refrigerating Effect per cu. ft. Cylinder Dis- placement. | 22.17 | 58.22 | 31.00 | 212.08 | 8.35 |

Properties of Ammonia.—Ammonia is a colorless, gaseous compound of nitrogen and hydrogen. Its chemical formula is NH₃, indicating that one atom of nitrogen unites with three atoms of hydrogen to form ammonia. Its boiling point at atmospheric pressure is —28° F. It has a melting point of —107.86° F.

Color and Odor.—Ammonia is a colorless, transparent liquid or gas. It has an extremely pungent, peculiar, and offensive odor which is easily recognizable and irrespirable.

Inflammability.—It does not support combustion. However, under high pressure it may form an explosive mixture when intermingled with oil vapor. It is decomposed into its elements by extreme heat and under such conditions, an explosive mixture may result. It is combustible when mixed with a sufficient proportion of air, being capable of exploding with considerable violence.

Corrosion of Metals.—It will attack copper and all of its alloys when water is present, but it has no chemical or corrosive action on iron and steel. Ammonium hydroxide has a

slight reaction on iron when in a very dilute concentration. With the higher concentrations used in ammonia absorption plants, no reaction occurs on iron.

Locating Leaks.—Ammonia leaks may be readily located by the "smoke" test which consists of placing a burning sulphur stick in the vicinity of the leak. A chemical reaction occurs and a dense white smoke apparently issues from the opening.

Stability Toward Heat.—It is a rather stable gas especially at temperatures under 300° F. However, the chemical bond is not as strong as with carbon dioxide and sulphur dioxide. A household compressor should always have a discharge gas temperature lower than 300° F.

Solubility in Water.—It is very soluble in water, the union of the two producing considerable heat and forming ammonium hydroxide until a certain concentration has been reached. The vapor may then be driven off by heating the ammonium hydroxide, and it is on this principle that the absorption system operates.

Properties of Butane.—Butane is one of the isomeric, inflammable gaseous hydrocarbons of the methane series. Its chemical formula is C_4H_{10} , indicating that four atoms of carbon unite with ten atoms of hydrogen to form butane. It has a boiling point of 31° F. at normal atmospheric pressure and a melting point of 211° F.

Color and Odor.—Butane is a colorless liquid or gas, with a slight ethereal odor and is slightly asphyxiating. The vapor is non-poisonous.

Inflammability.—It is inflammable, the gas burning with a yellow flame.

Corrosion of Metals.—It has no corrosive effect on copper, copper alloys or iron, even in the presence of moisture.

Locating Leaks.—It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—It is a stable gas which does not break up at temperatures encountered in normal operation. The critical temperature is 551.3° F.

Displacement Required.—The displacement required for a certain amount of refrigeration is about 7 per cent more than with sulphur dioxide.

Properties of Carbon Dioxide (Carbonic Acid Gas).—Carbon dioxide is a heavy, colorless gas; it is sometimes called carbonic acid gas. This is on account of the fact that the acid, carbonic acid, H_2CO_3 breaks down readily into water and carbon dioxide, CO_2 ; the latter is commonly called carbon dioxide or carbonic acid gas. It has a chemical symbol, CO_2 , which indicates that one atom of carbon unites with two atoms of oxygen to form carbon dioxide. At normal atmospheric pressure, it has a boiling temperature of -108.4° F. and if the liquid is sufficiently cooled, it is solidified into a snowlike substance, which evaporizes or sublimates at -160.6° F.

Color and Odor.—Carbon dioxide, sometimes called carbonic acid gas, is a colorless liquid or gas. It exists as a gas in very small quantities in the atmosphere and is non-odorous. It is harmless to breathe except in extremely large concentrations when the lack of oxygen would be noticed.

Inflammability.—It is not inflammable and does not support combustion.

Corrosion of Metals.—It has no corrosive effect on copper, copper alloys or iron.

Locating Leaks.—It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—It is a stable gas which does not break up at the temperature encountered in normal operation. This gas is very inert. The critical temperature is 87.80° F.

Solubility in Water.—It is slightly soluble in water, the percentage increasing at lower temperatures.

Displacement Required.—It requires about one-fourth the displacement of an ammonia machine to do the same amount of refrigeration.

Properties of Ethane.—Ethane is a gaseous hydrocarbon, and is a constituent of ordinary natural and illuminating gas. It is a second member of the methane series, and has the chemical symbol C_2H_6 . It has a boiling point of $-126.9^\circ F.$ and a melting point of $-277.6^\circ F.$

Color and Odor.—Ethane is a colorless liquid or gas of the hydrocarbon series. The gas is non-poisonous. It has an ethereal odor and is slightly asphyxiating.

Inflammability.—It is inflammable, burning with a yellow flame.

Corrosion of Metals.—It has no corrosive effect on metals and does not form injurious acids with water.

Locating Leaks.—It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—This gas is stable under the conditions of pressure and temperature required in refrigeration work.

Displacement Required.—The displacement required is about 40 per cent greater than with carbon dioxide.

Properties of Ether.—Ether is a light, volatile, inflammable gas, having a characteristic aromatic odor, and is obtained by the distillation of alcohol with sulphuric acid, and is thus sometimes termed "sulphuric ether." It has the chemical symbol $C_4H_{10}O$. Its boiling point is $94.1^\circ F.$, and its melting point is $-177.34^\circ F.$

Color and Odor.—Ether is a colorless gas or liquid with a strong ethereal smell.

Inflammability.—It burns with a luminous flame and explodes when mixed with air.

Corrosion of Metals.—It has no corrosive action on metals

Locating Leaks.—It is difficult to locate leaks, especially on the evaporating side, as this is usually operating at a vacuum. Air leaking into the system would cause no damage

from chemical action or corrosion; however, it would soon increase the condensing pressure, affecting the normal operation of the system.

Stability Towards Heat.—It is stable at the temperatures reached in the condensing element. The gas condenses during compression and superheats during expansion.

It is miscible with water.

Properties of Ethyl Chloride.—Ethyl chloride is a colorless and a very volatile liquid, having an aromatic odor. It is used widely as a local anaesthetic. Its chemical symbol is C_2H_5Cl . It has a boiling point of $53.96^\circ F.$, and a melting point of $-217.66^\circ F.$

Color and Odor. — Ethyl chloride is a colorless gas or liquid with a pungent ethereal smell and a sweetish taste.

Inflammability. — It is inflammable when mixed with a certain proportion of air. It burns with a green-edged flame. A certain quality of ethyl chloride has been produced in England which is claimed to be non-inflammable. This result is obtained by the addition of a certain amount of methyl bromide.

Corrosion of Metals. — It has no corrosive effect on metals.

Locating Leaks. — It is very difficult to locate leaks, especially on the evaporating side of the system, as the pressure of evaporation is considerably below atmospheric pressure.

Stability Towards Heat. — It is stable toward heat and does not fractionize at the temperatures reached in the condenser. The critical temperature is $361.0^\circ F.$

Solubility in Water.—It is slightly soluble in water and dissolves oils. Glycerine is used as a lubricant in some ethyl chloride systems.

Properties of Methyl Chloride.—Methyl chloride is the colorless, sweet-smelling gas which is obtained by the action of hydrochloric acid on methyl alcohol. It is easily liquefied by pressure and cold, and is used as a refrigerant and a local anaesthetic. It has a chemical symbol of CH_3Cl , and has a boiling point of $-10.66^\circ F.$, and a melting point of $-143.68^\circ F.$

Color and Odor.—Methyl chloride is a colorless, transparent liquid or gas. The odor resembles that of chloroform; however, it is not so heavy and is less sweet.

Inflammability.—It is inflammable in concentrations of at least 10 per cent and not more than 15 per cent with air. It requires a spark or white hot wire to explode it even at these concentrations.

Corrosion of Metals.—It does not attack copper, copper alloys or iron.

Locating Leaks.—Methyl chloride operates with a pressure greater than atmospheric on both the condensing and evaporating units of the system. A large leak would force methyl chloride gas into the room where its presence might be noticed by the peculiar odor. One method of testing for leaks is by means of an alcohol flame, for methyl chloride gas will impart a green color to the nearly colorless alcohol flame.

Stability Towards Heat.—It is very stable towards heat. It requires a red heat to decompose it into hydrochloric acid, methane, hydrogen, etc. The critical temperature is 289.6°F .

Solubility in Water.—Three to four volumes of methyl chloride gas will dissolve into one volume of water at ordinary temperature and atmospheric pressure. Methyl chloride in the presence of water may form a solid crystalline hydrate $\text{CH}_3\text{Cl} \cdot 6\text{H}_2\text{O}$.

Properties of Propane.—Propane is one of the heavy gaseous hydrocarbons of the paraffin series. It occurs, naturally, dissolved in crude petroleum. It has the chemical symbol C_3H_8 , a boiling point of -48.1°F ., and a melting point of -309.8°F .

Color and Odor.—Propane is a colorless liquid or gas of the hydrocarbon series. The gas is non-poisonous and is not dangerous to breathe until its density is sufficient to exclude the oxygen necessary during respiration. It has an ethereal odor and is slightly asphyxiating.

Inflammability.—It is inflammable. The gas burns with a yellow flame.

Corrosion of Metals.—It has no corrosive action on any metals and does not form injurious acids with water.

Locating Leaks.—It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—It is stable under the conditions required in refrigeration work. The critical temperature is 204.1° F.

Displacement Required.—The displacement required is practically the same as with ammonia.

Properties of Sulphur Dioxide.—Sulphur dioxide is a colorless gas, having a pungent, suffocating odor. It is produced by the burning of sulphur. It has a chemical symbol, SO_2 , and a boiling point of 14° F., and a melting point of -98.86° F.

Color and Odor.—Sulphur dioxide is a colorless liquid or gas. The gas is non-poisonous.

Inflammability.—It is not inflammable and does not support combustion.

Corrosion of Metals.—It has no corrosive effect on copper, copper alloys or iron. If there is water present, sulphurous acid is formed which will have a chemical action on metals such as iron, zinc, or copper. The moisture should be under 0.3 per cent by volume for commercial use.

Locating Leaks.—It is easy to locate leaks by a smoke test, using ammonia water applied with a brush.

Stability Towards Heat.—It is a very stable gas which will easily withstand the temperature conditions encountered in normal operation. The critical temperature is 314.8° F. The critical pressure is 1141.5 pounds per square inch absolute.

Solubility in Water.—One volume of water dissolves 80 volumes of this gas at 32° F., and 47.3 volumes at 60° F.

Displacement Required.—It requires about 2.6 times the displacement of an ammonia machine for the same amount of refrigeration.

Air.—Air was used as the refrigerant in some of the early machines. It was compressed, cooled to room temperature, and then expanded in a cylinder. These machines were very inefficient because of the large volume of air handled, which together with the expansion cylinder, caused large friction losses. Air has a very low heat capacity per unit volume. Considerable difficulty was experienced with the moisture freezing and clogging valves. The advantages of using air such as safety from leakage do not compensate for the disadvantages stated above.

Two general types of air machines have been produced. These are the open and closed cycle. The open cycle type continually uses new air from the atmosphere. There is considerable trouble from condensing and freezing water vapor within the apparatus. The closed cycle eliminates this disadvantage.

Water as a Refrigerant.—Several machines have been developed using water as the refrigerant. At a low vacuum water boils at temperatures as follows:

| | | | | |
|------------------------------|--------|--------|--------|--------|
| Vacuum, ins. of mercury..... | 29.74 | 29.67 | 29.56 | 29.40 |
| Boiling temperature | 32° F. | 40° F. | 50° F. | 60° F. |

It is difficult to produce a commercial pump to obtain such a low vacuum. The air in the water must also be discharged.

Sulphuric acid is used to absorb the water in some systems of this kind. A pump must be used to remove the air.

Small hand machines are made in Europe to operate on this system. They will cool a carafe of water in a few minutes or make a few pounds of ice in less than half an hour. This type of machine is used extensively in the tropics.

Non-Condensable Gases.—It is important to prevent the formation of non-condensing gases in a household ammonia absorption refrigerating machine. These gases are eliminated on the larger plants by frequent purging.

The United States Bureau of Standards has recently made a careful study of this subject and recommends the following method of eliminating, to a large extent, the formation of these gases:

1. The non-condensable gases found in ammonia absorption refrigeration machines are due to either or both of two causes, namely, (a) leaks of air into the system and (b) the corrosive action of the ammonia liquor on the metal of the plant.

2. When the foul air gas is mainly nitrogen, the gas is derived from air that has leaked into the system, and leaks should therefore be sought. The oxygen in the air is very quickly used up, and so will be present in only a very small percentage of its original amount. If the foul gas is hydrogen, the cause is corrosion by the ammoniacal liquor. A gas containing both nitrogen and hydrogen shows both causes to be present.

3. If a solution of sodium or potassium dichromate is added to the generator charge so that the charge in the generator will contain the salt to the extent of 0.2 per cent by weight, all foul gas formation from the corrosive action of the ammonia charge will be stopped. It is recommended that the dichromate be added in all cases, as it has been found that its presence decreases the very small amount of gas caused by even the highest grade ammonias.

Explosion Data on Gases.—The following explosion data on refrigerating and illuminating gases was taken from a report on refrigerating with gas presented at a meeting of the American Gas Association, 1925.

TABLE XIV—EXPLOSION DATA ON GASES

| | Ammonia | Ethyl Chloride | Methyl Chloride | Illuminat- ing Gas |
|---|---------------------|----------------|-----------------|-----------------------|
| Relative parts of diffusion (Air=1) | 1.301 | 0.658 | 0.750 | 1.240 |
| Gas in mixture required for complete combustion (%) | 21.83 | 6.05 | 10.69 | 17.00 |
| Apparent ignition temperature (°F.) | No values available | | | 1094 |
| Explosion limits with air— | | | | |
| High (%) | 26.8 | 14.0 | 15.0 | 21.0 |
| Low (%) | 13.1 | 4.3 | 8.9 | 7.0 |
| Explosion pressures with air (lbs. sq. in.) | 54 | 98 | 81 | 95 |
| Time required to develop maximum pressure (seconds) | 0.175 | 0.049 | 0.099 | 0.017 |

Relative Piston Displacement for Refrigerants.—As previously indicated, the relative piston displacement for the compressor cylinder depends upon a number of factors, such as a latent heat of evaporation, sensible heat of the liquid, relative specific volume, etc. Table XV has been prepared to show

the comparative displacements of the various refrigerants indicated when compared with the displacement required by carbon dioxide.

TABLE XV.—RELATIVE PISTON DISPLACEMENT FOR VARIOUS REFRIGERANTS

| | | |
|-----------------------|---|------|
| Carbon dioxide | = | 1. |
| Ammonia | = | 3.6 |
| Methyl Chloride | = | 6.8 |
| Sulphur Dioxide | = | 9.6 |
| Ethyl Chloride | = | 25.4 |

Solubility of Sulphur Dioxide in Water.—Weights in grams of sulphur dioxide gas which will be absorbed in 1,000 grams of water when the partial pressure of the liquid at the given temperature equals 700 millimeters are as follows:

| | | | | |
|-------|--------|--------|--------|--------|
| 0° C. | 10° C. | 20° C. | 30° C. | 40° C. |
| 228 | 162 | 113 | 78 | 54 |

(This was compiled from Landoit-Börnstein-Meyerhoffers "Physikalisch-Chemische Tabellen.")

Charging Refrigerants.—Refrigerants may be charged into refrigerating systems or thermostats in many different ways. Following are some of the principles used in this refrigerant charging process:

There are two simple methods of charging the liquid refrigerant from container A to container B in Fig. 3. It is assumed that the air has been exhausted from these containers and the connecting line. The container B may be at a higher elevation than A. By heating container A, the liquid is evaporated and slowly condenses in B. This is a slow process as sufficient heat must be applied to A to heat and evaporate the liquid refrigerant and enough heat must be extracted from B to condense the gas. Another method is to apply ice or cool B.

When the outlet pipe from C is below the liquid level in C the liquid refrigerant will pass to D in liquid form. It is only necessary to either warm C or cool D. This establishes a pressure difference which readily forces the liquid into container D.

In charging household systems, it is customary to first use a vacuum pump to eliminate the air and moisture from the refrigerating system. Then the refrigerant is charged in liquid

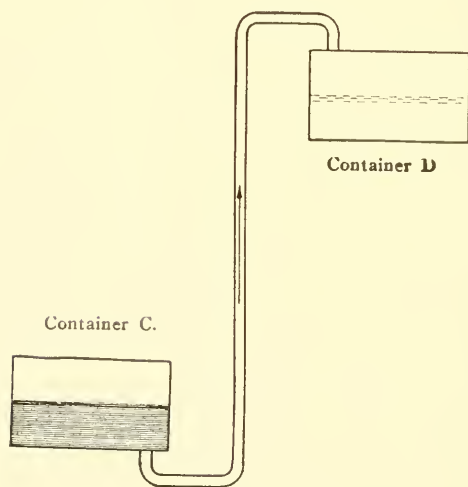
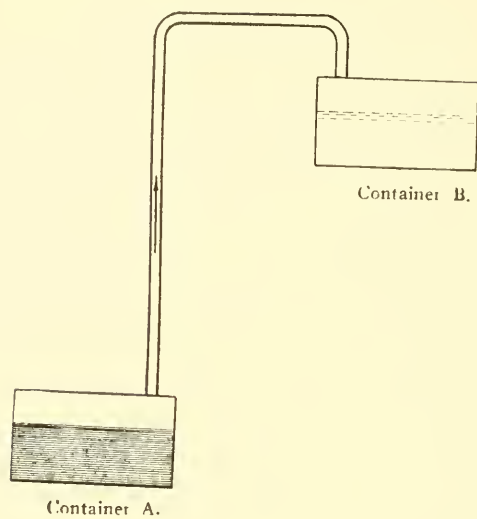


FIG. 3.—CHARGING OF REFRIGERANTS.

form. The amount of charge is regulated by weighing or using a glass liquid gauge on the charging receiver.

It is extremely dangerous to heat a cylinder containing liquid refrigerant. When the pressure drops in charging it is probably best to place the cylinder in a bucket of water in order to supply sufficient heat to evaporate the liquid refrigerant from the cylinder rapidly.

In charging a thermostat, it is very important to first eliminate the air. The best method is to use a vacuum pump, although it is possible to eliminate practically all of the air by repeatedly charging and discharging the thermostat bulb and line with the gas to be used. The liquid should fill about two-thirds of the bulb. An overcharged thermostat may cause considerable trouble.

Method of Determining the Density of a Gas.—The volume of any gas may be approximately determined from its molecular weight at atmospheric pressure of 14.7 lbs. and 60° F., as follows:

$$\text{Weight per cu. ft.} = \frac{\text{molecular weight}}{376}$$

$$\text{Cu. ft. per pound} = \frac{376}{\text{molecular weight}}$$

The volume of one cu. ft. of sulphur dioxide gas at 14.7 lbs. atmospheric pressure and 60° F. would be found as follows:

$$\frac{64}{376} = 0.170 \text{ lbs.}$$

The volume in cu. ft. per pound is found as follows:

$$\frac{376}{64} = 5.87$$

TABLE XVI.—MOLECULAR WEIGHT OF GASES

| Gas | Molecular Weight |
|---------------------------------------|------------------|
| Nitrogen—N ₂ | 28 |
| Oxygen—O ₂ | 32 |
| Carbon Dioxide—CO ₂ | 44 |
| Sulphur Dioxide—SO ₂ | 64 |
| Hydrogen—H ₂ | 2 |
| Ammonia—NH ₃ | 17 |
| Air | 28.8 |

CHAPTER IV.

REFRIGERANTS—TABLES.

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24. Compressibility of Liquids.—Table XLI.

HOUSEHOLD REFRIGERATION

TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(Continued.)

| Temp. °F. | Pressure. | | Volume vapor. ft./lb. | Density vapor. lbs./ft. ³ | Heat content. | | Latent heat. Btu./lb. | Entropy. | | Temp. °F. |
|--------------|------------------------------------|--------------------------------|-----------------------------|--|---------------------|--------------------|-----------------------------|------------------------|-----------------------|--------------|
| | Absolute. lbs./in. ² | Gage. lbs./in. ² | | | Liquid. Btu./lb. | Vapor. Btu./lb. | | Liquid. Btu./lb.°F. | Vapor. Btu./lb.°F. | |
| <i>t</i> | <i>p</i> | <i>g. p.</i> | <i>V</i> | <i>1/V</i> | <i>h</i> | <i>H</i> | <i>L</i> | <i>s</i> | <i>S</i> | <i>t</i> |
| -60 | 5.55 | *18.6 | 44.73 | 0.02235 | -21.2 | 589.6 | 610.8 | -0.0517 | 1.4769 | -60 |
| -59 | 5.74 | *18.2 | 43.37 | .02306 | -20.1 | 590.0 | 610.1 | -.0490 | .4741 | -59 |
| -58 | 5.93 | *17.8 | 42.05 | .02378 | -19.1 | 590.4 | 609.5 | -.0464 | .4713 | -58 |
| -57 | 6.13 | *17.4 | 40.79 | .02452 | -18.0 | 590.8 | 608.8 | -.0438 | .4686 | -57 |
| -56 | 6.33 | *17.0 | 39.56 | .02528 | -17.0 | 591.2 | 608.2 | -.0412 | .4658 | -56 |
| -55 | 6.54 | *16.6 | 38.38 | 0.02605 | -15.9 | 591.6 | 607.5 | -0.0386 | 1.4631 | -55 |
| -54 | 6.75 | *16.2 | 37.24 | .02685 | -14.8 | 592.1 | 606.9 | -.0360 | .4604 | -54 |
| -53 | 6.97 | *15.7 | 36.15 | .02766 | -13.8 | 592.4 | 606.2 | -.0334 | .4577 | -53 |
| -52 | 7.20 | *15.3 | 35.09 | .02850 | -12.7 | 592.9 | 605.6 | -.0307 | .4551 | -52 |
| -51 | 7.43 | *14.8 | 34.06 | .02936 | -11.7 | 593.2 | 604.9 | -.0281 | .4524 | -51 |
| -50 | 7.67 | *14.3 | 33.08 | 0.03023 | -10.6 | 593.7 | 604.3 | -0.0256 | 1.4497 | -50 |
| -49 | 7.91 | *13.8 | 32.12 | .03113 | -9.6 | 594.0 | 603.6 | -.0230 | .4471 | -49 |
| -48 | 8.16 | *13.3 | 31.20 | .03205 | -8.5 | 594.4 | 602.9 | -.0204 | .4445 | -48 |
| -47 | 8.42 | *12.8 | 30.31 | .03299 | -7.4 | 594.9 | 602.3 | -.0179 | .4419 | -47 |
| -46 | 8.68 | *12.2 | 29.45 | .03395 | -6.4 | 595.2 | 601.6 | -.0153 | .4393 | -46 |
| -45 | 8.95 | *11.7 | 28.62 | 0.03494 | -5.3 | 595.6 | 600.9 | -0.0127 | 1.4368 | -45 |
| -44 | 9.23 | *11.1 | 27.82 | .03598 | -4.3 | 596.0 | 600.3 | -.0102 | .4342 | -44 |
| -43 | 9.51 | *10.6 | 27.04 | .03698 | -3.2 | 596.4 | 599.6 | -.0076 | .4317 | -43 |
| -42 | 9.81 | *10.0 | 26.29 | .03804 | -2.1 | 596.8 | 598.9 | -.0051 | .4292 | -42 |
| -41 | 10.10 | *9.3 | 25.56 | .03912 | -1.1 | 597.2 | 598.3 | -.0025 | .4267 | -41 |
| -40 | 10.41 | *8.7 | 24.86 | 0.04022 | 0.0 | 597.6 | 597.6 | 0.0000 | 1.4242 | -40 |
| -39 | 10.72 | *8.1 | 24.18 | .04135 | 1.1 | 598.0 | 596.9 | .0025 | .4217 | -39 |
| -38 | 11.04 | *7.4 | 23.53 | .04251 | 2.1 | 598.3 | 596.2 | .0051 | .4193 | -38 |
| -37 | 11.37 | *6.8 | 22.89 | .04369 | 3.2 | 598.7 | 595.5 | .0076 | .4169 | -37 |
| -36 | 11.71 | *6.1 | 22.27 | .04489 | 4.3 | 599.1 | 594.8 | .0101 | .4144 | -36 |
| -35 | 12.05 | *5.4 | 21.68 | 0.04613 | 5.3 | 599.5 | 594.2 | 0.0126 | 1.4120 | -35 |
| -34 | 12.41 | *4.7 | 21.10 | .04739 | 6.4 | 599.9 | 593.5 | .0151 | .4096 | -34 |
| -33 | 12.77 | *3.9 | 20.54 | .04868 | 7.4 | 600.2 | 592.8 | .0176 | .4072 | -33 |
| -32 | 13.14 | *3.2 | 20.00 | .04999 | 8.5 | 600.6 | 592.1 | .0201 | .4048 | -32 |
| -31 | 13.52 | *2.4 | 19.48 | .05134 | 9.6 | 601.0 | 591.4 | .0226 | .4025 | -31 |
| -30 | 13.90 | *1.6 | 18.97 | 0.05271 | 10.7 | 601.4 | 590.7 | 0.0250 | 1.4001 | -30 |
| -29 | 14.30 | *0.8 | 18.48 | .05411 | 11.7 | 601.7 | 590.0 | .0275 | .3978 | -29 |
| -28 | 14.71 | 0.0 | 18.00 | .05555 | 12.8 | 602.1 | 589.3 | .0300 | .3955 | -28 |
| -27 | 15.12 | 0.4 | 17.54 | .05701 | 13.9 | 602.5 | 588.6 | .0325 | .3932 | -27 |
| -26 | 15.55 | 0.8 | 17.09 | .05850 | 14.9 | 602.8 | 587.9 | .0350 | .3909 | -26 |
| -25 | 15.98 | 1.3 | 16.66 | 0.06003 | 16.0 | 603.2 | 587.2 | 0.0374 | 1.3886 | -25 |
| -24 | 16.42 | 1.7 | 16.24 | .06158 | 17.1 | 603.6 | 586.5 | .0399 | .3863 | -24 |
| -23 | 16.88 | 2.2 | 15.83 | .06317 | 18.1 | 603.9 | 585.8 | .0423 | .3840 | -23 |
| -22 | 17.34 | 2.6 | 15.43 | .06479 | 19.2 | 604.3 | 585.1 | .0448 | .3818 | -22 |
| -21 | 17.81 | 3.1 | 15.05 | .06644 | 20.3 | 604.6 | 584.3 | .0472 | .3796 | -21 |
| -20 | 18.30 | 3.6 | 14.68 | 0.06813 | 21.4 | 605.0 | 583.6 | 0.0497 | 1.3774 | -20 |
| -19 | 18.79 | 4.1 | 14.32 | .06985 | 22.4 | 605.3 | 582.9 | .0521 | .3752 | -19 |
| -18 | 19.30 | 4.6 | 13.97 | .07161 | 23.5 | 605.7 | 582.2 | .0545 | .3729 | -18 |
| -17 | 19.81 | 5.1 | 13.62 | .07340 | 24.6 | 606.1 | 581.5 | .0570 | .3708 | -17 |
| -16 | 20.34 | 5.6 | 13.29 | .07522 | 25.6 | 606.4 | 580.8 | .0594 | .3686 | -16 |
| -15 | 20.88 | 6.2 | 12.97 | 0.07709 | 26.7 | 606.7 | 580.0 | 0.0618 | 1.3664 | -15 |
| -14 | 21.43 | 6.7 | 12.66 | .07898 | 27.8 | 607.1 | 579.3 | .0642 | .3643 | -14 |
| -13 | 21.99 | 7.3 | 12.36 | .08092 | 28.9 | 607.5 | 578.6 | .0666 | .3621 | -13 |
| -12 | 22.56 | 7.9 | 12.06 | .08289 | 30.0 | 607.8 | 577.8 | .0690 | .3600 | -12 |
| -11 | 23.15 | 8.5 | 11.78 | .08490 | 31.0 | 608.1 | 577.1 | .0714 | .3579 | -11 |
| -10 | 23.74 | 9.0 | 11.50 | 0.08695 | 32.1 | 608.5 | 576.4 | 0.0738 | 1.3558 | -10 |

* Inches of mercury below one standard atmosphere (29.92 in.).

REFRIGERANTS—TABLES

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TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(Continued.)

| Temp. °F. <i>t</i> | Pressure. | | Volume vapor, ft ³ /lb. | Density vapor, lbs./ft. ³ <i>1/V</i> | Heat content. | | Latent heat, Btu./lb. <i>L</i> | Entropy. | | Temp. °F. <i>t</i> |
|--------------------------|--|--|--|--|---------------------------------|--------------------------------|---|------------------------------------|-----------------------------------|--------------------------|
| | Absolute, lbs./in. ² <i>p</i> | Gage, lbs./in. ² <i>g. p.</i> | | | Liquid, Btu./lb. <i>h</i> | Vapor, Btu./lb. <i>H</i> | | Liquid, Btu./lb.°F. <i>s</i> | Vapor, Btu./lb.°F. <i>S</i> | |
| -10 | 23.74 | 9.0 | 11.50 | 0.08695 | 32.1 | 608.5 | 576.4 | 0.0738 | 1.3558 | -10 |
| -9 | 24.35 | 9.7 | 11.23 | .08904 | 33.2 | 608.8 | 575.6 | .0762 | .3537 | -9 |
| -8 | 24.97 | 10.3 | 10.97 | .09117 | 34.3 | 609.2 | 574.9 | .0786 | .3516 | -8 |
| -7 | 25.61 | 10.9 | 10.71 | .09334 | 35.4 | 609.5 | 574.1 | .0809 | .3495 | -7 |
| -6 | 26.26 | 11.6 | 10.47 | .09555 | 36.4 | 609.8 | 573.4 | .0833 | .3474 | -6 |
| -5 | 26.92 | 12.2 | 10.23 | .09780 | 37.5 | 610.1 | 572.6 | .0857 | 1.3454 | -5 |
| -4 | 27.59 | 12.9 | 9.991 | .1001 | 38.6 | 610.5 | 571.9 | .0880 | .3433 | -4 |
| -3 | 28.28 | 13.6 | 9.763 | .1024 | 39.7 | 610.8 | 571.1 | .0904 | .3413 | -3 |
| -2 | 28.98 | 14.3 | 9.541 | .1048 | 40.7 | 611.1 | 570.4 | .0928 | .3393 | -2 |
| -1 | 29.69 | 15.0 | 9.326 | .1072 | 41.8 | 611.4 | 569.6 | .0951 | .3372 | -1 |
| 0 | 30.42 | 15.7 | 9.116 | .1097 | 42.9 | 611.8 | 568.9 | .0975 | 1.3352 | 0 |
| 1 | 31.16 | 16.5 | 8.912 | .1122 | 44.0 | 612.1 | 568.1 | .0998 | .3332 | 1 |
| 2 | 31.92 | 17.2 | 8.714 | .1148 | 45.1 | 612.4 | 567.3 | .1022 | .3312 | 2 |
| 3 | 32.69 | 18.0 | 8.521 | .1174 | 46.2 | 612.7 | 566.5 | .1045 | .3292 | 3 |
| 4 | 33.47 | 18.8 | 8.333 | .1200 | 47.2 | 613.0 | 565.8 | .1069 | .3273 | 4 |
| 5 | 34.27 | 19.6 | 8.150 | .1227 | 48.3 | 613.3 | 565.0 | .1092 | 1.3253 | 5 |
| 6 | 35.09 | 20.4 | 7.971 | .1254 | 49.4 | 613.6 | 564.2 | .1115 | .3234 | 6 |
| 7 | 35.92 | 21.2 | 7.798 | .1282 | 50.5 | 613.9 | 563.4 | .1138 | .3214 | 7 |
| 8 | 36.77 | 22.1 | 7.629 | .1311 | 51.6 | 614.3 | 562.7 | .1162 | .3195 | 8 |
| 9 | 37.63 | 22.9 | 7.464 | .1340 | 52.7 | 614.6 | 561.9 | .1185 | .3176 | 9 |
| 10 | 38.51 | 23.8 | 7.304 | .1369 | 53.8 | 614.9 | 561.1 | .1208 | 1.3157 | 10 |
| 11 | 39.40 | 24.7 | 7.148 | .1399 | 54.9 | 615.2 | 560.3 | .1231 | .3137 | 11 |
| 12 | 40.31 | 25.6 | 6.996 | .1429 | 56.0 | 615.5 | 559.5 | .1254 | .3118 | 12 |
| 13 | 41.24 | 26.5 | 6.847 | .1460 | 57.1 | 615.8 | 558.7 | .1277 | .3099 | 13 |
| 14 | 42.18 | 27.5 | 6.703 | .1492 | 58.2 | 616.1 | 557.9 | .1300 | .3081 | 14 |
| 15 | 43.14 | 28.4 | 6.562 | .1524 | 59.2 | 616.3 | 557.1 | .1323 | 1.3062 | 15 |
| 16 | 44.12 | 29.4 | 6.425 | .1556 | 60.3 | 616.6 | 556.3 | .1346 | .3043 | 16 |
| 17 | 45.12 | 30.4 | 6.291 | .1590 | 61.4 | 616.9 | 555.5 | .1369 | .3025 | 17 |
| 18 | 46.13 | 31.4 | 6.161 | .1623 | 62.5 | 617.2 | 554.7 | .1392 | .3006 | 18 |
| 19 | 47.16 | 32.5 | 6.034 | .1657 | 63.6 | 617.5 | 553.9 | .1415 | .2988 | 19 |
| 20 | 48.21 | 33.5 | 5.910 | .1692 | 64.7 | 617.8 | 553.1 | .1437 | 1.2969 | 20 |
| 21 | 49.28 | 34.6 | 5.789 | .1728 | 65.8 | 618.0 | 552.2 | .1460 | .2951 | 21 |
| 22 | 50.36 | 35.7 | 5.671 | .1763 | 66.9 | 618.3 | 551.4 | .1483 | .2933 | 22 |
| 23 | 51.47 | 36.8 | 5.556 | .1800 | 68.0 | 618.6 | 550.6 | .1505 | .2915 | 23 |
| 24 | 52.59 | 37.9 | 5.443 | .1837 | 69.1 | 618.9 | 549.8 | .1528 | .2897 | 24 |
| 25 | 53.73 | 39.0 | 5.334 | .1875 | 70.2 | 619.1 | 548.9 | .1551 | 1.2879 | 25 |
| 26 | 54.90 | 40.2 | 5.227 | .1913 | 71.3 | 619.4 | 548.1 | .1573 | .2861 | 26 |
| 27 | 56.08 | 41.4 | 5.123 | .1952 | 72.4 | 619.7 | 547.3 | .1596 | .2843 | 27 |
| 28 | 57.28 | 42.6 | 5.021 | .1992 | 73.5 | 619.9 | 546.4 | .1618 | .2825 | 28 |
| 29 | 58.50 | 43.8 | 4.922 | .2032 | 74.6 | 620.2 | 545.6 | .1641 | .2808 | 29 |
| 30 | 59.74 | 45.0 | 4.825 | .2073 | 75.7 | 620.5 | 544.8 | .1663 | 1.2790 | 30 |
| 31 | 61.00 | 46.3 | 4.730 | .2114 | 76.8 | 620.7 | 543.9 | .1686 | .2773 | 31 |
| 32 | 62.29 | 47.6 | 4.637 | .2156 | 77.9 | 621.0 | 543.1 | .1708 | .2755 | 32 |
| 33 | 63.59 | 48.9 | 4.547 | .2199 | 79.0 | 621.2 | 542.2 | .1730 | .2738 | 33 |
| 34 | 64.91 | 50.2 | 4.459 | .2243 | 80.1 | 621.5 | 541.4 | .1753 | .2721 | 34 |
| 35 | 66.26 | 51.6 | 4.373 | .2287 | 81.2 | 621.7 | 540.5 | .1775 | 1.2704 | 35 |
| 36 | 67.63 | 52.9 | 4.289 | .2332 | 82.3 | 622.0 | 539.7 | .1797 | .2686 | 36 |
| 37 | 69.02 | 54.3 | 4.207 | .2377 | 83.4 | 622.2 | 538.8 | .1819 | .2669 | 37 |
| 38 | 70.43 | 55.7 | 4.126 | .2423 | 84.6 | 622.5 | 537.9 | .1841 | .2652 | 38 |
| 39 | 71.87 | 57.2 | 4.048 | .2470 | 85.7 | 622.7 | 537.0 | .1863 | .2635 | 39 |
| 40 | 73.32 | 58.6 | 3.971 | .2518 | 86.8 | 623.0 | 536.2 | .1885 | 1.2618 | 40 |

HOUSEHOLD REFRIGERATION

TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(Continued.)

| Temp. °F. | Pressure. | | Volume vapor. ft. ³ /lb. | Density vapor. lbs./ft. ³ | Heat content. | | Latent heat. Btu./lb. | Entropy. | | Temp. °F. |
|--------------|-----------------------------------|--------------------------------|---|--|---------------------|--------------------|-----------------------------|------------------------|-----------------------|--------------|
| | Absolute lbs./in. ² | Gage, lbs./in. ² | | | Liquid. Btu./lb. | Vapor. Btu./lb. | | Liquid. Btu./lb.°F. | Vapor. Btu./lb.°F. | |
| <i>t</i> | <i>p</i> | <i>g. p.</i> | <i>V</i> | <i>1/V</i> | <i>h</i> | <i>H</i> | <i>L</i> | <i>s</i> | <i>S</i> | <i>t</i> |
| 40 | 73.32 | 58.6 | 3.971 | 0.2518 | 86.8 | 623.0 | 536.2 | 0.1885 | 1.2618 | 40 |
| 41 | 74.80 | 60.1 | 3.897 | .2566 | 87.9 | 623.2 | 535.3 | .1908 | .2602 | 41 |
| 42 | 76.31 | 61.6 | 3.823 | .2616 | 89.0 | 623.4 | 534.4 | .1930 | .2585 | 42 |
| 43 | 77.83 | 63.1 | 3.752 | .2665 | 90.1 | 623.7 | 533.6 | .1952 | .2568 | 43 |
| 44 | 79.38 | 64.7 | 3.682 | .2716 | 91.2 | 623.9 | 532.7 | .1974 | .2552 | 44 |
| 45 | 80.96 | 66.3 | 3.614 | 0.2767 | 92.3 | 624.1 | 531.8 | 0.1996 | 1.2535 | 45 |
| 46 | 82.55 | 67.9 | 3.547 | .2819 | 93.5 | 624.4 | 530.9 | .2018 | .2519 | 46 |
| 47 | 84.18 | 69.5 | 3.481 | .2872 | 94.6 | 624.6 | 530.0 | .2040 | .2502 | 47 |
| 48 | 85.82 | 71.1 | 3.418 | .2926 | 95.7 | 624.8 | 529.1 | .2062 | .2486 | 48 |
| 49 | 87.49 | 72.8 | 3.355 | .2981 | 96.8 | 625.0 | 528.2 | .2083 | .2469 | 49 |
| 50 | 89.19 | 74.5 | 3.294 | 0.3036 | 97.9 | 625.2 | 527.3 | 0.2105 | 1.2453 | 50 |
| 51 | 90.91 | 76.2 | 3.234 | .3092 | 99.1 | 625.5 | 526.4 | .2127 | .2437 | 51 |
| 52 | 92.66 | 78.0 | 3.176 | .3149 | 100.2 | 625.7 | 525.5 | .2149 | .2421 | 52 |
| 53 | 94.43 | 79.7 | 3.119 | .3207 | 101.3 | 625.9 | 524.6 | .2171 | .2405 | 53 |
| 54 | 96.23 | 81.5 | 3.063 | .3265 | 102.4 | 626.1 | 523.7 | .2192 | .2389 | 54 |
| 55 | 98.06 | 83.4 | 3.008 | 0.3325 | 103.5 | 626.3 | 522.8 | 0.2214 | 1.2373 | 55 |
| 56 | 99.91 | 85.2 | 2.954 | .3385 | 104.7 | 626.5 | 521.8 | .2236 | .2357 | 56 |
| 57 | 101.8 | 87.1 | 2.902 | .3446 | 105.8 | 626.7 | 520.9 | .2257 | .2341 | 57 |
| 58 | 103.7 | 89.0 | 2.851 | .3508 | 106.9 | 626.9 | 520.0 | .2279 | .2325 | 58 |
| 59 | 105.6 | 90.9 | 2.800 | .3571 | 108.1 | 627.1 | 519.0 | .2301 | .2310 | 59 |
| 60 | 107.6 | 92.9 | 2.751 | 0.3635 | 109.2 | 627.3 | 518.1 | 0.2322 | 1.2294 | 60 |
| 61 | 109.6 | 94.9 | 2.703 | .3700 | 110.3 | 627.5 | 517.2 | .2344 | .2278 | 61 |
| 62 | 111.6 | 96.9 | 2.656 | .3765 | 111.5 | 627.7 | 516.2 | .2365 | .2262 | 62 |
| 63 | 113.6 | 98.9 | 2.610 | .3832 | 112.6 | 627.9 | 515.3 | .2387 | .2247 | 63 |
| 64 | 115.7 | 101.0 | 2.565 | .3899 | 113.7 | 628.0 | 514.3 | .2408 | .2231 | 64 |
| 65 | 117.8 | 103.1 | 2.520 | 0.3968 | 114.8 | 628.2 | 513.4 | 0.2430 | 1.2216 | 65 |
| 66 | 120.0 | 105.3 | 2.477 | .4037 | 116.0 | 628.4 | 512.4 | .2451 | .2201 | 66 |
| 67 | 122.1 | 107.4 | 2.435 | .4108 | 117.1 | 628.6 | 511.5 | .2473 | .2186 | 67 |
| 68 | 124.3 | 109.6 | 2.393 | .4179 | 118.3 | 628.8 | 510.5 | .2494 | .2170 | 68 |
| 69 | 126.5 | 111.8 | 2.352 | .4251 | 119.4 | 628.9 | 509.5 | .2515 | .2155 | 69 |
| 70 | 128.8 | 114.1 | 2.312 | 0.4325 | 120.5 | 629.1 | 508.6 | 0.2537 | 1.2140 | 70 |
| 71 | 131.1 | 116.4 | 2.273 | .4399 | 121.7 | 629.3 | 507.6 | .2558 | .2125 | 71 |
| 72 | 133.4 | 118.7 | 2.235 | .4474 | 122.8 | 629.4 | 506.6 | .2579 | .2110 | 72 |
| 73 | 135.7 | 121.0 | 2.197 | .4551 | 124.0 | 629.6 | 505.6 | .2601 | .2095 | 73 |
| 74 | 138.1 | 123.4 | 2.161 | .4628 | 125.1 | 629.8 | 504.7 | .2622 | .2080 | 74 |
| 75 | 140.5 | 125.8 | 2.125 | 0.4707 | 126.2 | 629.9 | 503.7 | 0.2643 | 1.2065 | 75 |
| 76 | 143.0 | 128.3 | 2.089 | .4786 | 127.4 | 630.1 | 502.7 | .2664 | .2050 | 76 |
| 77 | 145.4 | 130.7 | 2.055 | .4867 | 128.5 | 630.2 | 501.7 | .2685 | .2035 | 77 |
| 78 | 147.9 | 133.2 | 2.021 | .4949 | 129.7 | 630.4 | 500.7 | .2706 | .2020 | 78 |
| 79 | 150.5 | 135.8 | 1.988 | .5031 | 130.8 | 630.5 | 499.7 | .2728 | .2006 | 79 |
| 80 | 153.0 | 138.3 | 1.955 | 0.5115 | 132.0 | 630.7 | 498.7 | 0.2749 | 1.1991 | 80 |
| 81 | 155.6 | 140.9 | 1.923 | .5200 | 133.1 | 630.8 | 497.7 | .2769 | .1976 | 81 |
| 82 | 158.3 | 143.6 | 1.892 | .5287 | 134.3 | 631.0 | 496.7 | .2791 | .1962 | 82 |
| 83 | 161.0 | 146.3 | 1.861 | .5374 | 135.4 | 631.1 | 495.7 | .2812 | .1947 | 83 |
| 84 | 163.7 | 149.0 | 1.831 | .5462 | 136.6 | 631.3 | 494.7 | .2833 | .1933 | 84 |
| 85 | 166.4 | 151.7 | 1.801 | 0.5552 | 137.8 | 631.4 | 493.6 | 0.2854 | 1.1918 | 85 |

REFRIGERANTS—TABLES

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TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(Continued.)

| Temp. °F. <i>t</i> | Pressure. | | Volume vapor. ft./lb. <i>V</i> | Density vapor. lbs./ft. ³ <i>1/V</i> | Heat content. | | Latent heat. Btu./lb. <i>L</i> | Entropy. | | Temp. °F. <i>t</i> |
|--------------------------|--|--|---|--|---------------------------------|--------------------------------|---|------------------------------------|-----------------------------------|--------------------------|
| | Absolute. lbs./in. ² <i>p</i> | Gage. lbs./in. ² <i>g. p.</i> | | | Liquid. Btu./lb. <i>h</i> | Vapor. Btu./lb. <i>H</i> | | Liquid. Btu./lb.°F. <i>s</i> | Vapor. Btu./lb.°F. <i>S</i> | |
| 85 | 166.4 | 151.7 | 1.801 | 0.5552 | 137.8 | 631.4 | 493.6 | 0.2854 | 1.1918 | 85 |
| 86 | 169.2 | 154.5 | 1.772 | .5643 | 138.9 | 631.5 | 492.6 | .2875 | .1904 | 86 |
| 87 | 172.0 | 157.3 | 1.744 | .5735 | 140.1 | 631.7 | 491.6 | .2895 | .1889 | 87 |
| 88 | 174.8 | 160.1 | 1.716 | .5828 | 141.2 | 631.8 | 490.6 | .2917 | .1875 | 88 |
| 89 | 177.7 | 163.0 | 1.688 | .5923 | 142.4 | 631.9 | 489.5 | .2937 | .1860 | 89 |
| 90 | 180.6 | 165.9 | 1.661 | 0.6019 | 143.5 | 632.0 | 488.5 | 0.2958 | 1.1846 | 90 |
| 91 | 183.6 | 168.9 | 1.635 | .6116 | 144.7 | 632.1 | 487.4 | .2979 | .1832 | 91 |
| 92 | 186.6 | 171.9 | 1.609 | .6214 | 145.8 | 632.2 | 486.4 | .3000 | .1818 | 92 |
| 93 | 189.6 | 174.9 | 1.584 | .6314 | 147.0 | 632.3 | 485.3 | .3021 | .1804 | 93 |
| 94 | 192.7 | 178.0 | 1.559 | .6415 | 148.2 | 632.5 | 484.3 | .3041 | .1789 | 94 |
| 95 | 195.8 | 181.1 | 1.534 | 0.6517 | 149.4 | 632.6 | 483.2 | 0.3062 | 1.1775 | 95 |
| 96 | 198.9 | 184.2 | 1.510 | .6620 | 150.5 | 632.6 | 482.1 | .3083 | .1761 | 96 |
| 97 | 202.1 | 187.4 | 1.487 | .6725 | 151.7 | 632.8 | 481.1 | .3104 | .1747 | 97 |
| 98 | 205.3 | 190.6 | 1.464 | .6832 | 152.9 | 632.9 | 480.0 | .3125 | .1733 | 98 |
| 99 | 208.6 | 193.9 | 1.441 | .6939 | 154.0 | 632.9 | 478.9 | .3145 | .1719 | 99 |
| 100 | 211.9 | 197.2 | 1.419 | 0.7048 | 155.2 | 633.0 | 477.8 | 0.3166 | 1.1705 | 100 |
| 101 | 215.2 | 200.5 | 1.397 | .7159 | 156.4 | 633.1 | 476.7 | .3187 | .1691 | 101 |
| 102 | 218.6 | 203.9 | 1.375 | .7270 | 157.6 | 633.2 | 475.6 | .3207 | .1677 | 102 |
| 103 | 222.0 | 207.3 | 1.354 | .7384 | 158.7 | 633.3 | 474.6 | .3228 | .1663 | 103 |
| 104 | 225.4 | 210.7 | 1.334 | .7498 | 159.9 | 633.4 | 473.5 | .3248 | .1649 | 104 |
| 105 | 228.9 | 214.2 | 1.313 | 0.7615 | 161.1 | 633.4 | 472.3 | 0.3269 | 1.1635 | 105 |
| 106 | 232.5 | 217.8 | 1.293 | .7732 | 162.3 | 633.5 | 471.2 | .3289 | .1621 | 106 |
| 107 | 236.0 | 221.3 | 1.274 | .7852 | 163.5 | 633.6 | 470.1 | .3310 | .1607 | 107 |
| 108 | 239.7 | 225.0 | 1.254 | .7972 | 164.6 | 633.6 | 469.0 | .3330 | .1593 | 108 |
| 109 | 243.3 | 228.6 | 1.235 | .8095 | 165.8 | 633.7 | 467.9 | .3351 | .1580 | 109 |
| 110 | 247.0 | 232.3 | 1.217 | 0.8219 | 167.0 | 633.7 | 466.7 | 0.3372 | 1.1566 | 110 |
| 111 | 250.8 | 236.1 | 1.198 | .8344 | 168.2 | 633.8 | 465.6 | .3392 | .1552 | 111 |
| 112 | 254.5 | 239.8 | 1.180 | .8471 | 169.4 | 633.8 | 464.4 | .3413 | .1538 | 112 |
| 113 | 258.4 | 243.7 | 1.163 | .8600 | 170.6 | 633.9 | 463.3 | .3433 | .1524 | 113 |
| 114 | 262.2 | 247.5 | 1.145 | .8730 | 171.8 | 633.9 | 462.1 | .3453 | .1510 | 114 |
| 115 | 266.2 | 251.5 | 1.128 | 0.8862 | 173.0 | 633.9 | 460.9 | 0.3474 | 1.1497 | 115 |
| 116 | 270.1 | 255.4 | 1.112 | .8996 | 174.2 | 634.0 | 459.8 | .3495 | .1483 | 116 |
| 117 | 274.1 | 259.4 | 1.095 | .9132 | 175.4 | 634.0 | 458.6 | .3515 | .1469 | 117 |
| 118 | 278.2 | 263.5 | 1.079 | .9269 | 176.6 | 634.0 | 457.4 | .3535 | .1455 | 118 |
| 119 | 282.3 | 267.6 | 1.063 | .9408 | 177.8 | 634.0 | 456.2 | .3556 | .1441 | 119 |
| 120 | 286.4 | 271.7 | 1.047 | 0.9549 | 179.0 | 634.0 | 455.0 | 0.3576 | 1.1427 | 120 |
| 121 | 290.6 | 275.9 | 1.032 | .9692 | 180.2 | 634.0 | 453.8 | .3597 | .1414 | 121 |
| 122 | 294.8 | 280.1 | 1.017 | .9837 | 181.4 | 634.0 | 452.6 | .3618 | .1400 | 122 |
| 123 | 299.1 | 284.4 | 1.002 | .9983 | 182.6 | 634.0 | 451.4 | .3638 | .1386 | 123 |
| 124 | 303.4 | 288.7 | 0.987 | 1.0132 | 183.9 | 634.0 | 450.1 | .3659 | .1372 | 124 |
| 125 | 307.8 | 293.1 | 0.973 | 1.028 | 185.1 | 634.0 | 448.9 | 0.3679 | 1.1358 | 125 |

HOUSEHOLD REFRIGERATION

TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.

| Pressure (abs.), lbs./in. ² | Temp. °F. | Volume vapor, ft./lb. | Density vapor, lbs./ft. ³ | Heat content. | | Latent heat, Btu./lb. | Entropy | | | Pressure (abs.), lbs./in. ² |
|--|--------------|-----------------------------|--|---------------------|--------------------|-----------------------------|-------------------------|-----------------------|------------------------|--|
| | | | | Liquid, Btu./lb. | Vapor, Btu./lb. | | Liquid, Btu./lb. °F. | Evap. Btu./lb. °F. | Vapor, Btu./lb. °F. | |
| <i>p</i> | <i>t</i> | <i>V</i> | <i>1/V</i> | <i>h</i> | <i>H</i> | <i>L</i> | <i>s</i> | <i>L/T</i> | <i>S</i> | <i>p</i> |
| 5.0 | -63.11 | 49.31 | 0.02029 | -24.5 | 588.3 | 612.8 | -0.0599 | 1.5456 | 1.4857 | 5.0 |
| 5.5 | -60.27 | 45.11 | .02217 | -21.5 | 589.5 | 611.0 | -.0524 | .5301 | .4777 | 5.5 |
| 6.0 | -57.64 | 41.59 | .02405 | -18.7 | 590.6 | 609.3 | -.0455 | .5158 | .4703 | 6.0 |
| 6.5 | -55.18 | 38.59 | .02591 | -16.1 | 591.6 | 607.7 | -.0390 | .5026 | .4636 | 6.5 |
| 7.0 | -52.88 | 36.01 | .02777 | -13.7 | 592.5 | 606.2 | -.0330 | .4904 | .4574 | 7.0 |
| 7.5 | -50.70 | 33.77 | 0.02962 | -11.3 | 593.4 | 604.7 | -0.0274 | 1.4790 | 1.4516 | 7.5 |
| 8.0 | -48.64 | 31.79 | .03146 | - 9.2 | 594.2 | 603.4 | -.0221 | .4683 | .4462 | 8.0 |
| 8.5 | -46.69 | 30.04 | .03329 | - 7.1 | 595.0 | 602.1 | -.0171 | .4582 | .4411 | 8.5 |
| 9.0 | -44.83 | 28.48 | .03511 | - 5.1 | 595.7 | 600.8 | -.0123 | .4486 | .4363 | 9.0 |
| 9.5 | -43.05 | 27.08 | .03693 | - 3.2 | 596.4 | 599.6 | -.0077 | .4396 | .4319 | 9.5 |
| 10.0 | -41.34 | 25.81 | 0.03874 | - 1.4 | 597.1 | 598.5 | -0.0034 | 1.4310 | 1.4276 | 10.0 |
| 10.5 | -39.71 | 24.66 | .04055 | + 0.3 | 597.7 | 597.4 | +.0007 | .4228 | .4235 | 10.5 |
| 11.0 | -38.14 | 23.61 | .04235 | 2.0 | 598.3 | 596.3 | .0047 | .4149 | .4196 | 11.0 |
| 11.5 | -36.62 | 22.65 | .04414 | 3.6 | 598.9 | 595.3 | .0085 | .4074 | .4159 | 11.5 |
| 12.0 | -35.16 | 21.77 | .04593 | 5.1 | 599.4 | 594.3 | .0122 | .4002 | .4124 | 12.0 |
| 12.5 | -33.74 | 20.96 | 0.04772 | 6.7 | 600.0 | 593.3 | 0.0157 | 1.3933 | 1.4090 | 12.5 |
| 13.0 | -32.37 | 20.20 | .04950 | 8.1 | 600.5 | 592.4 | .0191 | .3866 | .4057 | 13.0 |
| 13.5 | -31.05 | 19.50 | .05128 | 9.6 | 601.0 | 591.4 | .0225 | .3801 | .4026 | 13.5 |
| 14.0 | -29.76 | 18.85 | .05305 | 10.9 | 601.4 | 590.5 | .0257 | .3739 | .3996 | 14.0 |
| 14.5 | -28.51 | 18.24 | .05482 | 12.2 | 601.9 | 589.7 | .0288 | .3679 | .3967 | 14.5 |
| 15.0 | -27.29 | 17.67 | 0.05658 | 13.6 | 602.4 | 588.8 | 0.0318 | 1.3620 | 1.3938 | 15.0 |
| 15.5 | -26.11 | 17.14 | .05834 | 14.8 | 602.8 | 588.0 | .0347 | .3564 | .3911 | 15.5 |
| 16.0 | -24.95 | 16.64 | .06010 | 16.0 | 603.2 | 587.2 | .0375 | .3510 | .3885 | 16.0 |
| 16.5 | -23.83 | 16.17 | .06186 | 17.2 | 603.6 | 586.4 | .0403 | .3456 | .3859 | 16.5 |
| 17.0 | -22.73 | 15.72 | .06361 | 18.4 | 604.0 | 585.6 | .0430 | .3405 | .3835 | 17.0 |
| 17.5 | -21.66 | 15.30 | 0.06535 | 19.6 | 604.4 | 584.8 | 0.0456 | 1.3354 | 1.3810 | 17.5 |
| 18.0 | -20.61 | 14.90 | .06710 | 20.7 | 604.8 | 584.1 | .0482 | .3305 | .3787 | 18.0 |
| 18.5 | -19.59 | 14.53 | .06884 | 21.8 | 605.1 | 583.3 | .0507 | .3258 | .3765 | 18.5 |
| 19.0 | -18.58 | 14.17 | .07058 | 22.9 | 605.5 | 582.6 | .0531 | .3211 | .3742 | 19.0 |
| 19.5 | -17.60 | 13.83 | .07232 | 23.9 | 605.8 | 581.9 | .0555 | .3166 | .3721 | 19.5 |
| 20.0 | -16.64 | 13.50 | 0.07405 | 25.0 | 606.2 | 581.2 | 0.0578 | 1.3122 | 1.3700 | 20.0 |
| 20.5 | -15.70 | 13.20 | .07578 | 26.0 | 606.5 | 580.5 | .0601 | .3078 | .3679 | 20.5 |
| 21.0 | -14.78 | 12.90 | .07751 | 27.0 | 606.8 | 579.8 | .0623 | .3036 | .3659 | 21.0 |
| 21.5 | -13.87 | 12.62 | .07924 | 27.9 | 607.1 | 579.2 | .0645 | .2995 | .3640 | 21.5 |
| 22.0 | -12.98 | 12.35 | .08096 | 28.9 | 607.4 | 578.5 | .0666 | .2955 | .3621 | 22.0 |
| 22.5 | -12.11 | 12.09 | 0.08268 | 29.8 | 607.7 | 577.9 | 0.0687 | 1.2915 | 1.3602 | 22.5 |
| 23.0 | -11.25 | 11.85 | .08440 | 30.8 | 608.1 | 577.3 | .0708 | .2876 | .3584 | 23.0 |
| 23.5 | -10.41 | 11.61 | .08612 | 31.7 | 608.3 | 576.6 | .0728 | .2838 | .3566 | 23.5 |
| 24.0 | - 9.58 | 11.39 | .08783 | 32.6 | 608.6 | 576.0 | .0748 | .2801 | .3549 | 24.0 |
| 24.5 | - 8.76 | 11.17 | .08955 | 33.5 | 608.9 | 575.4 | .0768 | .2764 | .3532 | 24.5 |
| 25.0 | - 7.96 | 10.96 | 0.09126 | 34.3 | 609.1 | 574.8 | 0.0787 | 1.2728 | 1.3515 | 25.0 |
| 25.5 | - 7.17 | 10.76 | .09297 | 35.2 | 609.4 | 574.2 | .0805 | .2693 | .3498 | 25.5 |
| 26.0 | - 6.39 | 10.56 | .09468 | 36.0 | 609.7 | 573.7 | .0824 | .2658 | .3482 | 26.0 |
| 26.5 | - 5.63 | 10.38 | .09638 | 36.8 | 609.9 | 573.1 | .0842 | .2625 | .3467 | 26.5 |
| 27.0 | - 4.87 | 10.20 | .09809 | 37.7 | 610.2 | 572.5 | .0860 | .2591 | .3451 | 27.0 |
| 27.5 | - 4.13 | 10.02 | 0.09979 | 38.4 | 610.4 | 572.0 | 0.0878 | 1.2558 | 1.3436 | 27.5 |
| 28.0 | - 3.40 | 9.853 | .1015 | 39.3 | 610.7 | 571.4 | .0895 | .2526 | .3421 | 28.0 |
| 28.5 | - 2.68 | 9.691 | .1032 | 40.0 | 610.9 | 570.9 | .0912 | .2494 | .3406 | 28.5 |
| 29.0 | - 1.97 | 9.534 | .1049 | 40.8 | 611.1 | 570.3 | .0929 | .2463 | .3392 | 29.0 |
| 29.5 | - 1.27 | 9.383 | .1066 | 41.6 | 611.4 | 569.8 | .0945 | .2433 | .3378 | 29.5 |
| 30.0 | - 0.57 | 9.236 | 0.1083 | 42.3 | 611.6 | 569.3 | 0.0962 | 1.2402 | 1.3361 | 30.0 |

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TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.—(Continued.)

| Pressure (abs.), lbs./in. ² | Temp. °F. | Volume vapor, ft. ³ /lb. | Density vapor, lbs./ft. ³ | Heat content. | | Latent heat, Btu./lb. | Entropy. | | | Pressure (abs.), lbs./in. ² |
|--|--------------|---|--|---------------------|--------------------|-----------------------------|-------------------------|------------------------|------------------------|--|
| | | | | Liquid, Btu./lb. | Vapor, Btu./lb. | | Liquid, Btu./lb. °F. | Evap., Btu./lb. °F. | Vapor, Btu./lb. °F. | |
| <i>p</i> | <i>t</i> | <i>V</i> | <i>1/V</i> | <i>h</i> | <i>H</i> | <i>L</i> | <i>s</i> | <i>L/T</i> | <i>S</i> | <i>p</i> |
| 30 | -0.57 | 9.236 | 0.1083 | 42.3 | 611.6 | 569.3 | 0.0962 | 1.2402 | 1.3364 | 30 |
| 31 | +0.79 | 8.955 | .1117 | 43.8 | 612.0 | 568.2 | .0993 | .2343 | .3336 | 31 |
| 32 | 2.11 | 8.693 | .1150 | 45.2 | 612.4 | 567.2 | .1024 | .2286 | .3310 | 32 |
| 33 | 3.40 | 8.445 | .1184 | 46.6 | 612.8 | 566.2 | .1055 | .2230 | .3285 | 33 |
| 34 | 4.66 | 8.211 | .1218 | 48.0 | 613.2 | 565.2 | .1084 | .2176 | .3260 | 34 |
| 35 | 5.89 | 7.991 | 0.1251 | 49.3 | 613.6 | 564.3 | 0.1113 | 1.2123 | 1.3236 | 35 |
| 36 | 7.09 | 7.782 | .1285 | 50.6 | 614.0 | 563.4 | .1141 | .2072 | .3213 | 36 |
| 37 | 8.27 | 7.584 | .1319 | 51.9 | 614.3 | 562.4 | .1168 | .2022 | .3190 | 37 |
| 38 | 9.42 | 7.396 | .1352 | 53.2 | 614.7 | 561.5 | .1195 | .1973 | .3168 | 38 |
| 39 | 10.55 | 7.217 | .1386 | 54.4 | 615.0 | 560.6 | .1221 | .1925 | .3146 | 39 |
| 40 | 11.66 | 7.047 | 0.1419 | 55.6 | 615.4 | 559.8 | 0.1246 | 1.1879 | 1.3125 | 40 |
| 41 | 12.74 | 6.885 | .1452 | 56.8 | 615.7 | 558.9 | .1271 | .1833 | .3104 | 41 |
| 42 | 13.81 | 6.731 | .1486 | 57.9 | 616.0 | 558.1 | .1296 | .1788 | .3084 | 42 |
| 43 | 14.85 | 6.583 | .1519 | 59.1 | 616.3 | 557.2 | .1320 | .1745 | .3065 | 43 |
| 44 | 15.88 | 6.442 | .1552 | 60.2 | 616.6 | 556.4 | .1343 | .1703 | .3046 | 44 |
| 45 | 16.88 | 6.307 | 0.1586 | 61.3 | 616.9 | 555.6 | 0.1366 | 1.1661 | 1.3027 | 45 |
| 46 | 17.87 | 6.177 | .1619 | 62.4 | 617.2 | 554.8 | .1389 | .1620 | .3009 | 46 |
| 47 | 18.84 | 6.053 | .1652 | 63.4 | 617.4 | 554.0 | .1411 | .1580 | .2991 | 47 |
| 48 | 19.80 | 5.934 | .1685 | 64.5 | 617.7 | 553.2 | .1433 | .1540 | .2973 | 48 |
| 49 | 20.74 | 5.820 | .1718 | 65.5 | 618.0 | 552.5 | .1454 | .1502 | .2956 | 49 |
| 50 | 21.67 | 5.710 | 0.1751 | 66.5 | 618.2 | 551.7 | 0.1475 | 1.1464 | 1.2939 | 50 |
| 51 | 22.58 | 5.604 | .1785 | 67.5 | 618.5 | 551.0 | .1496 | .1427 | .2923 | 51 |
| 52 | 23.48 | 5.502 | .1818 | 68.5 | 618.7 | 550.2 | .1516 | .1390 | .2906 | 52 |
| 53 | 24.36 | 5.404 | .1851 | 69.5 | 619.0 | 549.5 | .1536 | .1354 | .2890 | 53 |
| 54 | 25.23 | 5.309 | .1884 | 70.4 | 619.2 | 548.8 | .1556 | .1319 | .2875 | 54 |
| 55 | 26.09 | 5.218 | 0.1917 | 71.4 | 619.4 | 548.0 | 0.1575 | 1.1284 | 1.2859 | 55 |
| 56 | 26.94 | 5.129 | .1950 | 72.3 | 619.7 | 547.4 | .1594 | .1250 | .2844 | 56 |
| 57 | 27.77 | 5.044 | .1983 | 73.3 | 619.9 | 546.6 | .1613 | .1217 | .2830 | 57 |
| 58 | 28.59 | 4.962 | .2015 | 74.2 | 620.1 | 545.9 | .1631 | .1184 | .2815 | 58 |
| 59 | 29.41 | 4.882 | .2048 | 75.0 | 620.3 | 545.3 | .1650 | .1151 | .2801 | 59 |
| 60 | 30.21 | 4.805 | 0.2081 | 75.9 | 620.5 | 544.6 | 0.1668 | 1.1119 | 1.2787 | 60 |
| 61 | 31.00 | 4.730 | .2114 | 76.8 | 620.7 | 543.9 | .1686 | .1088 | .2773 | 61 |
| 62 | 31.78 | 4.658 | .2147 | 77.7 | 620.9 | 543.2 | .1703 | .1056 | .2759 | 62 |
| 63 | 32.55 | 4.588 | .2180 | 78.5 | 621.1 | 542.6 | .1720 | .1026 | .2746 | 63 |
| 64 | 33.31 | 4.519 | .2213 | 79.4 | 621.3 | 541.9 | .1737 | .0996 | .2733 | 64 |
| 65 | 34.06 | 4.453 | 0.2245 | 80.2 | 621.5 | 541.3 | 0.1754 | 1.0966 | 1.2720 | 65 |
| 66 | 34.81 | 4.389 | .2278 | 81.0 | 621.7 | 540.7 | .1770 | .0937 | .2707 | 66 |
| 67 | 35.54 | 4.327 | .2311 | 81.8 | 621.9 | 540.1 | .1787 | .0907 | .2694 | 67 |
| 68 | 36.27 | 4.267 | .2344 | 82.6 | 622.0 | 539.4 | .1803 | .0879 | .2682 | 68 |
| 69 | 36.99 | 4.208 | .2377 | 83.4 | 622.2 | 538.8 | .1819 | .0851 | .2670 | 69 |
| 70 | 37.70 | 4.151 | 0.2409 | 84.2 | 622.4 | 538.2 | 0.1835 | 1.0823 | 1.2658 | 70 |
| 71 | 38.40 | 4.095 | .2442 | 85.0 | 622.6 | 537.6 | .1850 | .0795 | .2645 | 71 |
| 72 | 39.09 | 4.041 | .2475 | 85.8 | 622.8 | 537.0 | .1866 | .0768 | .2634 | 72 |
| 73 | 39.78 | 3.988 | .2507 | 86.5 | 622.9 | 536.4 | .1881 | .0741 | .2622 | 73 |
| 74 | 40.46 | 3.937 | .2540 | 87.3 | 623.1 | 535.8 | .1896 | .0715 | .2611 | 74 |
| 75 | 41.13 | 3.887 | 0.2573 | 88.0 | 623.2 | 535.2 | 0.1910 | 1.0689 | 1.2599 | 75 |
| 76 | 41.80 | 3.838 | .2606 | 88.8 | 623.4 | 534.6 | .1925 | .0663 | .2588 | 76 |
| 77 | 42.46 | 3.790 | .2638 | 89.5 | 623.5 | 534.0 | .1940 | .0637 | .2577 | 77 |
| 78 | 43.11 | 3.744 | .2671 | 90.2 | 623.7 | 533.5 | .1954 | .0612 | .2566 | 78 |
| 79 | 43.76 | 3.699 | .2704 | 90.9 | 623.8 | 532.9 | .1968 | .0587 | .2555 | 79 |
| 80 | 44.40 | 3.655 | 0.2736 | 91.7 | 624.0 | 532.3 | 0.1982 | 1.0563 | 1.2545 | 80 |

HOUSEHOLD REFRIGERATION

TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.—(Continued.)

| Pressure (abs.), lbs./in. ² | Temp. °F. <i>t</i> | Volume vapor, ft. ³ /lb. <i>V</i> | Density vapor, lbs./ft. ³ <i>1/V</i> | Heat content. | | | Entropy. | | | Pressure (abs.), lbs./in. ² |
|--|--------------------------|---|--|---------------------------------|--------------------------------|---|-------------------------------------|-------------------------------------|------------------------------------|--|
| | | | | Liquid. Btu./lb. <i>h</i> | Vapor. Btu./lb. <i>H</i> | Latent heat, Btu./lb. <i>L</i> | Liquid. Btu./lb. °F. <i>s</i> | Evap. Btu./lb. °F. <i>L/T</i> | Vapor. Btu./lb. °F. <i>S</i> | |
| 80 | 44.40 | 3.655 | 0.2736 | 91.7 | 624.0 | 532.3 | 0.1982 | 1.0563 | 1.2545 | 80 |
| 81 | 45.03 | 3.612 | .2769 | 92.4 | 624.1 | 531.7 | .1996 | .0538 | .2534 | 81 |
| 82 | 45.66 | 3.570 | .2801 | 93.1 | 624.3 | 531.2 | .2010 | .0514 | .2524 | 82 |
| 83 | 46.28 | 3.528 | .2834 | 93.8 | 624.4 | 530.6 | .2024 | .0490 | .2514 | 83 |
| 84 | 46.89 | 3.488 | .2867 | 94.5 | 624.6 | 530.1 | .2037 | .0467 | .2504 | 84 |
| 85 | 47.50 | 3.449 | 0.2899 | 95.1 | 624.7 | 529.6 | 0.2051 | 1.0443 | 1.2494 | 85 |
| 86 | 48.11 | 3.411 | .2932 | 95.8 | 624.8 | 529.0 | .2064 | .0420 | .2484 | 86 |
| 87 | 48.71 | 3.373 | .2964 | 96.5 | 625.0 | 528.5 | .2077 | .0397 | .2474 | 87 |
| 88 | 49.30 | 3.337 | .2997 | 97.2 | 625.1 | 527.9 | .2090 | .0375 | .2465 | 88 |
| 89 | 49.89 | 3.301 | .3030 | 97.8 | 625.2 | 527.4 | .2103 | .0352 | .2455 | 89 |
| 90 | 50.47 | 3.266 | 0.3062 | 98.4 | 625.3 | 526.9 | 0.2115 | 1.0330 | 1.2445 | 90 |
| 91 | 51.05 | 3.231 | .3095 | 99.1 | 625.5 | 526.4 | .2128 | .0308 | .2436 | 91 |
| 92 | 51.62 | 3.198 | .3127 | 99.8 | 625.6 | 525.8 | .2141 | .0286 | .2427 | 92 |
| 93 | 52.19 | 3.165 | .3160 | 100.4 | 625.7 | 525.3 | .2153 | .0265 | .2418 | 93 |
| 94 | 52.76 | 3.132 | .3192 | 101.0 | 625.8 | 524.8 | .2165 | .0243 | .2408 | 94 |
| 95 | 53.32 | 3.101 | 0.3225 | 101.6 | 625.9 | 524.3 | 0.2177 | 1.0222 | 1.2399 | 95 |
| 96 | 53.87 | 3.070 | .3258 | 102.3 | 626.1 | 523.8 | .2190 | .0201 | .2391 | 96 |
| 97 | 54.42 | 3.039 | .3290 | 102.9 | 626.2 | 523.3 | .2201 | .0181 | .2382 | 97 |
| 98 | 54.97 | 3.010 | .3323 | 103.5 | 626.3 | 522.8 | .2213 | .0160 | .2373 | 98 |
| 99 | 55.51 | 2.980 | .3355 | 104.1 | 626.4 | 522.3 | .2225 | .0140 | .2365 | 99 |
| 100 | 56.05 | 2.952 | 0.3388 | 104.7 | 626.5 | 521.8 | 0.2237 | 1.0119 | 1.2356 | 100 |
| 102 | 57.11 | 2.896 | .3453 | 105.9 | 626.7 | 520.8 | .2260 | .0079 | .2339 | 102 |
| 104 | 58.16 | 2.843 | .3518 | 107.1 | 626.9 | 519.8 | .2282 | .0041 | .2323 | 104 |
| 106 | 59.19 | 2.791 | .3583 | 108.3 | 627.1 | 518.8 | .2305 | 1.0002 | .2307 | 106 |
| 108 | 60.21 | 2.741 | .3648 | 109.4 | 627.3 | 517.9 | .2327 | 0.9964 | .2291 | 108 |
| 110 | 61.21 | 2.693 | 0.3713 | 110.5 | 627.5 | 517.0 | 0.2348 | 0.9927 | 1.2275 | 110 |
| 112 | 62.20 | 2.647 | .3778 | 111.7 | 627.7 | 516.0 | .2369 | .9890 | .2259 | 112 |
| 114 | 63.17 | 2.602 | .3843 | 112.8 | 627.9 | 515.1 | .2390 | .9854 | .2244 | 114 |
| 116 | 64.13 | 2.559 | .3909 | 113.9 | 628.1 | 514.2 | .2411 | .9819 | .2230 | 116 |
| 118 | 65.08 | 2.517 | .3974 | 114.9 | 628.2 | 513.3 | .2431 | .9784 | .2215 | 118 |
| 120 | 66.02 | 2.476 | 0.4039 | 116.0 | 628.4 | 512.4 | 0.2452 | 0.9749 | 1.2201 | 120 |
| 122 | 66.94 | 2.437 | .4104 | 117.1 | 628.6 | 511.5 | .2471 | .9715 | .2186 | 122 |
| 124 | 67.86 | 2.399 | .4169 | 118.1 | 628.7 | 510.6 | .2491 | .9682 | .2173 | 124 |
| 126 | 68.76 | 2.362 | .4234 | 119.1 | 628.9 | 509.8 | .2510 | .9649 | .2159 | 126 |
| 128 | 69.65 | 2.326 | .4299 | 120.1 | 629.0 | 508.9 | .2529 | .9616 | .2145 | 128 |
| 130 | 70.53 | 2.291 | 0.4364 | 121.1 | 629.2 | 508.1 | 0.2548 | 0.9584 | 1.2132 | 130 |
| 132 | 71.40 | 2.258 | .4429 | 122.1 | 629.3 | 507.2 | .2567 | .9552 | .2119 | 132 |
| 134 | 72.26 | 2.225 | .4494 | 123.1 | 629.5 | 506.4 | .2585 | .9521 | .2106 | 134 |
| 136 | 73.11 | 2.193 | .4559 | 124.1 | 629.6 | 505.5 | .2603 | .9490 | .2093 | 136 |
| 138 | 73.95 | 2.162 | .4624 | 125.1 | 629.8 | 504.7 | .2621 | .9460 | .2081 | 138 |
| 140 | 74.79 | 2.132 | 0.4690 | 126.0 | 629.9 | 503.9 | 0.2638 | 0.9430 | 1.2068 | 140 |
| 142 | 75.61 | 2.103 | .4755 | 126.9 | 630.0 | 503.1 | .2656 | .9400 | .2056 | 142 |
| 144 | 76.42 | 2.075 | .4820 | 127.9 | 630.2 | 502.3 | .2673 | .9371 | .2044 | 144 |
| 146 | 77.23 | 2.047 | .4885 | 128.8 | 630.3 | 501.5 | .2690 | .9342 | .2032 | 146 |
| 148 | 78.03 | 2.020 | .4951 | 129.7 | 630.4 | 500.7 | .2707 | .9313 | .2020 | 148 |
| 150 | 78.81 | 1.994 | 0.5016 | 130.6 | 630.5 | 499.9 | 0.2724 | 0.9285 | 1.2009 | 150 |

REFRIGERANTS—TABLES

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TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.—(Continued.)

| Pressure (abs.), lbs./in. ² | Temp. °F. | Volume vapor, ft./lb. | Density vapor, lbs./ft. ³ | Heat content. | | Latent heat, Btu./lb. | Entropy. | | | Pressure (abs.), lbs./in. ² |
|--|--------------|-----------------------------|--|---------------------|--------------------|-----------------------------|------------------------|----------------------|-----------------------|--|
| | | | | Liquid, Btu./lb. | Vapor, Btu./lb. | | Liquid, Btu./lb.°F. | Evap. Btu./lb.°F. | Vapor, Btu./lb.°F. | |
| <i>p</i> | <i>t</i> | <i>V</i> | <i>1/V</i> | <i>h</i> | <i>II</i> | <i>L</i> | <i>s</i> | <i>L/T</i> | <i>S</i> | <i>p</i> |
| 150 | 78.81 | 1.994 | 0.5016 | 130.6 | 630.5 | 499.9 | 0.2724 | 0.9285 | 1.2009 | 150 |
| 152 | 79.60 | 1.968 | .5081 | 131.5 | 630.6 | 499.1 | .2740 | .9257 | .1997 | 152 |
| 154 | 80.37 | 1.943 | .5147 | 132.4 | 630.7 | 498.3 | .2756 | .9229 | .1985 | 154 |
| 156 | 81.13 | 1.919 | .5212 | 133.3 | 630.9 | 497.6 | .2772 | .9202 | .1974 | 156 |
| 158 | 81.89 | 1.895 | .5277 | 134.2 | 631.0 | 496.8 | .2788 | .9175 | .1963 | 158 |
| 160 | 82.64 | 1.872 | 0.5343 | 135.0 | 631.1 | 496.1 | 0.2804 | 0.9148 | 1.1952 | 160 |
| 162 | 83.39 | 1.849 | .5408 | 135.9 | 631.2 | 495.3 | .2820 | .9122 | .1942 | 162 |
| 164 | 84.12 | 1.827 | .5473 | 136.8 | 631.3 | 494.5 | .2835 | .9096 | .1931 | 164 |
| 166 | 84.85 | 1.805 | .5539 | 137.6 | 631.4 | 493.8 | .2850 | .9070 | .1920 | 166 |
| 168 | 85.57 | 1.784 | .5604 | 138.4 | 631.5 | 493.1 | .2866 | .9044 | .1910 | 168 |
| 170 | 86.29 | 1.764 | 0.5670 | 139.3 | 631.6 | 492.3 | 0.2881 | 0.9019 | 1.1900 | 170 |
| 172 | 87.00 | 1.744 | .5735 | 140.1 | 631.7 | 491.6 | .2895 | .8994 | .1889 | 172 |
| 174 | 87.71 | 1.724 | .5801 | 140.9 | 631.7 | 490.8 | .2910 | .8969 | .1879 | 174 |
| 176 | 88.40 | 1.705 | .5866 | 141.7 | 631.8 | 490.1 | .2925 | .8944 | .1869 | 176 |
| 178 | 89.10 | 1.686 | .5932 | 142.5 | 631.9 | 489.4 | .2939 | .8920 | .1859 | 178 |
| 180 | 89.78 | 1.667 | 0.5998 | 143.3 | 632.0 | 488.7 | 0.2954 | 0.8896 | 1.1850 | 180 |
| 182 | 90.46 | 1.649 | .6063 | 144.1 | 632.1 | 488.0 | .2968 | .8872 | .1840 | 182 |
| 184 | 91.14 | 1.632 | .6129 | 144.8 | 632.1 | 487.3 | .2982 | .8848 | .1830 | 184 |
| 186 | 91.80 | 1.614 | .6195 | 145.6 | 632.2 | 486.6 | .2996 | .8825 | .1821 | 186 |
| 188 | 92.47 | 1.597 | .6261 | 146.4 | 632.3 | 485.9 | .3010 | .8801 | .1811 | 188 |
| 190 | 93.13 | 1.581 | 0.6326 | 147.2 | 632.4 | 485.2 | 0.3024 | 0.8778 | 1.1802 | 190 |
| 192 | 93.78 | 1.564 | .6392 | 147.9 | 632.4 | 484.5 | .3037 | .8755 | .1792 | 192 |
| 194 | 94.43 | 1.548 | .6458 | 148.7 | 632.5 | 483.8 | .3050 | .8733 | .1783 | 194 |
| 196 | 95.07 | 1.533 | .6524 | 149.5 | 632.6 | 483.1 | .3064 | .8710 | .1774 | 196 |
| 198 | 95.71 | 1.517 | .6590 | 150.2 | 632.6 | 482.4 | .3077 | .8688 | .1765 | 198 |
| 200 | 96.34 | 1.502 | 0.6656 | 150.9 | 632.7 | 481.8 | 0.3090 | 0.8666 | 1.1756 | 200 |
| 205 | 97.90 | 1.466 | .6821 | 152.7 | 632.8 | 480.1 | .3122 | .8612 | .1734 | 205 |
| 210 | 99.43 | 1.431 | .6986 | 154.6 | 633.0 | 478.4 | .3154 | .8559 | .1713 | 210 |
| 215 | 100.94 | 1.398 | .7152 | 156.3 | 633.1 | 476.8 | .3185 | .8507 | .1692 | 215 |
| 220 | 102.42 | 1.367 | .7318 | 158.0 | 633.2 | 475.2 | .3216 | .8455 | .1671 | 220 |
| 225 | 103.87 | 1.336 | 0.7484 | 159.7 | 633.3 | 473.6 | 0.3246 | 0.8405 | 1.1651 | 225 |
| 230 | 105.30 | 1.307 | .7650 | 161.4 | 633.4 | 472.0 | .3275 | .8356 | .1631 | 230 |
| 235 | 106.71 | 1.279 | .7817 | 163.1 | 633.5 | 470.4 | .3304 | .8307 | .1611 | 235 |
| 240 | 108.09 | 1.253 | .7984 | 164.7 | 633.6 | 468.9 | .3332 | .8260 | .1592 | 240 |
| 245 | 109.46 | 1.227 | .8151 | 166.4 | 633.7 | 467.3 | .3360 | .8213 | .1573 | 245 |
| 250 | 110.80 | 1.202 | 0.8319 | 168.0 | 633.8 | 465.8 | 0.3388 | 0.8167 | 1.1555 | 250 |
| 255 | 112.12 | 1.178 | .8487 | 169.5 | 633.8 | 464.3 | .3415 | .8121 | .1536 | 255 |
| 260 | 113.42 | 1.155 | .8655 | 171.1 | 633.9 | 462.8 | .3441 | .8077 | .1518 | 260 |
| 265 | 114.71 | 1.133 | .8824 | 172.6 | 633.9 | 461.3 | .3468 | .8033 | .1501 | 265 |
| 270 | 115.97 | 1.112 | .8993 | 174.1 | 633.9 | 459.8 | .3494 | .7989 | .1483 | 270 |
| 275 | 117.22 | 1.091 | 0.9162 | 175.6 | 634.0 | 458.4 | 0.3519 | 0.7947 | 1.1466 | 275 |
| 280 | 118.45 | 1.072 | .9332 | 177.1 | 634.0 | 456.9 | .3545 | .7904 | .1449 | 280 |
| 285 | 119.66 | 1.052 | .9502 | 178.6 | 634.0 | 455.4 | .3569 | .7863 | .1432 | 285 |
| 290 | 120.86 | 1.034 | .9672 | 180.0 | 634.0 | 454.0 | .3594 | .7821 | .1415 | 290 |
| 295 | 122.05 | 1.016 | .9843 | 181.5 | 634.0 | 452.5 | .3618 | .7781 | .1399 | 295 |
| 300 | 123.21 | 0.999 | 1.0015 | 182.9 | 634.0 | 451.1 | 0.3642 | 0.7741 | 1.1383 | 300 |

TABLE XIX.—BUREAU OF STANDARDS TABLE OF PROPERTIES OF LIQUID AMMONIA.

Bureau of Standards Circular No. 142, April 16, 1925. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

| Temp. °F <i>t</i> | (AT SATURATION) | | | | | | Latent Heat of Pressure Variation Btu./lb. <i>l</i> | Variation of h with p (Coo- stant) Btu./lb. $\frac{dh}{dp}$ $\frac{100}{v} \left(\frac{dh}{dp} \right) t$ | Compress- ibility % Change in v $\frac{100}{v} \left(\frac{dv}{v} \right) t$ | Temp. °F <i>t</i> |
|-------------------------|--|--|---|---|---|---|---|--|--|-------------------------|
| | Pressure (Abs.) lb./in. ² <i>p</i> | Pressure (Gage) lb./in. ² <i>g p</i> | Volume ft. ³ /lb. <i>v</i> | Density lb./ft. ³ <i>l v</i> | Specific Heat Btu./lb. °F. <i>c</i> | Heat Content Above -10° Btu./lb. <i>h</i> | | | | |
| | <i>p</i> | <i>g p</i> | <i>v</i> | <i>l v</i> | <i>c</i> | <i>h</i> | | | | |
| Triple point | 0.88 | 28.1* | 0.01961 | 51.00 | — | — | — | — | — | -107.86 |
| | | 28.1* | .02182 | 45.83 | — | — | — | — | — | -107.86 |
| -100 | 1.24 | 27.4* | 0.02197 | 45.52 | 1.040† | -63.0† | 633† | *These figures were calculated from empirical equations given in Bureau of Standards Scientific Papers Nos. 313 and 315, and represent values obtained by extrapolation beyond the range covered in the experimental work. | | |
| -95 | 1.52 | 26.8* | .02207 | 45.32 | 1.042† | -57.8† | 631† | | | |
| -90 | 1.86 | 26.1* | .02216 | 45.12 | 1.043† | -52.6† | 628† | | | |
| -85 | 2.27 | 25.3* | .02226 | 44.92 | 1.045† | -47.4† | 625† | | | |
| -80 | 2.74 | 24.3* | .02236 | 44.72 | 1.046† | -42.2† | 622† | | | |
| -75 | 3.29 | 23.2* | 0.02246 | 44.52 | 1.048† | -36.9† | 619† | -0.0016 | 0.0026 | 0.00044 |
| -70 | 3.94 | 21.9* | .02256 | 44.32 | 1.050† | -31.7† | 616† | | | |
| -65 | 4.69 | 20.4* | .02267 | 44.11 | 1.052† | -26.4† | 613† | | | |
| -60 | 5.55 | 18.6* | .02278 | 43.9† | 1.054 | -21.18 | 610.8 | | | |
| -55 | 6.54 | 16.6* | .02288 | 43.70 | 1.056 | -15.90 | 607.5 | | | |
| -50 | 7.67 | 14.3* | 0.02299 | 43.49 | 1.058 | -10.61 | 604.3 | -0.0017 | 0.0026 | 0.00046 |
| -45 | 8.95 | 11.7* | .02310 | 43.28 | 1.060 | -5.31 | 600.9 | -0.0017 | .0026 | .00047 |
| -40 | 10.41 | 8.7* | .02322 | 43.08 | 1.062 | 0.00 | 597.6 | -0.0018 | .0025 | .00048 |
| -35 | 12.05 | 5.4* | .02333 | 42.86 | 1.064 | +5.32 | 594.2 | -0.0018 | .0025 | .00050 |
| -30 | 13.90 | 1.6* | .02345 | 42.65 | 1.066 | 10.66 | 590.7 | -0.0019 | .0025 | .00051 |
| -25 | 15.95 | 1.3* | 0.02357 | 42.44 | 1.068 | 16.00 | 587.2 | -0.0019 | 0.0024 | 0.00052 |
| -20 | 18.30 | 3.6 | .02369 | 42.22 | 1.070 | 21.36 | 583.6 | -0.0020 | .0024 | .00054 |
| -15 | 20.88 | 6.2 | .02381 | 42.00 | 1.073 | 26.73 | 580.0 | -0.0020 | .0024 | .00055 |
| -10 | 23.74 | 9.0 | .02393 | 41.78 | 1.075 | 32.11 | 576.4 | -0.0021 | .0023 | .00057 |
| -5 | 26.92 | 12.2 | .02406 | 41.56 | 1.078 | 37.51 | 572.6 | -0.0022 | .0023 | .00058 |
| 0 | 30.42 | 15.7 | 0.02419 | 41.34 | 1.080 | 42.92 | 568.9 | -0.0022 | 0.0022 | 0.00060 |
| 5 | 34.27 | 19.6 | .02432 | 41.11 | 1.083 | 48.35 | 565.0 | -0.0023 | .0022 | .00062 |
| 10 | 38.51 | 23.8 | .02446 | 40.89 | 1.085 | 53.79 | 561.1 | -0.0024 | .0021 | .00064 |
| 15 | 43.14 | 28.4 | .02460 | 40.66 | 1.088 | 59.24 | 557.1 | -0.0025 | .0021 | .00066 |
| 20 | 48.21 | 33.5 | .02474 | 40.43 | 1.091 | 64.71 | 553.1 | -0.0025 | .0020 | .00068 |
| 25 | 53.73 | 39.0 | 0.02488 | 40.20 | 1.094 | 70.20 | 548.9 | -0.0026 | 0.0020 | 0.00070 |
| 30 | 59.74 | 45.0 | .02503 | 39.96 | 1.097 | 75.71 | 544.8 | -0.0027 | .0019 | .00073 |
| 35 | 66.26 | 51.6 | .02518 | 39.72 | 1.100 | 81.23 | 540.5 | -0.0028 | .0019 | .00075 |
| 40 | 73.32 | 58.6 | .02533 | 39.49 | 1.104 | 86.77 | 536.2 | -0.0029 | .0018 | .00078 |
| 45 | 80.96 | 66.3 | .02548 | 39.24 | 1.108 | 92.34 | 531.8 | -0.0030 | .0017 | .00081 |
| 50 | 89.19 | 74.5 | 0.02564 | 39.00 | 1.112 | 97.93 | 527.3 | -0.0031 | 0.0017 | 0.00084 |
| 55 | 98.06 | 83.4 | .02581 | 38.75 | 1.116 | 103.54 | 522.8 | -0.0032 | .0016 | .00088 |
| 60 | 107.6 | 92.9 | .02597 | 38.50 | 1.120 | 109.15 | 518.1 | -0.0033 | .0015 | .00091 |
| 65 | 117.8 | 103.1 | .02614 | 38.25 | 1.125 | 114.85 | 513.4 | -0.0034 | .0014 | .00095 |
| 70 | 128.8 | 114.1 | .02632 | 38.00 | 1.129 | 120.54 | 508.6 | -0.0035 | .0013 | .00100 |
| 75 | 140.5 | 125.8 | 0.02650 | 37.74 | 1.133 | 126.25 | 503.7 | -0.0037 | 0.0012 | 0.00104 |
| 80 | 153.0 | 138.3 | .02668 | 37.48 | 1.138 | 131.99 | 498.7 | -0.0038 | .0011 | .00109 |
| 85 | 166.4 | 151.7 | .02687 | 37.21 | 1.142 | 137.75 | 493.6 | -0.0040 | .0010 | .00114 |
| 86† | 169.2 | 154.5 | .02673 | 37.16 | 1.143 | 127.40 | 492.6 | .0040 | .0010 | .00115 |
| 90 | 180.6 | 165.9 | .02707 | 36.95 | 1.147 | 143.54 | 488.5 | -0.0041 | .0009 | .00120 |
| 95 | 195.8 | 181.1 | .02727 | 36.67 | 1.151 | 149.36 | 483.2 | -0.0043 | .0008 | .00126 |
| 100 | 211.9 | 197.2 | 0.02747 | 36.40 | 1.156 | 155.21 | 477.8 | -0.0045 | 0.0006 | 0.00133 |
| 105 | 228.9 | 214.2 | .02769 | 36.12 | 1.162 | 161.09 | 472.3 | -0.0047 | .0005 | .00141 |
| 110 | 247.0 | 232.3 | .02790 | 35.84 | 1.168 | 167.01 | 466.7 | -0.0049 | .0003 | .00149 |
| 115 | 266.2 | 251.5 | .02813 | 35.55 | 1.176 | 172.97 | 460.9 | -0.0051 | .0001 | .00158 |
| 120 | 286.4 | 271.7 | .02836 | 35.26 | 1.183 | 178.98 | 455.0 | -0.0053 | .0000 | .00167 |
| 125 | 307.8 | 293.1 | 0.02860 | 34.96 | 1.189† | 185† | 449† | NOTES.—At the critical temperature of 271.4° F. (Cardoso and Gil) the pressure is 1,657 lbs., the volume .0656 cubic feet, the density 14.6 lbs., and the heat content 433 Btu. | | |
| 130 | 330.3 | 315.6 | .02885 | 34.66 | 1.197† | 191† | 443† | | | |
| 135 | 354.1 | 339.4 | .02911 | 34.35 | 1.205† | 197† | 436† | | | |
| 140 | 379.1 | 364.4 | .02938 | 34.04 | 1.213† | 203† | 430† | | | |
| 145 | 405.5 | 390.8 | .02966 | 33.72 | 1.222† | 210† | 423† | | | |
| 150 | 433.2 | 418.5 | 0.02995 | 33.39 | 1.23† | 216† | 416† | Values for gage pressure (g.p.), absolute pressure (p.), liquid volume (v.), and density (l/v), heat of the liquid (h) and latent heat (L), are given for single Fahrenheit degrees in Table 2. | | |
| 155 | 462.3 | 447.6 | .03025 | 33.06 | 1.24† | 222† | 409† | | | |
| 160 | 492.8 | 478.1 | .03056 | 32.72 | 1.25† | 229† | 401† | | | |
| 165 | 524.8 | 510.1 | .03089 | 32.37 | 1.26† | 235† | 394† | | | |
| 170 | 558.4 | 543.7 | .03124 | 32.01 | 1.27† | 241† | 386† | | | |
| Critical | 1,657. | 1,642.3 | .0656 | 14.6 | — | 433† | 0 | — | — | 271.4 |

*Inches of mercury, at 32°F., below one standard atmosphere (29.92 in. = 14.696 lbs. abs.)

†Standard temperatures.

REFRIGERANTS—TABLES

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TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF
SUPERHEATED AMMONIA VAPORS

Bureau of Standards Circular No. 142, April 16, 1923, Rearranged and Extended for
The American Society of Refrigerating Engineers, July, 1925.

| Tem. °F. | Abs. Pressure 5 lb./in. ² Gage Pressure 19.7* (Sat'n Temp.—63.11° F.) | | | Tem. °F. | Abs. Pressure 10 lb./in. ² Gage Pressure 9.6* (Sat'n Temp.—41.34° F.) | | | Tem. °F. | Abs. Pressure 15 lb./in. ² Gage Pressure 0.3 lb./in. ² (Sat'n Temp.—27.29° F.) | | |
|---------------|--|-----------------------------|----------------------------|---------------|--|-----------------------------|----------------------------|---------------|--|-----------------------------|----------------------------|
| | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (49.31) | (588.3) | (1.4857) | (at sat'n) | (25.81) | (597.1) | (1.4376) | (at sat'n) | (17.67) | (602.4) | (1.2938) |
| -50 | 51.05 | 595.2 | 1.5025 | -40 | 25.90 | 597.8 | 1.4293 | -30 | 18.01 | 606.4 | 1.4031 |
| -40 | 52.36 | 600.3 | 1.5149 | -30 | 26.58 | 603.2 | 1.4420 | -20 | 18.47 | 611.9 | 1.4154 |
| -30 | 53.67 | 605.4 | 1.5269 | -20 | 27.26 | 608.5 | 1.4542 | -10 | 18.47 | 611.9 | 1.4154 |
| -20 | 54.97 | 610.4 | 1.5385 | -10 | 27.92 | 613.7 | 1.4659 | 0 | 18.92 | 617.2 | 1.4272 |
| -10 | 56.26 | 615.4 | 1.5498 | 0 | 28.58 | 618.9 | 1.4773 | 10 | 19.37 | 622.5 | 1.4386 |
| 0 | 57.55 | 620.4 | 1.5608 | 10 | 29.24 | 624.0 | 1.4884 | 20 | 19.82 | 627.8 | 1.4497 |
| 10 | 58.84 | 625.4 | 1.5716 | 20 | 29.90 | 629.1 | 1.4992 | 30 | 20.26 | 633.0 | 1.4604 |
| 20 | 60.12 | 630.4 | 1.5821 | 30 | 30.55 | 634.2 | 1.5097 | 40 | 20.70 | 638.2 | 1.4709 |
| 30 | 61.41 | 635.4 | 1.5925 | 40 | 31.20 | 639.3 | 1.5200 | 50 | 21.14 | 643.4 | 1.4812 |
| 40 | 62.69 | 640.4 | 1.6026 | 50 | 31.85 | 644.4 | 1.5301 | 60 | 21.58 | 648.5 | 1.4912 |
| 50 | 63.96 | 645.5 | 1.6125 | 60 | 32.49 | 649.5 | 1.5400 | 70 | 22.01 | 653.7 | 1.5011 |
| 60 | 65.24 | 650.5 | 1.6223 | 70 | 33.14 | 654.6 | 1.5497 | 80 | 22.44 | 658.9 | 1.5108 |
| 70 | 66.51 | 655.5 | 1.6319 | 80 | 33.78 | 659.7 | 1.5593 | 90 | 22.88 | 664.0 | 1.5203 |
| 80 | 67.79 | 660.6 | 1.6413 | 90 | 34.42 | 664.8 | 1.5687 | 100 | 23.31 | 669.2 | 1.5296 |
| 90 | 69.06 | 665.6 | 1.6506 | 100 | 35.07 | 670.0 | 1.5779 | 110 | 23.74 | 674.4 | 1.5388 |
| 100 | 70.33 | 670.7 | 1.6598 | 110 | 35.71 | 675.1 | 1.5870 | 120 | 24.17 | 679.6 | 1.5478 |
| 110 | 71.60 | 675.8 | 1.6689 | 120 | 36.35 | 680.3 | 1.5960 | 130 | 24.60 | 684.8 | 1.5567 |
| 120 | 72.87 | 680.9 | 1.6778 | 130 | 36.99 | 685.4 | 1.6049 | 140 | 25.03 | 690.0 | 1.5655 |
| 130 | 74.14 | 686.1 | 1.6865 | 140 | 37.62 | 690.6 | 1.6136 | 150 | 25.46 | 695.3 | 1.5742 |
| 140 | 75.41 | 691.2 | 1.6952 | 150 | 38.26 | 695.8 | 1.6222 | 160 | 25.88 | 700.5 | 1.5827 |
| 150 | 76.68 | 696.4 | 1.7038 | 160 | 38.90 | 701.1 | 1.6307 | 170 | 26.31 | 705.8 | 1.5911 |
| 160 | 77.95 | 701.6 | 1.7122 | 170 | 39.54 | 706.3 | 1.6391 | 180 | 26.74 | 711.1 | 1.5995 |
| 170 | 79.21 | 706.8 | 1.7206 | 180 | 40.17 | 711.6 | 1.6474 | 190 | 27.16 | 716.4 | 1.6077 |
| 180 | 80.48 | 712.1 | 1.7289 | 190 | 40.81 | 716.9 | 1.6556 | 200 | 27.59 | 721.7 | 1.6158 |
| | | | | 200 | 41.45 | 722.2 | 1.6637 | 210 | 28.02 | 727.0 | 1.6239 |
| | | | | | | | | 220 | 28.44 | 732.4 | 1.6318 |
| | | | | | | | | 230 | 28.88 | 737.8 | 1.6397 |
| | | | | | | | | 240 | 29.29 | 743.2 | 1.6475 |
| | | | | | | | | 250 | 29.71 | 748.6 | 1.6552 |

| Tem. °F. | Abs. Pressure 20 lb./in. ² Gage Press. 5.3 lb./in. ² (Sat'n Temp.—16.64° F.) | | | Tem. °F. | Abs. Pressure 25 lb./in. ² Gage Press. 10.3 lb./in. ² (Sat'n Temp.—7.96° F.) | | | Tem. °F. | Abs. Pressure 30 lb./in. ² Gage Press. 15.3 lb./in. ² (Sat'n Temp.—0.57° F.) | | |
|---------------|--|-----------------------------|----------------------------|---------------|--|-----------------------------|----------------------------|---------------|--|-----------------------------|----------------------------|
| | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (13.50) | (606.2) | (1.3700) | (at sat'n) | (10.96) | (609.1) | (1.3515) | (at sat'n) | (9.236) | (611.6) | (1.3364) |
| -20 | 13.74 | 610.0 | 1.3784 | 0 | 11.19 | 613.8 | 1.3616 | 0 | 9.250 | 611.9 | 1.3371 |
| -10 | 13.74 | 610.0 | 1.3784 | 10 | 11.47 | 619.4 | 1.3738 | 10 | 9.492 | 617.8 | 1.3497 |
| 0 | 14.09 | 615.5 | 1.3907 | 20 | 11.75 | 625.0 | 1.3855 | 20 | 9.731 | 623.5 | 1.3618 |
| 10 | 14.44 | 621.0 | 1.4025 | 30 | 12.03 | 630.4 | 1.3967 | 30 | 9.966 | 629.1 | 1.3733 |
| 20 | 14.78 | 626.4 | 1.4138 | 40 | 12.30 | 635.8 | 1.4077 | 40 | 10.20 | 634.6 | 1.3846 |
| 30 | 15.11 | 631.7 | 1.4248 | 50 | 12.57 | 641.2 | 1.4183 | 50 | 10.43 | 640.1 | 1.3953 |
| 40 | 15.45 | 637.0 | 1.4356 | 60 | 12.84 | 646.5 | 1.4287 | 60 | 10.65 | 645.5 | 1.4059 |
| 50 | 15.78 | 642.3 | 1.4460 | 70 | 13.11 | 651.8 | 1.4388 | 70 | 10.88 | 650.9 | 1.4161 |
| 60 | 16.12 | 647.5 | 1.4562 | 80 | 13.37 | 657.1 | 1.4487 | 80 | 11.10 | 656.2 | 1.4261 |
| 70 | 16.45 | 652.8 | 1.4662 | 90 | 13.64 | 662.4 | 1.4584 | 90 | 11.33 | 661.6 | 1.4359 |
| 80 | 16.78 | 658.0 | 1.4760 | 100 | 13.90 | 667.7 | 1.4679 | 100 | 11.55 | 666.9 | 1.4456 |
| 90 | 17.10 | 663.2 | 1.4856 | 110 | 14.17 | 673.0 | 1.4772 | 110 | 11.77 | 672.2 | 1.4550 |
| 100 | 17.43 | 668.5 | 1.4950 | 120 | 14.43 | 678.2 | 1.4864 | 120 | 11.99 | 677.5 | 1.4642 |
| 110 | 17.76 | 673.7 | 1.5042 | 130 | 14.69 | 683.5 | 1.4954 | 130 | 12.21 | 682.9 | 1.4733 |
| 120 | 18.08 | 678.9 | 1.5133 | 140 | 14.95 | 688.8 | 1.5043 | 140 | 12.43 | 688.2 | 1.4823 |
| 130 | 18.41 | 684.2 | 1.5223 | 150 | 15.21 | 694.1 | 1.5131 | 150 | 12.65 | 693.5 | 1.4911 |
| 140 | 18.73 | 689.4 | 1.5312 | 160 | 15.47 | 699.4 | 1.5217 | 160 | 12.87 | 698.8 | 1.4998 |
| 150 | 19.05 | 694.7 | 1.5399 | 170 | 15.73 | 704.7 | 1.5303 | 170 | 13.08 | 704.2 | 1.5083 |
| 160 | 19.37 | 700.0 | 1.5485 | 180 | 15.99 | 710.1 | 1.5387 | 180 | 13.30 | 709.6 | 1.5168 |
| 170 | 19.70 | 705.3 | 1.5569 | 190 | 16.25 | 715.4 | 1.5470 | 190 | 13.52 | 714.9 | 1.5251 |
| 180 | 20.02 | 710.6 | 1.5653 | 200 | 16.50 | 720.8 | 1.5552 | 200 | 13.73 | 720.3 | 1.5334 |
| 190 | 20.34 | 715.9 | 1.5736 | 210 | 16.76 | 726.2 | 1.5633 | 210 | 13.95 | 725.7 | 1.5415 |
| 200 | 20.66 | 721.2 | 1.5817 | 220 | 17.02 | 731.6 | 1.5713 | 220 | 14.16 | 731.1 | 1.5495 |
| 210 | 20.98 | 726.6 | 1.5898 | 230 | 17.27 | 737.0 | 1.5792 | 230 | 14.38 | 736.6 | 1.5575 |
| 220 | 21.30 | 732.0 | 1.5978 | 240 | 17.53 | 742.5 | 1.5870 | 240 | 14.59 | 742.0 | 1.5653 |
| 230 | 21.62 | 737.4 | 1.6057 | 250 | 17.79 | 747.9 | 1.5948 | 250 | 14.81 | 747.5 | 1.5732 |
| 240 | 21.94 | 742.8 | 1.6135 | 260 | 18.04 | 753.4 | 1.6025 | 260 | 15.02 | 753.0 | 1.5808 |
| 250 | 22.26 | 748.3 | 1.6212 | 270 | 18.30 | 758.9 | 1.6101 | 270 | 15.23 | 758.5 | 1.5884 |
| | | | | | | | | 280 | 15.45 | 764.1 | 1.5960 |

NOTE:—"V" is Volume of Superheated Vapor, ft.³/lb.; "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

*Inches of mercury at 32° F. below one standard atmosphere (29.92 in. = 14,696 lbs. abs.)

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF
SUPERHEATED AMMONIA VAPORS—*Continued*
*Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for
The American Society of Refrigerating Engineers, July, 1925.*

| Abs. Pressure 35 lb./in. ² Gage Press. 20.3 lb./in. ² (Sat'n Temp. 5.89° F.) | | | | Abs. Pressure 40 lb./in. ² Gage Press. 25.3 lb./in. ² (Sat'n Temp. 11.66° F.) | | | | Abs. Pressure 50 lb./in. ² Gage Press. 35.3 lb./in. ² (Sat'n Temp. 21.67° F.) | | | |
|---|---------------------------------|-----------------------------|----------------------------|---|---------------------------------|-----------------------------|----------------------------|---|---------------------------------|-----------------------------|----------------------------|
| Temp. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Temp. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Temp. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (7.991) | (613.6) | (1.3236) | (at sat'n) | (7.047) | (615.4) | (1.3125) | (at sat'n) | (5.710) | (618.2) | (1.2939) |
| 10 | 8.078 | 616.1 | 1.3289 | 10 | 7.203 | 620.4 | 1.3231 | 30 | 5.838 | 623.4 | 1.3046 |
| 20 | 8.287 | 622.0 | 1.3413 | 20 | 7.387 | 626.3 | 1.3353 | 40 | 5.988 | 629.5 | 1.3169 |
| 30 | 8.493 | 627.7 | 1.3532 | 30 | 7.568 | 632.1 | 1.3470 | 50 | 6.135 | 635.4 | 1.3286 |
| 40 | 8.695 | 633.4 | 1.3646 | 40 | 7.746 | 637.8 | 1.3583 | 60 | 6.280 | 641.2 | 1.3399 |
| 50 | 8.895 | 638.9 | 1.3756 | 50 | 7.922 | 643.4 | 1.3692 | 70 | 6.423 | 646.9 | 1.3508 |
| 60 | 9.093 | 644.4 | 1.3863 | 60 | 8.096 | 648.9 | 1.3797 | 80 | 6.564 | 652.6 | 1.3613 |
| 70 | 9.289 | 649.9 | 1.3967 | 70 | 8.268 | 654.4 | 1.3900 | 90 | 6.704 | 658.2 | 1.3716 |
| 80 | 9.484 | 655.3 | 1.4069 | 80 | 8.439 | 659.9 | 1.4000 | 100 | 6.843 | 663.7 | 1.3816 |
| 90 | 9.677 | 660.7 | 1.4168 | 90 | 8.609 | 665.3 | 1.4098 | 110 | 6.980 | 669.2 | 1.3914 |
| 100 | 9.869 | 666.1 | 1.4265 | 100 | 8.777 | 670.7 | 1.4194 | 120 | 7.117 | 674.7 | 1.4009 |
| 110 | 10.06 | 671.5 | 1.4360 | 110 | 8.945 | 676.1 | 1.4288 | 130 | 7.252 | 680.2 | 1.4103 |
| 120 | 10.25 | 676.8 | 1.4453 | 120 | 9.112 | 681.5 | 1.4381 | 140 | 7.387 | 685.7 | 1.4195 |
| 130 | 10.44 | 682.2 | 1.4545 | 130 | 9.278 | 686.9 | 1.4471 | 150 | 7.521 | 691.1 | 1.4286 |
| 140 | 10.63 | 687.6 | 1.4635 | 140 | 9.444 | 692.3 | 1.4561 | 160 | 7.655 | 696.6 | 1.4374 |
| 150 | 10.82 | 692.9 | 1.4724 | 150 | 9.609 | 697.7 | 1.4648 | 170 | 7.788 | 702.1 | 1.4462 |
| 160 | 11.00 | 698.3 | 1.4811 | 160 | 9.774 | 703.1 | 1.4735 | 180 | 7.921 | 707.5 | 1.4548 |
| 170 | 11.19 | 703.7 | 1.4897 | 170 | 9.938 | 708.5 | 1.4820 | 190 | 8.053 | 713.0 | 1.4633 |
| 180 | 11.38 | 709.1 | 1.4982 | 180 | 10.10 | 714.0 | 1.4904 | 200 | 8.185 | 718.5 | 1.4716 |
| 190 | 11.56 | 714.5 | 1.5066 | 190 | 10.27 | 719.4 | 1.4987 | 210 | 8.317 | 724.0 | 1.4799 |
| 200 | 11.75 | 719.9 | 1.5148 | 200 | 10.43 | 724.9 | 1.5069 | 220 | 8.448 | 729.4 | 1.4880 |
| 210 | 11.94 | 725.3 | 1.5230 | 210 | 10.59 | 730.3 | 1.5150 | 230 | 8.579 | 734.9 | 1.4961 |
| 220 | 12.12 | 730.7 | 1.5311 | 220 | 10.75 | 735.8 | 1.5230 | 240 | 8.710 | 740.5 | 1.5040 |
| 230 | 12.31 | 736.2 | 1.5390 | 230 | 10.92 | 741.3 | 1.5309 | 250 | 8.840 | 746.0 | 1.5119 |
| 240 | 12.49 | 741.7 | 1.5469 | 240 | 11.08 | 746.8 | 1.5387 | 260 | 8.970 | 751.6 | 1.5197 |
| 250 | 12.68 | 747.2 | 1.5547 | 250 | 11.24 | 752.3 | 1.5465 | 270 | 9.100 | 757.2 | 1.5274 |
| 260 | 12.86 | 752.7 | 1.5624 | 260 | 11.40 | 757.8 | 1.5541 | 280 | 9.230 | 762.7 | 1.5350 |
| 270 | 13.04 | 758.2 | 1.5701 | 270 | 11.56 | 763.4 | 1.5617 | 290 | 9.360 | 768.4 | 1.5425 |
| 280 | 13.23 | 763.7 | 1.5776 | 280 | 11.72 | 768.9 | 1.5692 | 300 | 9.489 | 774.0 | 1.5500 |
| 290 | 13.41 | 769.2 | 1.5851 | 290 | 11.88 | 774.4 | 1.5767 | 310 | 9.618 | 779.6 | 1.5574 |
| Abs. Pressure 60 lb./in. ² Gage Press. 45.3 lb./in. ² (Sat'n Temp. 30.21° F.) | | | | Abs. Pressure 70 lb./in. ² Gage Press. 55.3 lb./in. ² (Sat'n Temp. 37.70° F.) | | | | Abs. Pressure 80 lb./in. ² Gage Press. 65.3 lb./in. ² (Sat'n Temp. 44.40° F.) | | | |
| Temp. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Temp. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Temp. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (4.805) | (620.5) | (1.2787) | (at sat'n) | (4.151) | (622.4) | (1.2658) | (at sat'n) | (3.655) | (624.0) | (1.2545) |
| 30 | 4.805 | 620.5 | 1.2787 | 30 | 4.177 | 623.9 | 1.2688 | 50 | 3.712 | 627.7 | 1.2619 |
| 40 | 4.933 | 626.8 | 1.2913 | 40 | 4.290 | 630.4 | 1.2816 | 60 | 3.812 | 634.3 | 1.2745 |
| 50 | 5.060 | 632.9 | 1.3035 | 50 | 4.401 | 636.6 | 1.2937 | 70 | 3.909 | 640.6 | 1.2866 |
| 60 | 5.184 | 639.0 | 1.3152 | 60 | 4.509 | 642.7 | 1.3054 | 80 | 4.005 | 646.7 | 1.2981 |
| 70 | 5.307 | 644.9 | 1.3265 | 70 | 4.615 | 648.7 | 1.3166 | 90 | 4.098 | 652.8 | 1.3092 |
| 80 | 5.428 | 650.7 | 1.3373 | 80 | 4.719 | 654.6 | 1.3274 | 100 | 4.190 | 658.7 | 1.3199 |
| 90 | 5.547 | 656.4 | 1.3479 | 90 | 4.822 | 660.4 | 1.3378 | 110 | 4.281 | 664.6 | 1.3303 |
| 100 | 5.665 | 662.1 | 1.3581 | 100 | 4.924 | 666.1 | 1.3480 | 120 | 4.371 | 670.4 | 1.3404 |
| 110 | 5.781 | 667.7 | 1.3681 | 110 | 5.025 | 671.8 | 1.3579 | 130 | 4.460 | 676.1 | 1.3502 |
| 120 | 5.897 | 673.3 | 1.3778 | 120 | 5.125 | 677.5 | 1.3676 | 140 | 4.548 | 681.8 | 1.3598 |
| 130 | 6.012 | 678.9 | 1.3873 | 130 | 5.224 | 683.1 | 1.3770 | 150 | 4.635 | 687.5 | 1.3692 |
| 140 | 6.126 | 684.4 | 1.3966 | 140 | 5.323 | 688.7 | 1.3863 | 160 | 4.722 | 693.2 | 1.3784 |
| 150 | 6.239 | 689.9 | 1.4058 | 150 | 5.420 | 694.3 | 1.3954 | 170 | 4.808 | 698.8 | 1.3874 |
| 160 | 6.352 | 695.5 | 1.4148 | 160 | 5.518 | 699.9 | 1.4043 | 180 | 4.893 | 704.4 | 1.3963 |
| 170 | 6.464 | 701.0 | 1.4236 | 170 | 5.615 | 705.5 | 1.4131 | 190 | 4.978 | 710.0 | 1.4050 |
| 180 | 6.576 | 706.5 | 1.4323 | 180 | 5.711 | 711.0 | 1.421 | 200 | 5.063 | 715.6 | 1.4136 |
| 190 | 6.687 | 712.0 | 1.4409 | 190 | 5.807 | 716.6 | 1.4302 | 210 | 5.147 | 721.3 | 1.4220 |
| 200 | 6.798 | 717.5 | 1.4493 | 200 | 5.902 | 722.2 | 1.4386 | 220 | 5.231 | 726.9 | 1.4304 |
| 210 | 6.909 | 723.1 | 1.4576 | 210 | 6.003 | 727.7 | 1.4469 | 230 | 5.315 | 732.5 | 1.4386 |
| 220 | 7.019 | 728.6 | 1.4658 | 220 | 6.103 | 733.3 | 1.4550 | 240 | 5.398 | 738.1 | 1.4467 |
| 230 | 7.129 | 734.1 | 1.4739 | 230 | 6.187 | 738.9 | 1.4631 | 250 | 5.482 | 743.8 | 1.4547 |
| 240 | 7.238 | 739.7 | 1.4819 | 240 | 6.281 | 744.5 | 1.4711 | 260 | 5.565 | 749.4 | 1.4626 |
| 250 | 7.348 | 745.3 | 1.4898 | 250 | 6.376 | 750.1 | 1.4789 | 270 | 5.647 | 755.0 | 1.4704 |
| 260 | 7.457 | 750.9 | 1.4976 | 260 | 6.470 | 755.8 | 1.4866 | 280 | 5.730 | 760.7 | 1.4781 |
| 270 | 7.566 | 756.5 | 1.5053 | 270 | 6.563 | 761.4 | 1.4943 | 290 | 5.812 | 766.4 | 1.4857 |
| 280 | 7.675 | 762.1 | 1.5130 | 280 | 6.657 | 767.1 | 1.5019 | 300 | 5.894 | 772.1 | 1.4933 |
| 290 | 7.783 | 767.7 | 1.5206 | 290 | 6.750 | 772.7 | 1.5095 | 310 | 5.976 | 777.8 | 1.5008 |
| 300 | 7.892 | 773.3 | 1.5281 | 300 | 6.844 | 778.4 | 1.5169 | 320 | 6.058 | 783.5 | 1.5081 |
| 310 | 8.000 | 779.0 | 1.5355 | 310 | 6.937 | 784.1 | 1.5243 | | | | |

NOTE:—"V" is Volume of Superheated Vapor, ft.³/lb.;—"H" is Heat Content, Btu./lb., and—"S" is Entropy, Btu./lb. °F.

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF
SUPERHEATED AMMONIA VAPORS—*Continued*
*Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for
The American Society of Refrigerating Engineers, July, 1925.*

| Abs. Pressure 90 lb./in. ² Gage Press. 75.3 lb./in. ² (Sat'n Temp. 50.47° F.) | | | | Abs. Pressure 100 lb./in. ² Gage Press. 85.3 lb./in. ² (Sat'n Temp. 56.05° F.) | | | | Abs. Pressure 110 lb./in. ² Gage Press. 95.3 lb./in. ² (Sat'n Temp. 61.21° F.) | | | |
|---|---------------------------------|-----------------------------|----------------------------|---|---------------------------------|-----------------------------|----------------------------|---|---------------------------------|-----------------------------|----------------------------|
| Tem. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Tem. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Tem. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (3.266) | (625.3) | (1.2445) | (at sat'n) | (2.952) | (626.5) | (1.2356) | (at sat'n) | (2.693) | (627.5) | (1.2276) |
| 50 | 60 | 63.53 | 631.8 | 60 | 2.985 | 629.3 | 1.2409 | 60 | 2.761 | 633.7 | 1.2392 |
| 60 | 3.442 | 638.3 | 1.2695 | 70 | 3.068 | 636.0 | 1.2539 | 70 | 2.837 | 640.5 | 1.2519 |
| 70 | 3.529 | 644.7 | 1.2814 | 80 | 3.149 | 642.6 | 1.2661 | 80 | 2.910 | 647.0 | 1.2640 |
| 80 | 3.614 | 650.9 | 1.2928 | 90 | 3.227 | 649.0 | 1.2778 | 90 | 2.981 | 653.4 | 1.2755 |
| 100 | 3.698 | 657.0 | 1.3038 | 100 | 3.304 | 655.2 | 1.2891 | 100 | 3.051 | 659.7 | 1.2866 |
| 110 | 3.780 | 663.0 | 1.3144 | 110 | 3.380 | 661.3 | 1.2999 | 110 | 3.120 | 665.8 | 1.2972 |
| 120 | 3.862 | 668.9 | 1.3247 | 120 | 3.454 | 667.3 | 1.3104 | 120 | 3.188 | 671.9 | 1.3076 |
| 130 | 3.942 | 674.7 | 1.3347 | 130 | 3.527 | 673.3 | 1.3206 | 130 | 3.255 | 677.8 | 1.3176 |
| 140 | 4.021 | 680.5 | 1.3444 | 140 | 3.600 | 679.2 | 1.3305 | 140 | 3.321 | 683.7 | 1.3274 |
| 150 | 4.100 | 686.3 | 1.3539 | 150 | 3.672 | 685.0 | 1.3401 | 150 | 3.386 | 689.6 | 1.3370 |
| 160 | 4.178 | 692.0 | 1.3633 | 160 | 3.743 | 690.8 | 1.3495 | 160 | 3.451 | 695.4 | 1.3463 |
| 170 | 4.255 | 697.7 | 1.3724 | 170 | 3.813 | 696.6 | 1.3588 | 170 | 3.515 | 701.2 | 1.3555 |
| 180 | 4.332 | 703.4 | 1.3813 | 180 | 3.883 | 702.3 | 1.3678 | 180 | 3.579 | 707.0 | 1.3644 |
| 190 | 4.408 | 709.0 | 1.3901 | 190 | 3.952 | 708.0 | 1.3767 | 190 | 3.642 | 712.8 | 1.3732 |
| 200 | 4.484 | 714.7 | 1.3988 | 200 | 4.021 | 713.7 | 1.3854 | 200 | 3.705 | 718.5 | 1.3819 |
| 210 | 4.560 | 720.4 | 1.4073 | 210 | 4.090 | 719.4 | 1.3940 | 210 | 3.768 | 724.3 | 1.3904 |
| 220 | 4.635 | 726.0 | 1.4157 | 220 | 4.158 | 725.1 | 1.4024 | 220 | 3.830 | 730.0 | 1.3988 |
| 230 | 4.710 | 731.7 | 1.4239 | 230 | 4.226 | 730.8 | 1.4108 | 230 | 3.892 | 735.7 | 1.4070 |
| 240 | 4.785 | 737.3 | 1.4321 | 240 | 4.294 | 736.5 | 1.4190 | 240 | 3.954 | 741.5 | 1.4151 |
| 250 | 4.859 | 743.0 | 1.4401 | 250 | 4.361 | 742.2 | 1.4271 | 250 | 4.015 | 747.2 | 1.4232 |
| 260 | 4.933 | 748.7 | 1.4481 | 260 | 4.428 | 747.9 | 1.4350 | 260 | 4.076 | 752.9 | 1.4311 |
| 270 | 5.007 | 754.4 | 1.4559 | 270 | 4.495 | 753.6 | 1.4429 | 270 | 4.137 | 758.7 | 1.4389 |
| 280 | 5.081 | 760.0 | 1.4637 | 280 | 4.562 | 759.4 | 1.4507 | 280 | 4.198 | 764.5 | 1.4466 |
| 290 | 5.155 | 765.8 | 1.4713 | 290 | 4.629 | 765.1 | 1.4584 | 290 | 4.259 | 770.2 | 1.4543 |
| 300 | 5.228 | 771.5 | 1.4789 | 300 | 4.695 | 770.8 | 1.4660 | 300 | 4.319 | 776.0 | 1.4619 |
| 310 | 5.301 | 777.2 | 1.4864 | 310 | 4.761 | 776.6 | 1.4736 | 310 | 4.379 | 781.8 | 1.4693 |
| 320 | 5.374 | 783.0 | 1.4938 | 320 | 4.827 | 782.4 | 1.4810 | 320 | 4.439 | 787.6 | 1.4767 |
| | | | | 330 | 4.893 | 788.2 | 1.4884 | 330 | 4.499 | 793.4 | 1.4841 |
| | | | | 340 | 4.959 | 794.0 | 1.4957 | 340 | 4.559 | 799.3 | 1.4859 |
| | | | | 350 | 5.024 | 799.8 | 1.5029 | 350 | | | |
| Abs. Pressure 120 lb./in. ² Gage Press. 105.3 lb./in. ² (Sat'n Temp. 66.02° F.) | | | | Abs. Pressure 130 lb./in. ² Gage Press. 115.3 lb./in. ² (Sat'n Temp. 70.53° F.) | | | | Abs. Pressure 140 lb./in. ² Gage Press. 125.3 lb./in. ² (Sat'n Temp. 74.79° F.) | | | |
| Tem. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Tem. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. | Tem. °F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb. °F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (2.476) | (628.4) | (1.2201) | (at sat'n) | (2.291) | (629.2) | (1.2132) | (at sat'n) | (2.132) | (629.9) | (1.2068) |
| 70 | 2.505 | 631.3 | 1.2255 | 70 | 2.355 | 636.0 | 1.2260 | 70 | 2.166 | 633.8 | 1.2140 |
| 80 | 2.576 | 638.3 | 1.2386 | 80 | 2.421 | 643.0 | 1.2388 | 80 | 2.228 | 640.9 | 1.2272 |
| 90 | 2.645 | 645.0 | 1.2510 | 90 | 2.484 | 649.7 | 1.2509 | 90 | 2.288 | 647.8 | 1.2396 |
| 100 | 2.712 | 651.6 | 1.2628 | 100 | 2.546 | 656.3 | 1.2625 | 100 | 2.347 | 654.5 | 1.2515 |
| 110 | 2.778 | 658.0 | 1.2741 | 110 | 2.606 | 662.7 | 1.2736 | 110 | 2.404 | 661.1 | 1.2628 |
| 120 | 2.842 | 664.2 | 1.2850 | 120 | 2.665 | 668.9 | 1.2843 | 120 | 2.460 | 667.4 | 1.2738 |
| 130 | 2.905 | 670.4 | 1.2956 | 130 | 2.724 | 675.1 | 1.2947 | 130 | 2.515 | 673.7 | 1.2843 |
| 140 | 2.967 | 676.5 | 1.3058 | 140 | 2.781 | 681.2 | 1.3048 | 140 | 2.569 | 679.9 | 1.2945 |
| 150 | 3.029 | 682.5 | 1.3157 | 150 | 2.838 | 687.2 | 1.3146 | 150 | 2.622 | 686.0 | 1.3045 |
| 160 | 3.089 | 688.4 | 1.3254 | 160 | 2.894 | 693.2 | 1.3241 | 160 | 2.675 | 692.0 | 1.3141 |
| 170 | 3.149 | 694.3 | 1.3348 | 170 | 2.949 | 699.1 | 1.3335 | 170 | 2.727 | 698.0 | 1.3236 |
| 180 | 3.209 | 700.2 | 1.3441 | 180 | 3.004 | 705.0 | 1.3426 | 180 | 2.779 | 704.0 | 1.3328 |
| 190 | 3.268 | 706.0 | 1.3531 | 190 | 3.059 | 710.9 | 1.3516 | 190 | 2.830 | 709.9 | 1.3418 |
| 200 | 3.326 | 711.8 | 1.3620 | 200 | 3.113 | 716.7 | 1.3604 | 200 | 2.880 | 715.8 | 1.3507 |
| 210 | 3.385 | 717.6 | 1.3707 | 210 | 3.167 | 722.5 | 1.3690 | 210 | 2.931 | 721.6 | 1.3594 |
| 220 | 3.443 | 723.4 | 1.3793 | 220 | 3.220 | 728.3 | 1.3775 | 220 | 2.981 | 727.5 | 1.3679 |
| 230 | 3.500 | 729.2 | 1.3877 | 230 | 3.273 | 734.1 | 1.3858 | 230 | 3.030 | 733.3 | 1.3763 |
| 240 | 3.557 | 734.9 | 1.3960 | 240 | 3.326 | 739.9 | 1.3941 | 240 | 3.080 | 739.2 | 1.3846 |
| 250 | 3.614 | 740.7 | 1.4042 | 250 | 3.379 | 745.7 | 1.4022 | 250 | 3.129 | 745.0 | 1.3928 |
| 260 | 3.671 | 746.5 | 1.4123 | 260 | 3.431 | 751.5 | 1.4102 | 260 | 3.179 | 750.8 | 1.4008 |
| 270 | 3.727 | 752.2 | 1.4202 | 270 | 3.483 | 757.3 | 1.4181 | 270 | 3.227 | 756.7 | 1.4088 |
| 280 | 3.783 | 758.0 | 1.4281 | 280 | 3.535 | 763.1 | 1.4259 | 280 | 3.275 | 762.5 | 1.4166 |
| 290 | 3.839 | 763.8 | 1.4359 | 290 | 3.587 | 769.0 | 1.4336 | 290 | 3.323 | 768.3 | 1.4243 |
| 300 | 3.895 | 769.6 | 1.4435 | 300 | 3.639 | 774.8 | 1.4412 | 300 | 3.371 | 774.2 | 1.4320 |
| 310 | 3.951 | 775.4 | 1.4511 | 310 | 3.690 | 780.6 | 1.4487 | 310 | 3.420 | 780.0 | 1.4395 |
| 320 | 4.006 | 781.2 | 1.4586 | 320 | 3.742 | 786.5 | 1.4562 | 320 | 3.467 | 785.9 | 1.4470 |
| 330 | 4.061 | 787.0 | 1.4660 | 330 | 3.793 | 792.3 | 1.4636 | 330 | 3.515 | 791.8 | 1.4544 |
| 340 | 4.117 | 792.9 | 1.4734 | 340 | | | | 340 | 3.563 | 797.7 | 1.4617 |
| 350 | 4.172 | 798.7 | 1.4807 | 350 | 3.844 | 798.2 | 1.4709 | 350 | 3.610 | 803.6 | 1.4690 |

Notes:—"V" is Volume of Superheated Vapor, ft.³/lb., "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF
SUPERHEATED AMMONIA VAPORS—Continued
Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for
The American Society of Refrigerating Engineers, July, 1925.

| Abs. Pressure 150 lb./in. ² Gage Pressure 135.3 lb./in. ² (Sat'n Temp. 78.81° F.) | | | | | Abs. Pressure 160 lb./in. ² Gage Pressure 154.3 lb./in. ² (Sat'n Temp. 82.64° F.) | | | | | Abs. Pressure 170 lb./in. ² Gage Pressure 155.3 lb./in. ² (Sat'n Temp. 86.29° F.) | | | | | Abs. Pressure 180 lb./in. ² Gage Pressure 165.3 lb./in. ² (Sat'n Temp. 89.78° F.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|----------|----------|----------|----------|--|----------|----------|----------|----------|--|----------|----------|----------|----------|--|----------|----------|----------|----------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|
| Tem. °F. | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | Tem. °F. | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | Tem. °F. | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | Tem. °F. | <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (at sat'n) | (1.994) | (630.6) | (1.8009) | | (at sat'n) | (1.872) | (681.1) | (1.1958) | | (1.764) | (681.6) | (1.1900) | | (1.667) | (682.0) | (1.1850) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 90 | 2.001 | 631.4 | 1.2025 | 90 | 1.914 | 636.6 | 1.2055 | 1.784 | 634.4 | 1.1952 | 1.668 | 632.2 | 1.1853 | 90 | 2.061 | 638.8 | 1.2161 | 100 | 2.023 | 651.0 | 1.2311 | 1.889 | 649.1 | 1.2215 | 1.770 | 647.3 | 1.2123 | 1.818 | 654.4 | 1.2247 | 1.910 | 668.0 | 1.2477 | 1.955 | 674.6 | 1.2586 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 |
| 100 | 2.118 | 643.9 | 1.2289 | 110 | 2.023 | 651.0 | 1.2311 | 1.889 | 649.1 | 1.2215 | 1.770 | 647.3 | 1.2123 | 1.818 | 654.4 | 1.2247 | 1.910 | 668.0 | 1.2477 | 1.955 | 674.6 | 1.2586 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | |
| 110 | 2.174 | 652.8 | 1.2410 | 120 | 2.075 | 657.8 | 1.2429 | 1.939 | 656.1 | 1.2336 | 1.818 | 654.4 | 1.2247 | 1.910 | 668.0 | 1.2477 | 1.955 | 674.6 | 1.2586 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | |
| 120 | 2.228 | 659.4 | 1.2526 | 130 | 2.125 | 664.4 | 1.2542 | 1.988 | 662.8 | 1.2452 | 1.865 | 661.3 | 1.2364 | 1.910 | 668.0 | 1.2477 | 1.955 | 674.6 | 1.2586 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | |
| 130 | 2.281 | 665.9 | 1.2638 | 140 | 2.175 | 670.9 | 1.2652 | 2.035 | 669.4 | 1.2563 | 1.910 | 668.0 | 1.2477 | 1.955 | 674.6 | 1.2586 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | |
| 140 | 2.334 | 672.3 | 1.2745 | 150 | 2.224 | 677.2 | 1.2757 | 2.081 | 675.9 | 1.2669 | 1.955 | 674.6 | 1.2586 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | |
| 150 | 2.385 | 678.6 | 1.2849 | 160 | 2.272 | 683.5 | 1.2859 | 2.127 | 682.3 | 1.2773 | 1.999 | 681.0 | 1.2691 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 160 | 2.435 | 684.8 | 1.2949 | 170 | 2.319 | 689.7 | 1.2958 | 2.172 | 688.5 | 1.2873 | 2.042 | 687.3 | 1.2792 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 170 | 2.485 | 690.9 | 1.3047 | 180 | 2.365 | 695.8 | 1.3054 | 2.216 | 694.7 | 1.2971 | 2.084 | 693.6 | 1.2891 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 180 | 2.534 | 696.9 | 1.3142 | 190 | 2.411 | 701.9 | 1.3148 | 2.260 | 700.8 | 1.3066 | 2.126 | 699.8 | 1.2987 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 190 | 2.583 | 702.9 | 1.3236 | 200 | 2.457 | 707.9 | 1.3240 | 2.303 | 706.9 | 1.3159 | 2.167 | 705.9 | 1.3081 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 200 | 2.631 | 708.9 | 1.3327 | 210 | 2.502 | 713.9 | 1.3331 | 2.346 | 713.0 | 1.3249 | 2.208 | 712.0 | 1.3172 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | 2.484 | 756.9 | 1.3768 | 2.523 | 759.7 | 1.3847 | 2.561 | 765.8 | 1.3926 | 2.599 | 771.7 | 1.4004 | 2.637 | 777.7 | 1.4081 | 2.675 | 783.6 | 1.4156 | 2.713 | 789.6 | 1.4231 | 2.750 | 795.6 | 1.4305 | 2.788 | 801.5 | 1.4379 | 2.825 | 807.5 | 1.4451 | 2.863 | 813.5 | 1.4523 | 2.900 | 819.5 | 1.4594 | 2.937 | 825.5 | 1.4665 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 210 | 2.679 | 714.8 | 1.3416 | 220 | 2.547 | 719.9 | 1.3419 | 2.389 | 719.0 | 1.3338 | 2.248 | 718.0 | 1.3262 | 2.288 | 723.1 | 1.3350 | 2.328 | 730.1 | 1.3436 | 2.367 | 736.1 | 1.3521 | 2.407 | 742.0 | 1.3605 | 2.446 | 747.9 | 1.3686 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

TABLE XX.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SUPERHEATED AMMONIA VAPORS.—(Continued.)

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

| Temp. °F. | Abs. Pressure 230 lb./in. ² Gage Pressure 215.3 lb./in. ² (Sat'n. Temp. 103.30° F.) | | | Abs. Pressure 240 lb./in. ² Gage Pressure 225.3 lb./in. ² (Sat'n. Temp. 108.09° F.) | | | Abs. Pressure 250 lb./in. ² Gage Pressure 235.3 lb./in. ² (Sat'n. Temp. 110.80° F.) | | | Abs. Pressure 260 lb./in. ² Gage Pressure 245.3 lb./in. ² (Sat'n. Temp. 115.12° F.) | | |
|--------------|---|---------|----------|---|---------|----------|---|---------|----------|---|---------|----------|
| °F. | V | H | S | V | H | S | V | H | S | V | H | S |
| (atm'n) | (1.307) | (633.4) | (1.1610) | (1.235) | (635.6) | (1.1392) | (1.202) | (653.5) | (1.1553) | (1.154) | (655.9) | (1.1315) |
| 110 | 1.328 | 637.4 | 1.1700 | 1.261 | 635.3 | 1.1621 | 1.240 | 641.5 | 1.1690 | 1.182 | 639.5 | 1.1617 |
| 120 | 1.370 | 645.4 | 1.1840 | 1.302 | 643.5 | 1.1764 | 1.278 | 649.6 | 1.1827 | 1.220 | 647.8 | 1.1757 |
| 130 | 1.410 | 653.1 | 1.1971 | 1.342 | 651.3 | 1.1898 | 1.316 | 657.2 | 1.1956 | 1.257 | 655.6 | 1.1889 |
| 140 | 1.449 | 660.4 | 1.2095 | 1.380 | 658.8 | 1.2025 | | | | | | |
| 150 | 1.487 | 667.6 | 1.2213 | 1.416 | 666.1 | 1.2145 | 1.352 | 664.6 | 1.2078 | 1.292 | 663.1 | 1.2014 |
| 160 | 1.524 | 674.5 | 1.2325 | 1.452 | 673.1 | 1.2259 | 1.386 | 671.8 | 1.2195 | 1.326 | 670.4 | 1.2132 |
| 170 | 1.559 | 681.3 | 1.2434 | 1.487 | 680.0 | 1.2369 | 1.420 | 678.7 | 1.2306 | 1.359 | 677.5 | 1.2245 |
| 180 | 1.594 | 687.9 | 1.2538 | 1.521 | 686.7 | 1.2475 | 1.453 | 685.5 | 1.2414 | 1.391 | 684.4 | 1.2354 |
| 190 | 1.629 | 694.4 | 1.2640 | 1.554 | 693.3 | 1.2577 | 1.486 | 692.2 | 1.2517 | 1.422 | 691.1 | 1.2458 |
| 200 | 1.663 | 700.9 | 1.2738 | 1.587 | 699.8 | 1.2677 | 1.518 | 698.8 | 1.2617 | 1.453 | 697.7 | 1.2560 |
| 210 | 1.696 | 707.2 | 1.2834 | 1.619 | 706.2 | 1.2773 | 1.549 | 705.3 | 1.2715 | 1.484 | 703.3 | 1.2658 |
| 220 | 1.729 | 713.5 | 1.2927 | 1.651 | 712.6 | 1.2867 | 1.580 | 711.7 | 1.2810 | 1.514 | 710.7 | 1.2754 |
| 230 | 1.762 | 719.8 | 1.3018 | 1.683 | 718.9 | 1.2959 | 1.610 | 718.0 | 1.2902 | 1.543 | 717.1 | 1.2847 |
| 240 | 1.794 | 726.0 | 1.3107 | 1.714 | 725.1 | 1.3049 | 1.640 | 724.3 | 1.2993 | 1.572 | 723.4 | 1.2938 |
| 250 | 1.826 | 732.1 | 1.3195 | 1.745 | 731.3 | 1.3137 | 1.670 | 730.5 | 1.3081 | 1.601 | 729.7 | 1.3027 |
| 260 | 1.857 | 738.3 | 1.3281 | 1.777 | 737.5 | 1.3224 | 1.699 | 736.7 | 1.3168 | 1.630 | 736.0 | 1.3115 |
| 270 | 1.889 | 744.4 | 1.3365 | 1.805 | 743.6 | 1.3308 | 1.729 | 742.9 | 1.3253 | 1.658 | 742.2 | 1.3200 |
| 280 | 1.920 | 750.5 | 1.3448 | 1.835 | 749.8 | 1.3392 | 1.758 | 749.1 | 1.3337 | 1.686 | 748.4 | 1.3285 |
| 290 | 1.951 | 756.5 | 1.3530 | 1.865 | 755.9 | 1.3474 | 1.786 | 755.2 | 1.3420 | 1.714 | 754.5 | 1.3367 |
| 300 | 1.982 | 762.6 | 1.3610 | 1.895 | 762.0 | 1.3554 | 1.815 | 761.3 | 1.3501 | 1.741 | 760.7 | 1.3449 |
| 310 | 2.012 | 768.7 | 1.3689 | 1.924 | 768.0 | 1.3633 | 1.843 | 767.4 | 1.3581 | 1.769 | 766.8 | 1.3529 |
| 320 | 2.043 | 774.7 | 1.3767 | 1.954 | 774.1 | 1.3712 | 1.872 | 773.5 | 1.3659 | 1.796 | 772.9 | 1.3608 |
| 330 | 2.073 | 780.8 | 1.3844 | 1.983 | 780.2 | 1.3790 | 1.900 | 779.6 | 1.3737 | 1.823 | 779.0 | 1.3686 |
| 340 | 2.103 | 786.8 | 1.3921 | 2.012 | 786.3 | 1.3866 | 1.928 | 785.7 | 1.3814 | 1.850 | 785.2 | 1.3763 |
| 350 | 2.133 | 793.0 | 1.3996 | 2.040 | 792.4 | 1.3942 | 1.955 | 791.9 | 1.3889 | 1.877 | 791.4 | 1.3839 |
| 360 | 2.163 | 798.9 | 1.4070 | 2.069 | 798.4 | 1.4016 | 1.983 | 797.9 | 1.3964 | 1.904 | 797.4 | 1.3914 |
| 370 | 2.193 | 805.0 | 1.4144 | 2.098 | 804.5 | 1.4090 | 2.011 | 804.0 | 1.4038 | 1.930 | 803.5 | 1.3988 |
| 380 | 2.222 | 811.1 | 1.4217 | 2.126 | 810.6 | 1.4163 | 2.038 | 810.1 | 1.4111 | 1.957 | 809.6 | 1.4062 |
| 390 | 2.252 | 817.2 | 1.4289 | 2.155 | 816.7 | 1.4235 | 2.065 | 816.2 | 1.4183 | 1.983 | 815.8 | 1.4134 |
| 400 | 2.281 | 823.3 | 1.4360 | 2.183 | 822.8 | 1.4307 | 2.093 | 822.3 | 1.4255 | 2.009 | 821.9 | 1.4206 |
| Temp. °F. | Abs. Pressure 270 lb./in. ² Gage Pressure 255.3 lb./in. ² (Sat'n. Temp. 115.97° F.) | | | Abs. Pressure 280 lb./in. ² Gage Pressure 265.3 lb./in. ² (Sat'n. Temp. 120.85° F.) | | | Abs. Pressure 290 lb./in. ² Gage Pressure 275.3 lb./in. ² (Sat'n. Temp. 120.80° F.) | | | Abs. Pressure 300 lb./in. ² Gage Pressure 285.3 lb./in. ² (Sat'n. Temp. 123.21° F.) | | |
| (atm'n) | (1.112) | (633.9) | (1.1483) | (1.072) | (634.0) | (1.1449) | (1.034) | (634.0) | (1.1415) | (0.999) | (634.0) | (1.1383) |
| 120 | 1.128 | 637.5 | 1.1544 | 1.078 | 635.4 | 1.1473 | 1.068 | 642.1 | 1.1554 | 1.023 | 640.1 | 1.1487 |
| 130 | 1.166 | 645.0 | 1.1689 | 1.115 | 644.0 | 1.1621 | 1.103 | 650.5 | 1.1695 | 1.058 | 648.7 | 1.1632 |
| 140 | 1.202 | 653.9 | 1.1823 | 1.151 | 652.2 | 1.1759 | | | | | | |
| 150 | 1.236 | 661.6 | 1.1950 | 1.184 | 660.1 | 1.1888 | 1.136 | 658.5 | 1.1827 | 1.091 | 656.9 | 1.1767 |
| 160 | 1.267 | 669.0 | 1.2071 | 1.217 | 667.6 | 1.2011 | 1.168 | 666.1 | 1.1952 | 1.123 | 664.7 | 1.1894 |
| 170 | 1.302 | 676.2 | 1.2185 | 1.249 | 674.9 | 1.2127 | 1.199 | 673.5 | 1.2070 | 1.153 | 672.2 | 1.2014 |
| 180 | 1.333 | 683.2 | 1.2296 | 1.279 | 681.9 | 1.2239 | 1.229 | 680.7 | 1.2183 | 1.183 | 679.5 | 1.2129 |
| 190 | 1.364 | 690.0 | 1.2401 | 1.309 | 688.9 | 1.2346 | 1.259 | 687.7 | 1.2292 | 1.211 | 686.5 | 1.2239 |
| 200 | 1.394 | 696.7 | 1.2504 | 1.339 | 695.6 | 1.2449 | 1.287 | 694.6 | 1.2396 | 1.239 | 693.5 | 1.2344 |
| 210 | 1.423 | 703.3 | 1.2603 | 1.367 | 702.3 | 1.2550 | 1.315 | 701.3 | 1.2497 | 1.267 | 700.3 | 1.2447 |
| 220 | 1.452 | 709.8 | 1.2700 | 1.396 | 708.8 | 1.2647 | 1.343 | 707.9 | 1.2596 | 1.294 | 706.9 | 1.2546 |
| 230 | 1.481 | 716.2 | 1.2794 | 1.424 | 715.3 | 1.2742 | 1.370 | 714.4 | 1.2691 | 1.320 | 713.5 | 1.2642 |
| 240 | 1.509 | 722.6 | 1.2885 | 1.451 | 721.8 | 1.2834 | 1.397 | 720.9 | 1.2781 | 1.346 | 720.0 | 1.2736 |
| 250 | 1.537 | 728.9 | 1.2975 | 1.478 | 728.1 | 1.2924 | 1.423 | 727.3 | 1.2875 | 1.372 | 726.5 | 1.2827 |
| 260 | 1.565 | 735.2 | 1.3063 | 1.505 | 734.4 | 1.3013 | 1.449 | 733.7 | 1.2964 | 1.397 | 732.9 | 1.2917 |
| 270 | 1.592 | 741.4 | 1.3149 | 1.532 | 740.7 | 1.3099 | 1.475 | 740.0 | 1.3051 | 1.422 | 739.2 | 1.3004 |
| 280 | 1.620 | 747.7 | 1.3234 | 1.558 | 747.0 | 1.3184 | 1.501 | 746.3 | 1.3137 | 1.447 | 745.5 | 1.3090 |
| 290 | 1.646 | 753.9 | 1.3317 | 1.584 | 753.2 | 1.3268 | 1.526 | 752.5 | 1.3221 | 1.472 | 751.8 | 1.3175 |
| 300 | 1.673 | 760.0 | 1.3399 | 1.610 | 759.4 | 1.3350 | 1.551 | 758.7 | 1.3303 | 1.496 | 758.1 | 1.3257 |
| 310 | 1.700 | 766.2 | 1.3480 | 1.635 | 765.6 | 1.3431 | 1.576 | 764.9 | 1.3384 | 1.520 | 764.3 | 1.3338 |
| 320 | 1.726 | 772.3 | 1.3559 | 1.661 | 771.7 | 1.3511 | 1.601 | 771.1 | 1.3464 | 1.544 | 770.5 | 1.3419 |
| 330 | 1.752 | 778.5 | 1.3647 | 1.686 | 777.9 | 1.3590 | 1.625 | 777.3 | 1.3543 | 1.568 | 776.7 | 1.3498 |
| 340 | 1.778 | 784.6 | 1.3714 | 1.712 | 784.0 | 1.3667 | 1.650 | 783.5 | 1.3621 | 1.592 | 782.9 | 1.3576 |
| 350 | 1.801 | 790.8 | 1.3790 | 1.737 | 790.3 | 1.3743 | 1.674 | 789.7 | 1.3697 | 1.616 | 789.1 | 1.3653 |
| 360 | 1.830 | 796.9 | 1.3866 | 1.762 | 796.3 | 1.3819 | 1.698 | 795.8 | 1.3773 | 1.639 | 795.3 | 1.3729 |
| 370 | 1.856 | 803.0 | 1.3940 | 1.787 | 802.5 | 1.3893 | 1.722 | 802.0 | 1.3848 | 1.662 | 801.5 | 1.3804 |
| 380 | 1.881 | 809.1 | 1.4014 | 1.811 | 808.7 | 1.3967 | 1.747 | 808.2 | 1.3922 | 1.686 | 807.7 | 1.3878 |
| 390 | 1.907 | 815.3 | 1.4086 | 1.836 | 814.8 | 1.4040 | 1.770 | 814.3 | 1.3995 | 1.709 | 813.9 | 1.3951 |
| 400 | 1.932 | 821.4 | 1.4158 | 1.861 | 821.0 | 1.4112 | 1.794 | 820.5 | 1.4067 | 1.732 | 820.1 | 1.4024 |

NOTE:—"V" is Volume of Superheated Vapor, ft.³/lb.; "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

TABLE XXI.—PROPERTIES OF SATURATED CARBON DIOXIDE VAPOR—CO₂ (Temperature Table)

Mollier (Amagat), Hodsdon, Ice and Cold Storage, London (1914).

| Temp. | Pressure | | | Volume | | Density | | Heat Content Above 32° F. | | | Entropy From 32° F. | | | |
|----------|------------------------------|---|---|---------------------------------|--------------------------------|--------------------------------|-------------------------------|------------------------------|--------------------|-------------------|------------------------|-------------------|-------------------|--------------|
| °F. | Abs. lb./in. ² | Gage [†] Atmos. at./in. ² | Gage [†] lb./in. ² | Liquid ft. ³ /lb. | Vapor ft. ³ /lb. | Liquid lb./ft. ³ | Vapor lb./ft. ³ | Liquid Btu./lb. | Latent Btu./lb. | Vapor Btu./lb. | Liquid Btu./lb. | Evap. Btu./lb. | Vapor Btu./lb. | Temp. °F. |
| <i>t</i> | <i>p</i> | <i>a-g p</i> | <i>g p</i> | <i>v</i> | <i>V</i> | <i>I/v</i> | <i>I/V</i> | <i>h+</i> | <i>L=</i> | <i>H</i> | <i>s</i> | <i>L/T</i> | <i>S</i> | <i>t</i> |
| -22 | 212.9 | 13.48 | 198.2 | 0.0155 | 0.4319 | 64.52 | 2.315 | -24.78 | 126.7 | 102.0 | -0.0533 | 0.2898 | 0.2365 | -22 |
| -21 | 216.7 | 13.74 | 202.0 | 0.0155 | .4242 | 64.43 | 2.358 | -24.37 | 126.4 | 102.0 | -0.0524 | .2883 | .2359 | -21 |
| -20 | 220.6 | 14.00 | 205.9 | 0.0155 | .4166 | 64.34 | 2.401 | -23.96 | 126.0 | 102.0 | -0.0514 | .2867 | .2353 | -20 |
| -19 | 224.4 | 14.27 | 209.7 | .0156 | .4091 | 64.25 | 2.444 | -23.54 | 125.6 | 102.1 | -0.0505 | .2852 | .2348 | -19 |
| -18 | 228.4 | 14.53 | 213.7 | .0156 | .4018 | 64.15 | 2.489 | -23.13 | 125.2 | 102.1 | -0.0495 | .2837 | .2342 | -18 |
| -17 | 232.3 | 14.80 | 217.6 | .0156 | .3946 | 64.05 | 2.534 | -22.71 | 124.9 | 102.1 | -0.0486 | .2822 | .2336 | -17 |
| -16 | 236.4 | 15.08 | 221.7 | .0156 | .3876 | 63.94 | 2.580 | -22.30 | 124.5 | 102.2 | -0.0476 | .2807 | .2331 | -16 |
| -15 | 240.5 | 15.36 | 225.8 | 0.0157 | .3807 | 63.84 | 2.627 | -21.88 | 124.1 | 102.2 | -0.0467 | .2792 | .2325 | -15 |
| -14 | 244.6 | 15.64 | 229.9 | 0.0157 | .3739 | 63.73 | 2.674 | -21.46 | 123.7 | 102.2 | -0.0458 | .2777 | .2319 | -14 |
| -13 | 248.8 | 15.92 | 234.1 | 0.0157 | .3673 | 63.61 | 2.723 | -21.03 | 123.3 | 102.2 | -0.0448 | .2761 | .2313 | -13 |
| -12 | 253.0 | 16.21 | 238.3 | 0.0157 | .3608 | 63.49 | 2.772 | -20.61 | 122.9 | 102.3 | -0.0439 | .2746 | .2307 | -12 |
| -11 | 258.3 | 16.50 | 242.6 | .0158 | .3544 | 63.37 | 2.822 | -20.18 | 122.5 | 102.3 | -0.0429 | .2731 | .2302 | -11 |
| -10 | 261.7 | 16.80 | 247.0 | 0.0158 | .3482 | 63.25 | 2.872 | -19.76 | 122.0 | 102.3 | -0.0420 | .2716 | .2296 | -10 |
| -9 | 266.1 | 17.10 | 251.4 | .0158 | .3420 | 63.13 | 2.924 | -19.33 | 121.6 | 102.3 | -0.0410 | .2700 | .2290 | -9 |
| -8 | 270.6 | 17.41 | 255.9 | 0.0159 | .3360 | 63.01 | 2.976 | -18.90 | 121.2 | 102.3 | -0.0401 | .2685 | .2284 | -8 |
| -7 | 275.1 | 17.72 | 260.4 | .0159 | .3302 | 62.88 | 3.029 | -18.47 | 120.8 | 102.3 | -0.0391 | .2669 | .2278 | -7 |
| -6 | 279.7 | 18.03 | 265.0 | .0159 | .3243 | 62.76 | 3.083 | -18.04 | 120.3 | 102.3 | -0.0382 | .2654 | .2273 | -6 |
| -5 | 284.4 | 18.35 | 269.7 | 0.0160 | .3186 | 62.63 | 3.138 | -17.61 | 119.9 | 102.3 | -0.0372 | .2639 | .2267 | -5 |
| -4 | 289.1 | 18.67 | 274.4 | .0160 | .3131 | 62.50 | 3.194 | -17.17 | 119.5 | 102.3 | -0.0362 | .2623 | .2261 | -4 |
| -3 | 293.9 | 18.99 | 279.2 | .0160 | .3076 | 62.37 | 3.251 | -16.73 | 119.0 | 102.3 | -0.0353 | .2608 | .2255 | -3 |
| -2 | 298.7 | 19.32 | 284.0 | .0161 | .3022 | 62.23 | 3.309 | -16.29 | 118.6 | 102.3 | -0.0343 | .2592 | .2249 | -2 |
| -1 | 303.6 | 19.66 | 288.9 | 0.0161 | .2969 | 62.09 | 3.368 | -15.85 | 118.1 | 102.3 | -0.0334 | .2577 | .2243 | -1 |
| 0 | 308.6 | 20.00 | 293.9 | 0.0161 | .2918 | 61.95 | 3.427 | -15.41 | 117.7 | 102.2 | -0.0324 | .2561 | .2237 | 0 |
| 1 | 313.7 | 20.34 | 299.0 | .0162 | .2867 | 61.80 | 3.488 | -14.96 | 117.2 | 102.2 | -0.0314 | .2545 | .2231 | 1 |
| 2 | 318.7 | 20.68 | 304.0 | 0.0162 | .2817 | 61.65 | 3.550 | -14.51 | 116.7 | 102.2 | -0.0304 | .2530 | .2225 | 2 |
| 3 | 323.9 | 21.03 | 309.2 | 0.0163 | .2768 | 61.51 | 3.612 | -14.07 | 116.2 | 102.2 | -0.0295 | .2514 | .2219 | 3 |
| 4 | 329.1 | 21.39 | 314.4 | .0163 | .2720 | 61.36 | 3.676 | -13.61 | 115.8 | 102.1 | -0.0285 | .2498 | .2213 | 4 |
| 5 | 334.4 | 21.75 | 319.7 | 0.0163 | .2673 | 61.22 | 3.741 | -13.16 | 115.3 | 102.1 | -0.0275 | .2482 | .2207 | 5 |
| 6 | 339.8 | 22.11 | 325.1 | .0164 | .2627 | 61.07 | 3.807 | -12.71 | 114.8 | 102.1 | -0.0266 | .2466 | .2201 | 6 |
| 7 | 345.2 | 22.48 | 330.5 | 0.0164 | .2581 | 60.92 | 3.874 | -12.25 | 114.3 | 102.0 | -0.0256 | .2451 | .2195 | 7 |
| 8 | 350.7 | 22.85 | 336.0 | 0.0165 | .2537 | 60.77 | 3.942 | -11.79 | 113.8 | 102.0 | -0.0246 | .2435 | .2189 | 8 |
| 9 | 356.2 | 23.23 | 341.5 | .0165 | .2493 | 60.63 | 4.011 | -11.33 | 113.3 | 102.0 | -0.0236 | .2419 | .2183 | 9 |
| 10 | 361.8 | 23.61 | 347.1 | 0.0165 | .2450 | 60.48 | 4.082 | -10.87 | 112.8 | 101.9 | -0.0226 | .2402 | .2176 | 10 |
| 11 | 367.5 | 24.00 | 352.8 | .0166 | .2408 | 60.33 | 4.154 | -10.40 | 112.3 | 101.9 | -0.0216 | .2386 | .2170 | 11 |
| 12 | 373.3 | 24.39 | 358.6 | .0166 | .2366 | 60.18 | 4.227 | -9.934 | 111.7 | 101.8 | -0.0206 | .2370 | .2164 | 12 |
| 13 | 379.1 | 24.79 | 364.4 | .0167 | .2325 | 60.03 | 4.301 | -9.464 | 111.2 | 101.7 | -0.0196 | .2354 | .2158 | 13 |
| 14 | 385.0 | 25.19 | 370.3 | .0167 | .2285 | 59.88 | 4.377 | -8.992 | 110.7 | 101.7 | -0.0186 | .2338 | .2151 | 14 |
| 15 | 391.0 | 25.60 | 376.3 | 0.0167 | .2245 | 59.73 | 4.454 | -8.515 | 110.1 | 101.6 | -0.0176 | .2321 | .2145 | 15 |
| 16 | 397.1 | 26.01 | 382.4 | .0168 | .2207 | 59.58 | 4.532 | -8.038 | 109.6 | 101.5 | -0.0166 | .2305 | .2139 | 16 |
| 17 | 403.2 | 26.43 | 388.5 | .0168 | .2168 | 59.42 | 4.611 | -7.557 | 109.0 | 101.5 | -0.0156 | .2288 | .2132 | 17 |
| 18 | 409.4 | 26.85 | 394.7 | .0169 | .2131 | 59.27 | 4.692 | -7.076 | 108.5 | 101.4 | -0.0146 | .2272 | .2126 | 18 |
| 19 | 415.7 | 27.28 | 401.0 | .0169 | .2094 | 59.11 | 4.775 | -6.591 | 107.9 | 101.3 | -0.0136 | .2255 | .2119 | 19 |
| 20 | 422.0 | 27.71 | 407.3 | 0.0170 | .2058 | 58.95 | 4.859 | -6.102 | 107.3 | 101.2 | -0.0126 | .2239 | .2113 | 20 |
| 21 | 428.4 | 28.14 | 413.7 | .0170 | .2023 | 58.79 | 4.944 | -5.610 | 106.7 | 101.1 | -0.0115 | .2222 | .2106 | 21 |
| 22 | 434.9 | 28.58 | 420.2 | .0171 | .1987 | 58.64 | 5.031 | -5.117 | 106.1 | 101.0 | -0.0105 | .2205 | .2100 | 22 |
| 23 | 441.4 | 29.03 | 426.7 | .0171 | .1953 | 58.47 | 5.120 | -4.621 | 105.6 | 100.9 | -0.0095 | .2188 | .2093 | 23 |
| 24 | 448.1 | 29.48 | 433.4 | .0172 | .1919 | 58.31 | 5.211 | -4.121 | 104.9 | 100.8 | -0.0085 | .2171 | .2087 | 24 |
| 25 | 454.8 | 29.94 | 440.0 | 0.0172 | .1886 | 58.14 | 5.303 | -3.618 | 104.3 | 100.7 | -0.0074 | .2154 | .2080 | 25 |
| 26 | 461.6 | 30.40 | 446.9 | .0172 | .1853 | 57.98 | 5.396 | -3.110 | 103.7 | 100.6 | -0.0064 | .2137 | .2073 | 26 |
| 27 | 468.5 | 30.87 | 453.8 | .0173 | .1821 | 57.81 | 5.492 | -2.601 | 103.1 | 100.5 | -0.0053 | .2120 | .2066 | 27 |
| 28 | 475.4 | 31.34 | 460.7 | .0174 | .1789 | 57.64 | 5.589 | -2.087 | 102.5 | 100.4 | -0.0043 | .2102 | .2059 | 28 |
| 29 | 482.5 | 31.82 | 467.8 | .0174 | .1758 | 57.47 | 5.688 | -1.570 | 101.8 | 100.2 | -0.0032 | .2085 | .2053 | 29 |

*Rearranged and symbols changed, to conform to A. S. R. F. Standard, by Editor A. S. R. F. Data.

†Gage pressure supplied by Editor A. S. R. F. Data.

‡Standard ton temperatures.

REFRIGERANTS—TABLES

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TABLE XXI.—PROPERTIES OF SATURATED CARBON DIOXIDE VAPOR—
CO₂ (Temperature Table)—(Continued)

| Temp. ° F. <i>t</i> | Pressure | | | Volume | | | Density | | | Heat Content Above 32° F. | | | Entropy From 32° F. | | | Temp. ° F. <i>t</i> |
|---------------------------|-----------------------------|--|--|---|--|--|---|----------------------------------|----------------------------------|-------------------------------|--------------------------------|---------------------------------|-------------------------------|-------|--|---------------------------|
| | Abs. lb./in. <i>p</i> | Gage [†] Atmos. at./in. <i>a-g p</i> | Gage [†] lb./in. <i>g p</i> | Liquid ft. ³ /lb. <i>v</i> | Vapor ft. ³ /lb. <i>V</i> | Liquid lb./ft. ³ <i>l</i> | Vapor lb./ft. ³ <i>l/V</i> | Liquid Btu./lb. <i>h</i> + | Latent Btu./lb. <i>L</i> = | Vapor Btu./lb. <i>H</i> | Liquid Btu./lb. <i>s</i> | Evap. Btu./lb. <i>L/T</i> | Vapor Btu./lb. <i>S</i> | | | |
| 30 | 489.6 | 32.31 | 474.9 | 0.0175 | 0.1728 | 57.30 | 5.789 | - 0.049 | 101.2 | 100.1 | -0.0021 | 0.2067 | 0.2046 | 30 | | |
| 31 | 496.8 | 32.79 | 482.1 | 0.0175 | 0.1697 | 57.12 | 5.892 | - 0.025 | 100.5 | 99.98 | - .0011 | .2049 | .2039 | 31 | | |
| 32 | 504.1 | 33.29 | 489.4 | 0.0176 | 0.1668 | 56.95 | 5.996 | 0.000 | 99.83 | 99.83 | - .0000 | .2032 | .2032 | 32 | | |
| 33 | 511.4 | 33.79 | 496.7 | 0.0176 | 0.1639 | 56.77 | 6.103 | + 0.531 | 99.16 | 99.69 | + .0011 | .2014 | .2025 | 33 | | |
| 34 | 518.9 | 34.30 | 504.2 | 0.0177 | 0.1610 | 56.59 | 6.212 | + 1.066 | 98.47 | 99.54 | + .0022 | .1996 | .2017 | 34 | | |
| 35 | 526.4 | 34.81 | 511.7 | 0.0177 | 0.1581 | 56.41 | 6.323 | 1.604 | 97.77 | 99.38 | 0.0033 | 0.1978 | 0.2010 | 35 | | |
| 36 | 534.0 | 35.33 | 519.3 | 0.0178 | 0.1554 | 56.22 | 6.437 | 2.149 | 97.07 | 99.22 | .0044 | .1959 | .2003 | 36 | | |
| 37 | 541.7 | 35.85 | 527.0 | 0.0178 | 0.1526 | 56.03 | 6.553 | 2.697 | 96.35 | 99.05 | .0055 | .1941 | .1996 | 37 | | |
| 38 | 549.5 | 36.38 | 534.8 | 0.0179 | 0.1499 | 55.84 | 6.671 | 3.248 | 95.62 | 98.87 | .0066 | .1922 | .1988 | 38 | | |
| 39 | 557.4 | 36.92 | 542.7 | 0.0180 | 0.1472 | 55.65 | 6.792 | 3.806 | 94.88 | 98.69 | .0077 | .1904 | .1981 | 39 | | |
| 40 | 565.4 | 37.46 | 550.7 | 0.0180 | 0.1446 | 55.45 | 6.915 | 4.367 | 94.13 | 98.50 | 0.0088 | 0.1885 | 0.1973 | 40 | | |
| 41 | 573.4 | 38.01 | 558.7 | 0.0181 | 0.1420 | 55.25 | 7.040 | 4.932 | 93.37 | 98.31 | .0099 | .1866 | .1965 | 41 | | |
| 42 | 581.6 | 38.56 | 566.9 | 0.0182 | 0.1395 | 55.04 | 7.169 | 5.503 | 92.60 | 98.10 | .0111 | .1847 | .1958 | 42 | | |
| 43 | 589.8 | 39.12 | 575.1 | 0.0182 | 0.1370 | 54.84 | 7.300 | 6.080 | 91.82 | 97.90 | .0122 | .1828 | .1950 | 43 | | |
| 44 | 598.1 | 39.69 | 583.4 | 0.0183 | 0.1345 | 54.62 | 7.434 | 6.664 | 91.02 | 97.68 | .0134 | .1808 | .1942 | 44 | | |
| 45 | 606.5 | 40.26 | 591.8 | 0.0184 | 0.1321 | 54.41 | 7.571 | 7.251 | 90.21 | 97.46 | 0.0146 | 0.1788 | 0.1934 | 45 | | |
| 46 | 615.0 | 40.84 | 600.3 | 0.0185 | 0.1297 | 54.19 | 7.711 | 7.844 | 89.39 | 97.23 | .0157 | .1769 | .1926 | 46 | | |
| 47 | 623.6 | 41.43 | 608.9 | 0.0185 | 0.1273 | 53.97 | 7.854 | 8.443 | 88.55 | 96.99 | .0169 | .1749 | .1918 | 47 | | |
| 48 | 632.3 | 42.02 | 617.6 | 0.0186 | 0.1250 | 53.74 | 8.000 | 9.049 | 87.70 | 96.75 | .0181 | .1729 | .1910 | 48 | | |
| 49 | 641.1 | 42.63 | 626.4 | 0.0187 | 0.1227 | 53.51 | 8.151 | 9.664 | 86.83 | 96.50 | .0193 | .1708 | .1901 | 49 | | |
| 50 | 650.0 | 43.22 | 635.3 | 0.0188 | 0.1204 | 53.28 | 8.304 | 10.28 | 85.95 | 96.24 | 0.0205 | 0.1687 | 0.1893 | 50 | | |
| 51 | 659.0 | 43.83 | 644.3 | 0.0189 | 0.1182 | 53.04 | 8.461 | 10.91 | 85.06 | 95.97 | .0218 | .1666 | .1884 | 51 | | |
| 52 | 668.1 | 44.45 | 653.4 | 0.0189 | 0.1160 | 52.80 | 8.622 | 11.55 | 84.14 | 95.69 | .0230 | .1645 | .1875 | 52 | | |
| 53 | 677.3 | 45.07 | 662.6 | 0.0190 | 0.1138 | 52.55 | 8.787 | 12.19 | 83.21 | 95.40 | .0243 | .1624 | .1867 | 53 | | |
| 54 | 686.5 | 45.70 | 671.8 | 0.0191 | 0.1116 | 52.30 | 8.957 | 12.84 | 82.26 | 95.10 | .0255 | .1602 | .1858 | 54 | | |
| 55 | 695.9 | 46.34 | 681.2 | 0.0192 | 0.1095 | 52.05 | 9.132 | 13.49 | 81.29 | 94.78 | 0.0268 | 0.1580 | 0.1849 | 55 | | |
| 56 | 705.4 | 46.98 | 690.7 | 0.0193 | 0.1074 | 51.79 | 9.313 | 14.16 | 80.30 | 94.46 | .0281 | .1558 | .1839 | 56 | | |
| 57 | 714.9 | 47.63 | 700.2 | 0.0194 | 0.1053 | 51.53 | 9.497 | 14.84 | 79.30 | 94.13 | .0294 | .1536 | .1830 | 57 | | |
| 58 | 724.6 | 48.29 | 709.9 | 0.0195 | 0.1032 | 51.26 | 9.686 | 15.53 | 78.27 | 93.79 | .0307 | .1513 | .1820 | 58 | | |
| 59 | 734.3 | 48.96 | 719.6 | 0.0196 | 0.1012 | 50.99 | 9.880 | 16.22 | 77.22 | 93.44 | .0321 | .1490 | .1811 | 59 | | |
| 60 | 744.2 | 49.63 | 729.5 | 0.0197 | 0.0992 | 50.71 | 10.08 | 16.93 | 76.14 | 93.07 | 0.0335 | 0.1466 | 0.1801 | 60 | | |
| 61 | 754.2 | 50.30 | 739.5 | 0.0198 | 0.0972 | 50.42 | 10.29 | 17.65 | 75.04 | 92.69 | .0348 | .1442 | .1790 | 61 | | |
| 62 | 764.3 | 50.99 | 749.6 | 0.0200 | 0.0953 | 50.11 | 10.50 | 18.38 | 73.91 | 92.29 | .0363 | .1417 | .1780 | 62 | | |
| 63 | 774.5 | 51.68 | 759.8 | 0.0201 | 0.0933 | 49.80 | 10.72 | 19.13 | 72.75 | 91.88 | .0377 | .1393 | .1770 | 63 | | |
| 64 | 784.7 | 52.38 | 770.0 | 0.0202 | 0.0914 | 49.47 | 10.95 | 19.88 | 71.57 | 91.45 | .0391 | .1367 | .1759 | 64 | | |
| 65 | 795.1 | 53.09 | 780.4 | 0.0203 | 0.0894 | 49.14 | 11.18 | 20.66 | 70.35 | 91.01 | 0.0406 | 0.1342 | 0.1748 | 65 | | |
| 66 | 805.6 | 53.80 | 790.9 | 0.0205 | 0.0875 | 48.80 | 11.42 | 21.45 | 69.10 | 90.55 | .0421 | .1315 | .1736 | 66 | | |
| 67 | 816.2 | 54.53 | 801.5 | 0.0206 | 0.0856 | 48.44 | 11.67 | 22.25 | 67.81 | 90.07 | .0436 | .1288 | .1725 | 67 | | |
| 68 | 827.0 | 55.28 | 812.3 | 0.0208 | 0.0838 | 48.08 | 11.94 | 23.08 | 66.49 | 89.56 | .0452 | .1261 | .1713 | 68 | | |
| 69 | 837.8 | 55.99 | 823.1 | 0.0210 | 0.0819 | 47.69 | 12.21 | 23.92 | 65.12 | 89.04 | .0468 | .1233 | .1701 | 69 | | |
| 70 | 848.7 | 56.74 | 834.0 | 0.0211 | 0.0800 | 47.29 | 12.49 | 24.78 | 63.71 | 88.49 | 0.0484 | 0.1204 | 0.1688 | 70 | | |
| 71 | 859.8 | 57.49 | 845.1 | 0.0213 | 0.0782 | 46.87 | 12.82 | 25.67 | 62.25 | 87.92 | .0501 | .1174 | .1675 | 71 | | |
| 72 | 870.9 | 58.25 | 856.2 | 0.0215 | 0.0763 | 46.44 | 13.10 | 26.58 | 60.74 | 87.32 | .0518 | .1143 | .1661 | 72 | | |
| 73 | 882.2 | 59.01 | 867.5 | 0.0217 | 0.0745 | 45.99 | 13.43 | 27.52 | 59.17 | 86.69 | .0536 | .1111 | .1647 | 73 | | |
| 74 | 893.6 | 59.79 | 878.9 | 0.0220 | 0.0726 | 45.53 | 13.77 | 28.49 | 57.54 | 86.03 | .0554 | .1079 | .1633 | 74 | | |
| 75 | 905.1 | 60.57 | 890.4 | 0.0222 | 0.0708 | 45.05 | 14.13 | 29.50 | 55.83 | 85.33 | 0.0573 | 0.1045 | 0.1618 | 75 | | |
| 76 | 916.7 | 61.36 | 902.0 | 0.0224 | 0.0689 | 44.56 | 14.51 | 30.54 | 54.05 | 84.59 | .0592 | .1019 | .1602 | 76 | | |
| 77 | 928.4 | 62.16 | 913.7 | 0.0227 | 0.0671 | 44.06 | 14.90 | 31.62 | 52.17 | 83.80 | .0613 | .0973 | .1585 | 77 | | |
| 78 | 940.3 | 62.96 | 925.6 | 0.0230 | 0.0652 | 43.55 | 15.34 | 32.76 | 50.20 | 82.96 | .0634 | .0934 | .1568 | 78 | | |
| 79 | 952.2 | 63.78 | 937.5 | 0.0232 | 0.0633 | 43.04 | 15.81 | 33.95 | 48.11 | 82.06 | .0656 | .0894 | .1550 | 79 | | |
| 80 | 964.3 | 64.60 | 949.6 | 0.0235 | 0.0613 | 42.50 | 16.32 | 35.21 | 45.88 | 81.09 | 0.0679 | 0.0851 | 0.1530 | 80 | | |
| 81 | 976.5 | 65.43 | 961.8 | 0.0238 | 0.0592 | 41.95 | 16.90 | 36.54 | 43.49 | 80.03 | .0704 | .0805 | .1509 | 81 | | |
| 82 | 988.8 | 66.27 | 974.1 | 0.0242 | 0.0570 | 41.30 | 17.53 | 37.98 | 40.90 | 78.88 | .0731 | .0755 | .1486 | 82 | | |
| 83 | 1001.0 | 67.11 | 986.3 | 0.0246 | 0.0548 | 40.62 | 18.25 | 39.53 | 38.07 | 77.60 | .0759 | .0702 | .1461 | 83 | | |
| 84 | 1014.0 | 67.97 | 999.3 | 0.0251 | 0.0524 | 39.84 | 19.07 | 41.25 | 34.90 | 76.15 | .0791 | .0642 | .1433 | 84 | | |
| 85 | 1027.0 | 68.83 | 1012.3 | 0.0258 | 0.0500 | 38.76 | 20.00 | 43.18 | 31.29 | 74.47 | 0.0826 | 0.0575 | 0.1401 | 85 | | |
| 86 | 1039.0 | 69.70 | 1024.3 | 0.0267 | 0.0474 | 37.41 | 21.09 | 45.45 | 27.00 | 72.46 | .0868 | .0495 | .1363 | 86 | | |
| 87 | 1052.0 | 70.58 | 1037.3 | 0.0283 | 0.0446 | 35.34 | 22.42 | 48.32 | 21.52 | 69.84 | .0921 | .0394 | .1314 | 87 | | |
| 88 | 1065.0 | 71.47 | 1050.3 | 0.0305 | 0.0401 | 32.79 | 24.95 | 52.78 | 12.84 | 65.62 | .1002 | .0235 | .1237 | 88 | | |
| 88.43 | 1071.0 | 71.86 | 1056.3 | 0.0346 | 0.0346 | 28.90 | 28.90 | 59.23 | 0.00 | 59.23 | .1120 | .0000 | .1120 | 88.43 | | |

†Gage pressures supplied by Editor A. S. R. E. Data.

‡Standard ton temperatures.

TABLE XXII.—PROPERTIES OF SATURATED VAPOR OF BUTANE:— C_4H_{10}

Linde Air Products Company Laboratory. Refrigerating Engineering, June, 1926.
A. S. R. E. Data Book.

| Temp. ° F. | Pressure | | Volume | | Density | | Heat Content Above ° F. | | | Entropy From ° F. | | Temp. ° F. |
|---------------|---------------------|---------------------|---------------------------------|--------------------------------|--------------------------------|-------------------------------|-------------------------|--------------------|-------------------|-------------------------|------------------------|---------------|
| | Abs. lb./sq. in. | Gage lb./sq. in. | Liquid ft. ³ /lb. | Vapor ft. ³ /lb. | Liquid lb./ft. ³ | Vapor lb./ft. ³ | Liquid Btu./lb. | Latent Btu./lb. | Vapor Btu./lb. | Liquid Btu./lb. ° F. | Vapor Btu./lb. ° F. | |
| <i>t</i> | <i>p</i> | <i>g p</i> | <i>v</i> | <i>V</i> | <i>l/v</i> | <i>l/V</i> | <i>h</i> | <i>L</i> | <i>H</i> | <i>s</i> | <i>S</i> | <i>t</i> |
| 0 | 7.3 | 15.0* | 0.02591 | 11.1 | 38.59 | 0.0901 | 0.0 | 170.5 | 170.5 | 0.000 | 0.370 | 0 |
| 1 | 7.5 | 14.7 | .02593 | 10.9 | 38.56 | .0917 | 0.5 | 170.5 | 171.0 | .001 | .370 | 1 |
| 2 | 7.7 | 14.3 | .02596 | 10.7 | 38.52 | .0935 | 1.0 | 170.0 | 171.0 | .002 | .370 | 2 |
| 3 | 7.8 | 13.9 | .02598 | 10.4 | 38.49 | .0962 | 1.5 | 170.0 | 171.5 | .003 | .370 | 3 |
| 4 | 8.0 | 13.6 | .02601 | 10.2 | 38.45 | .0980 | 2.0 | 170.0 | 172.0 | .005 | .370 | 4 |
| 5† | 8.2 | 13.2* | 0.02603 | 9.98 | 38.41 | 0.100 | 2.5 | 169.5 | 172.0 | 0.006 | 0.370 | 5† |
| 6 | 8.4 | 12.8 | .02606 | 9.78 | 38.38 | .102 | 3.0 | 169.5 | 172.5 | .007 | .370 | 6 |
| 7 | 8.6 | 12.4 | .02608 | 9.57 | 38.35 | .104 | 3.5 | 169.5 | 173.0 | .008 | .370 | 7 |
| 8 | 8.8 | 12.0 | .02610 | 9.37 | 38.31 | .107 | 4.0 | 169.5 | 173.5 | .009 | .370 | 8 |
| 9 | 9.0 | 11.6 | .02612 | 9.16 | 38.28 | .109 | 4.5 | 169.0 | 173.5 | .010 | .370 | 9 |
| 10 | 9.2 | 11.1* | 0.02615 | 8.95 | 38.24 | 0.112 | 5.5 | 168.5 | 174.0 | 0.011 | 0.370 | 10 |
| 11 | 9.4 | 10.7 | .02617 | 8.78 | 38.21 | .114 | 6.0 | 168.5 | 174.5 | .012 | .370 | 11 |
| 12 | 9.7 | 10.3 | .02619 | 8.59 | 38.18 | .116 | 6.5 | 168.5 | 175.0 | .013 | .370 | 12 |
| 13 | 9.9 | 9.9 | .02622 | 8.41 | 38.14 | .119 | 7.0 | 168.0 | 175.0 | .015 | .370 | 13 |
| 14 | 10.1 | 9.5 | .02624 | 8.22 | 38.11 | .122 | 7.5 | 168.0 | 175.5 | .016 | .370 | 14 |
| 15 | 10.4 | 8.8* | 0.02627 | 8.05 | 38.07 | 0.124 | 8.0 | 168.0 | 176.0 | 0.017 | 0.370 | 15 |
| 16 | 10.6 | 8.5 | .02629 | 7.88 | 38.04 | .127 | 8.5 | 167.5 | 176.0 | .018 | .371 | 16 |
| 17 | 10.8 | 8.0 | .02632 | 7.72 | 38.00 | .130 | 9.0 | 167.5 | 176.5 | .019 | .371 | 17 |
| 18 | 11.1 | 7.5 | .02634 | 7.56 | 37.97 | .132 | 9.5 | 167.5 | 177.0 | .020 | .371 | 18 |
| 19 | 11.3 | 7.0 | .02636 | 7.40 | 37.93 | .135 | 10.0 | 167.5 | 177.5 | .021 | .371 | 19 |
| 20 | 11.6 | 6.3* | 0.02639 | 7.23 | 37.89 | 0.138 | 10.5 | 167.0 | 177.5 | 0.022 | 0.371 | 20 |
| 21 | 11.8 | 6.0 | .02641 | 7.10 | 37.86 | .141 | 11.0 | 167.0 | 178.0 | .023 | .371 | 21 |
| 22 | 12.1 | 5.5 | .02643 | 6.97 | 37.83 | .143 | 11.5 | 167.0 | 178.5 | .025 | .371 | 22 |
| 23 | 12.4 | 4.9 | .02646 | 6.82 | 37.79 | .147 | 12.0 | 166.5 | 178.5 | .026 | .371 | 23 |
| 24 | 12.7 | 4.3 | .02648 | 6.68 | 37.76 | .150 | 12.5 | 166.5 | 179.0 | .027 | .371 | 24 |
| 25 | 13.0 | 3.6* | 0.02651 | 6.55 | 37.72 | 0.153 | 13.0 | 166.0 | 179.0 | 0.028 | 0.371 | 25 |
| 30 | 14.4 | 0.6* | .02664 | 5.90 | 37.54 | .169 | 16.0 | 165.5 | 181.5 | .033 | .371 | 30 |
| 35 | 16.0 | 1.3 | .02676 | 5.37 | 37.37 | .186 | 19.0 | 164.5 | 183.5 | .039 | .371 | 35 |
| 40 | 17.7 | 3.0 | .02689 | 4.88 | 37.19 | .205 | 21.5 | 163.5 | 185.0 | .044 | .371 | 40 |
| 45 | 19.6 | 4.9 | .02703 | 4.47 | 37.00 | .224 | 24.5 | 162.5 | 187.0 | .050 | .372 | 45 |
| 50 | 21.6 | 6.9 | 0.02716 | 4.07 | 36.82 | 0.246 | 27.0 | 161.5 | 188.5 | 0.056 | 0.373 | 50 |
| 55 | 23.8 | 9.1 | .02730 | 3.73 | 36.63 | .268 | 30.0 | 160.5 | 190.5 | .061 | .373 | 55 |
| 60 | 26.3 | 11.6 | .02743 | 3.40 | 36.45 | .294 | 33.0 | 159.5 | 192.5 | .067 | .374 | 60 |
| 65 | 28.9 | 14.2 | .02759 | 3.12 | 36.24 | .321 | 36.0 | 158.5 | 194.5 | .072 | .374 | 65 |
| 70 | 31.6 | 16.9 | .02773 | 2.88 | 36.06 | .347 | 38.5 | 157.5 | 196.0 | .078 | .375 | 70 |
| 75 | 34.5 | 19.8 | 0.02789 | 2.65 | 35.86 | 0.377 | 41.5 | 156.5 | 198.0 | 0.083 | 0.375 | 75 |
| 80 | 37.6 | 22.9 | .02805 | 2.46 | 35.65 | .407 | 44.5 | 155.0 | 199.5 | .089 | .376 | 80 |
| 85 | 40.9 | 26.2 | .02821 | 2.28 | 35.45 | .439 | 47.5 | 154.0 | 201.5 | .094 | .376 | 85 |
| 86† | 41.6 | 26.9 | 0.02825 | 2.24 | 35.40 | .446 | 48.5 | 153.5 | 202.0 | .095 | .376 | 86† |
| 90 | 44.5 | 29.8 | .02838 | 2.10 | 35.24 | .476 | 51.0 | 152.0 | 203.0 | .100 | .377 | 90 |
| 95 | 48.2 | 33.5 | 0.02854 | 1.96 | 35.04 | 0.510 | 54.0 | 151.0 | 205.0 | 0.105 | 0.377 | 95 |
| 100 | 52.2 | 37.5 | .02870 | 1.81 | 34.84 | .552 | 57.0 | 149.5 | 206.5 | .111 | .378 | 100 |
| 105 | 56.4 | 41.7 | .02889 | 1.70 | 34.62 | .588 | 60.5 | 148.0 | 208.5 | .117 | .380 | 105 |
| 110 | 60.8 | 46.1 | .02906 | 1.58 | 34.41 | .633 | 63.5 | 147.0 | 210.5 | .122 | .380 | 110 |
| 115 | 65.6 | 50.9 | .02925 | 1.48 | 34.19 | .676 | 66.5 | 145.5 | 212.0 | .128 | .381 | 115 |
| 120 | 70.8 | 56.1 | 0.02945 | 1.38 | 33.96 | 0.725 | 70.0 | 143.5 | 213.5 | 0.134 | 0.382 | 120 |
| 125 | 76.0 | 61.3 | .02966 | 1.30 | 33.72 | .769 | 73.5 | 142.0 | 215.5 | .139 | .382 | 125 |
| 130 | 81.4 | 66.7 | .02986 | 1.21 | 33.49 | .826 | 76.5 | 140.5 | 217.0 | .145 | .384 | 130 |
| 135 | 87.0 | 72.3 | .03009 | 1.14 | 33.23 | .877 | 80.0 | 139.0 | 219.0 | .151 | .385 | 135 |
| 140 | 92.6 | 77.9 | .03032 | 1.07 | 32.98 | .934 | 83.5 | 137.5 | 221.0 | .157 | .386 | 140 |

* Inches of Mercury below one standard atmosphere (29.92 in. = 14.696 lbs./sq. in. abs.)
† Standard Ten Temperatures.

PROPERTIES OF SATURATED VAPOR OF SEVERAL REFRIGERANTS

Starr, Practical Refrigerating Engineers' Pocket Book, Nickerson & Collins Co.

TABLE XXIII.—CARBON BISULPHIDE—CS₂ TABLE XXIV.—CARBON TETRACHLORIDE, CCl₄

| Temp | Pressure | | Volume | Density | Heat Content above 32° F. | | | | |
|----------|----------|----------|---------------------|---------------------|---------------------------|------------|----------------------|--|--|
| °F | Absolute | Gage | ft ³ /lb | lb./ft ³ | Liquid | Latent | Vapor* | | |
| <i>t</i> | <i>p</i> | <i>p</i> | <i>V</i> | <i>I/V</i> | Btu./lb. <i>h</i> + | <i>L</i> = | Btu./lb. <i>H</i> | | |
| 0 | 1 10 | 27 7 | 53 76 | 0 0186 | -8 60 | 165 5 | 156 90 | | |
| 5 | 1 23 | 27 32 | 48 07 | 0 0208 | -7 20 | 165 0 | 157 80 | | |
| 10 | 1 46 | 26 95 | 43 47 | 0 0230 | -5 60 | 164 5 | 158 90 | | |
| 15 | 1 67 | 26 52 | 38 91 | 0 0257 | -4 40 | 164 0 | 159 60 | | |
| 20 | 1 89 | 26 07 | 34 84 | 0 0287 | -3 00 | 163 2 | 160 20 | | |
| 25 | 2 11 | 25 63 | 32 10 | 0 0324 | -1 82 | 162 9 | 161 08 | | |
| 30 | 2 36 | 25 11 | 29 49 | 0 0339 | -0 50 | 162 2 | 161 70 | | |
| 35 | 2 47 | 24 89 | 28 32 | 0 0353 | 0 00 | 162 0 | 162 00 | | |
| 40 | 3 03 | 23 75 | 23 52 | 0 0425 | +2 05 | 161 2 | 163 25 | | |
| 45 | 3 40 | 23 00 | 22 00 | 0 0454 | 2 40 | 160 7 | 163 10 | | |
| 50 | 3 90 | 21 95 | 20 60 | 0 0482 | 4 24 | 160 0 | 164 24 | | |
| 55 | 4 40 | 20 98 | 19 20 | 0 0521 | 5 80 | 159 8 | 165 60 | | |
| 60 | 4 95 | 19 84 | 18 00 | 0 0555 | 7 20 | 159 2 | 166 40 | | |
| 65 | 5 40 | 18 93 | 15 00 | 0 0666 | 8 50 | 158 8 | 167 30 | | |
| 70 | 5 85 | 18 03 | 13 20 | 0 0758 | 9 80 | 158 1 | 167 90 | | |
| 75 | 6 50 | 16 09 | 11 80 | 0 0874 | 10 80 | 157 5 | 168 30 | | |
| 80 | 7 30 | 15 07 | 10 40 | 0 0961 | 11 70 | 156 9 | 168 60 | | |
| 85 | 8 21 | 13 21 | 9 80 | 0 1020 | 12 60 | 156 2 | 168 80 | | |
| 86½* | 8 40 | 12 82 | 9 15 | 1058 | 12 84 | 156 1 | 168 94 | | |
| 90 | 9 15 | 11 29 | 8 30 | 0 1204 | 13 80 | 155 6 | 169 40 | | |
| 95 | 10 00 | 9 54 | 7 60 | 0 1315 | 15 00 | 155 0 | 170 00 | | |
| 100 | 11 08 | 7 37 | 7 03 | 0 1369 | 16 15 | 154 4 | 170 55 | | |
| 105 | 12 30 | 4 89 | 6 40 | 0 1562 | 17 40 | 153 8 | 171 20 | | |
| 110 | 13 50 | 2 44 | 5 80 | 0 1724 | 18 30 | 153 2 | 171 50 | | |
| 114 5 | 14 70 | 0 00 | 5 45 | 0 1834 | 19 10 | 152 6 | 171 70 | | |
| 115 | 14 80 | 0 10 | 5 40 | 0 1851 | 19 25 | 152 6 | 171 85 | | |
| 120 | 16 10 | 1 40 | 5 10 | 0 1960 | 20 01 | 152 0 | 172 01 | | |

| Temp | Pressure | | Volume | Density | Heat Content above 32° F. | | | | |
|----------|----------|----------|---------------------|---------------------|---------------------------|------------|----------------------|--|--|
| °F | Absolute | Gage | ft ³ /lb | lb./ft ³ | Liquid | Latent | Vapor | | |
| <i>t</i> | <i>p</i> | <i>p</i> | <i>V</i> | <i>I/V</i> | Btu./lb. <i>h</i> + | <i>L</i> = | Btu./lb. <i>H</i> | | |
| 20 | 0 40 | 29 1 | 69 5 | 0 01438 | -2 00 | 91 45 | 92 45 | | |
| 25 | 56 | 28 8 | 61 0 | 0 01639 | -1 20 | 91 00 | 92 80 | | |
| 30 | 60 | 28 7 | 53 0 | 0 01886 | -0 25 | 93 70 | 93 45 | | |
| 32 | 64 | 28 6 | 52 6 | 0 01917 | 0 00 | 93 60 | 93 60 | | |
| 40 | 84 | 28 2 | 40 0 | 0 02500 | +1 60 | 93 20 | 94 80 | | |
| 45 | 0 95 | 28 0 | 35 0 | 0 02857 | 2 58 | 92 90 | 95 48 | | |
| 52 | 1 07 | 27 7 | 34 0 | 0 03113 | 3 58 | 92 60 | 96 18 | | |
| 55 | 1 25 | 27 4 | 27 0 | 0 03703 | 4 40 | 92 30 | 96 70 | | |
| 60 | 1 42 | 27 0 | 24 0 | 0 04166 | 5 95 | 92 20 | 98 15 | | |
| 65 | 1 60 | 26 7 | 21 5 | 0 04651 | 6 50 | 91 70 | 98 20 | | |
| 70 | 1 85 | 26 2 | 19 5 | 0 05128 | 8 20 | 91 40 | 99 60 | | |
| 75 | 2 15 | 25 5 | 17 5 | 0 05714 | 8 50 | 91 05 | 99 55 | | |
| 80 | 2 40 | 25 0 | 16 0 | 0 06345 | 9 80 | 90 07 | 99 87 | | |
| 85 | 2 70 | 24 4 | 14 5 | 0 06896 | 10 60 | 90 04 | 100 64 | | |
| 86½* | 2 78 | 24 2 | 14 2 | 0 07037 | 10 80 | 90 04 | 100 83 | | |
| 90 | 3 12 | 23 5 | 13 0 | 0 07692 | 11 60 | 90 02 | 101 62 | | |
| 95 | 3 60 | 22 6 | 11 0 | 0 0909 | 12 40 | 89 70 | 102 10 | | |
| 100 | 4 00 | 21 8 | 10 0 | 0 1009 | 13 40 | 89 40 | 102 80 | | |
| 105 | 4 42 | 20 9 | 9 0 | 0 1111 | 14 60 | 89 20 | 103 80 | | |
| 110 | 4 89 | 20 1 | 8 5 | 0 1176 | 15 80 | 88 70 | 104 50 | | |
| 115 | 5 35 | 19 1 | 8 0 | 0 1260 | 16 95 | 88 30 | 105 25 | | |
| 120 | 5 95 | 17 8 | 7 5 | 0 1333 | 18 06 | 87 90 | 105 90 | | |
| 125 | 6 50 | 16 7 | 7 0 | 0 1428 | 18 90 | 87 50 | 106 40 | | |
| 130 | 7 20 | 15 2 | 6 3 | 0 1587 | 19 95 | 87 10 | 107 05 | | |
| 135 | 7 90 | 13 9 | 5 5 | 0 1818 | 20 99 | 86 70 | 107 69 | | |
| 140 | 8 65 | 12 3 | 4 8 | 0 2066 | 21 46 | 86 32 | 107 78 | | |
| 170 | 14 70 | 0 | 2 8 | 0 3571 | 26 90 | 83 00 | 109 90 | | |

TABLE XXV.—CHLOROFORM—CHCl₃

| <i>t</i> | <i>p</i> | <i>p</i> | <i>V</i> | <i>I/V</i> | <i>h</i> | <i>L</i> | <i>H</i> |
|----------|----------|----------|----------|------------|----------|----------|----------|
| 20 | 0 08 | 29 76 | 50 00 | 0 02012 | -4 00 | 121 60 | 117 60 |
| 25 | 1 00 | 27 83 | 44 00 | 0 0227 | -2 5 | 120 20 | 117 70 |
| 32 | 1 15 | 27 58 | 38 10 | 0 02626 | 0 00 | 120 60 | 120 60 |
| 50 | 2 03 | 25 79 | 23 65 | 0 04232 | 4 19 | 118 87 | 123 06 |
| 68 | 3 15 | 23 51 | 18 50 | 0 06505 | 8 40 | 117 14 | 125 54 |
| 86½ | 4 80 | 20 15 | 10 50 | 0 0952 | 12 63 | 115 38 | 128 01 |
| 104 | 7 52 | 14 61 | 7 14 | 0 1403 | 16 86 | 113 63 | 130 49 |
| 122 | 10 30 | 8 96 | 5 06 | 0 1979 | 20 13 | 111 83 | 131 96 |
| 140.5 | 14 70 | 1 00 | 4 95 | 0 2200 | 23 70 | 109 60 | 132 70 |

TABLE XXVI.—ETHYL ETHER^a—(C₂H₅)₂O

| <i>t</i> | <i>p</i> | <i>p</i> | <i>V</i> | <i>I/V</i> | <i>h</i> | <i>L</i> | <i>H</i> |
|----------|----------|----------|----------|------------|----------|----------|----------|
| 0 | 1 3 | 27 28 | 38 0 | 0 0263 | -18 00 | 171 0 | 153 00 |
| 5 | 1 5 | 26 87 | 35 0 | 0 0285 | -15 00 | 170 8 | 155 80 |
| 10 | 1 8 | 26 26 | 32 5 | 0 0332 | -12 00 | 170 4 | 158 43 |
| 15 | 2 2 | 25 46 | 30 0 | 0 0332 | -9 50 | 170 2 | 161 70 |
| 20 | 2 5 | 24 84 | 27 0 | 0 0372 | -6 50 | 170 0 | 163 50 |
| 25 | 2 9 | 24 03 | 24 3 | 0 0417 | -4 00 | 169 6 | 165 60 |
| 30 | 3 4 | 23 00 | 21 4 | 0 0468 | -1 50 | 169 4 | 167 90 |
| 35 | 3 9 | 22 00 | 19 3 | 0 0518 | +1 40 | 168 8 | 170 20 |
| 40 | 4 4 | 21 09 | 17 0 | 0 0588 | 4 00 | 168 4 | 172 40 |
| 45 | 4 9 | 19 97 | 15 0 | 0 0666 | 6 60 | 168 0 | 174 60 |
| 50 | 5 5 | 18 72 | 13 2 | 0 0757 | 9 57 | 167 6 | 177 17 |
| 70 | 8 8 | 12 05 | 7 8 | 0 1280 | 20 40 | 165 4 | 185 44 |
| 75 | 9 8 | 10 92 | 7 0 | 0 1430 | 23 40 | 164 8 | 188 20 |
| 80 | 10 9 | 7 33 | 6 2 | 0 1620 | 26 40 | 164 2 | 190 60 |
| 85 | 12 2 | 5 09 | 5 5 | 0 1880 | 29 00 | 163 8 | 192 80 |
| 86½* | 12 3 | 4 62 | 5 4 | 0 1880 | 29 50 | 163 5 | 193 00 |
| 90 | 13 4 | 2 72 | 5 1 | 0 1960 | 31 50 | 163 0 | 194 50 |
| 95 | 14 7 | 0 00 | 4 8 | 0 2130 | 34 00 | 162 2 | 196 20 |
| 100 | 16 0 | 1 31 | 4 5 | 0 2220 | 36 50 | 161 5 | 197 56 |

TABLE XXVII.—NITROUS OXIDE—N₂O

| Temp | Pressure | | Volume | Density | Heat Latent | |
|----------|----------|----------|----------|----------|-------------|-------------|
| °F | Absolute | Gage | Liquid | Vapor | Liquid | Vapor |
| <i>t</i> | <i>p</i> | <i>p</i> | <i>v</i> | <i>V</i> | <i>I, v</i> | <i>I, V</i> |
| -130 | 14 2 | 0 5 | 0 01232 | 5 940 | 81 17 | 0 165 |
| -121 | 19 6 | 4 9 | 0 01248 | 4 370 | 80 13 | 23 |
| -112 | 26 8 | 12 0 | 0 01264 | 3 200 | 79 11 | 30 |
| -103 | 35 5 | 20 8 | 0 01280 | 2 480 | 78 12 | 40 |
| -94 | 47 3 | 32 6 | 0 01296 | 1 880 | 77 16 | 53 |
| -85 | 59 6 | 44 9 | 0 01312 | 1 510 | 76 22 | 66 |
| -76 | 75 0 | 60 3 | 0 01314 | 1 220 | 76 10 | 82 |
| -67 | 92 3 | 77 6 | 0 01376 | 0 9990 | 72 67 | 1 00 |
| -58 | 113 0 | 98 3 | 0 01408 | 8 270 | 71 02 | 1 20 |
| -49 | 135 0 | 120 3 | 0 01440 | 6 960 | 69 44 | 1 40 |
| -40 | 160 0 | 145 3 | 0 01472 | 6 000 | 67 93 | 1 65 |
| -31 | 190 0 | 175 3 | 0 01504 | 5 120 | 66 49 | 1 95 |
| -22 | 223 0 | 208 3 | 0 01536 | 4 430 | 65 10 | 2 25 |
| -13 | 257 0 | 242 3 | 0 01568 | 3 950 | 63 77 | 2 50 |
| -4 | 295 0 | 280 3 | 0 01600 | 3 470 | 62 50 | 2 85 |
| +5 | 333 0 | 318 3 | 0 01632 | 3 080 | 61 27 | 3 25 |
| 14 | 375 0 | 360 3 | 0 01680 | 2 690 | 59 52 | 3 70 |
| 23 | 422 0 | 405 3 | 0 01728 | 2 340 | 57 87 | 4 25 |
| 32 | 471 0 | 456 3 | 0 01776 | 2 017 | 56 30 | 4 95 |
| 41 | 528 0 | 513 3 | 0 01845 | 1 744 | 54 19 | 5 70 |
| 50 | 592 0 | 577 3 | 0 01920 | 1 496 | 52 08 | 6 65 |
| 59 | 663 0 | 648 3 | 0 02016 | 1 276 | 45 60 | 7 80 |
| 68 | 745 0 | 730 3 | 0 02140 | 1 076 | 46 73 | 9 30 |
| 77 | 832 0 | 817 3 | 0 02300 | 0 896 | 43 48 | 11 20 |
| 86 | 930 0 | 915 3 | 0 02560 | 0 726 | 39 06 | 13 80 |
| 95 | 1035 0 | 1020 3 | 0 03136 | 0 634 | 31 88 | 18 70 |
| 96 | 1055 0 | 1040 3 | 0 03498 | 0 537 | 28 58 | 23 50 |
| 97 | 1065 0 | 1040 3 | 0 04080 | 0 408 | 24 51 | 24 50 |

TABLE XXVIII.—PROPERTIES OF SATURATED VAPOR OF ETHANE—C₂H₆
(H. D. Edwards)

| Temp. °F t. | Pressure | | Specific Volume | | Density | | Heat Content Above—40° | Temp °F t. |
|-------------------|------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|---------------------------------------|--------------------------------------|---------------------------|------------------|
| | Abs. lb./in. ² p. | Gage lb./in. ² g.p. | Liquid ft. ³ /lb. v | Vapor ft. ³ /lb. V | Liquid lb./ft. ³ 1/v | Vapor lb./ft. ³ 1/V | Latent Btu./lb.; L= | |
| | | | | | | | | |
| -150 | 7.0 | *15.6 | 0.02849 | 16.7 | 35.10 | 0.060 | 242 | -150 |
| -145 | 8.0 | *13.6 | 0.02865 | 14.1 | 34.90 | 0.071 | 240 | -145 |
| -140 | 9.7 | *10.1 | 0.02888 | 12.1 | 34.63 | 0.083 | 238 | -140 |
| -135 | 11.2 | * 7.1 | 0.02901 | 10.5 | 34.47 | 0.095 | 236 | -135 |
| -130 | 13.2 | * 3.0 | 0.02924 | 8.85 | 34.20 | 0.113 | 235 | -130 |
| -125 | 15.5 | 0.8 | 0.02939 | 1.69 | 34.02 | 0.130 | 233 | -125 |
| -120 | 18.2 | 3.5 | 0.02961 | 6.89 | 33.77 | 0.145 | 231 | -120 |
| -115 | 21.4 | 6.7 | 0.02976 | 5.88 | 33.60 | 0.170 | 229 | -115 |
| -110 | 24.8 | 10.1 | 0.03001 | 5.27 | 33.32 | 0.190 | 227 | -110 |
| -105 | 28.5 | 13.8 | 0.03018 | 4.55 | 33.13 | 0.220 | 225 | -105 |
| -100 | 32.4 | 17.7 | 0.0305 | 4.13 | 32.8 | 0.242 | 224 | -100 |
| -95 | 36.4 | 21.7 | 0.0307 | 3.57 | 32.6 | 0.280 | 222 | -95 |
| -90 | 41.0 | 26.3 | 0.0309 | 3.23 | 32.4 | 0.310 | 220 | -90 |
| -85 | 46.0 | 31.3 | 0.0311 | 2.86 | 32.2 | 0.350 | 218 | -85 |
| -80 | 51.2 | 36.5 | 0.0313 | 2.56 | 31.9 | 0.390 | 216 | -80 |
| -75 | 56.8 | 42.1 | 0.0315 | 2.35 | 31.7 | 0.425 | 214 | -75 |
| -70 | 63.0 | 48.3 | 0.0318 | 2.10 | 31.5 | 0.477 | 212 | -70 |
| -65 | 70.3 | 55.6 | 0.0320 | 1.94 | 31.3 | 0.515 | 210 | -65 |
| -60 | 78.2 | 63.5 | 0.0322 | 1.75 | 31.0 | 0.570 | 208 | -60 |
| -55 | 80.6 | 75.9 | 0.0325 | 1.63 | 30.8 | 0.615 | 206 | -55 |
| -50 | 95.9 | 81.2 | 0.0327 | 1.50 | 30.5 | 0.666 | 204 | -50 |
| -45 | 105.0 | 90.3 | 0.0330 | 1.39 | 30.3 | 0.720 | 201 | -45 |
| -40 | 114.5 | 99.8 | 0.0333 | 1.28 | 30.0 | 0.780 | 199 | -40 |
| -35 | 124.5 | 109.8 | 0.0336 | 1.18 | 29.8 | 0.845 | 196 | -35 |
| -30 | 135.0 | 120.3 | 0.0339 | 1.13 | 29.5 | 0.875 | 194 | -30 |
| -25 | 146.7 | 132.0 | 0.0342 | 1.05 | 29.2 | 0.950 | 192 | -25 |
| -20 | 159.5 | 144.8 | 0.0345 | 0.976 | 28.9 | 1.03 | 190 | -20 |
| -15 | 172 | 157 | 0.0350 | 0.855 | 28.6 | 1.17 | 187 | -15 |
| -10 | 187 | 172 | 0.0353 | 0.819 | 28.3 | 1.22 | 185 | -10 |
| -5 | 202 | 187 | 0.0357 | 0.730 | 28.0 | 1.37 | 182 | -5 |
| 0 | 219 | 204 | 0.0361 | 0.689 | 27.7 | 1.45 | 179 | 0 |
| +5 | 236 | 221 | 0.0365 | 0.629 | 27.4 | 1.59 | 176 | +5 |
| +10 | 254 | 239 | 0.0370 | 0.581 | 27.0 | 1.72 | 174 | +10 |
| +15 | 272 | 257 | 0.0375 | 0.538 | 26.7 | 1.86 | 171 | +15 |
| +20 | 292 | 277 | 0.0379 | 0.495 | 26.3 | 2.02 | 168 | +20 |
| +25 | 307 | 292 | 0.0385 | 0.457 | 26.0 | 2.19 | 165 | +25 |
| +30 | 335 | 320 | 0.0390 | 0.422 | 25.6 | 2.37 | 162 | +30 |
| +35 | 358 | 343 | 0.0397 | 0.389 | 25.2 | 2.57 | 158 | +35 |
| +40 | 383 | 368 | 0.0403 | 0.360 | 24.8 | 2.78 | 155 | +40 |
| +45 | 405 | 390 | 0.0410 | 0.330 | 24.4 | 3.03 | 150 | +45 |
| +50 | 428 | 413 | 0.0417 | 0.305 | 24.0 | 3.28 | 146 | +50 |
| +55 | 453 | 438 | 0.0426 | 0.279 | 23.5 | 3.58 | 141 | +55 |
| +60 | 481 | 466 | 0.0435 | 0.256 | 23.0 | 3.90 | 136 | +60 |
| +65 | 511 | 496 | 0.0444 | 0.238 | 22.5 | 4.20 | 130 | +65 |
| +70 | 543 | 528 | 0.0461 | 0.214 | 21.7 | 4.67 | 124 | +70 |
| +75 | 584 | 569 | 0.0478 | 0.182 | 20.9 | 5.50 | 115 | +75 |
| +80 | 625 | 610 | 0.0508 | 0.163 | 19.7 | 6.14 | 107 | +80 |
| +85 | 672 | 657 | 0.0549 | 0.128 | 18.2 | 7.80 | 78 | +85 |
| +89.8 | 718 | 703 | 0.0775 | 0.0775 | 12.9 | 12.9 | 0 | +89.8 |

* Inches of mercury below one standard atmosphere (29.92 in.=14.697 lbs./sq. in. abs.)
 Note:—References: Vapor Pressures. From 7 to 32 lbs./sq. in. abs. by Maass & Wright, J. Am. Chem. Soc., 43, p. 1098, 1921. From 31 to 347 lbs./sq. in. abs. by Kuenen and Robson, Phil. Mag., (6) 3, p. 149, 1902. From 162 to 734 lbs./sq. in. abs. A. Hainlen, Lieb. Ann., 282, p. 229, 1894. Liquid and Vapor Densities. From—162° F. to—101° F. experimental data on liquid by Maass & Wright, J. Am. Chem. Soc., 43, p. 1104, 1921. Remainder of liquid and all of Vapor data as well as latent heats, calculated by The Laboratory of The Linde Air Products Co., Buffalo, N. Y. Probable accuracy of Density, Liquids, 1%; Vapor, 3%; Latent Heats, 10%.

TABLE XXIX.—PROPERTIES OF SATURATED VAPOR OF ETHYL CHLORIDE C_2H_5Cl .

Hodsdon, 1919. *Refrigerating World*, Aug., (1922). Henning, Ohnes, Regnault and others; compiled by Starr. *Practical Refrigerating Engineers' Hand Book*, Nickerson & Collins Co., Chicago, 1922.

| Tem. °F. <i>t</i> | Pressure | | Volume | | Density | | Heat Content Above — 32°F. | | |
|-------------------------|--|--|---|--|--|---|----------------------------------|----------------------------------|-------------------------------|
| | Abs. lb./in. ² <i>p</i> | Gage lb./in. ² <i>g p</i> | Liquid ft. ³ /lb. <i>v</i> | Vapor ft. ³ /lb. <i>V</i> | Liquid lb./ft. ³ <i>l/v</i> | Vapor lb./ft. ³ <i>l/V</i> | Liquid Btu./lb. <i>h +</i> | Latent Btu./lb. <i>L =</i> | Vapor Btu./lb. <i>H</i> |
| -22 | 2.20 | -12.5 | 0.01657 | 34.4 | 60.35 | 0.0291 | -23.1 | 181.3 | 158.2 |
| -13 | 2.85 | -11.85 | .01669 | 26.95 | 59.92 | .0371 | -19.2 | 179.9 | 160.7 |
| -4 | 3.66 | -11.04 | .01682 | 21.33 | 59.45 | .0469 | -15.4 | 178.5 | 163.1 |
| +15 | 4.65 | -10.05 | .01695 | 17.06 | 59.00 | .0586 | -11.6 | 177.0 | 165.4 |
| 14 | 5.85 | - 8.85 | .01708 | 13.77 | 58.55 | .0726 | - 7.7 | 175.5 | 167.8 |
| 23 | 7.28 | - 7.42 | 0.01721 | 11.21 | 58.10 | 0.0892 | - 3.8 | 174.0 | 170.2 |
| 32 | 8.99 | - 5.71 | .01735 | 9.21 | 57.64 | .1086 | 0.0 | 172.5 | 172.5 |
| 41 | 11.01 | - 3.69 | .01749 | 7.62 | 57.18 | .1311 | + 3.8 | 170.9 | 174.7 |
| 50 | 13.37 | - 1.33 | .01763 | 6.36 | 56.72 | .1573 | 7.7 | 169.3 | 177.0 |
| 59 | 16.11 | + 1.41 | .01777 | 5.34 | 56.27 | .1873 | 11.6 | 167.7 | 179.3 |
| 68 | 19.29 | 4.50 | 0.01792 | 4.51 | 55.80 | 0.2215 | 15.4 | 166.0 | 181.4 |
| 77 | 22.94 | 8.24 | .01807 | 3.84 | 55.34 | .2604 | 19.2 | 164.3 | 183.5 |
| 86 | 27.10 | 12.40 | .01822 | 3.29 | 54.88 | .3043 | 23.1 | 162.6 | 185.7 |
| 95 | 31.82 | 17.12 | .01838 | 2.83 | 54.41 | .3536 | 26.9 | 160.8 | 187.7 |
| 104 | 37.17 | 22.47 | 0.01854 | 2.44 | 53.94 | 0.4090 | 30.8 | 159.0 | 189.9 |
| 113 | 43.16 | 28.46 | .01870 | 2.13 | 53.47 | .4704 | 34.6 | 157.2 | 191.8 |
| 122 | 49.88 | 35.18 | .01887 | 1.86 | 53.00 | .5382 | 38.5 | 155.3 | 193.8 |
| 131 | 57.36 | 42.66 | .01904 | 1.63 | 52.52 | .6135 | 42.3 | 153.3 | 195.6 |
| -22 | 2.13 | -12.57 | 0.0163 | 34.2 | 61.5 | 0.029 | -23.1 | 193.0 | 170.0 |
| -13 | 2.80 | -11.90 | .0164 | 26.5 | 61.0 | .038 | -19.2 | 192.0 | 172.5 |
| -4 | 3.63 | -11.07 | .0164 | 20.9 | 60.6 | .048 | -15.4 | 191.0 | 175.5 |
| +15 | 4.63 | -10.07 | .0167 | 16.7 | 60.1 | .061 | -11.5 | 190.0 | 178.5 |
| 14 | 5.84 | - 8.86 | .0169 | 13.5 | 59.7 | .074 | - 7.7 | 188.5 | 181.0 |
| 23 | 7.28 | - 7.42 | 0.0169 | 11.0 | 59.2 | 0.091 | 3.85 | 187.5 | 183.5 |
| 32 | 9.00 | - 5.70 | .0170 | 9.1 | 58.8 | .110 | 0 | 186.0 | 186.0 |
| 41 | 11.00 | - 3.70 | .0172 | 7.6 | 58.3 | .132 | + 3.85 | 184.5 | 188.0 |
| 50 | 13.55 | - 1.15 | .0174 | 6.25 | 57.9 | .160 | 7.7 | 182.5 | 190.0 |
| 54.5 | 14.70 | 0.00 | .0175 | 5.6 | 57.6 | 0.179 | 9.52 | 181.5 | 191.5 |
| 59 | 16.10 | + 1.40 | 0.0176 | 5.35 | 57.3 | 0.187 | 11.5 | 180.5 | 192.5 |
| 68 | 19.26 | 4.56 | .0176 | 4.55 | 56.9 | .220 | 15.4 | 179.5 | 194.0 |
| 77 | 22.90 | 8.20 | .0177 | 3.90 | 56.5 | .256 | 19.2 | 176.5 | 196.0 |
| 86 | 27.05 | 12.35 | .0178 | 3.35 | 56.0 | .299 | 23.1 | 174.0 | 197.5 |
| 95 | 31.77 | 17.07 | .0180 | 2.89 | 55.6 | .345 | 27.0 | 172.0 | 199.0 |
| 104 | 37.11 | 22.41 | 0.0182 | 2.57 | 55.1 | 0.374 | 30.8 | 169.0 | 200.0 |

Gage pressures table supplied by Editor A. S. R. E. Data Book.

‡Standard ton temperatures.

TABLE XXX.—PROPERTIES OF SATURATED VAPOR OF ISOBUTANE—
 C_4H_{10} *Linde Air Products Company Laboratory. Refrigeration Engineering, June, 1926.
A. S. R. E. Data Book.*

| Temp. ° F. | Pressure | | Volume | | Density | | Heat Content Above 0° F. | | | Entropy From 0° F. | | Temp. ° F. |
|---------------|------------------------------|------------------------------|---------------------------------|--------------------------------|--------------------------------|-------------------------------|-----------------------------|--------------------|-------------------|-----------------------|----------------------|---------------|
| | Abs. lb./in. ² | Gage lb./in. ² | Liquid ft. ³ /lb. | Vapor ft. ³ /lb. | Liquid lb./ft. ³ | Vapor lb./ft. ³ | Liquid Btu./lb. | Latent Btu./lb. | Vapor Btu./lb. | Liquid Btu./lb.°F. | Vapor Btu./lb.°F. | |
| <i>t</i> | <i>p</i> | <i>g p</i> | <i>v</i> | <i>V</i> | <i>l/v</i> | <i>l/V</i> | <i>h</i> | <i>L</i> | <i>H</i> | <i>s</i> | <i>S</i> | <i>t</i> |
| -20 | 7.50 | 14.6* | 0.02610 | 11.00 | 38.35 | 0.0952 | -9.0 | 165.5 | 156.5 | -0.020 | 0.356 | -20 |
| -15 | 8.30 | 13.0* | .02620 | 9.90 | 38.15 | .101 | -7.0 | 164.0 | 157.0 | -0.015 | .354 | -15 |
| -10 | 9.28 | 11.0* | .02635 | 8.91 | 37.95 | .112 | -4.5 | 163.0 | 158.5 | -0.010 | .353 | -10 |
| -5 | 10.4 | 8.8* | .02645 | 7.99 | 37.80 | .125 | -2.5 | 162.0 | 159.5 | -0.005 | .351 | -5 |
| 0 | 11.6 | 6.3* | .02660 | 7.17 | 37.60 | .139 | 0.0 | 160.5 | 160.5 | 0.000 | 0.350 | 0 |
| +1 | 11.9 | 5.7* | .02663 | 7.02 | 37.55 | .142 | 0.5 | 160.5 | 161.0 | .001 | .350 | +1 |
| 2 | 12.2 | 5.1* | .02667 | 6.87 | 37.50 | .146 | +1.0 | 160.0 | 161.0 | .002 | .350 | 2 |
| 3 | 12.5 | 4.5* | .02670 | 6.72 | 37.46 | .149 | 1.5 | 160.0 | 161.5 | .003 | .350 | 3 |
| 4 | 12.8 | 4.0* | .02672 | 6.57 | 37.43 | .152 | 2.0 | 159.5 | 161.5 | .004 | .350 | 4 |
| 5† | 13.1 | 3.3* | .02675 | 6.41 | 37.40 | .156 | 2.5 | 159.5 | 162.0 | 0.005 | 0.348 | 5† |
| 6 | 13.3 | 2.7* | .02677 | 6.28 | 37.35 | .159 | 3.0 | 159.0 | 162.0 | .006 | .349 | 6 |
| 7 | 13.6 | 2.1* | .02680 | 6.15 | 37.31 | .163 | 3.5 | 159.0 | 162.5 | .007 | .349 | 7 |
| 8 | 13.9 | 1.5* | .02683 | 6.02 | 37.27 | .166 | 4.0 | 158.5 | 162.5 | .009 | .349 | 8 |
| 9 | 14.2 | 0.9* | .02686 | 5.88 | 37.23 | .170 | 4.5 | 158.5 | 163.0 | .010 | .349 | 9 |
| 10 | 14.6 | 0.2* | .02690 | 5.75 | 37.20 | .174 | 5.0 | 158.5 | 163.5 | 0.011 | 0.348 | 10 |
| 11 | 14.8 | 0.1 | .02692 | 5.65 | 37.15 | .177 | 5.5 | 158.0 | 163.5 | .012 | .348 | 11 |
| 12 | 15.2 | 0.5 | .02695 | 5.52 | 37.11 | .181 | 6.0 | 158.0 | 164.0 | .013 | .348 | 12 |
| 13 | 15.6 | 0.9 | .02698 | 5.41 | 37.07 | .185 | 6.5 | 157.5 | 164.0 | .014 | .348 | 13 |
| 14 | 15.9 | 1.2 | .02700 | 5.30 | 37.04 | .190 | 7.0 | 157.5 | 164.5 | .015 | .348 | 14 |
| 15 | 16.3 | 1.6 | .02705 | 5.18 | 37.00 | .193 | 7.5 | 157.0 | 164.5 | 0.016 | 0.347 | 15 |
| 16 | 16.7 | 2.0 | .02706 | 5.08 | 36.96 | .197 | 8.0 | 157.0 | 165.0 | .017 | .347 | 16 |
| 17 | 17.0 | 2.3 | .02709 | 4.98 | 36.92 | .201 | 8.5 | 156.5 | 165.0 | .018 | .347 | 17 |
| 18 | 17.4 | 2.7 | .02711 | 4.88 | 36.88 | .205 | 9.0 | 156.5 | 165.5 | .019 | .347 | 18 |
| 19 | 17.8 | 3.1 | .02714 | 4.78 | 36.84 | .209 | 9.5 | 156.0 | 165.5 | .020 | .347 | 19 |
| 20 | 18.2 | 3.5 | .02717 | 4.68 | 36.80 | .214 | 10.0 | 156.0 | 166.0 | 0.021 | 0.346 | 20 |
| 21 | 18.6 | 3.9 | .02720 | 4.59 | 36.76 | .218 | 10.5 | 155.5 | 166.0 | .022 | .346 | 21 |
| 22 | 19.0 | 4.3 | .02723 | 4.50 | 36.72 | .222 | 11.0 | 155.5 | 166.5 | .023 | .346 | 22 |
| 23 | 19.4 | 4.7 | .02726 | 4.41 | 36.68 | .227 | 11.5 | 155.5 | 167.0 | .025 | .346 | 23 |
| 24 | 19.8 | 5.1 | .02729 | 4.32 | 36.64 | .231 | 12.5 | 154.5 | 167.0 | .026 | .346 | 24 |
| 25 | 20.2 | 5.5 | .02730 | 4.24 | 36.60 | .236 | 13.0 | 154.5 | 167.5 | 0.027 | 0.346 | 25 |
| 26 | 20.6 | 5.9 | .02735 | 4.15 | 36.56 | .241 | 13.5 | 154.0 | 167.5 | .028 | .346 | 26 |
| 27 | 21.0 | 6.3 | .02737 | 4.07 | 36.53 | .246 | 14.0 | 154.0 | 168.0 | .029 | .346 | 27 |
| 28 | 21.5 | 6.8 | .02741 | 4.00 | 36.48 | .250 | 14.5 | 154.0 | 168.5 | .030 | .346 | 28 |
| 29 | 21.9 | 7.2 | .02744 | 3.93 | 36.44 | .254 | 15.0 | 153.5 | 168.5 | .031 | .346 | 29 |
| 30 | 22.3 | 7.6 | .02745 | 3.86 | 36.40 | .259 | 15.5 | 153.5 | 169.0 | 0.032 | 0.346 | 30 |
| 35 | 24.6 | 9.9 | .02760 | 3.52 | 36.20 | .284 | 18.0 | 152.5 | 170.5 | .038 | .346 | 35 |
| 40 | 26.9 | 12.2 | .02780 | 3.22 | 36.00 | .311 | 21.0 | 151.0 | 172.0 | .044 | .346 | 40 |
| 45 | 29.5 | 14.8 | .02795 | 2.96 | 35.80 | .338 | 24.0 | 150.0 | 174.0 | .049 | .346 | 45 |
| 50 | 32.5 | 17.8 | .02810 | 2.71 | 35.60 | .369 | 27.0 | 148.5 | 175.5 | .055 | .346 | 50 |
| 55 | 35.5 | 20.8 | .02825 | 2.49 | 35.40 | .402 | 30.0 | 147.5 | 177.5 | 0.061 | 0.347 | 55 |
| 60 | 38.7 | 24.0 | .02840 | 2.28 | 35.20 | .439 | 33.0 | 146.0 | 179.0 | .067 | .348 | 60 |
| 65 | 42.2 | 27.5 | .02855 | 2.10 | 35.00 | .476 | 36.5 | 144.5 | 181.0 | .073 | .349 | 65 |
| 70 | 45.8 | 31.1 | .02875 | 1.94 | 34.80 | .515 | 39.5 | 143.5 | 183.0 | .079 | .350 | 70 |
| 75 | 49.7 | 35.0 | .02890 | 1.79 | 34.60 | .559 | 43.0 | 142.0 | 185.0 | .086 | .351 | 75 |
| 80 | 53.9 | 39.2 | .02910 | 1.66 | 34.35 | .602 | 46.5 | 140.5 | 187.0 | 0.092 | 0.352 | 80 |
| 85 | 58.6 | 43.9 | .02930 | 1.54 | 34.10 | .649 | 50.0 | 139.0 | 189.0 | .098 | .353 | 85 |
| 86† | 59.5 | 44.8 | .02935 | 1.52 | 34.10 | .658 | 50.5 | 139.0 | 189.5 | .099 | .354 | 86† |
| 90 | 63.3 | 48.6 | .02950 | 1.42 | 33.90 | .704 | 53.5 | 137.5 | 191.0 | .105 | .356 | 90 |
| 95 | 68.4 | 53.7 | .02965 | 1.32 | 33.70 | .758 | 57.5 | 136.0 | 193.5 | .112 | .358 | 95 |
| 100 | 73.7 | 59.0 | .02990 | 1.23 | 33.45 | .813 | 61.0 | 134.5 | 195.5 | 0.118 | 0.359 | 100 |
| 105 | 79.3 | 64.6 | .03005 | 1.14 | 33.25 | .877 | 65.0 | 133.0 | 198.0 | .125 | .360 | 105 |
| 110 | 85.1 | 70.4 | .03030 | 1.07 | 33.00 | .935 | 69.0 | 131.0 | 200.0 | .132 | .362 | 110 |
| 115 | 91.4 | 76.7 | .03050 | 0.990 | 32.80 | 1.01 | 73.0 | 129.5 | 202.5 | .139 | .364 | 115 |
| 120 | 98.0 | 83.3 | .03075 | .926 | 32.50 | 1.08 | 77.0 | 127.5 | 204.5 | .147 | .367 | 120 |
| 125 | 104.8 | 90.1 | .03095 | 0.867 | 32.30 | 1.15 | 81.5 | 126.0 | 207.0 | 0.154 | 0.369 | 125 |
| 130 | 112.0 | 97.3 | .03125 | .811 | 32.00 | 1.23 | 86.0 | 124.0 | 210.0 | .161 | .371 | 130 |
| 135 | 119.3 | 104.6 | .03145 | .760 | 31.80 | 1.32 | 90.5 | 122.0 | 212.5 | .169 | .375 | 135 |
| 140 | 126.8 | 112.1 | .03175 | .716 | 31.50 | 1.40 | 95.0 | 120.5 | 215.5 | .176 | .377 | 140 |

* Inches of Mercury below one standard atmosphere (29.82 in. = 14.696 lbs./sq. in. abs.)

† Standard Ton Temperatures.

TABLE XXXI.—SATURATED METHYL CHLORIDE ($\text{CH}_3 \text{Cl}$) VAPOR*Calculated in English Units by Starr from work of Ohnes and Holst.**"Practical Refrigerating Engineers' Pocketbook" Published by Nickerson & Collins Co., Chicago.*

| Temp. Deg. Fahr. | Abs. Press. Lbs. per Sq. In. | Heat Content of Liquid | Heat of Vapor- ization | Spec. Vol. Cu. Ft. per Lb. | Density Lbs. per Cu. Ft. |
|------------------------|------------------------------------|------------------------------|------------------------------|----------------------------------|--------------------------------|
| -40 | 6.96 | -34.0 | 183.3 | 12.57 | 0.07955 |
| -35 | 7.60 | -31.5 | 183.0 | 11.00 | 0.0909 |
| -30 | 9.00 | -29.0 | 182.6 | 9.70 | 0.103 |
| -25 | 10.20 | -26.7 | 182.0 | 8.60 | 0.1162 |
| -20 | 11.80 | -24.5 | 181.4 | 7.80 | 0.1282 |
| -15 | 13.00 | -22.3 | 180.9 | 7.00 | 0.1428 |
| -10 | 15.10 | -20.0 | 180.3 | 6.25 | 0.1600 |
| -5 | 16.80 | -17.5 | 180.0 | 5.60 | 0.1785 |
| 0 | 19.00 | -15.1 | 179.2 | 5.05 | 0.1980 |
| 5 | 20.70 | -12.8 | 178.3 | 4.53 | 0.2207 |
| 10 | 23.00 | -10.2 | 177.8 | 4.15 | 0.2409 |
| 15 | 24.90 | -8.0 | 177.03 | 3.70 | 0.2702 |
| 20 | 28.50 | -5.6 | 176.05 | 3.25 | 0.3076 |
| 25 | 32.00 | -3.2 | 175.8 | 2.90 | 0.3448 |
| 30 | 35.00 | -1.6 | 174.8 | 2.71 | 0.3690 |
| 32 | 36.62 | 0.0 | 174.6 | 2.67 | 0.3745 |
| 40 | 42.90 | +3.7 | 173.0 | 2.25 | 0.4444 |
| 45 | 46.50 | +8.5 | 171.0 | 1.94 | 0.5154 |
| 50 | 62.00 | +13.2 | 169.0 | 1.62 | 0.9803 |
| 65 | 68.00 | 15.5 | 167.85 | 1.50 | 0.6666 |
| 70 | 73.10 | 17.8 | 166.8 | 1.39 | 0.7194 |
| 75 | 80.00 | 20.2 | 165.6 | 1.27 | 0.7842 |
| 80 | 87.00 | 22.5 | 164.2 | 1.15 | 0.8695 |
| 85 | 94.30 | 25.0 | 163.0 | 1.05 | 0.9523 |
| 90 | 104.00 | 27.2 | 161.6 | 0.995 | 1.0051 |
| 95 | 110.10 | 29.6 | 160.4 | 0.938 | 1.0661 |
| 100 | 119.50 | 31.8 | 158.8 | 0.855 | 1.1695 |
| 110 | 137.50 | 36.3 | 156.1 | 0.77 | 1.2987 |

NOTE.—To get gauge pressures 14.7 lbs. are subtracted from the absolute pressures given in the tables. When the absolute pressure is below 14.7 lb. the absolute pressure is subtracted from 14.7 lbs. and this result is multiplied by 2.0355 (for approximate results, 2.0 may be used). This gives the vacuum in inches of mercury below the atmospheric pressure of 14.7 lbs.

TABLE XXXII.—PROPERTIES OF SATURATED VAPOR OF PROPANE—C₃H₈

Linde Air Products Company Laboratory. Refrigeration Engineering, June 1926.
A. S. R. E. Data Book.

| Temp. ° F | Pressure | | Volume | | Density | | Heat Content Above 0° F | | | Entropy From 0° F | | Temp ° F |
|--------------|------------------------------|------------------------------|---------------------------------|--------------------------------|--------------------------------|-------------------------------|-------------------------|--------------------|-------------------|-----------------------|----------------------|-------------|
| | Abs. lb./in. ² | Gage lb./in. ² | Liquid ft. ³ /lb. | Vapor ft. ³ /lb. | Liquid lb./ft. ³ | Vapor lb./ft. ³ | Liquid Btu./lb. | Latent Btu./lb. | Vapor Btu./lb. | Liquid Btu./lb. °F | Vapor Btu./lb. °F | |
| <i>t</i> | <i>p</i> | <i>g p</i> | <i>v</i> | <i>V</i> | <i>l/v</i> | <i>l/V</i> | <i>h +</i> | <i>L =</i> | <i>H</i> | <i>s</i> | <i>S</i> | <i>t</i> |
| -75 | 6.37 | 17.0* | 0.02660 | 11.5 | 37.59 | 0.0690 | -39.5 | 190.5 | 151.0 | -0.092 | 0.404 | -75 |
| -70 | 7.37 | 14.9* | 0.2674 | 12.9 | 37.40 | 0.0775 | -37.0 | 189.5 | 152.5 | -0.086 | 0.400 | -70 |
| -65 | 8.48 | 12.7* | 0.2688 | 11.3 | 37.20 | 0.0885 | -34.5 | 188.0 | 153.5 | -0.080 | 0.397 | -65 |
| -60 | 9.72 | 10.1* | 0.2703 | 9.93 | 37.00 | 0.111 | -32.0 | 187.0 | 155.0 | -0.074 | 0.393 | -60 |
| -55 | 11.1 | 7.3* | 0.2717 | 8.70 | 36.80 | 0.115 | -29.0 | 185.5 | 156.5 | -0.067 | 0.391 | -55 |
| -50 | 12.6 | 4.3* | 0.02732 | 7.74 | 36.60 | 0.129 | -26.5 | 184.5 | 158.0 | -0.061 | 0.389 | -50 |
| -45 | 14.4 | 0.6* | 0.2748 | 6.89 | 36.39 | 0.145 | -24.0 | 183.0 | 159.0 | -0.055 | 0.386 | -45 |
| -40 | 16.2 | 1.5 | 0.2763 | 6.13 | 36.19 | 0.163 | -21.5 | 181.5 | 160.0 | -0.049 | 0.384 | -40 |
| -35 | 18.1 | 3.4 | 0.2779 | 5.51 | 35.99 | 0.181 | -19.0 | 180.0 | 161.0 | -0.042 | 0.382 | -35 |
| -30 | 20.3 | 5.6 | 0.2795 | 4.93 | 35.78 | 0.203 | -16.0 | 179.0 | 163.0 | -0.036 | 0.380 | -30 |
| -25 | 22.7 | 8.0 | 0.02811 | 4.46 | 35.58 | 0.224 | -13.5 | 177.5 | 164.0 | -0.030 | 0.378 | -25 |
| -20 | 25.4 | 10.7 | 0.2827 | 4.00 | 35.37 | 0.250 | -11.0 | 176.0 | 165.0 | -0.024 | 0.377 | -20 |
| -15 | 28.3 | 13.6 | 0.2844 | 3.60 | 35.16 | 0.278 | -8.0 | 175.0 | 167.0 | -0.018 | 0.375 | -15 |
| -10 | 31.4 | 16.7 | 0.2860 | 3.26 | 34.96 | 0.307 | -5.5 | 173.5 | 168.0 | -0.012 | 0.374 | -10 |
| -5 | 34.7 | 20.0 | 0.2878 | 2.97 | 34.75 | 0.337 | -2.5 | 172.0 | 169.5 | -0.006 | 0.372 | -5 |
| 0 | 38.2 | 23.5 | 0.02895 | 2.71 | 34.54 | 0.369 | 0.0 | 170.5 | 170.5 | 0.000 | 0.371 | 0 |
| + 1 | 39.0 | 24.3 | 0.2899 | 2.66 | 34.49 | 0.376 | 0.5 | 170.5 | 171.0 | 0.001 | 0.371 | + 1 |
| 2 | 39.7 | 25.0 | 0.2903 | 2.61 | 34.45 | 0.383 | 1.0 | 170.5 | 171.5 | 0.002 | 0.371 | 2 |
| 3 | 40.5 | 25.8 | 0.2906 | 2.57 | 34.41 | 0.389 | 1.5 | 170.0 | 171.5 | 0.003 | 0.371 | 3 |
| 4 | 41.3 | 26.6 | 0.2910 | 2.52 | 34.37 | 0.396 | 2.0 | 170.0 | 172.0 | 0.004 | 0.371 | 4 |
| 5† | 42.1 | 27.4 | 0.02913 | 2.48 | 34.33 | 0.403 | + 3.0 | 169.5 | 172.0 | + 0.006 | 0.370 | 5† |
| 6 | 42.9 | 28.2 | 0.2916 | 2.43 | 34.29 | 0.411 | 3.5 | 169.0 | 172.5 | 0.007 | 0.370 | 6 |
| 7 | 43.7 | 29.0 | 0.2920 | 2.39 | 34.25 | 0.418 | 4.0 | 168.5 | 172.5 | 0.008 | 0.370 | 7 |
| 8 | 44.5 | 29.8 | 0.2924 | 2.35 | 34.20 | 0.426 | 4.5 | 168.5 | 173.0 | 0.009 | 0.370 | 8 |
| 9 | 45.3 | 30.6 | 0.2927 | 2.31 | 34.16 | 0.433 | 5.0 | 168.0 | 173.0 | 0.010 | 0.370 | 9 |
| 10 | 46.1 | 31.4 | 0.02931 | 2.27 | 34.12 | 0.441 | 5.5 | 168.0 | 173.5 | 0.012 | 0.370 | 10 |
| 11 | 47.0 | 32.3 | 0.2935 | 2.23 | 34.07 | 0.448 | 6.0 | 168.0 | 174.0 | 0.013 | 0.370 | 11 |
| 12 | 47.9 | 33.2 | 0.2939 | 2.19 | 34.03 | 0.456 | 6.5 | 167.5 | 174.0 | 0.014 | 0.370 | 12 |
| 13 | 48.8 | 34.1 | 0.2943 | 2.15 | 33.98 | 0.465 | 7.5 | 167.0 | 174.5 | 0.015 | 0.370 | 13 |
| 14 | 49.7 | 35.0 | 0.2946 | 2.11 | 33.94 | 0.474 | 8.0 | 166.5 | 174.5 | 0.016 | 0.370 | 14 |
| 15 | 50.6 | 35.9 | 0.02950 | 2.07 | 33.90 | 0.483 | 8.5 | 166.5 | 175.0 | 0.018 | 0.369 | 15 |
| 16 | 51.6 | 36.9 | 0.2954 | 2.04 | 33.85 | 0.491* | 9.0 | 166.0 | 175.0 | 0.019 | 0.369 | 16 |
| 17 | 52.5 | 37.8 | 0.2959 | 2.00 | 33.80 | 0.500 | 9.5 | 166.0 | 175.5 | 0.020 | 0.369 | 17 |
| 18 | 53.5 | 38.8 | 0.2963 | 1.97 | 33.75 | 0.509 | 10.0 | 165.5 | 175.5 | 0.021 | 0.369 | 18 |
| 19 | 54.5 | 39.8 | 0.2966 | 1.93 | 33.71 | 0.518 | 10.5 | 165.5 | 176.0 | 0.022 | 0.369 | 19 |
| 20 | 55.5 | 40.8 | 0.02970 | 1.90 | 33.67 | 0.526 | 11.0 | 165.0 | 176.0 | 0.024 | 0.368 | 20 |
| 25 | 60.9 | 46.2 | 0.2991 | 1.74 | 33.43 | 0.575 | 14.0 | 163.5 | 177.5 | 0.030 | 0.368 | 25 |
| 30 | 66.3 | 51.6 | 0.3012 | 1.60 | 33.20 | 0.625 | 17.0 | 162.0 | 179.0 | 0.035 | 0.366 | 30 |
| 35 | 72.0 | 57.3 | 0.3033 | 1.48 | 32.97 | 0.676 | 20.0 | 160.5 | 180.5 | 0.041 | 0.366 | 35 |
| 40 | 78.0 | 63.3 | 0.3055 | 1.37 | 32.73 | 0.730 | 23.0 | 159.0 | 182.0 | 0.047 | 0.366 | 40 |
| 45 | 84.6 | 69.9 | 0.03078 | 1.27 | 32.49 | 0.787 | 26.0 | 157.5 | 183.5 | 0.053 | 0.365 | 45 |
| 50 | 91.8 | 77.1 | 0.3102 | 1.18 | 32.24 | 0.847 | 29.0 | 156.0 | 185.0 | 0.059 | 0.365 | 50 |
| 55 | 99.3 | 84.6 | 0.3125 | 1.10 | 32.00 | 0.909 | 32.0 | 154.5 | 186.5 | 0.065 | 0.365 | 55 |
| 60 | 107.1 | 92.4 | 0.3150 | 1.01 | 31.75 | 0.990 | 35.0 | 153.0 | 188.0 | 0.070 | 0.364 | 60 |
| 65 | 115.4 | 100.7 | 0.3174 | 0.945 | 31.50 | 1.06 | 38.0 | 151.5 | 189.5 | 0.076 | 0.364 | 65 |
| 70 | 124.0 | 109.3 | 0.03201 | 0.883 | 31.24 | 1.13 | 41.0 | 149.5 | 190.5 | 0.082 | 0.364 | 70 |
| 75 | 133.2 | 118.5 | 0.3229 | 0.825 | 30.97 | 1.21 | 44.0 | 148.0 | 192.0 | 0.088 | 0.364 | 75 |
| 80 | 142.8 | 128.1 | 0.3257 | 0.770 | 30.70 | 1.30 | 47.5 | 146.0 | 193.5 | 0.093 | 0.364 | 80 |
| 85 | 153.1 | 138.4 | 0.3287 | 0.722 | 30.42 | 1.39 | 50.5 | 144.5 | 195.0 | 0.099 | 0.364 | 85 |
| 86† | 155.3 | 140.5 | 0.3292 | 0.717 | 30.38 | 1.40 | 51.0 | 144.0 | 195.0 | 0.100 | 0.364 | 86† |
| 90 | 164.0 | 149.0 | 0.03317 | 0.673 | 30.15 | 1.49 | 54.0 | 142.5 | 196.5 | 0.105 | 0.364 | 90 |
| 95 | 175.0 | 160.0 | 0.3348 | 0.632 | 29.87 | 1.58 | 57.0 | 140.5 | 197.5 | 0.111 | 0.364 | 95 |
| 100 | 187.0 | 172.0 | 0.3381 | 0.591 | 29.58 | 1.69 | 60.0 | 138.5 | 199.0 | 0.116 | 0.363 | 100 |
| 105 | 200.0 | 185.0 | 0.3416 | 0.553 | 29.27 | 1.81 | 63.5 | 136.5 | 200.0 | 0.122 | 0.363 | 105 |
| 110 | 212.0 | 197.0 | 0.3453 | 0.520 | 28.96 | 1.92 | 67.0 | 134.0 | 201.0 | 0.128 | 0.363 | 110 |
| 115 | 226.0 | 211.0 | 0.03493 | 0.488 | 28.63 | 2.05 | 70.5 | 131.5 | 202.0 | 0.134 | 0.363 | 115 |
| 120 | 240.0 | 225.0 | 0.3534 | 0.459 | 28.30 | 2.18 | 73.5 | 129.0 | 202.5 | 0.140 | 0.363 | 120 |
| 125 | 254.0 | 239.0 | 0.3575 | 0.432 | 27.97 | 2.31 | 77.0 | 126.5 | 203.5 | 0.145 | 0.361 | 125 |

* Inches of Mercury below one standard atmosphere (29.52 in. = 14.696 lbs./sq. in. abs.)
† Standard Ten Temperatures.

REFRIGERANTS—TABLES

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TABLE XXXIII.—PROPERTIES OF SATURATED VAPOR OF SULPHUR DIOXIDE—SO₂

David L. Fiske, Urbana, Ill.—1925. A. S. R. E. Data Book.

| Temp. °F. <i>t</i> | Pressure | | Volume | | | Density | | Heat Content Above — 40° | | |
|--------------------------|--|--|---|--|--|---|--|----------------------------------|----------------------------------|-------------------------------|
| | Abs. lb./in. ² <i>p</i> | Gage lb./in. ² <i>g p</i> | Liquid ft. ³ /lb. <i>v</i> | Vapor ft. ³ /lb. <i>V</i> | | Liquid lb./ft. ³ <i>l</i> /v | Vapor lb./ft. ³ <i>l</i> /V | Liquid Btu./lb. <i>h</i> + | Latent Btu./lb. <i>L</i> = | Vapor Btu./lb. <i>H</i> |
| -40 | 3.136 | 23.51* | 0.010440 | 22.42 | | 95.79 | 0.04460 | 0.00 | 178.61 | 178.61 |
| -35 | 3.693 | 22.41* | .010486 | 19.23 | | 95.36 | .05200 | 1.45 | 177.82 | 179.27 |
| -30 | 4.331 | 21.10* | .010532 | 16.56 | | 94.94 | .06039 | 2.93 | 176.97 | 179.90 |
| -25 | 5.058 | 19.63* | 0.010580 | 14.31 | | 94.52 | 0.06988 | 4.44 | 176.06 | 180.50 |
| -20 | 5.883 | 17.93* | .010627 | 12.42 | | 94.10 | .08119 | 5.98 | 175.09 | 181.07 |
| -15 | 6.814 | 16.05* | .010674 | 10.81 | | 93.68 | .09250 | 7.56 | 174.06 | 181.62 |
| -10 | 7.863 | 13.91* | .010721 | 9.44 | | 93.27 | .1025 | 9.16 | 172.97 | 182.13 |
| -5 | 9.038 | 11.52* | .010770 | 8.28 | | 92.85 | .1208 | 10.79 | 171.83 | 182.62 |
| 0 | 10.35 | 8.85* | 0.010820 | 7.280 | | 92.42 | 0.1374 | 12.44 | 170.63 | 183.07 |
| 1 | 10.63 | 8.27* | .010830 | 7.099 | | 92.33 | .1408 | 12.79 | 170.38 | 183.17 |
| 2 | 10.91 | 7.74* | .010810 | 6.923 | | 92.25 | .1444 | 13.12 | 170.13 | 183.25 |
| 3 | 11.20 | 7.11* | .010850 | 6.751 | | 92.16 | .1481 | 13.45 | 169.88 | 183.33 |
| 4 | 11.50 | 6.50* | .010860 | 6.584 | | 92.06 | .1591 | 13.78 | 169.63 | 183.41 |
| 5† | 11.81 | 5.87* | 0.010870 | 6.421 | | 92.00 | 0.1558 | 14.11 | 169.38 | 183.49 |
| 6 | 12.12 | 5.24* | .010880 | 6.266 | | 91.91 | .1596 | 14.45 | 169.12 | 183.57 |
| 7 | 12.43 | 4.61* | .010890 | 6.114 | | 91.83 | .1628 | 14.79 | 168.86 | 183.65 |
| 8 | 12.75 | 3.96* | .010900 | 5.967 | | 91.74 | .1676 | 15.13 | 168.60 | 183.73 |
| 9 | 13.08 | 3.29* | .010910 | 5.822 | | 91.66 | .1717 | 15.46 | 168.34 | 183.80 |
| 10 | 13.42 | 2.59* | 0.010920 | 5.682 | | 91.58 | 0.1760 | 15.80 | 168.07 | 183.87 |
| 11 | 13.77 | 1.88* | .010930 | 5.548 | | 91.49 | .1803 | 16.14 | 167.80 | 183.94 |
| 12 | 14.12 | 1.17* | .010940 | 5.417 | | 91.41 | .1846 | 16.48 | 167.53 | 184.01 |
| 13 | 14.48 | 0.44* | .010950 | 5.289 | | 91.33 | .1890 | 16.81 | 167.26 | 184.07 |
| 14 | 14.84 | .14 | .010960 | 5.164 | | 91.24 | .1936 | 17.15 | 166.97 | 184.14 |
| 15 | 15.21 | .51 | 0.010971 | 5.042 | | 91.16 | 0.1983 | 17.49 | 166.72 | 184.21 |
| 16 | 15.59 | .89 | .010981 | 4.926 | | 91.07 | .2030 | 17.84 | 166.44 | 184.28 |
| 17 | 15.98 | 1.28 | .010992 | 4.812 | | 90.98 | .2078 | 18.18 | 166.16 | 184.34 |
| 18 | 16.37 | 1.67 | .011003 | 4.701 | | 90.89 | .2127 | 18.52 | 165.88 | 184.40 |
| 19 | 16.77 | 2.07 | .011014 | 4.593 | | 90.80 | .2177 | 18.86 | 165.60 | 184.46 |
| 20 | 17.18 | 2.48 | 0.011025 | 4.487 | | 90.71 | 0.2228 | 19.20 | 165.32 | 184.52 |
| 21 | 17.60 | 2.90* | .011036 | 4.386 | | 90.62 | .2280 | 19.55 | 165.03 | 184.58 |
| 22 | 18.03 | 3.33 | .011047 | 4.287 | | 90.53 | .2332 | 19.90 | 164.74 | 184.64 |
| 23 | 18.46 | 3.76 | .011058 | 4.190 | | 90.44 | .2387 | 20.24 | 164.45 | 184.69 |
| 24 | 18.89 | 4.19 | .011070 | 4.096 | | 90.33 | .2441 | 20.58 | 164.16 | 184.74 |
| 25 | 19.34 | 4.64 | 0.011082 | 3.994 | | 90.24 | 0.2494 | 20.92 | 163.87 | 184.79 |
| 26 | 19.80 | 5.10 | .011093 | 3.915 | | 90.15 | .2559 | 21.26 | 163.58 | 184.84 |
| 27 | 20.26 | 5.56 | .011104 | 3.829 | | 90.06 | .2611 | 21.61 | 163.28 | 184.89 |
| 28 | 20.73 | 6.03 | .011116 | 3.744 | | 89.96 | .2671 | 21.96 | 162.98 | 184.94 |
| 29 | 21.21 | 6.51 | .011128 | 3.662 | | 89.86 | .2731 | 22.30 | 162.68 | 184.98 |
| 30 | 21.70 | 7.00 | 0.011140 | 3.581 | | 89.76 | 0.2800 | 22.64 | 162.38 | 185.02 |
| 31 | 22.20 | 7.50 | .011152 | 3.503 | | 89.67 | .2854 | 22.98 | 162.08 | 185.06 |
| 32 | 22.71 | 8.01 | .011164 | 3.437 | | 89.58 | .2909 | 23.33 | 161.77 | 185.10 |
| 33 | 23.23 | 8.53 | .011176 | 3.355 | | 89.48 | .2980 | 23.68 | 161.46 | 185.14 |
| 34 | 23.75 | 9.05 | .011188 | 3.283 | | 89.39 | .3046 | 24.03 | 161.15 | 185.18 |
| 35 | 24.28 | 9.58 | 0.011200 | 3.212 | | 89.29 | 0.3113 | 24.38 | 160.84 | 185.22 |
| 36 | 24.82 | 10.12 | .011212 | 3.144 | | 89.18 | .3181 | 24.72 | 160.53 | 185.25 |
| 37 | 25.39 | 10.69 | .011224 | 3.078 | | 89.09 | .3249 | 25.07 | 160.21 | 185.28 |
| 38 | 25.95 | 11.25 | .011236 | 3.013 | | 89.00 | .3319 | 25.42 | 159.89 | 185.31 |
| 39 | 26.52 | 11.82 | .011248 | 2.949 | | 88.90 | .3391 | 25.77 | 159.57 | 185.34 |
| 40 | 27.10 | 12.40 | 0.011260 | 2.887 | | 88.81 | 0.3464 | 26.12 | 159.25 | 185.37 |
| 41 | 27.69 | 12.99 | .011272 | 2.827 | | 88.71 | .3538 | 26.47 | 158.93 | 185.40 |
| 42 | 28.29 | 13.59 | .011284 | 2.769 | | 88.62 | .3611 | 26.81 | 158.61 | 185.42 |
| 43 | 28.90 | 14.20 | .011296 | 2.712 | | 88.52 | .3687 | 27.16 | 158.28 | 185.44 |
| 44 | 29.52 | 14.82 | .011308 | 2.656 | | 88.43 | .3765 | 27.51 | 157.95 | 185.46 |
| 45 | 30.15 | 15.45 | 0.011320 | 2.601 | | 88.34 | 0.3844 | 27.86 | 157.62 | 185.48 |
| 46 | 30.79 | 16.09 | .011332 | 2.548 | | 88.24 | .3925 | 28.21 | 157.29 | 185.50 |
| 47 | 31.44 | 16.74 | .011344 | 2.497 | | 88.15 | .4005 | 28.56 | 156.96 | 185.52 |
| 48 | 32.10 | 17.40 | .011356 | 2.446 | | 88.05 | .4088 | 28.92 | 156.62 | 185.54 |
| 49 | 32.77 | 18.07 | .011368 | 2.397 | | 87.96 | .4172 | 29.27 | 156.28 | 185.55 |
| 50 | 33.45 | 18.75 | 0.011380 | 2.348 | | 87.87 | 0.4259 | 29.61 | 155.95 | 185.56 |
| 51 | 34.15 | 19.45 | .011392 | 2.302 | | 87.78 | .4345 | 29.96 | 155.61 | 185.57 |
| 52 | 34.86 | 20.16 | .011404 | 2.256 | | 87.67 | .4433 | 30.31 | 155.27 | 185.58 |
| 53 | 35.58 | 20.88 | .011416 | 2.211 | | 87.60 | .4523 | 30.66 | 154.93 | 185.59 |
| 54 | 36.31 | 21.61 | .011428 | 2.167 | | 87.51 | .4615 | 31.00 | 154.59 | 185.59 |

* Inches of mercury below one standard atmosphere (29.92 in.) 14.696 lb. abs.

† For Internal Latent heat see Re. Eng. Vol. II, No. 6, p. 255, (Dec. 1924).

‡ Standard ton temperatures.

TABLE XXXIII.—PROPERTIES OF SATURATED VAPOR OF SULPHUR DIOXIDE—SO₂—(Continued)

| Tem. °F. <i>t</i> | Pressure | | Volume | | Density | | Heat Content Above — 40° | | |
|-------------------------|--|--|---|--|--|---|---------------------------------|---------------------------------|-------------------------------|
| | Abs. lb./in. ² <i>p</i> | Gage lb./in. ² <i>g p</i> | Liquid ft. ³ /lb. <i>v</i> | Vapor ft. ³ /lb. <i>V</i> | Liquid lb./ft. ³ <i>l/v</i> | Vapor lb./ft. ³ <i>l/V</i> | Liquid Btu./lb. <i>h+</i> | Latent Btu./lb. <i>L=</i> | Vapor Btu./lb. <i>H</i> |
| 55 | 37.05 | 22.35 | 0.011440 | 2.124 | 87.41 | 0.4708 | 31.36 | 154.24 | 185.60 |
| 56 | 37.80 | 23.10 | 0.011452 | 2.083 | 87.31 | .4801 | 31.72 | 153.89 | 185.61 |
| 57 | 38.56 | 23.86 | 0.011464 | 2.043 | 87.22 | .4894 | 32.08 | 153.54 | 185.62 |
| 58 | 39.33 | 24.63 | 0.011476 | 2.003 | 87.13 | .4992 | 32.42 | 153.19 | 185.61 |
| 59 | 40.12 | 25.42 | 0.011488 | 1.964 | 87.04 | .5092 | 32.76 | 152.84 | 185.60 |
| 60 | 40.93 | 26.23 | 0.011500 | 1.926 | 86.95 | 0.5194 | 33.10 | 152.49 | 185.59 |
| 61 | 41.75 | 27.05 | 0.011512 | 1.889 | 86.86 | .5294 | 33.44 | 152.14 | 185.58 |
| 62 | 42.58 | 27.88 | 0.011524 | 1.853 | 86.77 | .5396 | 33.79 | 151.78 | 185.57 |
| 63 | 43.42 | 28.72 | 0.011536 | 1.816 | 86.68 | .5507 | 34.14 | 151.42 | 185.56 |
| 64 | 44.27 | 29.57 | 0.011548 | 1.783 | 86.59 | .5609 | 34.49 | 151.06 | 185.55 |
| 65 | 45.13 | 30.43 | 0.011560 | 1.749 | 86.50 | 0.5717 | 34.84 | 150.70 | 185.54 |
| 66 | 46.00 | 31.30 | 0.011572 | 1.716 | 86.41 | .5827 | 35.19 | 150.34 | 185.53 |
| 67 | 46.88 | 32.18 | 0.011585 | 1.683 | 86.32 | .5943 | 35.54 | 149.98 | 185.52 |
| 68 | 47.78 | 33.08 | 0.011598 | 1.652 | 86.22 | .6054 | 35.88 | 149.62 | 185.50 |
| 69 | 48.69 | 33.99 | 0.011611 | 1.621 | 86.12 | .6170 | 36.23 | 149.25 | 185.48 |
| 70 | 49.62 | 34.92 | 0.011626 | 1.590 | 86.02 | 0.6290 | 36.58 | 148.88 | 185.46 |
| 71 | 50.57 | 35.87 | 0.011639 | 1.557 | 85.92 | .6423 | 36.93 | 148.51 | 185.44 |
| 72 | 51.54 | 36.84 | 0.011652 | 1.532 | 85.82 | .6527 | 37.28 | 148.14 | 185.42 |
| 73 | 52.51 | 37.81 | 0.011666 | 1.503 | 85.72 | .6657 | 37.63 | 147.77 | 185.40 |
| 74 | 53.48 | 38.78 | 0.011680 | 1.476 | 85.62 | .6777 | 37.97 | 147.40 | 185.37 |
| 75 | 54.47 | 39.77 | 0.011693 | 1.448 | 85.52 | 0.6907 | 38.32 | 147.02 | 185.34 |
| 76 | 55.48 | 40.78 | 0.011706 | 1.422 | 85.42 | .7030 | 38.67 | 146.64 | 185.31 |
| 77 | 56.51 | 41.81 | 0.011719 | 1.396 | 85.33 | .7163 | 39.01 | 146.26 | 185.27 |
| 78 | 57.56 | 42.86 | 0.011732 | 1.371 | 85.23 | .7295 | 39.36 | 145.88 | 185.24 |
| 79 | 58.62 | 43.92 | 0.011746 | 1.343 | 85.13 | .7446 | 39.71 | 145.50 | 185.21 |
| 80 | 59.68 | 44.98 | 0.011760 | 1.321 | 85.03 | 0.7570 | 40.05 | 145.12 | 185.17 |
| 81 | 60.77 | 46.07 | 0.011773 | 1.297 | 84.93 | .7720 | 40.39 | 144.74 | 185.13 |
| 82 | 61.88 | 47.18 | 0.011786 | 1.274 | 84.84 | .7850 | 40.73 | 144.36 | 185.09 |
| 83 | 63.01 | 48.31 | 0.011800 | 1.253 | 84.74 | .7980 | 41.08 | 143.97 | 185.05 |
| 84 | 64.14 | 49.44 | 0.011814 | 1.229 | 84.64 | .8140 | 41.43 | 143.58 | 185.01 |
| 85 | 65.28 | 50.58 | 0.011828 | 1.207 | 84.54 | 0.8285 | 41.78 | 143.19 | 184.97 |
| 86 | 66.45 | 51.75 | 0.011841 | 1.185 | 84.44 | .8440 | 42.12 | 142.80 | 184.92 |
| 87 | 67.64 | 52.94 | 0.011854 | 1.164 | 84.35 | .8590 | 42.46 | 142.41 | 184.87 |
| 88 | 68.84 | 54.14 | 0.011868 | 1.144 | 84.25 | .8740 | 42.80 | 142.02 | 184.82 |
| 89 | 70.04 | 55.34 | 0.011882 | 1.124 | 84.15 | .8898 | 43.15 | 141.62 | 184.77 |
| 90 | 71.25 | 56.55 | 0.011896 | 1.104 | 84.05 | 0.9058 | 43.50 | 141.22 | 184.72 |
| 91 | 72.46 | 57.76 | 0.011909 | 1.084 | 83.96 | .9225 | 43.85 | 140.82 | 184.67 |
| 92 | 73.70 | 59.00 | 0.011923 | 1.065 | 83.86 | .9390 | 44.19 | 140.42 | 184.61 |
| 93 | 74.98 | 60.18 | 0.011937 | 1.047 | 83.77 | .9551 | 44.53 | 140.02 | 184.55 |
| 94 | 76.30 | 61.60 | 0.011951 | 1.028 | 83.67 | .9730 | 44.86 | 139.62 | 184.49 |
| 95 | 77.60 | 62.90 | 0.011965 | 1.011 | 83.57 | 0.9890 | 45.20 | 139.23 | 184.43 |
| 96 | 79.03 | 64.33 | 0.011979 | .9931 | 83.47 | 1.007 | 45.54 | 138.83 | 184.37 |
| 97 | 80.40 | 65.70 | 0.011993 | .9759 | 83.37 | 1.025 | 45.88 | 138.43 | 184.31 |
| 98 | 81.77 | 67.07 | 0.012008 | .9591 | 83.27 | 1.043 | 46.22 | 138.03 | 184.25 |
| 99 | 83.14 | 68.34 | 0.012002 | .9425 | 83.17 | 1.061 | 46.56 | 137.62 | 184.18 |
| 100 | 84.52 | 69.82 | 0.012037 | 0.9262 | 83.07 | 1.080 | 46.90 | 137.20 | 184.10 |
| 105 | 91.85 | 77.15 | 0.012110 | .8498 | 82.57 | 1.176 | 48.88 | 135.14 | 183.72 |
| 110 | 99.76 | 85.06 | 0.012190 | .7804 | 82.03 | 1.281 | 50.26 | 133.05 | 183.31 |
| 115 | 108.02 | 93.32 | 0.012275 | .7174 | 81.46 | 1.394 | 51.93 | 130.92 | 182.85 |
| 120 | 120.93 | 106.23 | 0.012360 | .6598 | 80.90 | 1.515 | 53.58 | 128.78 | 182.36 |
| 125 | 126.43 | 111.73 | 0.012445 | 0.6079 | 80.35 | 1.645 | 55.31 | 126.51 | 181.82 |
| 130 | 136.48 | 121.78 | 0.012530 | .5595 | 79.81 | 1.787 | 56.85 | 124.39 | 181.24 |
| 135 | 147.21 | 132.51 | 0.012620 | .5158 | 79.23 | 1.947 | 58.47 | 122.15 | 180.62 |
| 140 | 158.61 | 143.91 | 0.012720 | .4758 | 78.61 | 2.102 | 60.04 | 119.90 | 179.94 |

† Standard ton temperatures.

TABLE XXXIV.—PROPERTIES OF SUPERHEATED VAPOR OF SULPHUR DIOXIDE—SO₂David L. Fiske, Urbana, Ill.—1925. *A. S. R. E. Data Book.*

| Temp. °F. | Abs. Pressure 4 lb./in. ² Gage Pressure 21.7 in. vac. (Sat'n. Temp. — 32.60° F.) | | | Abs. Pressure 6 lb./in. ² Gage Pressure 17.7 in. vac. (Sat'n. Temp. — 19.37° F.) | | | Abs. Pressure 8 lb./in. ² Gage Pressure 13.6 in. vac. (Sat'n. Temp. — 8.99° F.) | | | Abs. Pressure 10 lb./in. ² Gage Pressure 9.6 in. vac. (Sat'n. Temp. — 1.34° F.) | | |
|--------------|---|-----------------------------|------------------------|---|-----------------------------|------------------------|--|-----------------------------|------------------------|--|-----------------------------|------------------------|
| | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n) | (17.30) | (179.57) | (0.42043) | (12.22) | (181.14) | (0.41151) | (9.220) | (182.25) | (0.40432) | (7.520) | (182.95) | (0.40000) |
| —20 | 18.40 | 181.5 | 0.42487 | 12.75 | 184.3 | 0.41850 | 9.516 | 183.7 | 0.40871 | 7.545 | 183.2 | 0.40046 |
| —10 | 18.83 | 183.0 | 0.42836 | 13.04 | 185.9 | 0.42198 | 9.751 | 185.4 | 0.41230 | 7.744 | 185.0 | 0.40342 |
| 0 | 19.27 | 184.6 | 0.43179 | 13.34 | 187.5 | 0.42538 | 9.983 | 187.1 | 0.41579 | 7.939 | 186.7 | 0.40802 |
| 10 | 20.14 | 187.7 | 0.43847 | 13.63 | 189.1 | 0.42869 | 10.21 | 188.8 | 0.41922 | 8.030 | 188.4 | 0.41159 |
| 20 | 20.57 | 189.3 | 0.44161 | 13.93 | 190.7 | 0.43196 | 10.44 | 190.5 | 0.42256 | 8.316 | 190.1 | 0.41505 |
| 30 | 21.00 | 190.9 | 0.44491 | 14.23 | 192.3 | 0.43517 | 10.66 | 192.2 | 0.42582 | 8.500 | 191.8 | 0.41837 |
| 40 | 21.42 | 192.5 | 0.44806 | 14.52 | 193.9 | 0.43833 | 10.88 | 193.8 | 0.42903 | 8.681 | 193.5 | 0.42161 |
| 50 | 21.85 | 194.1 | 0.45116 | 14.71 | 195.6 | 0.44140 | 11.10 | 195.5 | 0.43216 | 8.860 | 195.2 | 0.42480 |
| 60 | 22.27 | 196.7 | 0.45421 | 15.11 | 197.2 | 0.44443 | 11.32 | 197.1 | 0.43524 | 9.038 | 196.9 | 0.42795 |
| 70 | 22.70 | 199.3 | 0.45722 | 15.40 | 199.9 | 0.44741 | 11.54 | 198.8 | 0.43825 | 9.214 | 198.6 | 0.43104 |
| 80 | 23.12 | 198.9 | 0.46018 | 15.69 | 200.5 | 0.45035 | 11.75 | 200.4 | 0.44123 | 9.389 | 200.3 | 0.43407 |
| 90 | 23.54 | 200.5 | 0.46311 | 15.97 | 202.2 | 0.45326 | 11.97 | 202.1 | 0.44416 | 9.563 | 202.0 | 0.43705 |
| 100 | 23.96 | 202.1 | 0.46600 | 16.26 | 203.8 | 0.45613 | 12.18 | 203.7 | 0.44705 | 9.736 | 203.7 | 0.43997 |
| 110 | 24.39 | 203.8 | 0.46885 | 16.54 | 205.3 | 0.45896 | 12.39 | 205.4 | 0.44990 | 9.908 | 205.4 | 0.44283 |
| 120 | 24.81 | 205.2 | 0.47167 | 16.82 | 207.1 | 0.46176 | 12.61 | 207.0 | 0.45271 | 10.08 | 207.1 | 0.44565 |
| 130 | 25.23 | 207.1 | 0.47445 | 17.09 | 208.8 | 0.46451 | 12.82 | 208.8 | 0.45543 | 10.25 | 208.8 | 0.44842 |
| 140 | 25.65 | 208.8 | 0.47720 | 17.35 | 210.4 | 0.46722 | 13.03 | 210.3 | 0.45820 | 10.42 | 210.5 | 0.45116 |
| 150 | 26.08 | 210.4 | 0.47991 | 17.62 | 212.1 | 0.46990 | 13.24 | 212.0 | 0.46089 | 10.59 | 212.2 | 0.45396 |
| 160 | 26.50 | 212.1 | 0.48259 | 17.88 | 213.7 | 0.47254 | 13.46 | 213.6 | 0.46353 | 10.76 | 213.8 | 0.45651 |
| 170 | 26.92 | 213.8 | 0.48523 | 18.13 | 215.4 | 0.47514 | 13.66 | 215.3 | 0.46614 | 10.93 | 215.4 | 0.45913 |
| 180 | 27.34 | 215.4 | 0.48785 | 18.38 | 217.0 | 0.47769 | 13.88 | 216.9 | 0.46871 | 11.10 | 217.0 | 0.46171 |
| 190 | 27.76 | 217.0 | 0.49045 | | | | | | | | | |
| 200 | 28.18 | 218.6 | 0.49302 | | | | | | | | | |
| 210 | 28.60 | 220.2 | 0.49558 | | | | | | | | | |
| 220 | 29.02 | 221.8 | 0.49813 | | | | | | | | | |
| 230 | 29.44 | 223.4 | 0.50068 | | | | | | | | | |
| 240 | 29.86 | 225.0 | 0.50322 | | | | | | | | | |
| 250 | 30.28 | 226.6 | 0.50577 | | | | | | | | | |
| 260 | 30.70 | 228.2 | 0.50831 | | | | | | | | | |
| 270 | 31.12 | 229.8 | 0.51086 | | | | | | | | | |
| 280 | 31.54 | 231.4 | 0.51340 | | | | | | | | | |
| 290 | 31.96 | 233.0 | 0.51595 | | | | | | | | | |
| 300 | 32.38 | 234.6 | 0.51849 | | | | | | | | | |
| 310 | 32.80 | 236.2 | 0.52104 | | | | | | | | | |
| 320 | 33.22 | 237.8 | 0.52358 | | | | | | | | | |
| 330 | 33.64 | 239.4 | 0.52612 | | | | | | | | | |
| 340 | 34.06 | 241.0 | 0.52867 | | | | | | | | | |
| 350 | 34.48 | 242.6 | 0.53121 | | | | | | | | | |
| 360 | 34.90 | 244.2 | 0.53376 | | | | | | | | | |
| 370 | 35.32 | 245.8 | 0.53630 | | | | | | | | | |
| 380 | 35.74 | 247.4 | 0.53885 | | | | | | | | | |
| 390 | 36.16 | 249.0 | 0.54139 | | | | | | | | | |
| 400 | 36.58 | 250.6 | 0.54394 | | | | | | | | | |
| 410 | 37.00 | 252.2 | 0.54648 | | | | | | | | | |
| 420 | 37.42 | 253.8 | 0.54903 | | | | | | | | | |
| 430 | 37.84 | 255.4 | 0.55157 | | | | | | | | | |
| 440 | 38.26 | 257.0 | 0.55412 | | | | | | | | | |
| 450 | 38.68 | 258.6 | 0.55666 | | | | | | | | | |
| 460 | 39.10 | 260.2 | 0.55921 | | | | | | | | | |
| 470 | 39.52 | 261.8 | 0.56175 | | | | | | | | | |
| 480 | 39.94 | 263.4 | 0.56430 | | | | | | | | | |
| 490 | 40.36 | 265.0 | 0.56684 | | | | | | | | | |
| 500 | 40.78 | 266.6 | 0.56939 | | | | | | | | | |
| 510 | 41.20 | 268.2 | 0.57193 | | | | | | | | | |
| 520 | 41.62 | 269.8 | 0.57448 | | | | | | | | | |
| 530 | 42.04 | 271.4 | 0.57702 | | | | | | | | | |
| 540 | 42.46 | 273.0 | 0.57957 | | | | | | | | | |
| 550 | 42.88 | 274.6 | 0.58211 | | | | | | | | | |
| 560 | 43.30 | 276.2 | 0.58466 | | | | | | | | | |
| 570 | 43.72 | 277.8 | 0.58720 | | | | | | | | | |
| 580 | 44.14 | 279.4 | 0.58975 | | | | | | | | | |
| 590 | 44.56 | 281.0 | 0.59229 | | | | | | | | | |
| 600 | 44.98 | 282.6 | 0.59484 | | | | | | | | | |
| 610 | 45.40 | 284.2 | 0.59738 | | | | | | | | | |
| 620 | 45.82 | 285.8 | 0.59993 | | | | | | | | | |
| 630 | 46.24 | 287.4 | 0.60247 | | | | | | | | | |
| 640 | 46.66 | 289.0 | 0.60502 | | | | | | | | | |
| 650 | 47.08 | 290.6 | 0.60756 | | | | | | | | | |
| 660 | 47.50 | 292.2 | 0.61011 | | | | | | | | | |
| 670 | 47.92 | 293.8 | 0.61265 | | | | | | | | | |
| 680 | 48.34 | 295.4 | 0.61520 | | | | | | | | | |
| 690 | 48.76 | 297.0 | 0.61774 | | | | | | | | | |
| 700 | 49.18 | 298.6 | 0.62029 | | | | | | | | | |
| 710 | 49.60 | 300.2 | 0.62283 | | | | | | | | | |
| 720 | 50.02 | 301.8 | 0.62538 | | | | | | | | | |
| 730 | 50.44 | 303.4 | 0.62792 | | | | | | | | | |
| 740 | 50.86 | 305.0 | 0.63047 | | | | | | | | | |
| 750 | 51.28 | 306.6 | 0.63301 | | | | | | | | | |
| 760 | 51.70 | 308.2 | 0.63556 | | | | | | | | | |
| 770 | 52.12 | 309.8 | 0.63810 | | | | | | | | | |
| 780 | 52.54 | 311.4 | 0.64065 | | | | | | | | | |
| 790 | 52.96 | 313.0 | 0.64319 | | | | | | | | | |
| 800 | 53.38 | 314.6 | 0.64574 | | | | | | | | | |
| 810 | 53.80 | 316.2 | 0.64828 | | | | | | | | | |
| 820 | 54.22 | 317.8 | 0.65083 | | | | | | | | | |
| 830 | 54.64 | 319.4 | 0.65337 | | | | | | | | | |
| 840 | 55.06 | 321.0 | 0.65592 | | | | | | | | | |
| 850 | 55.48 | 322.6 | 0.65846 | | | | | | | | | |
| 860 | 55.90 | 324.2 | 0.66101 | | | | | | | | | |
| 870 | 56.32 | 325.8 | 0.66355 | | | | | | | | | |
| 880 | 56.74 | 327.4 | 0.66610 | | | | | | | | | |
| 890 | 57.16 | 329.0 | 0.66864 | | | | | | | | | |
| 900 | 57.58 | 330.6 | 0.67119 | | | | | | | | | |
| 910 | 58.00 | 332.2 | 0.67373 | | | | | | | | | |
| 920 | 58.42 | 333.8 | 0.67628 | | | | | | | | | |
| 930 | 58.84 | 335.4 | 0.67882 | | | | | | | | | |
| 940 | 59.26 | 337.0 | 0.68137 | | | | | | | | | |
| 950 | 59.68 | 338.6 | 0.68391 | | | | | | | | | |
| 960 | 60.10 | 340.2 | 0.68646 | | | | | | | | | |
| 970 | 60.52 | 341.8 | 0.68900 | | | | | | | | | |
| 980 | 60.94 | 343.4 | 0.69155 | | | | | | | | | |
| 990 | 61.36 | 345.0 | 0.69409 | | | | | | | | | |
| 1000 | 61.78 | 346.6 | 0.69664 | | | | | | | | | |

Note: *V* is Volume of Superheated Vapor, ft.³/lb.; *H* is Heat Content, Btu./lb., and *S* is Entropy, Btu./lb.°F.

TABLE XXXIV.—PROPERTIES OF SUPERHEATED VAPOR OF SULPHUR DIOXIDE—SO₂.—(Continued)

| Temp. °F. | Abs. Pressure 40 lb./in. ² Gage Pressure 25.30 lb./in. ² (Sat'n. Temp. 58.5° F.) | | | Abs. Pressure 50 lb./in. ² Gage Pressure 35.30 lb./in. ² (Sat'n. Temp. 70.4° F.) | | | Abs. Pressure 60 lb./in. ² Gage Pressure 45.30 lb./in. ² (Sat'n. Temp. 80.2° F.) | | | Abs. Pressure 70 lb./in. ² Gage Pressure 55.30 lb./in. ² (Sat'n. Temp. 88.9° F.) | | |
|--------------|--|-----------------------------|------------------------|---|-----------------------------|------------------------|--|-----------------------------|------------------------|--|-----------------------------|------------------------|
| | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n.) | (1.970) | (185.60) | (0.36470) | (1.577) | (185.45) | (0.35520) | (1.314) | (185.16) | (0.35272) | (1.128) | (184.77) | (0.34789) |
| 60 | 1.980 | 185.9 | 0.36544 | | | | | | | | | |
| 70 | 2.064 | 188.7 | .37064 | | | | | | | | | |
| 80 | 2.121 | 191.3 | .37544 | 1.668 | 188.4 | .36366 | | | | | | |
| 90 | 2.185 | 193.6 | .37992 | 1.723 | 191.2 | .36887 | | | | | | |
| 100 | 2.246 | 196.1 | .38415 | 1.775 | 193.9 | .37369 | 1.288 | 191.4 | 0.36403 | 1.181 | 187.6 | 0.35443 |
| 110 | 2.304 | 198.3 | .38810 | 1.825 | 196.4 | 0.37815 | 1.346 | 194.3 | 0.36906 | 1.228 | 191.6 | 0.36020 |
| 120 | 2.360 | 200.4 | .39183 | 1.872 | 198.8 | .38234 | 1.403 | 197.0 | .37375 | 1.272 | 194.8 | .36545 |
| 130 | 2.413 | 202.5 | .39541 | 1.917 | 201.1 | .38627 | 1.459 | 199.5 | .37810 | 1.313 | 197.6 | .37028 |
| 140 | 2.465 | 204.6 | .39881 | 1.961 | 203.3 | .38998 | 1.514 | 201.9 | .38217 | 1.352 | 200.3 | .37478 |
| 150 | 2.515 | 206.5 | .40209 | 2.003 | 205.4 | .39353 | 1.563 | 204.2 | .38603 | 1.389 | 202.9 | .37897 |
| 160 | 2.565 | 208.5 | .40525 | 2.044 | 207.5 | 0.39691 | 1.608 | 206.5 | 0.38963 | 1.424 | 205.3 | 0.38291 |
| 170 | 2.614 | 210.4 | .40831 | 2.084 | 209.6 | .40015 | 1.650 | 208.6 | .39310 | 1.457 | 207.6 | .38662 |
| 180 | 2.662 | 212.3 | .41127 | 2.123 | 211.6 | .40327 | 1.689 | 210.7 | .39639 | 1.489 | 209.9 | .39014 |
| 190 | 2.709 | 214.2 | .41416 | 2.161 | 213.4 | .40628 | 1.726 | 212.8 | .39956 | 1.521 | 212.0 | .39348 |
| 200 | 2.755 | 216.0 | .41694 | 2.199 | 215.4 | .40919 | 1.751 | 214.8 | .40260 | 1.551 | 214.1 | .39670 |
| 210 | 2.800 | 217.9 | .41966 | 2.237 | 217.3 | 0.41200 | 1.785 | 216.8 | 0.40554 | 1.580 | 216.1 | 0.39978 |
| 220 | 2.845 | 219.7 | .42233 | 2.274 | 219.2 | .41477 | 1.819 | 218.7 | .40839 | 1.608 | 218.1 | .40275 |
| 230 | 2.889 | 221.5 | .42494 | 2.311 | 221.1 | .41748 | 1.853 | 220.7 | .41118 | 1.636 | 220.1 | .40564 |
| 240 | 2.933 | 223.3 | .42751 | 2.347 | 223.0 | .42015 | 1.885 | 222.6 | .41391 | 1.664 | 222.1 | .40845 |
| 250 | 2.977 | 225.1 | .43007 | 2.383 | 224.9 | .42275 | 1.917 | 224.5 | .41657 | 1.691 | 224.1 | .41120 |
| 260 | 3.021 | 227.0 | 0.43262 | 2.418 | 226.7 | 0.42535 | 1.948 | 226.4 | 0.41917 | 1.718 | 226.0 | 0.41389 |
| 270 | | | | 2.454 | 228.5 | .42791 | 1.979 | 228.2 | .42175 | 1.745 | 227.9 | .41653 |
| 280 | | | | 2.489 | 230.3 | .43045 | 2.010 | 230.1 | .42431 | 1.771 | 229.8 | .41912 |
| 290 | | | | | | | 2.040 | 232.0 | .42685 | 1.798 | 231.7 | .42167 |
| 300 | | | | | | | 2.070 | 233.8 | 0.42935 | 1.824 | 233.5 | 0.42418 |
| Temp. °F. | Abs. Pressure 80 lb./in. ² Gage Pressure 65.30 lb./in. ² (Sat'n. Temp. 96.8° F.) | | | Abs. Pressure 100 lb./in. ² Gage Pressure 85.30 lb./in. ² (Sat'n. Temp. 110.15° F.) | | | Abs. Pressure 120 lb./in. ² Gage Pressure 105.30 lb./in. ² (Sat'n. Temp. 121.52° F.) | | | Abs. Pressure 140 lb./in. ² Gage Pressure 125.30 lb./in. ² (Sat'n. Temp. 131.64° F.) | | |
| | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. | Volume ft. ³ /lb. | Heat Content Btu./lb. | Entropy Btu./lb.°F. |
| <i>t</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> | <i>V</i> | <i>H</i> | <i>S</i> |
| (at sat'n.) | (0.8909) | (184.38) | (0.34357) | (0.7780) | (183.30) | (0.33003) | (0.6430) | (182.19) | (0.33954) | (0.5451) | (181.04) | (0.32888) |
| 100 | 0.993 | 185.6 | 0.34571 | | | | | | | | | |
| 110 | 1.040 | 189.1 | .35214 | | | | | | | | | |
| 120 | 1.084 | 192.5 | .35797 | 0.8190 | 187.3 | 0.34296 | | | | | | |
| 130 | 1.125 | 195.7 | .36330 | .8575 | 191.0 | .34942 | | | | | | |
| 140 | 1.163 | 198.6 | .36819 | .8928 | 194.6 | .35528 | 0.7085 | 190.1 | 0.34264 | 0.5734 | 185.1 | 0.33089 |
| 150 | 1.199 | 201.3 | 0.37276 | 0.9255 | 197.9 | 0.36061 | 0.7403 | 193.9 | 0.34904 | 0.6055 | 189.7 | 0.33777 |
| 160 | 1.232 | 203.9 | .37692 | .9561 | 200.9 | .36558 | .7700 | 197.4 | .35484 | .6345 | 193.6 | .34442 |
| 170 | 1.263 | 206.4 | .38093 | .9848 | 203.7 | .37009 | .7972 | 200.6 | .36012 | .6613 | 196.3 | .35041 |
| 180 | 1.292 | 208.7 | .38461 | 1.012 | 206.4 | .37431 | .8228 | 203.7 | .36494 | .6861 | 200.8 | .35588 |
| 190 | 1.320 | 211.0 | .38813 | 1.038 | 209.0 | .37829 | .8470 | 206.7 | .36936 | .7092 | 204.0 | .36088 |
| 200 | 1.347 | 213.3 | 0.39150 | 1.062 | 211.5 | 0.38203 | 0.8699 | 209.4 | 0.37348 | 0.7309 | 207.1 | 0.36548 |
| 210 | 1.374 | 215.5 | .39471 | 1.086 | 213.8 | .38556 | .8916 | 212.0 | .37737 | .7513 | 210.0 | .36976 |
| 220 | 1.400 | 217.5 | .39780 | 1.109 | 216.1 | .38892 | .9124 | 214.5 | .38104 | .7707 | 212.7 | .37379 |
| 230 | 1.426 | 219.6 | .40079 | 1.131 | 218.4 | .39214 | .9324 | 217.0 | .38451 | .7892 | 215.4 | .37758 |
| 240 | 1.451 | 221.6 | .40369 | 1.152 | 220.5 | .39524 | .9515 | 219.3 | .38785 | .8070 | 217.9 | .38118 |
| 250 | 1.476 | 223.6 | 0.40651 | 1.173 | 222.6 | 0.39824 | 0.9700 | 221.5 | 0.39106 | 0.8241 | 220.3 | 0.38461 |
| 260 | 1.500 | 225.6 | .40926 | 1.191 | 224.7 | .40114 | .9880 | 223.7 | .39416 | .8405 | 222.6 | .38789 |
| 270 | 1.524 | 227.6 | .41195 | 1.213 | 226.8 | .40397 | 1.006 | 225.9 | .39713 | .8564 | 224.9 | .39105 |
| 280 | 1.547 | 229.5 | .41459 | 1.232 | 228.8 | .40673 | 1.023 | 228.0 | .40002 | .8720 | 227.1 | .39408 |
| 290 | 1.570 | 231.5 | .41719 | 1.251 | 230.8 | .40944 | 1.040 | 230.1 | .40284 | .8870 | 229.3 | .39701 |
| 300 | 1.593 | 233.4 | 0.41974 | 1.268 | 232.8 | 0.41207 | 1.056 | 232.2 | 0.40558 | 0.9017 | 231.5 | 0.39985 |
| 310 | | | | 1.284 | 234.8 | .41464 | 1.072 | 234.3 | .40825 | .9161 | 233.8 | .40261 |
| 320 | | | | 1.299 | 236.7 | .41716 | 1.088 | 236.3 | .41085 | .9302 | 235.7 | .40529 |
| 330 | | | | | | | 1.104 | 238.3 | .41338 | .9441 | 237.7 | .40791 |
| 340 | | | | | | | 1.120 | 240.3 | 0.41583 | 0.9579 | 239.7 | 0.41049 |

Note: *V* is Volume of Superheated Vapor, ft.³/lb.; *H* is Heat Content, Btu./lb.; and *S* is Entropy, Btu./lb.°F.

TABLE XXXV.—STANDARD TON DATA 86° and 5° F. VARIOUS REFRIGERANTS (Saturated Vapors).
 Compiled by Editor A. S. R. E. Data Book from various sources, including A. S. R. E. Circular No. 2, *Properties of Refrigerants, and*
 4. S. R. E. Circular No. 9, *Tables of Thermodynamic Properties of Refrigerants, A. S. R. E. Data Book.*

| Refrigerant | R-11 Carbon Dioxide CO ₂ | | R-28 Nitrous Oxide N ₂ O | | R-21 Ethane C ₂ H ₆ | | R-22 Propane C ₃ H ₈ | | R-2 Ammonia NH ₃ | | R-15 Methyl Chloride CH ₂ Cl | | R-9 Sulphur Dioxide SO ₂ | | R-18 Ethyl Chloride C ₂ H ₅ Cl | |
|---|--|---------|---|--------|---|---------|--|-----------------|-----------------------------------|----------------|---|------------------|---|-----------------|--|-----------------|
| Subject | 86° | 5° | 86° | 5° | 86° | 5° | 86° | 5° | 86° | 5° | 86° | 5° | 86° | 5° | 86° | 5° |
| Absolute pressure, lb./in. ².....p..... | 1039.0 | 334.4 | 986.0 | 330.0 | 681.0 | 236.0 | 158.0 | 45.2 | 169.2 | 34.27 | 95.53 | 20.89 | 66.45 | 11.81 | 27.10 | 4.65 |
| Gage pressure, lb./in. ².....g.p..... | 1024.3 | 319.7 | 971.5 | 315.3 | 666.0 | 221.0 | 143.0 | 30.5 | 154.5 | 19.57 | 90.83 | 6.19 | 51.75 | 5.87 | 12.40 | -10.05 |
| Atmospheres gage, At/in. ².....a.g.p..... | 69.7 | 21.75 | 69.7 | 21.75 | 66.6 | 21.75 | 10.3 | 4.3 | 22.2 | 2.8 | 6.5 | 0.43 | 3.7 | 0.42 | 0.9 | -0.7 |
| Volume-Liquid, ft. ³ /lb.....v..... | 0.0267 | 0.0163 | 0.0256 | 0.0163 | 0.0569 | 0.0365 | 0.0329 | 0.0291 | 0.02691 | 0.02432 | 0.01793 | 0.01634 | 0.01184 | 0.01087 | 0.01822 | 0.01695 |
| Volume-Vapor, ft. ³ /lb.....v..... | 0.0474 | 0.2573 | 0.0726 | 0.3080 | 0.122 | 0.629 | 0.681 | 2.34 | 1.772 | 8.150 | 1.075 | 4.530 | 1.185 | 6.421 | 3.29 | 17.06 |
| Density-Liquid, lb./ft. ³.....l/v..... | 37.41 | 61.22 | 39.06 | 61.27 | 17.80 | 27.40 | 30.37 | 34.33 | 37.16 | 41.11 | 55.8 | 61.0 | 84.44 | 92.00 | 54.88 | 59.00 |
| Density-Vapor, lb./ft. ³.....l/v..... | 21.09 | 3.741 | 13.80 | 5.25 | 8.20 | 1.59 | 1.47 | 4.27 | 0.5643 | 0.1227 | 0.930 | 0.2209 | 0.844 | 0.1558 | 0.3043 | 0.0586 |
| Heat-Liquid, Btu./lb.....h..... | 45.45 | -13.16 | ..... | ..... | ..... | ..... | 51.0 | 3.0 | 138.9 | 48.35 | 59.34 | 21.19 | 42.12 | 14.11 | 23.1 | -11.6 |
| Heat-Latent, Btu./lb.....h..... | 27.00 | 115.30 | 51.1 | 121.4 | 70.0 | 176.0 | 144.0 | 169.5 | 492.6 | 568.0 | 629.0 | 178.50 | 142.80 | 169.58 | 162.6 | 177.0 |
| Heat-Vapor, Btu./lb.....h..... | 72.46 | 102.14 | ..... | ..... | ..... | ..... | 195.0 | 172.0 | 631.5 | 613.35 | 222.25 | 198.76 | 184.92 | 183.49 | 185.7 | 165.4 |
| Entropy-Liquid, Btu./lb. °F..... | 0.0688 | -0.0275 | ..... | ..... | ..... | ..... | 0.100 | 0.006 | 0.2875 | 0.1092 | ..... | ..... | 0.0878 | 0.0315 | 0.0445 | 0.0241 |
| Entropy-Evaporation, Btu./lb. °F..... | 0.0495 | 0.2482 | ..... | ..... | ..... | ..... | 0.264 | 0.364 | 0.9029 | 1.2161 | ..... | ..... | 0.2617 | 0.3645 | 0.2978 | 0.3807 |
| Entropy-Vapor, Btu./lb. °F..... | 0.1363 | 0.2207 | ..... | ..... | ..... | ..... | 0.364 | 0.370 | 1.1904 | 1.3253 | ..... | ..... | 0.3495 | 0.3961 | 0.3423 | 0.3566 |
| Compressibility-Liquid..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.00115 | 0.00062 | ..... | ..... | ..... | ..... | ..... | ..... |
| Specific heat-Liquid..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Specific heat-Vapor, cp..... | 0.3095 | ..... | ..... | ..... | 0.397 | ..... | ..... | 0.365 | 0.79 | 0.91 | ..... | 0.24 | ..... | 0.511 | ..... | 0.273 |
| Specific heat-Vapor, cv..... | 0.1558 | ..... | ..... | ..... | 0.324** | ..... | ..... | 0.316** | 0.4011 (-°) | ..... | ..... | 0.20 | ..... | 1.256(16-34°C.) | ..... | 1.1257 (73° C.) |
| Ratio, cp/cv..... | 1.3063 (32° F.) | ..... | ..... | ..... | 1.224 (50° F.) | ..... | ..... | 1.153 (-°) | ..... | ..... | ..... | 1.1991(66.68°C.) | ..... | ..... | ..... | ..... |
| Specific gravity..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Liquid (water 1) | ..... | ..... | ..... | ..... | 5459(-126.9°F.) | ..... | ..... | 5853 (-48.1°F.) | 6318(-28.03°F.) | 998(-11.36°F.) | ..... | ..... | ..... | ..... | ..... | ..... |
| Vapor (air 1)..... | 1.5290† | ..... | 1.5297† | ..... | 1.0493† | ..... | ..... | 1.562† | 0.5963† | ..... | 1.784† | ..... | ..... | ..... | ..... | ..... |
| Critical pressure, lb./in. ² Abs..... | 1071.00 | ..... | ..... | ..... | 718.0 | 661.5 | 661.5 | 661.5 | 271.2 | 969.2 | 969.2 | 1141.5 | ..... | ..... | 784.0 | ..... |
| Critical temperature, °F..... | 87.80 | ..... | ..... | ..... | 89.8 | 204.1 | 204.1 | 204.1 | 271.2 | 289.6 | 289.6 | 314.8 | ..... | ..... | 361.0 | ..... |
| Molecular weight..... | 44.000† | ..... | 44.016† | ..... | 30.046† | 49.062† | 49.062† | 49.062† | 17.031† | 50.481† | 50.481† | 64.065† | ..... | ..... | 64.49† | ..... |
| Melting point (1 at) °F..... | -180.6† | ..... | -152.3† | ..... | -277.6† | -309.8† | -309.8† | -309.8† | -107.86† | -143.68† | -143.68† | -98.86† | ..... | ..... | -217.66† | ..... |
| Boiling point (1 at) °F..... | -108.4† | ..... | -128.2† | ..... | -126.9† | -48.1† | -48.1† | -48.1† | -28.0** | -10.66† | -10.66† | 14.00† | ..... | ..... | 53.96† | ..... |

* Values of mercury below are standard atmosphere (29.92 in.) 14.696 lbs. abs. ** Supplied by Editor.
 † From International Critical Tables. ‡ From International Critical Tables. § From International Critical Tables. ¶ From International Critical Tables. †† Carbon dioxide not liquid at atmospheric pressure.

TABLE XXXVI.—SOLUBILITY OF AMMONIA IN WATER.*

Siebel—Compend of Mechanical Refrigeration. Nickerson & Collins Co., Chicago.

[illegible]

*For convenience the bodies of the above tables give the ammonia content of the saturated solutions at the various temperatures and pressures in both pounds of ammonia per pound of water and volumes of ammonia per volume of water.—Editor A. S. R. E. Data Book.

TABLE XXXVII.—HEAT OF ASSOCIATION OF AMMONIA.*

Mollier-Starr's Practical Refrigerating Engineers' Hand Book. Nickerson & Collins Co., Chicago.

[illegible]

*The above table, "Heat of Association of Ammonia," gives the heat of association and disassociation of one pound of ammonia entering or leaving ammonia solutions of various strengths. The total heat liberated or taken up respectively when a pound of ammonia is absorbed or driven out of ammonia solutions of various strengths is the heat of association plus the latent heat of vaporization, corresponding to the observed temperature or pressure. See tables of Properties of Anhydrous Ammonia.

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)
 Temperatures ° F. corresponding to various percent concentrations (2 to 50%) and absolute pressures (10 to 200 pounds.)
Mollier, Experiments; Macintire, Computations, Starr's Practical Refrigerating Engineers' Hand Book, Nickerson & Collins Co.

| Per cent, NH ₃ | Absolute pressure. | | | | | | | | | | | | | | | | | | | 25 | 26 |
|------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----|----|----|----|
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| 2..... | 169.0 | 173.0 | 178.5 | 181.8 | 185.6 | 189.5 | 193.2 | 197.0 | 201.5 | 203.5 | 206.5 | 209.5 | 212.3 | 215.0 | 217.5 | 220.1 | 222.4 | | | | |
| 4..... | 161.0 | 165.4 | 169.5 | 173.3 | 177.0 | 180.9 | 184.7 | 188.4 | 191.5 | 194.6 | 197.5 | 200.9 | 203.0 | 205.6 | 207.9 | 210.5 | 212.8 | | | | |
| 6..... | 153.0 | 157.0 | 161.0 | 165.0 | 168.5 | 172.5 | 176.0 | 179.1 | 182.4 | 185.7 | 188.8 | 191.4 | 194.0 | 196.5 | 199.0 | 201.4 | 203.7 | | | | |
| 8..... | 143.5 | 148.3 | 152.7 | 156.4 | 160.5 | 164.0 | 167.9 | 170.8 | 174.0 | 177.9 | 180.1 | 182.7 | 185.3 | 188.0 | 190.3 | 192.5 | 195.0 | | | | |
| 10..... | 137.4 | 141.0 | 144.5 | 148.4 | 151.8 | 155.0 | 158.8 | 162.0 | 165.0 | 168.0 | 171.1 | 173.9 | 176.5 | 179.1 | 181.4 | 183.7 | 186.0 | | | | |
| 12..... | 129.0 | 132.5 | 136.7 | 140.6 | 144.3 | 147.8 | 151.3 | 154.6 | 157.6 | 160.4 | 163.1 | 165.6 | 168.0 | 170.6 | 172.9 | 175.0 | 177.2 | | | | |
| 14..... | 120.5 | 124.6 | 129.0 | 133.0 | 136.7 | 140.0 | 143.6 | 147.0 | 150.0 | 152.7 | 155.5 | 158.0 | 160.6 | 162.9 | 165.1 | 167.4 | 169.7 | | | | |
| 16..... | 113.0 | 117.0 | 121.4 | 125.4 | 129.5 | 132.6 | 136.0 | 139.0 | 142.0 | 144.6 | 147.4 | 149.8 | 152.1 | 154.6 | 156.9 | 159.0 | 161.3 | | | | |
| 18..... | 107.5 | 110.0 | 113.5 | 116.5 | 119.5 | 122.5 | 125.0 | 127.3 | 130.4 | 133.4 | 137.0 | 139.7 | 142.3 | 144.7 | 147.0 | 149.2 | 151.4 | | | | |
| 20..... | 99.0 | 103.0 | 106.8 | 110.5 | 114.0 | 117.6 | 120.6 | 123.9 | 126.7 | 129.5 | 132.0 | 134.5 | 137.0 | 139.3 | 141.6 | 143.7 | 145.7 | | | | |
| 22..... | 92.0 | 95.5 | 99.2 | 103.0 | 106.5 | 110.0 | 113.3 | 116.2 | 119.1 | 122.0 | 124.6 | 127.0 | 129.5 | 131.6 | 133.9 | 136.0 | 138.0 | | | | |
| 24..... | 86.0 | 89.7 | 93.5 | 97.0 | 100.0 | 103.1 | 106.0 | 109.0 | 111.8 | 114.5 | 117.0 | 119.6 | 122.4 | 124.8 | 127.0 | 129.4 | 131.5 | | | | |
| 26..... | 79.2 | 82.6 | 86.0 | 90.0 | 93.0 | 96.0 | 99.5 | 102.4 | 105.3 | 108.0 | 110.6 | 113.2 | 115.6 | 118.1 | 120.1 | 122.1 | 124.1 | | | | |
| 28..... | 73.4 | 77.0 | 81.0 | 84.4 | 87.8 | 90.7 | 93.5 | 96.0 | 98.8 | 101.3 | 103.6 | 106.2 | 108.7 | 111.0 | 113.3 | 115.5 | 117.3 | | | | |
| 30..... | 66.5 | 70.5 | 74.5 | 77.5 | 80.9 | 83.8 | 86.7 | 89.6 | 92.1 | 94.7 | 97.0 | 99.3 | 101.8 | 104.0 | 106.3 | 108.5 | 110.5 | | | | |
| 32..... | 61.0 | 64.5 | 68.0 | 71.0 | 74.0 | 77.0 | 79.8 | 82.3 | 85.0 | 87.5 | 90.0 | 92.3 | 94.5 | 96.9 | 99.0 | 101.0 | 103.0 | | | | |
| 34..... | 55.0 | 59.0 | 62.4 | 65.6 | 68.8 | 71.6 | 74.3 | 76.8 | 79.4 | 81.7 | 84.0 | 86.5 | 88.5 | 90.6 | 92.8 | 94.8 | 96.8 | | | | |
| 36..... | 49.0 | 52.7 | 56.5 | 60.0 | 63.0 | 66.0 | 69.0 | 71.7 | 73.8 | 76.1 | 78.5 | 80.5 | 82.6 | 84.7 | 86.8 | 88.9 | 90.8 | | | | |
| 38..... | 43.0 | 47.0 | 50.5 | 54.0 | 57.0 | 60.0 | 63.0 | 65.5 | 68.0 | 70.2 | 72.5 | 74.5 | 76.6 | 78.7 | 80.7 | 82.7 | 84.6 | | | | |
| 40..... | 37.0 | 41.0 | 44.5 | 48.0 | 51.0 | 53.5 | 56.2 | 59.5 | 61.0 | 63.5 | 66.0 | 68.2 | 70.4 | 72.6 | 74.8 | 76.9 | 79.0 | | | | |
| 42..... | 31.6 | 35.7 | 39.4 | 42.9 | 46.0 | 48.6 | 51.4 | 53.9 | 56.3 | 58.7 | 61.0 | 63.2 | 65.2 | 67.3 | 69.1 | 71.0 | 73.9 | | | | |
| 44..... | 27.5 | 30.2 | 34.0 | 37.0 | 40.5 | 43.5 | 45.9 | 48.5 | 50.8 | 53.0 | 55.3 | 57.4 | 59.4 | 61.6 | 63.5 | 65.4 | 67.1 | | | | |
| 46..... | 21.2 | 24.9 | 28.5 | 31.7 | 34.9 | 37.6 | 40.4 | 43.0 | 45.4 | 47.6 | 49.7 | 51.7 | 53.8 | 55.0 | 57.8 | 59.8 | 61.5 | | | | |
| 48..... | 16.0 | 19.8 | 23.0 | 26.0 | 29.0 | 32.0 | 34.9 | 37.4 | 40.0 | 42.2 | 44.4 | 46.5 | 48.5 | 50.5 | 52.4 | 54.2 | 56.0 | | | | |
| 50..... | 11.0 | 14.6 | 18.0 | 21.0 | 24.0 | 26.9 | 29.7 | 32.0 | 34.4 | 36.6 | 38.9 | 40.9 | 42.8 | 44.7 | 46.6 | 48.5 | 50.3 | | | | |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Percent, NH ₃ | Absolute pressure. | | | | | | | | | | | | | | |
|-----------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 43 |
| 2..... | 224.6 | 226.9 | 229.0 | 231.1 | 233.1 | 235.1 | 237.0 | 238.9 | 240.7 | 242.4 | 244.2 | 246.0 | 247.6 | 249.4 | 254.2 |
| 4..... | 215.3 | 217.7 | 219.9 | 221.9 | 224.0 | 226.0 | 228.0 | 229.8 | 231.6 | 233.4 | 235.3 | 237.0 | 238.7 | 240.3 | 245.0 |
| 6..... | 205.0 | 208.1 | 210.6 | 212.4 | 214.5 | 216.4 | 218.3 | 220.1 | 222.0 | 223.5 | 225.0 | 226.5 | 228.0 | 229.5 | 233.0 |
| 8..... | 407.3 | 190.5 | 201.7 | 203.7 | 205.6 | 207.5 | 209.3 | 211.3 | 213.0 | 214.9 | 216.6 | 218.1 | 219.9 | 221.4 | 224.5 |
| 10..... | 188.4 | 190.5 | 192.7 | 194.6 | 196.6 | 198.7 | 200.5 | 202.3 | 204.1 | 205.9 | 207.3 | 209.0 | 210.6 | 212.3 | 215.2 |
| 12..... | 179.4 | 181.5 | 183.4 | 185.5 | 187.4 | 189.4 | 191.2 | 193.0 | 195.0 | 196.7 | 198.4 | 200.0 | 201.7 | 203.3 | 206.3 |
| 14..... | 171.8 | 173.6 | 175.8 | 177.6 | 179.5 | 181.4 | 183.2 | 185.0 | 186.8 | 188.5 | 190.2 | 192.0 | 193.6 | 195.2 | 198.2 |
| 16..... | 163.4 | 165.4 | 167.4 | 169.4 | 171.3 | 173.2 | 175.1 | 177.0 | 178.9 | 180.6 | 182.3 | 183.7 | 185.4 | 187.1 | 191.4 |
| 18..... | 155.5 | 157.4 | 159.9 | 161.2 | 163.0 | 165.0 | 166.8 | 168.4 | 170.0 | 171.8 | 173.4 | 175.1 | 176.7 | 178.3 | 182.7 |
| 20..... | 147.8 | 149.8 | 151.8 | 153.8 | 155.7 | 157.6 | 159.3 | 161.0 | 162.5 | 164.3 | 165.9 | 167.3 | 168.7 | 170.2 | 174.2 |
| 22..... | 140.0 | 142.0 | 144.0 | 146.0 | 147.9 | 149.7 | 151.5 | 153.2 | 155.0 | 156.5 | 158.0 | 159.6 | 161.0 | 162.7 | 167.0 |
| 24..... | 133.5 | 135.4 | 137.3 | 139.2 | 141.0 | 142.8 | 144.4 | 146.0 | 147.6 | 149.2 | 150.8 | 152.2 | 153.7 | 155.2 | 159.4 |
| 26..... | 126.1 | 128.1 | 130.0 | 131.9 | 133.7 | 135.5 | 137.2 | 138.9 | 140.4 | 142.0 | 143.6 | 145.2 | 146.6 | 148.2 | 152.2 |
| 28..... | 119.4 | 121.3 | 123.0 | 125.0 | 126.6 | 128.3 | 129.8 | 131.5 | 133.1 | 134.6 | 136.0 | 137.5 | 139.0 | 140.6 | 144.8 |
| 30..... | 112.5 | 114.4 | 116.0 | 117.8 | 119.6 | 121.2 | 122.8 | 124.5 | 126.0 | 127.4 | 129.0 | 130.5 | 132.0 | 133.5 | 137.4 |
| 32..... | 105.0 | 107.8 | 109.0 | 111.0 | 113.0 | 114.9 | 116.7 | 118.0 | 119.8 | 121.3 | 122.8 | 124.3 | 125.5 | 127.1 | 131.0 |
| 34..... | 98.8 | 100.8 | 102.7 | 104.5 | 106.3 | 108.0 | 109.6 | 111.3 | 112.8 | 114.5 | 115.8 | 117.3 | 118.5 | 120.0 | 123.8 |
| 36..... | 92.7 | 94.4 | 96.2 | 98.1 | 100.0 | 101.7 | 103.2 | 104.9 | 106.5 | 108.0 | 109.5 | 111.0 | 112.3 | 113.5 | 117.5 |
| 38..... | 86.4 | 88.2 | 90.0 | 91.8 | 93.5 | 95.1 | 96.6 | 98.2 | 99.5 | 101.0 | 102.5 | 104.0 | 105.4 | 106.8 | 110.5 |
| 40..... | 80.2 | 82.2 | 84.1 | 86.0 | 87.7 | 89.2 | 90.8 | 92.4 | 93.7 | 95.3 | 96.7 | 98.0 | 99.4 | 101.0 | 104.7 |
| 42..... | 74.5 | 76.1 | 77.8 | 79.4 | 81.0 | 82.5 | 84.0 | 85.5 | 86.9 | 88.2 | 89.7 | 91.2 | 92.6 | 94.0 | 98.0 |
| 44..... | 68.8 | 70.4 | 72.0 | 73.6 | 75.1 | 76.7 | 78.2 | 79.6 | 81.1 | 82.4 | 83.7 | 85.0 | 86.5 | 87.8 | 91.7 |
| 46..... | 63.3 | 65.0 | 66.5 | 68.1 | 69.6 | 71.2 | 72.7 | 74.0 | 75.4 | 76.7 | 78.2 | 79.6 | 80.9 | 82.0 | 85.7 |
| 48..... | 58.0 | 59.8 | 61.3 | 62.7 | 64.3 | 65.8 | 67.3 | 68.7 | 70.3 | 71.5 | 72.8 | 74.2 | 75.5 | 76.7 | 80.4 |
| 50..... | 52.0 | 53.5 | 55.1 | 56.8 | 58.3 | 59.9 | 61.3 | 62.5 | 64.1 | 65.5 | 66.9 | 68.3 | 69.7 | 70.9 | 74.7 |

HOUSEHOLD REFRIGERATION

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ . | Absolute pressure. | | | | | | | | | | | | | | | 59 | 60 |
|--------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | | |
| 2..... | 255.6 | 257.1 | 258.6 | 260.0 | 261.5 | 262.9 | 264.3 | 265.8 | 267.1 | 268.4 | 269.8 | 271.2 | 272.4 | 273.8 | 274.9 | 276.0 | 277.9 |
| 4..... | 246.4 | 247.9 | 249.5 | 250.8 | 252.2 | 253.6 | 255.0 | 256.4 | 257.9 | 259.2 | 260.4 | 261.7 | 262.9 | 264.0 | 265.3 | 266.6 | 267.7 |
| 6..... | 235.0 | 236.5 | 238.0 | 239.6 | 241.0 | 242.5 | 244.0 | 245.4 | 246.8 | 248.0 | 249.3 | 250.6 | 251.8 | 253.0 | 254.4 | 255.5 | 256.7 |
| 8..... | 227.4 | 228.7 | 230.3 | 231.7 | 233.1 | 234.5 | 236.0 | 237.3 | 238.6 | 239.8 | 241.0 | 242.3 | 243.5 | 244.7 | 245.8 | 247.0 | 248.2 |
| 10..... | 218.3 | 219.8 | 221.2 | 222.8 | 224.3 | 225.7 | 227.0 | 228.3 | 229.7 | 230.8 | 232.3 | 233.6 | 234.8 | 236.0 | 237.3 | 238.4 | 239.6 |
| 12..... | 209.3 | 210.7 | 211.9 | 213.3 | 214.6 | 215.9 | 217.2 | 218.4 | 219.8 | 221.0 | 222.4 | 223.5 | 224.6 | 225.7 | 226.8 | 228.0 | 229.2 |
| 14..... | 201.1 | 202.5 | 204.0 | 205.3 | 206.5 | 207.8 | 209.1 | 210.2 | 211.7 | 212.4 | 214.0 | 215.2 | 216.3 | 217.4 | 218.5 | 219.7 | 220.8 |
| 16..... | 192.9 | 194.1 | 195.5 | 196.8 | 198.0 | 199.4 | 200.5 | 201.8 | 203.0 | 204.1 | 205.3 | 206.5 | 207.7 | 208.8 | 209.8 | 210.9 | 212.0 |
| 18..... | 184.0 | 185.5 | 186.8 | 188.1 | 189.4 | 190.7 | 192.0 | 193.1 | 194.4 | 195.5 | 196.7 | 197.8 | 198.9 | 199.9 | 201.0 | 202.0 | 203.1 |
| 20..... | 175.5 | 177.0 | 178.5 | 179.9 | 181.0 | 182.2 | 183.6 | 184.8 | 186.0 | 187.2 | 188.4 | 189.7 | 190.8 | 192.0 | 193.2 | 194.2 | 195.4 |
| 22..... | 168.3 | 169.5 | 170.9 | 172.1 | 173.4 | 174.6 | 175.9 | 177.0 | 178.2 | 179.5 | 180.6 | 181.7 | 182.8 | 183.9 | 184.9 | 185.9 | 187.0 |
| 24..... | 160.8 | 162.0 | 163.5 | 164.9 | 166.1 | 167.3 | 168.7 | 170.0 | 171.2 | 172.4 | 173.6 | 174.8 | 175.8 | 177.0 | 178.0 | 179.0 | 180.0 |
| 26..... | 153.5 | 155.0 | 156.2 | 157.5 | 158.6 | 159.9 | 161.0 | 162.5 | 163.5 | 164.5 | 165.6 | 166.7 | 167.8 | 168.9 | 170.0 | 171.0 | 172.1 |
| 28..... | 146.0 | 147.4 | 148.9 | 150.1 | 151.5 | 152.7 | 154.0 | 155.2 | 156.5 | 157.6 | 158.8 | 160.0 | 161.0 | 162.0 | 163.0 | 164.1 | 165.2 |
| 30..... | 138.8 | 140.1 | 141.3 | 142.6 | 143.8 | 145.1 | 146.1 | 147.3 | 148.4 | 149.7 | 150.8 | 151.8 | 152.9 | 153.9 | 154.9 | 155.9 | 157.0 |
| 32..... | 132.1 | 133.5 | 134.7 | 135.8 | 137.0 | 138.1 | 139.4 | 140.4 | 141.4 | 142.5 | 143.5 | 144.6 | 145.6 | 146.6 | 147.6 | 148.7 | 149.7 |
| 34..... | 125.0 | 126.2 | 127.5 | 128.6 | 129.9 | 131.0 | 132.0 | 133.0 | 134.1 | 135.2 | 136.3 | 137.3 | 138.3 | 139.5 | 140.5 | 141.4 | 142.4 |
| 36..... | 118.7 | 120.0 | 121.1 | 122.4 | 123.5 | 124.7 | 125.8 | 126.9 | 127.9 | 129.0 | 130.0 | 131.0 | 132.0 | 133.0 | 134.0 | 135.0 | 136.0 |
| 38..... | 111.9 | 113.2 | 114.5 | 115.7 | 117.0 | 118.1 | 119.4 | 120.5 | 121.7 | 122.8 | 123.9 | 125.0 | 126.0 | 127.0 | 128.0 | 129.0 | 130.0 |
| 40..... | 105.9 | 107.0 | 108.1 | 109.5 | 110.6 | 111.8 | 112.9 | 114.0 | 115.2 | 116.3 | 117.3 | 118.3 | 119.4 | 120.5 | 121.5 | 122.4 | 123.4 |
| 42..... | 99.2 | 100.5 | 101.7 | 103.0 | 104.0 | 105.1 | 106.3 | 107.4 | 108.5 | 109.6 | 110.6 | 111.6 | 112.5 | 113.5 | 114.5 | 115.5 | 116.4 |
| 44..... | 93.0 | 94.3 | 95.5 | 96.7 | 97.9 | 99.0 | 100.1 | 101.2 | 102.3 | 103.4 | 104.4 | 105.5 | 106.5 | 107.4 | 108.3 | 109.3 | 110.3 |
| 46..... | 86.9 | 88.1 | 89.4 | 90.5 | 91.7 | 92.8 | 94.0 | 95.0 | 96.1 | 97.2 | 98.3 | 99.4 | 100.3 | 101.3 | 102.3 | 103.3 | 104.2 |
| 48..... | 81.5 | 82.6 | 83.8 | 84.9 | 86.0 | 87.1 | 88.3 | 89.4 | 90.4 | 91.5 | 92.5 | 93.5 | 94.5 | 95.5 | 96.5 | 97.5 | 98.5 |
| 50..... | 75.9 | 77.0 | 78.1 | 79.3 | 80.4 | 81.4 | 82.6 | 83.7 | 84.8 | 85.9 | 86.9 | 87.9 | 88.8 | 89.8 | 90.8 | 91.7 | 92.6 |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ . | Absolute pressure. | | | | | | | | | | | | | | | | |
|--------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 |
| 2..... | 278.6 | 279.7 | 280.8 | 282.0 | 283.2 | 284.3 | 285.4 | 286.5 | 287.7 | 288.8 | 290.0 | 291.0 | 292.0 | 293.0 | 294.0 | 295.0 | 296.0 |
| 4..... | 268.9 | 270.2 | 271.2 | 272.3 | 273.5 | 274.6 | 275.7 | 276.9 | 277.9 | 278.9 | 280.0 | 281.0 | 282.0 | 283.0 | 284.0 | 285.0 | 285.9 |
| 6..... | 259.1 | 260.3 | 261.4 | 262.5 | 263.6 | 264.8 | 265.9 | 267.0 | 268.0 | 269.0 | 270.0 | 271.0 | 272.0 | 273.0 | 274.0 | 274.9 | 275.9 |
| 8..... | 249.4 | 250.6 | 251.6 | 252.7 | 253.8 | 255.0 | 256.0 | 257.1 | 258.1 | 259.0 | 260.0 | 261.0 | 262.0 | 263.0 | 264.0 | 264.9 | 265.8 |
| 10..... | 240.9 | 242.0 | 243.0 | 244.1 | 245.2 | 246.3 | 247.4 | 248.4 | 249.5 | 250.5 | 251.5 | 252.5 | 253.5 | 254.1 | 255.0 | 255.9 | 256.8 |
| 12..... | 230.2 | 231.5 | 232.5 | 233.5 | 234.5 | 235.7 | 236.8 | 237.9 | 238.9 | 240.0 | 240.9 | 241.8 | 242.7 | 243.7 | 244.6 | 245.5 | 246.5 |
| 14..... | 221.8 | 222.9 | 223.9 | 225.0 | 226.0 | 227.0 | 228.0 | 229.0 | 230.1 | 231.2 | 232.3 | 233.0 | 234.0 | 234.9 | 235.8 | 236.8 | 237.7 |
| 16..... | 213.0 | 214.0 | 215.1 | 216.1 | 217.2 | 218.2 | 219.3 | 220.3 | 221.3 | 222.3 | 223.1 | 224.1 | 225.1 | 226.0 | 227.0 | 227.9 | 228.8 |
| 18..... | 204.2 | 205.2 | 206.3 | 207.3 | 208.4 | 209.5 | 210.5 | 211.5 | 212.5 | 213.5 | 214.3 | 215.3 | 216.3 | 217.2 | 218.1 | 219.0 | 220.0 |
| 20..... | 196.4 | 197.4 | 198.4 | 199.4 | 200.3 | 201.3 | 202.2 | 203.1 | 204.1 | 205.0 | 205.7 | 206.7 | 207.6 | 208.5 | 209.2 | 210.2 | 211.1 |
| 22..... | 188.0 | 189.0 | 190.0 | 191.1 | 192.1 | 193.1 | 194.0 | 195.0 | 196.0 | 196.9 | 197.8 | 198.7 | 199.7 | 200.5 | 201.4 | 202.3 | 203.1 |
| 24..... | 181.2 | 182.2 | 183.1 | 184.1 | 185.1 | 186.0 | 187.0 | 188.0 | 189.0 | 190.0 | 190.7 | 191.6 | 192.5 | 193.4 | 194.2 | 195.1 | 196.0 |
| 26..... | 173.1 | 174.2 | 175.2 | 176.2 | 177.2 | 178.2 | 179.2 | 180.1 | 181.0 | 182.0 | 183.0 | 184.0 | 184.9 | 185.7 | 186.5 | 187.3 | 188.2 |
| 28..... | 166.3 | 167.3 | 168.2 | 169.1 | 170.0 | 171.0 | 172.0 | 172.9 | 173.8 | 174.7 | 175.4 | 176.3 | 177.3 | 178.0 | 178.8 | 179.7 | 180.4 |
| 30..... | 158.0 | 159.0 | 159.9 | 160.9 | 161.9 | 162.8 | 163.7 | 164.6 | 165.5 | 166.4 | 167.2 | 168.1 | 169.0 | 169.9 | 170.8 | 171.7 | 172.4 |
| 32..... | 150.7 | 151.5 | 152.5 | 153.4 | 154.2 | 155.2 | 156.1 | 157.0 | 157.9 | 158.8 | 159.7 | 160.5 | 161.4 | 162.3 | 163.1 | 164.0 | 164.9 |
| 34..... | 143.0 | 144.4 | 145.3 | 146.2 | 147.2 | 148.1 | 149.0 | 150.0 | 151.0 | 151.9 | 152.7 | 153.6 | 154.5 | 155.3 | 156.0 | 157.0 | 157.8 |
| 36..... | 137.0 | 137.9 | 138.0 | 139.8 | 140.8 | 141.7 | 142.6 | 143.5 | 144.4 | 145.3 | 146.0 | 146.9 | 147.8 | 148.6 | 149.5 | 150.2 | 151.0 |
| 38..... | 131.0 | 131.9 | 132.8 | 133.7 | 134.6 | 135.5 | 136.4 | 137.3 | 138.1 | 138.7 | 139.6 | 140.5 | 141.3 | 142.0 | 142.8 | 143.6 | 144.3 |
| 40..... | 124.3 | 125.2 | 126.1 | 127.0 | 128.0 | 128.9 | 129.8 | 130.5 | 131.4 | 132.3 | 133.0 | 133.9 | 134.5 | 135.4 | 136.2 | 137.0 | 137.8 |
| 42..... | 117.4 | 118.3 | 119.1 | 120.0 | 120.9 | 121.7 | 122.5 | 123.3 | 124.1 | 124.9 | 125.6 | 126.4 | 127.2 | 128.0 | 128.8 | 129.5 | 130.3 |
| 44..... | 111.2 | 112.0 | 112.9 | 113.8 | 114.7 | 115.5 | 116.3 | 117.1 | 118.0 | 118.8 | 119.5 | 120.3 | 121.0 | 121.9 | 122.6 | 123.3 | 124.0 |
| 46..... | 105.1 | 106.0 | 106.8 | 107.7 | 108.5 | 109.4 | 110.3 | 111.0 | 111.8 | 112.6 | 113.3 | 114.1 | 115.0 | 115.6 | 116.5 | 117.2 | 117.9 |
| 48..... | 99.4 | 100.2 | 101.1 | 101.9 | 102.8 | 103.6 | 104.4 | 105.3 | 106.0 | 106.7 | 107.5 | 108.2 | 109.0 | 109.8 | 110.4 | 111.2 | 111.8 |
| 50..... | 93.5 | 94.4 | 95.3 | 96.1 | 97.0 | 97.8 | 98.5 | 99.3 | 100.0 | 100.8 | 101.6 | 102.5 | 103.2 | 104.0 | 104.7 | 105.4 | 106.3 |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ | Absolute pressure. | | | | | | | | | | | | | | | | |
|------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 |
| 2..... | 207.0 | 208.0 | 209.0 | 209.9 | 300.8 | 301.7 | 302.6 | 303.5 | 304.4 | 305.3 | 306.1 | 306.8 | 307.8 | 308.7 | 309.5 | 310.4 | 311.1 |
| 4..... | 286.8 | 287.7 | 288.6 | 289.5 | 290.4 | 291.3 | 292.1 | 293.0 | 293.9 | 294.7 | 295.6 | 296.5 | 297.3 | 298.1 | 299.0 | 299.8 | 300.7 |
| 6..... | 276.8 | 277.7 | 278.5 | 279.5 | 280.4 | 281.3 | 282.2 | 283.0 | 283.9 | 284.8 | 285.6 | 286.5 | 287.4 | 288.1 | 289.0 | 289.8 | 290.5 |
| 8..... | 266.7 | 267.8 | 268.5 | 269.5 | 270.3 | 271.2 | 272.0 | 272.9 | 273.8 | 274.6 | 275.5 | 276.4 | 277.3 | 278.0 | 278.9 | 279.7 | 280.5 |
| 10..... | 257.8 | 258.7 | 259.5 | 260.3 | 261.2 | 262.0 | 262.9 | 263.8 | 264.6 | 265.3 | 266.2 | 267.0 | 267.9 | 268.6 | 269.5 | 270.3 | 271.1 |
| 12..... | 247.5 | 248.4 | 249.4 | 250.3 | 251.2 | 252.0 | 252.9 | 253.8 | 254.7 | 255.6 | 256.5 | 257.3 | 258.1 | 258.9 | 259.7 | 260.5 | 261.2 |
| 14..... | 238.6 | 239.5 | 240.5 | 241.4 | 242.2 | 243.0 | 243.9 | 244.8 | 245.7 | 246.4 | 247.2 | 248.1 | 248.9 | 249.6 | 250.4 | 251.1 | 251.9 |
| 16..... | 229.7 | 230.6 | 231.6 | 232.3 | 233.2 | 234.0 | 235.0 | 235.9 | 236.7 | 237.4 | 238.2 | 239.0 | 239.9 | 240.7 | 241.4 | 242.2 | 242.9 |
| 18..... | 220.9 | 221.8 | 222.6 | 223.5 | 224.3 | 225.1 | 226.0 | 226.8 | 227.7 | 228.5 | 229.3 | 230.1 | 230.9 | 231.6 | 232.4 | 233.2 | 233.9 |
| 20..... | 212.0 | 212.9 | 213.8 | 214.6 | 215.3 | 216.1 | 216.9 | 217.8 | 218.6 | 219.3 | 220.1 | 221.0 | 221.8 | 222.6 | 223.3 | 224.0 | 224.7 |
| 22..... | 204.0 | 204.8 | 205.6 | 206.4 | 207.1 | 208.0 | 208.8 | 209.6 | 210.4 | 211.1 | 211.9 | 212.7 | 213.5 | 214.3 | 215.0 | 215.7 | 216.4 |
| 24..... | 196.9 | 197.7 | 198.4 | 199.2 | 200.0 | 200.8 | 201.5 | 202.2 | 203.0 | 203.7 | 204.5 | 205.2 | 206.0 | 206.6 | 207.3 | 208.1 | 208.9 |
| 26..... | 189.0 | 189.9 | 190.7 | 191.5 | 192.3 | 193.0 | 193.7 | 194.5 | 195.3 | 196.0 | 196.8 | 197.5 | 198.2 | 198.9 | 199.7 | 200.4 | 201.0 |
| 28..... | 181.2 | 182.0 | 182.8 | 183.6 | 184.3 | 185.1 | 185.9 | 186.7 | 187.3 | 188.0 | 188.8 | 189.5 | 190.3 | 190.9 | 191.6 | 192.3 | 193.0 |
| 30..... | 173.1 | 174.0 | 174.9 | 175.8 | 176.6 | 177.2 | 178.1 | 178.9 | 179.8 | 180.4 | 181.2 | 182.0 | 182.7 | 183.4 | 184.0 | 184.8 | 185.4 |
| 32..... | 165.8 | 166.5 | 167.3 | 168.1 | 169.0 | 169.8 | 170.6 | 171.3 | 172.0 | 172.7 | 173.5 | 174.2 | 175.0 | 175.8 | 176.5 | 177.2 | 177.9 |
| 34..... | 158.6 | 159.4 | 160.2 | 161.0 | 161.7 | 162.5 | 163.3 | 164.0 | 164.7 | 165.5 | 166.3 | 167.0 | 167.8 | 168.5 | 169.3 | 170.0 | 170.7 |
| 36..... | 151.8 | 152.5 | 153.3 | 154.0 | 154.7 | 155.5 | 156.3 | 157.0 | 157.7 | 158.5 | 159.2 | 160.0 | 160.7 | 161.4 | 162.0 | 163.5 | 163.5 |
| 38..... | 145.1 | 145.9 | 146.7 | 147.3 | 148.1 | 148.9 | 149.6 | 150.4 | 151.1 | 151.8 | 152.4 | 153.1 | 153.8 | 154.6 | 155.2 | 155.8 | 256.4 |
| 40..... | 138.5 | 139.2 | 140.0 | 140.7 | 141.4 | 142.2 | 142.7 | 143.5 | 144.2 | 144.9 | 145.6 | 146.2 | 147.0 | 147.7 | 148.3 | 149.0 | 149.7 |
| 42..... | 131.0 | 131.8 | 132.5 | 133.3 | 134.0 | 134.7 | 135.5 | 136.1 | 136.9 | 137.5 | 138.3 | 139.0 | 139.8 | 140.4 | 141.0 | 141.8 | 142.5 |
| 44..... | 124.8 | 125.5 | 126.3 | 127.0 | 127.8 | 128.4 | 129.2 | 129.9 | 130.6 | 131.3 | 131.9 | 132.6 | 133.4 | 134.0 | 134.7 | 135.2 | 136.0 |
| 46..... | 118.7 | 119.3 | 120.1 | 120.7 | 121.5 | 122.2 | 122.9 | 123.5 | 124.2 | 125.0 | 125.7 | 126.3 | 126.9 | 127.6 | 128.3 | 128.9 | 129.6 |
| 48..... | 112.5 | 113.2 | 114.0 | 114.6 | 115.3 | 116.0 | 116.7 | 117.3 | 118.0 | 118.7 | 119.3 | 120.0 | 120.6 | 121.3 | 121.9 | 122.6 | 123.2 |
| 50..... | 106.9 | 107.5 | 108.3 | 109.0 | 109.8 | 110.3 | 111.0 | 111.7 | 112.2 | 113.0 | 113.7 | 114.3 | 114.9 | 115.5 | 116.2 | 116.9 | 117.3 |

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TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₄ | | Absolute pressure. | | | | | | | | | | | | | | | | | |
|------------------------------|-------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|--|
| | | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | |
| 2..... | 312.0 | 312.8 | 313.7 | 314.5 | 315.4 | 316.2 | 316.8 | 317.7 | 318.5 | 319.3 | 320.0 | 320.8 | 321.5 | 322.3 | 323.0 | 323.7 | 324.5 | | |
| 4..... | 301.5 | 302.3 | 303.1 | 304.0 | 304.7 | 305.6 | 306.3 | 307.1 | 308.1 | 308.7 | 309.5 | 310.3 | 311.0 | 311.9 | 312.6 | 313.4 | 314.1 | | |
| 6..... | 291.3 | 292.1 | 293.0 | 293.6 | 294.4 | 295.3 | 295.8 | 296.6 | 297.4 | 298.1 | 298.9 | 299.6 | 300.4 | 301.2 | 301.9 | 302.6 | 303.4 | | |
| 8..... | 281.3 | 282.0 | 282.8 | 283.5 | 284.4 | 285.1 | 285.8 | 286.6 | 287.4 | 288.2 | 289.0 | 289.6 | 290.4 | 291.2 | 291.9 | 292.5 | 293.4 | | |
| 10..... | 271.9 | 272.8 | 273.5 | 274.3 | 275.0 | 275.8 | 276.4 | 277.1 | 278.1 | 278.7 | 279.4 | 280.1 | 280.9 | 281.4 | 282.3 | 282.9 | 283.5 | | |
| 12..... | 262.0 | 262.7 | 263.4 | 264.1 | 264.9 | 265.6 | 266.4 | 267.0 | 267.8 | 268.5 | 269.2 | 269.9 | 270.5 | 271.3 | 272.0 | 272.7 | 273.4 | | |
| 14..... | 252.6 | 253.4 | 254.4 | 255.5 | 256.1 | 256.6 | 257.0 | 257.3 | 257.9 | 258.6 | 259.8 | 260.4 | 261.1 | 261.8 | 262.5 | 263.0 | 263.9 | | |
| 16..... | 243.7 | 244.7 | 245.7 | 246.5 | 247.3 | 248.0 | 248.7 | 249.3 | 249.9 | 250.6 | 251.7 | 252.1 | 252.6 | 253.2 | 254.0 | 254.7 | 255.7 | | |
| 18..... | 234.6 | 235.3 | 236.0 | 236.6 | 237.2 | 238.0 | 238.5 | 239.4 | 240.0 | 240.7 | 241.7 | 242.0 | 242.7 | 243.5 | 244.4 | 245.3 | 246.3 | | |
| 20..... | 225.5 | 226.3 | 227.0 | 227.8 | 228.5 | 229.1 | 229.9 | 230.5 | 231.2 | 231.9 | 232.6 | 233.2 | 233.9 | 234.5 | 235.2 | 235.9 | 236.5 | | |
| 22..... | 217.1 | 217.9 | 218.5 | 219.2 | 220.0 | 220.6 | 221.1 | 222.0 | 222.7 | 223.2 | 224.0 | 224.5 | 225.3 | 225.9 | 226.5 | 227.1 | 227.8 | | |
| 24..... | 209.7 | 210.4 | 211.1 | 211.7 | 212.4 | 213.0 | 213.7 | 214.3 | 215.0 | 215.6 | 216.1 | 216.8 | 217.4 | 218.0 | 218.7 | 219.2 | 220.0 | | |
| 26..... | 201.8 | 202.4 | 203.1 | 203.8 | 204.5 | 205.1 | 205.6 | 206.4 | 207.1 | 207.8 | 208.4 | 209.0 | 209.7 | 210.3 | 211.0 | 211.5 | 212.0 | | |
| 28..... | 193.6 | 194.4 | 195.1 | 195.7 | 196.4 | 197.1 | 197.6 | 198.4 | 199.0 | 199.6 | 200.3 | 200.9 | 201.4 | 202.0 | 202.5 | 203.1 | 203.8 | | |
| 30..... | 186.1 | 186.9 | 187.4 | 188.0 | 188.7 | 189.4 | 189.9 | 190.6 | 191.3 | 191.9 | 192.5 | 193.1 | 193.6 | 194.2 | 194.8 | 195.4 | 196.1 | | |
| 32..... | 178.6 | 179.3 | 180.0 | 180.6 | 181.3 | 182.0 | 182.5 | 183.1 | 183.9 | 184.5 | 185.1 | 185.8 | 186.3 | 186.9 | 187.6 | 188.2 | 188.8 | | |
| 34..... | 171.3 | 172.0 | 172.6 | 173.3 | 174.0 | 174.6 | 175.0 | 175.9 | 176.5 | 177.2 | 177.8 | 178.4 | 179.0 | 179.5 | 180.4 | 180.9 | 181.5 | | |
| 36..... | 164.1 | 164.8 | 165.5 | 166.0 | 166.7 | 167.3 | 168.0 | 168.6 | 169.3 | 169.8 | 170.5 | 171.0 | 171.7 | 172.3 | 172.9 | 173.5 | 174.0 | | |
| 38..... | 157.0 | 157.5 | 158.4 | 159.0 | 159.7 | 160.3 | 160.9 | 161.4 | 162.1 | 162.7 | 163.3 | 164.0 | 164.5 | 165.2 | 165.8 | 166.4 | 167.0 | | |
| 40..... | 150.3 | 150.8 | 151.5 | 152.1 | 152.8 | 153.4 | 154.0 | 154.6 | 155.2 | 155.8 | 156.4 | 157.0 | 157.6 | 158.1 | 158.8 | 159.4 | 160.0 | | |
| 42..... | 143.1 | 143.8 | 144.5 | 145.2 | 145.8 | 146.4 | 147.0 | 147.8 | 148.3 | 149.0 | 149.7 | 150.3 | 150.9 | 151.5 | 152.0 | 152.7 | 153.3 | | |
| 44..... | 136.6 | 137.2 | 137.9 | 138.5 | 139.2 | 139.9 | 140.5 | 141.1 | 141.8 | 142.4 | 143.0 | 143.7 | 144.3 | 144.8 | 145.4 | 146.0 | 146.6 | | |
| 46..... | 130.3 | 130.8 | 131.5 | 132.1 | 132.9 | 133.4 | 134.0 | 134.7 | 135.2 | 135.9 | 136.5 | 137.0 | 137.7 | 138.3 | 138.9 | 139.5 | 140.0 | | |
| 48..... | 123.8 | 124.5 | 125.1 | 125.7 | 126.3 | 127.0 | 127.5 | 128.1 | 128.7 | 129.3 | 129.9 | 130.6 | 131.1 | 131.6 | 132.3 | 132.9 | 133.9 | | |
| 50..... | 118.0 | 118.6 | 119.2 | 119.9 | 120.4 | 121.0 | 121.5 | 122.1 | 122.8 | 123.4 | 123.8 | 124.3 | 125.0 | 125.5 | 126.3 | 126.9 | 127.5 | | |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Percent. NH ₃ . | Absolute pressure. | | | | | | | | | | | | | | |
|-------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 |
| 2..... | 325.2 | 325.9 | 326.5 | 327.3 | 328.0 | 328.6 | 329.4 | 330.0 | 330.7 | 331.3 | 332.0 | 332.7 | 333.4 | 334.0 | 334.7 |
| 4..... | 314.9 | 315.6 | 316.3 | 317.0 | 317.7 | 318.4 | 319.0 | 319.6 | 320.3 | 321.0 | 321.7 | 322.3 | 323.0 | 323.6 | 324.2 |
| 6..... | 304.1 | 304.8 | 305.5 | 306.2 | 306.9 | 307.5 | 308.2 | 308.9 | 309.6 | 310.2 | 310.9 | 311.5 | 312.2 | 312.8 | 313.5 |
| 8..... | 294.2 | 294.9 | 295.5 | 296.2 | 296.9 | 297.5 | 298.2 | 298.9 | 299.6 | 300.3 | 300.9 | 301.5 | 302.1 | 302.7 | 303.4 |
| 10..... | 284.3 | 284.9 | 285.5 | 286.2 | 286.9 | 287.5 | 288.2 | 288.8 | 289.4 | 290.3 | 290.8 | 291.4 | 291.9 | 292.7 | 293.2 |
| 12..... | 274.1 | 274.7 | 275.4 | 276.0 | 276.8 | 277.4 | 278.0 | 278.7 | 279.3 | 280.0 | 280.6 | 281.3 | 281.8 | 282.5 | 283.1 |
| 14..... | 264.5 | 265.1 | 265.9 | 266.5 | 267.1 | 267.8 | 268.4 | 269.1 | 269.7 | 270.4 | 271.0 | 271.7 | 272.3 | 272.9 | 273.5 |
| 16..... | 255.3 | 256.0 | 256.6 | 257.3 | 257.9 | 258.5 | 259.1 | 259.8 | 260.4 | 261.0 | 261.6 | 262.3 | 262.9 | 263.5 | 264.0 |
| 18..... | 246.0 | 246.7 | 247.3 | 248.0 | 248.5 | 249.1 | 249.8 | 250.5 | 251.0 | 251.7 | 252.2 | 252.8 | 253.4 | 254.0 | 254.6 |
| 20..... | 237.1 | 237.8 | 238.3 | 239.0 | 239.6 | 240.3 | 240.9 | 241.5 | 242.0 | 242.7 | 243.3 | 243.7 | 244.4 | 245.0 | 245.6 |
| 22..... | 228.4 | 229.0 | 229.7 | 230.3 | 230.9 | 231.6 | 232.2 | 232.8 | 233.4 | 234.0 | 234.5 | 235.1 | 235.6 | 236.3 | 237.0 |
| 24..... | 220.7 | 221.2 | 221.7 | 222.4 | 223.0 | 223.7 | 224.2 | 224.8 | 225.5 | 226.0 | 226.6 | 227.1 | 227.8 | 228.4 | 228.9 |
| 26..... | 212.6 | 213.4 | 214.0 | 214.6 | 215.2 | 215.8 | 216.3 | 217.0 | 217.6 | 218.1 | 218.7 | 219.3 | 219.9 | 220.4 | 221.0 |
| 28..... | 204.5 | 205.0 | 205.6 | 206.3 | 206.9 | 207.4 | 208.1 | 208.7 | 209.3 | 209.9 | 210.5 | 211.0 | 211.6 | 212.2 | 212.8 |
| 30..... | 196.9 | 197.4 | 198.0 | 198.5 | 199.2 | 199.8 | 200.3 | 200.9 | 201.3 | 202.0 | 202.5 | 203.0 | 203.6 | 204.1 | 204.7 |
| 32..... | 189.4 | 190.0 | 190.6 | 191.1 | 191.8 | 192.4 | 192.9 | 193.4 | 194.0 | 194.5 | 195.1 | 195.6 | 196.1 | 196.6 | 197.2 |
| 34..... | 182.0 | 182.6 | 183.2 | 183.8 | 184.3 | 184.9 | 185.8 | 186.6 | 187.2 | 187.6 | 188.2 | 188.7 | 189.3 | 189.8 | 190.4 |
| 36..... | 174.6 | 175.2 | 175.8 | 176.4 | 177.0 | 177.6 | 178.2 | 178.7 | 179.3 | 179.8 | 180.3 | 180.9 | 181.4 | 182.0 | 182.5 |
| 38..... | 167.7 | 168.2 | 168.8 | 169.3 | 170.0 | 170.5 | 171.0 | 171.6 | 172.2 | 172.7 | 173.2 | 173.8 | 174.2 | 174.8 | 175.3 |
| 40..... | 160.6 | 161.1 | 161.8 | 162.3 | 162.9 | 163.4 | 164.0 | 164.5 | 165.0 | 165.6 | 166.1 | 166.7 | 167.2 | 167.8 | 168.3 |
| 42..... | 153.9 | 154.4 | 155.0 | 155.6 | 156.1 | 156.7 | 157.3 | 157.8 | 158.3 | 158.8 | 159.3 | 160.0 | 160.4 | 161.0 | 161.5 |
| 44..... | 147.1 | 147.7 | 148.2 | 148.8 | 149.4 | 150.0 | 150.5 | 151.0 | 151.5 | 152.0 | 152.6 | 153.1 | 153.6 | 154.2 | 154.7 |
| 46..... | 140.6 | 141.1 | 141.7 | 142.2 | 142.8 | 143.3 | 143.9 | 144.5 | 145.0 | 145.5 | 146.0 | 146.5 | 147.0 | 147.6 | 148.0 |
| 48..... | 134.0 | 134.5 | 135.0 | 135.6 | 136.2 | 136.7 | 137.2 | 137.8 | 138.4 | 138.9 | 139.4 | 140.0 | 141.5 | 141.0 | 141.6 |
| 50..... | 128.1 | 128.5 | 129.1 | 129.8 | 130.2 | 130.9 | 131.3 | 131.8 | 132.4 | 132.9 | 133.3 | 133.9 | 134.2 | 134.7 | 135.2 |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ | Absolute pressure. | | | | | | | | | | | | | | |
|------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 |
| 2..... | 336.7 | 337.4 | 338.0 | 338.7 | 339.3 | 339.9 | 340.5 | 341.2 | 341.8 | 342.4 | 343.0 | 343.6 | 344.2 | 344.8 | 345.4 |
| 4..... | 326.1 | 326.7 | 327.4 | 328.0 | 328.5 | 329.2 | 329.9 | 330.5 | 331.1 | 331.6 | 332.3 | 333.0 | 333.5 | 334.0 | 334.6 |
| 6..... | 315.4 | 316.0 | 316.5 | 317.2 | 317.9 | 318.4 | 319.0 | 319.8 | 320.3 | 321.0 | 321.6 | 322.2 | 322.8 | 323.4 | 324.0 |
| 8..... | 305.2 | 305.8 | 306.4 | 307.0 | 307.5 | 308.1 | 308.7 | 309.4 | 309.9 | 310.5 | 311.1 | 311.6 | 312.3 | 312.8 | 313.3 |
| 10..... | 295.1 | 295.7 | 296.3 | 296.9 | 297.4 | 298.2 | 298.7 | 299.4 | 299.9 | 300.6 | 301.1 | 301.8 | 302.4 | 302.9 | 303.4 |
| 12..... | 285.0 | 285.6 | 286.0 | 287.3 | 287.9 | 288.5 | 289.2 | 289.7 | 289.7 | 290.3 | 290.9 | 291.5 | 292.0 | 292.5 | 293.0 |
| 14..... | 275.5 | 276.0 | 276.5 | 277.2 | 277.7 | 278.3 | 278.9 | 279.4 | 279.6 | 280.0 | 280.6 | 281.2 | 282.3 | 282.8 | 283.4 |
| 16..... | 265.9 | 266.4 | 267.0 | 267.6 | 268.3 | 268.8 | 269.4 | 269.8 | 270.0 | 270.6 | 271.0 | 271.7 | 272.2 | 272.7 | 273.4 |
| 18..... | 256.4 | 257.0 | 257.4 | 258.0 | 258.6 | 259.1 | 259.8 | 260.3 | 260.9 | 261.4 | 262.0 | 262.5 | 263.1 | 263.6 | 264.1 |
| 20..... | 247.3 | 247.9 | 248.4 | 249.0 | 249.6 | 250.2 | 250.7 | 251.3 | 251.8 | 252.4 | 252.9 | 253.5 | 254.0 | 254.5 | 255.0 |
| 22..... | 238.6 | 239.3 | 239.8 | 240.4 | 241.0 | 241.5 | 242.0 | 242.5 | 243.1 | 243.6 | 244.2 | 244.7 | 245.2 | 245.7 | 246.2 |
| 24..... | 230.7 | 231.3 | 231.7 | 232.3 | 232.9 | 233.4 | 233.9 | 234.5 | 235.0 | 235.6 | 236.1 | 236.7 | 237.2 | 237.7 | 238.3 |
| 26..... | 222.8 | 223.4 | 224.0 | 224.5 | 225.1 | 225.6 | 226.0 | 226.7 | 227.1 | 227.6 | 228.1 | 228.7 | 229.2 | 229.7 | 230.2 |
| 28..... | 214.5 | 215.0 | 215.5 | 216.1 | 216.6 | 217.3 | 217.7 | 218.3 | 218.8 | 219.4 | 219.9 | 220.4 | 220.9 | 221.4 | 222.0 |
| 30..... | 206.3 | 206.9 | 207.5 | 208.0 | 208.5 | 209.0 | 209.7 | 210.2 | 210.7 | 211.2 | 211.7 | 212.2 | 212.7 | 213.2 | 213.7 |
| 32..... | 198.8 | 198.4 | 199.9 | 200.4 | 201.0 | 201.4 | 202.0 | 202.5 | 203.0 | 203.5 | 204.0 | 204.5 | 205.0 | 205.6 | 206.1 |
| 34..... | 191.4 | 191.9 | 192.4 | 192.9 | 193.4 | 194.0 | 194.5 | 195.0 | 195.5 | 196.0 | 196.5 | 197.0 | 197.5 | 198.0 | 198.5 |
| 36..... | 184.1 | 184.7 | 185.0 | 185.7 | 186.2 | 186.7 | 187.2 | 187.6 | 188.3 | 188.7 | 189.3 | 189.7 | 190.3 | 190.7 | 191.3 |
| 38..... | 177.0 | 177.5 | 178.0 | 178.5 | 179.0 | 179.5 | 180.0 | 180.6 | 181.0 | 181.5 | 182.0 | 182.5 | 183.0 | 183.5 | 184.0 |
| 40..... | 170.0 | 170.5 | 170.9 | 171.4 | 172.0 | 172.5 | 173.0 | 173.5 | 174.0 | 174.5 | 175.0 | 175.5 | 176.0 | 176.5 | 177.0 |
| 42..... | 163.0 | 163.5 | 164.0 | 164.5 | 165.0 | 165.5 | 166.0 | 166.5 | 167.0 | 167.5 | 168.0 | 168.5 | 169.0 | 169.5 | 170.0 |
| 44..... | 156.2 | 156.7 | 157.1 | 157.7 | 158.2 | 158.7 | 159.1 | 159.7 | 160.2 | 160.7 | 161.1 | 161.6 | 162.0 | 162.5 | 163.0 |
| 46..... | 149.6 | 150.2 | 150.5 | 151.0 | 151.5 | 152.0 | 152.5 | 153.0 | 153.5 | 154.0 | 154.5 | 155.0 | 155.5 | 156.0 | 156.5 |
| 48..... | 143.2 | 143.7 | 144.0 | 144.7 | 145.2 | 145.8 | 146.2 | 146.7 | 147.2 | 147.7 | 148.1 | 148.6 | 149.1 | 149.6 | 150.1 |
| 50..... | 136.8 | 137.2 | 137.7 | 138.2 | 138.6 | 139.2 | 139.6 | 140.2 | 140.7 | 141.1 | 141.6 | 142.0 | 142.5 | 143.0 | 143.4 |

HOUSEHOLD REFRIGERATION

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ | Absolute pressure. | | | | | | | | | | | | | | | | |
|------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 | 162 |
| 2..... | 347.1 | 337.0 | 337.5 | | | | | | | | | | | | | | |
| 4..... | 336.4 | 337.0 | 337.5 | 337.4 | 337.9 | | | | | | | | | | | | |
| 6..... | 335.7 | 336.3 | 336.9 | 337.4 | 337.9 | 317.8 | 318.3 | 300.0 | 300.4 | 310.0 | 310.5 | 311.0 | 311.6 | 312.1 | 312.6 | 313.0 | 313.6 |
| 8..... | 315.0 | 315.5 | 316.2 | 316.6 | 317.3 | 307.8 | 308.4 | 298.5 | 299.0 | 299.6 | 300.2 | 300.7 | 301.2 | 301.7 | 302.2 | 302.5 | 303.2 |
| 10..... | 305.0 | 305.6 | 306.3 | 306.8 | 307.4 | 297.5 | 298.0 | 288.8 | 289.3 | 289.9 | 290.4 | 290.9 | 291.4 | 292.0 | 292.4 | 292.9 | 293.3 |
| 12..... | 294.7 | 295.3 | 295.8 | 296.4 | 297.0 | 287.7 | 288.3 | 279.1 | 279.6 | 280.3 | 280.7 | 281.3 | 281.7 | 282.2 | 282.8 | 283.1 | 283.7 |
| 14..... | 285.0 | 285.6 | 286.1 | 286.7 | 287.3 | 278.1 | 278.6 | 269.5 | 270.0 | 270.5 | 271.0 | 271.4 | 271.9 | 272.5 | 273.0 | 273.3 | 273.8 |
| 16..... | 275.5 | 276.0 | 276.5 | 277.0 | 277.5 | 268.5 | 269.0 | 260.5 | 261.0 | 261.5 | 262.0 | 262.5 | 263.0 | 263.5 | 264.1 | 264.5 | 265.0 |
| 18..... | 265.7 | 266.4 | 266.9 | 267.4 | 268.0 | 258.6 | 259.2 | 250.7 | 251.3 | 251.9 | 252.4 | 252.9 | 253.4 | 253.9 | 254.4 | 254.9 | 255.5 |
| 20..... | 256.7 | 257.3 | 257.6 | 258.1 | 258.6 | 250.4 | 250.9 | 242.3 | 242.8 | 243.3 | 243.8 | 244.3 | 244.8 | 245.3 | 245.8 | 246.3 | 246.8 |
| 22..... | 247.9 | 248.4 | 248.9 | 249.4 | 250.0 | 241.3 | 241.9 | 232.7 | 233.3 | 233.9 | 234.5 | 235.1 | 235.6 | 236.2 | 236.7 | 237.3 | 237.8 |
| 24..... | 239.9 | 240.3 | 240.8 | 241.3 | 241.9 | 232.7 | 233.3 | 224.2 | 224.8 | 225.4 | 226.0 | 226.6 | 227.2 | 227.8 | 228.4 | 229.0 | 229.6 |
| 26..... | 231.6 | 232.3 | 232.8 | 233.3 | 233.9 | 224.2 | 224.8 | 215.7 | 216.3 | 216.9 | 217.5 | 218.1 | 218.7 | 219.3 | 219.9 | 220.5 | 221.1 |
| 28..... | 223.5 | 224.0 | 224.5 | 225.0 | 225.5 | 216.7 | 217.3 | 208.8 | 209.4 | 210.0 | 210.6 | 211.2 | 211.8 | 212.4 | 213.0 | 213.6 | 214.2 |
| 30..... | 215.3 | 215.8 | 216.3 | 216.7 | 217.3 | 210.7 | 211.3 | 202.1 | 202.7 | 203.3 | 203.9 | 204.5 | 205.1 | 205.7 | 206.3 | 206.9 | 207.5 |
| 32..... | 207.5 | 208.0 | 208.5 | 209.0 | 209.4 | 200.8 | 201.3 | 191.7 | 192.1 | 192.6 | 193.1 | 193.6 | 194.1 | 194.6 | 195.1 | 195.6 | 196.1 |
| 34..... | 199.9 | 200.3 | 200.8 | 201.3 | 201.7 | 192.1 | 192.6 | 182.5 | 183.0 | 183.5 | 184.0 | 184.5 | 185.0 | 185.5 | 186.0 | 186.5 | 187.0 |
| 36..... | 192.6 | 193.1 | 193.6 | 194.1 | 194.5 | 185.1 | 185.6 | 175.0 | 175.5 | 176.0 | 176.5 | 177.0 | 177.5 | 178.0 | 178.5 | 179.0 | 179.5 |
| 38..... | 185.4 | 185.9 | 186.3 | 186.8 | 187.3 | 176.6 | 177.1 | 166.0 | 166.5 | 167.0 | 167.5 | 168.0 | 168.5 | 169.0 | 169.5 | 170.0 | 170.5 |
| 40..... | 178.2 | 178.6 | 179.1 | 179.6 | 180.1 | 170.5 | 171.0 | 160.0 | 160.5 | 161.0 | 161.5 | 162.0 | 162.5 | 163.0 | 163.5 | 164.0 | 164.5 |
| 42..... | 171.5 | 172.0 | 172.4 | 172.9 | 173.3 | 163.8 | 164.3 | 153.0 | 153.5 | 154.0 | 154.5 | 155.0 | 155.5 | 156.0 | 156.5 | 157.0 | 157.5 |
| 44..... | 164.5 | 165.0 | 165.4 | 165.9 | 166.3 | 156.8 | 157.3 | 146.0 | 146.5 | 147.0 | 147.5 | 148.0 | 148.5 | 149.0 | 149.5 | 150.0 | 150.5 |
| 46..... | 157.7 | 158.1 | 158.6 | 159.0 | 159.4 | 149.8 | 150.3 | 140.0 | 140.5 | 141.0 | 141.5 | 142.0 | 142.5 | 143.0 | 143.5 | 144.0 | 144.5 |
| 48..... | 151.5 | 152.0 | 152.4 | 152.9 | 153.3 | 143.7 | 144.2 | 134.0 | 134.5 | 135.0 | 135.5 | 136.0 | 136.5 | 137.0 | 137.5 | 138.0 | 138.5 |
| 50..... | 144.7 | 145.1 | 145.5 | 146.0 | 146.4 | 140.8 | 141.3 | 131.0 | 131.5 | 132.0 | 132.5 | 133.0 | 133.5 | 134.0 | 134.5 | 135.0 | 135.5 |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ . | Absolute pressure. | | | | | | | | | | | | | | | | |
|--------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 163 | 164 | 165 | 166 | 167 | 168 | 160 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 |
| 2..... | 314.1 | 314.7 | 315.1 | 315.6 | 316.1 | 316.6 | 317.1 | 317.6 | 318.1 | 318.7 | 319.2 | 319.7 | 320.3 | 320.8 | 321.2 | 321.7 | 322.2 |
| 4..... | 303.1 | 304.1 | 304.6 | 305.1 | 305.6 | 306.1 | 306.6 | 307.1 | 307.6 | 308.1 | 308.6 | 309.1 | 309.6 | 310.1 | 310.6 | 311.0 | 311.6 |
| 6..... | 293.7 | 294.4 | 295.2 | 295.8 | 296.2 | 296.6 | 296.8 | 297.1 | 297.6 | 298.1 | 298.5 | 299.0 | 299.5 | 300.0 | 300.5 | 301.0 | 301.5 |
| 8..... | 284.1 | 284.6 | 285.5 | 286.0 | 286.4 | 286.9 | 287.3 | 287.8 | 288.3 | 288.7 | 289.2 | 289.6 | 290.1 | 290.5 | 291.0 | 291.5 | 291.9 |
| 10..... | 274.3 | 274.8 | 275.2 | 275.7 | 276.1 | 276.7 | 277.2 | 277.6 | 278.0 | 278.5 | 279.0 | 279.5 | 280.0 | 280.5 | 281.0 | 281.4 | 281.9 |
| 12..... | 265.0 | 265.5 | 266.0 | 266.5 | 267.0 | 267.5 | 267.9 | 268.4 | 268.9 | 269.3 | 269.9 | 270.3 | 270.8 | 271.3 | 271.8 | 272.3 | 272.8 |
| 14..... | 256.2 | 256.6 | 257.0 | 257.5 | 258.0 | 258.4 | 258.9 | 259.3 | 259.7 | 260.2 | 260.6 | 261.1 | 261.6 | 262.1 | 262.5 | 263.0 | 263.4 |
| 16..... | 246.8 | 248.5 | 249.0 | 249.4 | 249.9 | 250.3 | 250.6 | 251.0 | 251.5 | 252.0 | 252.5 | 253.0 | 253.4 | 253.8 | 254.3 | 254.6 | 255.1 |
| 18..... | 239.7 | 240.7 | 241.1 | 241.5 | 242.0 | 242.5 | 243.0 | 243.4 | 243.8 | 244.2 | 244.6 | 245.0 | 245.5 | 246.0 | 246.3 | 246.8 | 247.2 |
| 20..... | 231.6 | 232.0 | 232.5 | 232.9 | 233.3 | 233.7 | 234.0 | 234.5 | 234.9 | 235.4 | 235.8 | 236.3 | 236.7 | 237.1 | 237.5 | 238.0 | 238.5 |
| 22..... | 223.5 | 224.0 | 224.4 | 224.9 | 225.3 | 225.8 | 226.3 | 226.7 | 227.1 | 227.5 | 228.0 | 228.4 | 228.8 | 229.3 | 229.7 | 230.1 | 230.6 |
| 24..... | 215.0 | 215.4 | 215.9 | 216.3 | 216.6 | 217.0 | 217.3 | 217.7 | 218.2 | 218.6 | 219.0 | 219.5 | 220.0 | 220.4 | 220.8 | 221.2 | 221.6 |
| 26..... | 207.4 | 207.8 | 208.1 | 208.4 | 208.8 | 209.2 | 209.7 | 210.0 | 210.4 | 210.9 | 211.3 | 211.7 | 212.0 | 212.5 | 213.0 | 213.4 | 213.8 |
| 28..... | 200.3 | 200.6 | 201.0 | 201.4 | 201.9 | 202.2 | 202.6 | 203.0 | 203.3 | 203.7 | 204.0 | 204.4 | 204.8 | 205.2 | 205.6 | 206.0 | 206.4 |
| 30..... | 193.0 | 193.4 | 193.8 | 194.1 | 194.6 | 194.9 | 195.2 | 195.6 | 195.9 | 196.3 | 196.7 | 197.0 | 197.4 | 197.8 | 198.2 | 198.6 | 199.0 |
| 32..... | 186.0 | 186.4 | 186.9 | 187.2 | 187.7 | 188.0 | 188.5 | 188.9 | 189.3 | 189.8 | 190.2 | 190.5 | 190.9 | 191.2 | 191.6 | 192.0 | 192.4 |
| 34..... | 178.9 | 179.2 | 179.6 | 180.0 | 180.3 | 180.6 | 181.0 | 181.4 | 181.9 | 182.2 | 182.5 | 183.0 | 183.3 | 183.7 | 184.1 | 184.5 | 184.9 |
| 36..... | 171.8 | 172.2 | 173.5 | 173.9 | 174.3 | 174.6 | 174.9 | 175.3 | 175.6 | 176.0 | 176.3 | 176.7 | 177.0 | 177.3 | 177.6 | 178.0 | 178.4 |
| 38..... | 165.0 | 165.3 | 165.7 | 166.0 | 166.4 | 166.8 | 167.2 | 167.5 | 167.9 | 168.3 | 168.6 | 169.0 | 169.3 | 169.7 | 170.2 | 170.5 | 170.9 |
| 40..... | 158.7 | 159.0 | 159.4 | 159.8 | 160.2 | 160.5 | 160.9 | 161.2 | 161.5 | 161.9 | 162.2 | 162.7 | 163.0 | 163.3 | 163.7 | 164.1 | 164.5 |
| 42..... | 152.0 | 152.3 | 152.7 | 153.1 | 153.6 | 154.1 | 154.5 | 154.9 | 155.2 | 155.5 | 155.9 | 156.3 | 156.7 | 157.2 | 157.6 | 158.1 | 158.5 |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent. NH ₃ . | Absolute pressure. | | | | | | | | | | |
|--------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 |
| 2..... | | | | | | | | | | | |
| 4..... | | | | | | | | | | | |
| 6..... | | | | | | | | | | | |
| 8..... | | | | | | | | | | | |
| 10..... | 322.7 | 323.1 | 323.6 | 324.0 | 324.5 | 325.0 | 325.5 | 326.0 | 326.5 | 326.0 | 327.0 |
| 12..... | 312.0 | 312.5 | 313.0 | 313.4 | 313.9 | 314.3 | 314.7 | 315.2 | 315.7 | 316.1 | 316.5 |
| 14..... | 302.0 | 302.4 | 302.9 | 303.3 | 303.7 | 304.2 | 304.6 | 305.1 | 305.6 | 306.0 | 306.5 |
| 16..... | 292.0 | 292.5 | 293.0 | 293.5 | 293.9 | 294.4 | 294.9 | 295.3 | 295.7 | 296.2 | 296.6 |
| 18..... | 282.4 | 282.9 | 283.3 | 283.7 | 284.2 | 284.7 | 285.1 | 285.6 | 286.0 | 286.5 | 287.0 |
| 20..... | 273.3 | 273.6 | 274.1 | 274.6 | 275.0 | 275.5 | 276.0 | 276.5 | 277.0 | 277.5 | 278.0 |
| 22..... | 263.9 | 264.3 | 264.7 | 265.2 | 265.6 | 266.1 | 266.5 | 267.0 | 267.5 | 268.0 | 268.5 |
| 24..... | 255.5 | 256.0 | 256.5 | 257.0 | 257.4 | 257.8 | 258.2 | 258.7 | 259.1 | 259.6 | 260.0 |
| 26..... | 247.2 | 247.6 | 248.0 | 248.4 | 248.9 | 249.3 | 249.7 | 250.2 | 250.6 | 251.0 | 251.5 |
| 28..... | 238.9 | 239.3 | 239.8 | 240.2 | 240.6 | 241.0 | 241.5 | 241.9 | 242.4 | 242.8 | 243.2 |
| 30..... | 231.1 | 231.4 | 231.8 | 232.2 | 232.6 | 233.1 | 233.5 | 234.0 | 234.4 | 234.8 | 235.1 |
| 32..... | 222.0 | 222.5 | 223.0 | 223.4 | 223.8 | 224.2 | 224.7 | 225.1 | 225.5 | 226.0 | 226.4 |
| 34..... | 214.2 | 214.5 | 215.0 | 215.4 | 215.9 | 216.3 | 216.7 | 217.0 | 217.5 | 218.0 | 218.3 |
| 36..... | 206.8 | 207.2 | 207.5 | 207.9 | 208.3 | 208.7 | 209.0 | 209.3 | 209.8 | 210.2 | 210.6 |
| 38..... | 199.3 | 199.7 | 200.0 | 200.3 | 200.7 | 201.1 | 201.6 | 201.9 | 202.3 | 202.6 | 203.0 |
| 40..... | 192.8 | 193.2 | 193.6 | 193.9 | 194.3 | 194.7 | 195.0 | 195.3 | 195.7 | 196.1 | 196.5 |
| 42..... | 185.3 | 185.7 | 186.0 | 186.4 | 186.9 | 187.3 | 187.6 | 188.0 | 188.3 | 188.8 | 189.2 |
| 44..... | 178.2 | 178.5 | 178.9 | 179.3 | 179.7 | 180.1 | 180.5 | 180.9 | 181.3 | 181.7 | 182.0 |
| 46..... | 171.3 | 171.7 | 172.0 | 172.4 | 172.8 | 173.1 | 173.6 | 174.0 | 174.3 | 174.7 | 175.2 |
| 48..... | 164.9 | 165.3 | 165.8 | 166.0 | 166.4 | 166.7 | 167.1 | 167.5 | 167.9 | 168.3 | 168.6 |
| 50..... | 158.7 | 159.1 | 159.5 | 159.9 | 160.3 | 160.7 | 161.0 | 161.4 | 161.8 | 162.0 | 162.4 |

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(Continued)

| Per cent, NH ₃ | Absolute Pressure. | | | | | | | | | |
|------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 200 |
| 2..... | | | | | | | | | | |
| 4..... | | | | | | | | | | |
| 6..... | | | | | | | | | | |
| 8..... | | | | | | | | | | |
| 10..... | | | | | | | | | | |
| 12..... | 327.7 | 328.2 | 328.5 | 329.0 | 329.4 | 329.9 | 330.3 | 330.7 | 331.1 | 331.6 |
| 14..... | 317.0 | 317.3 | 317.9 | 318.3 | 318.7 | 319.1 | 319.6 | 320.0 | 320.4 | 320.7 |
| 16..... | 307.0 | 307.4 | 307.9 | 308.4 | 308.8 | 309.3 | 309.8 | 310.3 | 310.7 | 311.1 |
| 18..... | 297.1 | 297.6 | 298.0 | 298.5 | 299.0 | 299.5 | 300.0 | 300.5 | 300.9 | 301.3 |
| 20..... | 287.4 | 287.9 | 288.4 | 288.9 | 289.3 | 289.9 | 290.3 | 290.8 | 291.3 | 291.7 |
| 22..... | 278.3 | 278.9 | 279.3 | 279.9 | 280.3 | 280.8 | 281.3 | 281.7 | 282.1 | 282.7 |
| 24..... | 268.9 | 269.3 | 269.8 | 270.3 | 270.7 | 271.2 | 271.6 | 272.1 | 272.5 | 273.0 |
| 26..... | 260.5 | 260.9 | 261.4 | 261.8 | 262.3 | 262.7 | 263.2 | 263.6 | 264.0 | 264.5 |
| 28..... | 251.9 | 252.3 | 252.8 | 253.2 | 253.5 | 253.9 | 254.4 | 254.8 | 255.3 | 255.8 |
| 30..... | 243.7 | 244.0 | 244.5 | 244.9 | 245.4 | 245.8 | 246.3 | 246.7 | 247.2 | 247.5 |
| 32..... | 235.6 | 236.0 | 236.4 | 236.8 | 237.2 | 237.7 | 238.2 | 238.7 | 239.0 | 239.3 |
| 34..... | 226.9 | 227.3 | 227.7 | 228.2 | 228.7 | 229.1 | 229.5 | 230.0 | 230.4 | 230.8 |
| 36..... | 218.7 | 219.2 | 219.6 | 220.0 | 221.4 | 220.8 | 221.2 | 221.7 | 222.0 | 222.5 |
| 38..... | 211.0 | 211.3 | 211.6 | 212.0 | 212.4 | 212.9 | 213.2 | 213.7 | 214.0 | 214.4 |
| 40..... | 203.3 | 203.8 | 204.2 | 204.5 | 204.9 | 205.2 | 205.6 | 206.0 | 206.4 | 206.8 |
| 42..... | 197.0 | 197.3 | 197.7 | 198.1 | 198.4 | 198.7 | 199.2 | 199.4 | 199.9 | 200.1 |
| 44..... | 189.5 | 190.0 | 190.3 | 190.7 | 191.1 | 191.5 | 191.9 | 192.3 | 192.7 | 193.0 |
| 46..... | 182.4 | 182.8 | 183.2 | 183.5 | 183.9 | 184.3 | 184.7 | 185.1 | 185.5 | 185.9 |
| 48..... | 175.5 | 175.9 | 176.3 | 176.7 | 177.1 | 177.4 | 177.9 | 178.3 | 178.7 | 179.0 |
| 50..... | 169.0 | 169.3 | 169.7 | 170.1 | 170.5 | 170.9 | 171.2 | 171.7 | 172.0 | 172.5 |
| 52..... | 162.8 | 163.2 | 163.5 | 163.9 | 164.2 | 164.7 | 165.0 | 165.3 | 165.6 | 166.0 |

TABLE XXXIX.—PROPERTIES OF AQUA-AMMONIA ABOVE 50%, (Percent Concentration Table)
 Temperatures ° F. corresponding to various percent concentrations (50 to 100%) and absolute pressures (1 to 155 pounds).
 Accuracy: To first decimal place of degrees. Boiling temperatures shown make continuously smooth curves with those of the preceding table.

Von Strombeck, Mollier, Experiments; Starr, Computations. Starr's Practical Engineers' Hand Book.

| PER CENT AMMONIA | Pounds Absolute Pressure | | | | | | | | | | | | | |
|---------------------|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|--|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 | 25 | |
| 52% | -57.0 | -40.0 | -28.0 | -19.5 | -12.0 | -6.0 | +1.0 | +3.5 | +7.0 | +10.0 | 25.5 | 39.0 | 49.0 | |
| 54% | -60.5 | -43.0 | -31.5 | -22.5 | -16.0 | -9.0 | -4.0 | +0.5 | +4.0 | +7.0 | 24.5 | 35.0 | 45.5 | |
| 56% | -63.0 | -47.5 | -34.5 | -25.5 | -19.0 | -12.5 | -7.0 | -2.5 | +1.0 | +4.0 | 20.5 | 32.0 | 42.0 | |
| 58% | -65.0 | -50.0 | -37.0 | -28.0 | -21.0 | -16.0 | -10.0 | -5.5 | -2.0 | +1.0 | 17.0 | 29.0 | 39.0 | |
| 60% | -67.0 | -52.0 | -39.5 | -30.5 | -23.5 | -17.5 | -12.5 | -8.5 | -5.0 | -1.5 | 15.0 | 26.0 | 36.0 | |
| 62% | -70.0 | -55.0 | -42.5 | -33.5 | -26.0 | -20.0 | -15.0 | -11.0 | -7.5 | -4.0 | 11.5 | 23.0 | 33.0 | |
| 64% | -72.0 | -57.5 | -44.5 | -36.0 | -28.5 | -22.5 | -18.0 | -13.5 | -10.0 | -7.0 | 8.5 | 20.0 | 30.0 | |
| 66% | -74.0 | -60.0 | -47.0 | -38.5 | -31.0 | -25.0 | -20.0 | -16.0 | -12.0 | -9.0 | 7.9 | 17.5 | 27.0 | |
| 68% | -77.0 | -62.5 | -50.0 | -40.0 | -33.0 | -27.0 | -22.0 | -17.5 | -14.5 | -11.5 | +4.5 | 15.0 | 24.5 | |
| 70% | -79.0 | -65.0 | -51.5 | -42.5 | -35.0 | -29.0 | -24.0 | -20.5 | -17.0 | -14.0 | +2.5 | 12.5 | 22.0 | |
| 72% | -81.0 | -67.0 | -53.5 | -45.0 | -37.0 | -31.5 | -27.0 | -23.0 | -19.5 | -16.5 | -1.0 | 10.0 | 19.0 | |
| 74% | -82.5 | -69.0 | -55.5 | -47.0 | -39.5 | -33.5 | -29.0 | -25.0 | -21.5 | -18.5 | -2.5 | 7.5 | 17.5 | |
| 76% | -84.5 | -70.5 | -57.5 | -49.0 | -42.0 | -36.0 | -31.5 | -27.0 | -23.5 | -20.5 | -5.0 | 5.5 | 15.0 | |
| 78% | -86.0 | -72.5 | -59.5 | -51.0 | -43.5 | -38.0 | -33.0 | -29.0 | -25.0 | -22.5 | -7.5 | 3.5 | 13.0 | |
| 80% | -87.5 | -74.5 | -61.5 | -53.0 | -45.5 | -39.5 | -35.0 | -31.0 | -27.0 | -24.5 | -10.0 | +1.0 | 10.5 | |
| 82% | -91.0 | -77.0 | -63.0 | -54.5 | -47.0 | -41.0 | -37.0 | -33.0 | -30.0 | -26.5 | -11.5 | -1.0 | 8.5 | |
| 84% | -92.5 | -79.5 | -65.0 | -55.0 | -49.0 | -42.5 | -38.5 | -35.0 | -32.0 | -28.5 | -13.0 | -3.0 | 6.5 | |
| 86% | -94.0 | -80.5 | -67.0 | -57.5 | -50.5 | -44.5 | -40.0 | -37.0 | -34.0 | -30.5 | -15.0 | -5.0 | 4.5 | |
| 88% | -95.0 | -81.5 | -69.0 | -59.5 | -53.0 | -47.0 | -42.5 | -39.0 | -35.5 | -32.5 | -17.0 | -6.5 | 2.5 | |
| 90% | -96.0 | -83.0 | -71.0 | -62.0 | -55.0 | -49.0 | -44.0 | -40.5 | -37.0 | -34.5 | -19.0 | -8.0 | 0.5 | |
| 92% | -98.0 | -84.0 | -72.0 | -63.5 | -56.0 | -50.5 | -45.5 | -42.0 | -38.5 | -35.5 | -20.5 | -10.5 | 1.0 | |
| 94% | -99.0 | -85.0 | -74.5 | -65.0 | -58.0 | -52.5 | -47.5 | -43.5 | -40.0 | -37.0 | -22.0 | -12.0 | 3.0 | |
| 96% | -100.0 | -85.5 | -75.5 | -66.0 | -59.5 | -54.5 | -49.0 | -45.0 | -42.0 | -38.5 | -23.5 | -13.5 | 4.5 | |
| 98% | -101.5 | -86.0 | -77.0 | -67.0 | -61.0 | -55.5 | -50.5 | -46.0 | -43.5 | -40.0 | -25.5 | -14.5 | 6.5 | |
| 100% | -105.0 | -90.0 | -80.0 | -68.5 | -62.5 | -57.0 | -52.0 | -48.5 | -45.0 | -42.0 | -27.5 | -16.5 | 8.0 | |

TABLE XXIX.—PROPERTIES OF AQUA-AMMONIA, ABOVE 50%, (Percent Concentration Table)—(Continued).

| Per Cent Ammonia | Pounds Absolute Pressure | | | | | | | | | | | | |
|---------------------|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 140 | 145 | 150 | 155 |
| 52% | 118.0 | 120.5 | 124.0 | 126.0 | 129.5 | 132.0 | 134.5 | 137.0 | 139.0 | 141.5 | 144.0 | 146.0 | 148.0 |
| 54% | 113.5 | 116.5 | 120.0 | 122.5 | 125.5 | 128.0 | 130.5 | 132.5 | 135.0 | 137.5 | 139.5 | 142.0 | 144.0 |
| 56% | 109.5 | 113.0 | 116.0 | 118.5 | 121.5 | 124.0 | 126.5 | 128.5 | 130.5 | 133.0 | 135.5 | 138.0 | 140.0 |
| 58% | 106.0 | 109.5 | 113.0 | 115.5 | 118.5 | 120.5 | 123.0 | 125.0 | 127.5 | 129.5 | 132.5 | 134.5 | 136.0 |
| 60% | 103.0 | 106.0 | 109.0 | 111.5 | 114.5 | 116.5 | 119.5 | 121.5 | 123.5 | 125.0 | 128.5 | 130.5 | 132.0 |
| 62% | 100.5 | 103.0 | 106.0 | 108.5 | 110.5 | 113.5 | 115.5 | 118.0 | 120.5 | 123.0 | 125.5 | 127.0 | 128.5 |
| 64% | 98.5 | 99.5 | 103.0 | 105.0 | 107.5 | 110.0 | 112.5 | 115.0 | 117.0 | 119.5 | 122.0 | 124.0 | 125.5 |
| 66% | 93.5 | 96.5 | 99.5 | 102.0 | 104.5 | 107.0 | 109.5 | 111.5 | 113.5 | 115.5 | 118.0 | 120.5 | 122.0 |
| 68% | 89.5 | 93.5 | 96.5 | 98.0 | 101.5 | 104.0 | 106.5 | 108.5 | 110.5 | 113.0 | 115.5 | 117.0 | 119.0 |
| 70% | 87.5 | 90.5 | 93.5 | 95.0 | 98.5 | 101.0 | 103.5 | 105.5 | 108.0 | 110.0 | 112.5 | 114.5 | 116.0 |
| 72% | 85.5 | 88.0 | 90.5 | 92.0 | 95.5 | 98.0 | 100.5 | 103.0 | 105.0 | 107.0 | 109.5 | 111.5 | 113.0 |
| 74% | 82.5 | 85.0 | 87.5 | 89.0 | 92.5 | 95.0 | 97.5 | 100.5 | 102.5 | 104.5 | 106.5 | 108.5 | 110.0 |
| 76% | 79.5 | 82.0 | 84.5 | 86.0 | 89.5 | 92.0 | 94.0 | 97.5 | 99.5 | 101.5 | 103.5 | 105.5 | 107.5 |
| 78% | 77.5 | 79.5 | 82.0 | 83.5 | 87.0 | 89.5 | 91.5 | 94.5 | 96.5 | 99.5 | 101.5 | 103.5 | 105.0 |
| 80% | 74.5 | 77.0 | 80.0 | 81.5 | 85.0 | 87.5 | 89.5 | 92.5 | 94.5 | 97.5 | 99.5 | 101.5 | 102.5 |
| 82% | 72.0 | 74.5 | 77.5 | 79.0 | 82.5 | 85.0 | 87.0 | 90.5 | 92.0 | 94.5 | 96.5 | 98.0 | 99.5 |
| 84% | 70.0 | 72.5 | 75.5 | 77.0 | 80.5 | 83.0 | 85.0 | 87.5 | 89.0 | 91.5 | 93.5 | 95.0 | 96.5 |
| 86% | 67.5 | 70.0 | 73.0 | 74.5 | 78.0 | 80.5 | 82.5 | 85.0 | 87.0 | 89.5 | 91.0 | 93.0 | 94.5 |
| 88% | 65.0 | 67.5 | 70.5 | 72.0 | 75.5 | 78.0 | 80.5 | 82.5 | 85.0 | 87.0 | 89.0 | 90.5 | 92.5 |
| 90% | 63.0 | 65.0 | 68.0 | 70.0 | 73.5 | 76.0 | 78.5 | 80.5 | 82.5 | 85.0 | 86.5 | 88.5 | 90.5 |
| 92% | 60.5 | 63.0 | 66.0 | 68.0 | 71.5 | 74.0 | 76.5 | 78.5 | 80.5 | 82.5 | 84.5 | 86.5 | 88.5 |
| 94% | 59.5 | 62.0 | 65.0 | 67.0 | 70.5 | 73.0 | 75.5 | 77.5 | 80.5 | 82.5 | 84.5 | 86.5 | 88.0 |
| 96% | 57.5 | 60.0 | 63.0 | 65.0 | 68.5 | 71.0 | 73.5 | 75.5 | 78.5 | 80.5 | 82.5 | 84.5 | 86.0 |
| 98% | 55.5 | 58.0 | 60.5 | 63.0 | 66.5 | 69.0 | 71.5 | 73.5 | 76.5 | 78.5 | 80.5 | 82.5 | 84.0 |
| 100% | 53.5 | 56.0 | 58.5 | 61.0 | 63.5 | 66.0 | 68.0 | 70.5 | 72.5 | 74.5 | 76.5 | 78.5 | 80.0 |

TABLE XXXIX.—PROPERTIES OF AQUA-AMMONIA, ABOVE 50%, (Percent Concentration Table)—(Continued).

| Per Cent Ammonia | Pounds Absolute Pressure | | | | | | | | | |
|---------------------|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 160 | 165 | 170 | 175 | 180 | 185 | 190 | 195 | 200 | 205 |
| 52% | 150.0 | 152.5 | 154.0 | 157.0 | 158.5 | 160.0 | 161.5 | 163.5 | 165.0 | 167.0 |
| 54% | 146.0 | 148.0 | 150.0 | 152.0 | 154.0 | 156.0 | 157.5 | 159.5 | 161.0 | 162.5 |
| 56% | 142.0 | 144.0 | 146.0 | 148.0 | 150.0 | 151.5 | 153.5 | 155.0 | 157.0 | 158.5 |
| 58% | 138.0 | 140.5 | 142.5 | 144.0 | 146.0 | 148.0 | 149.5 | 152.5 | 153.0 | 155.5 |
| 60% | 134.0 | 136.5 | 138.5 | 140.5 | 142.5 | 144.0 | 146.0 | 147.5 | 149.0 | 151.0 |
| 62% | 131.0 | 133.0 | 135.0 | 137.0 | 139.0 | 140.5 | 142.5 | 144.0 | 145.5 | 147.0 |
| 64% | 127.5 | 130.0 | 131.5 | 133.5 | 135.5 | 137.5 | 139.0 | 140.5 | 142.0 | 144.0 |
| 66% | 124.5 | 126.5 | 128.5 | 130.5 | 132.5 | 134.0 | 135.5 | 137.0 | 139.0 | 140.5 |
| 68% | 121.0 | 123.0 | 125.0 | 127.0 | 129.0 | 130.5 | 132.5 | 134.0 | 135.5 | 137.0 |
| 70% | 118.0 | 120.0 | 122.0 | 124.0 | 126.0 | 127.5 | 129.5 | 131.0 | 132.5 | 134.5 |
| 72% | 115.0 | 117.0 | 119.0 | 121.0 | 123.0 | 124.5 | 126.5 | 128.0 | 129.5 | 131.0 |
| 74% | 112.5 | 114.5 | 116.5 | 118.0 | 120.0 | 121.5 | 123.0 | 125.0 | 126.5 | 128.0 |
| 76% | 110.0 | 112.0 | 113.5 | 115.5 | 117.5 | 119.0 | 120.5 | 122.0 | 124.0 | 125.5 |
| 78% | 107.0 | 109.0 | 111.0 | 112.5 | 114.5 | 116.0 | 118.0 | 119.5 | 121.0 | 122.5 |
| 80% | 104.5 | 106.5 | 108.5 | 110.0 | 112.0 | 114.0 | 115.5 | 117.5 | 118.5 | 120.0 |
| 82% | 102.0 | 104.0 | 106.0 | 107.5 | 109.0 | 111.0 | 112.5 | 114.0 | 116.0 | 117.5 |
| 84% | 99.5 | 101.5 | 103.0 | 105.0 | 107.0 | 108.5 | 110.5 | 112.0 | 113.5 | 115.0 |
| 86% | 97.0 | 99.0 | 101.0 | 102.5 | 104.5 | 106.0 | 107.5 | 109.5 | 110.5 | 112.5 |
| 88% | 95.0 | 96.5 | 98.5 | 100.5 | 102.0 | 103.5 | 105.5 | 107.0 | 108.5 | 110.0 |
| 90% | 92.5 | 94.5 | 96.0 | 98.0 | 99.5 | 101.0 | 103.0 | 104.5 | 106.0 | 107.5 |
| 92% | 90.5 | 92.0 | 94.0 | 95.5 | 97.5 | 99.0 | 101.5 | 102.5 | 104.0 | 105.5 |
| 94% | 87.5 | 90.0 | 91.5 | 93.5 | 95.5 | 96.5 | 98.5 | 100.0 | 101.5 | 103.0 |
| 96% | 86.0 | 88.0 | 90.0 | 91.5 | 93.0 | 95.0 | 96.5 | 98.0 | 99.5 | 101.0 |
| 98% | 84.0 | 86.0 | 88.0 | 89.5 | 92.0 | 93.0 | 94.5 | 96.0 | 97.5 | 99.0 |
| 100% | 82.5 | 85.5 | 87.5 | 89.0 | 91.0 | 92.5 | 94.0 | 95.5 | 97.0 | 98.5 |

TABLE XL.—SOLUBILITY OF GASES IN WATER AT ATMOSPHERIC PRESSURE

| 1 Vol. Water dis- solves Vols. Gas. | 32° F. | 39.2° F. | 50° F. | 60° F. | 70° F. |
|--|--------|----------|--------|--------|--------|
| Air | 0.0247 | 0.0224 | 0.0195 | 0.0179 | 0.0171 |
| Ammonia | 1049.6 | 941.9 | 812.8 | 727.2 | 654.0 |
| Carbon Dioxide | 1.7987 | 1.5126 | 1.1847 | 1.0020 | 0.9014 |
| Sulphur Dioxide | 79.789 | 69.828 | 56.647 | 47.276 | 39.374 |
| Marsh Gas | 0.0545 | 0.0499 | 0.0437 | 0.0391 | 0.0350 |
| Nitrogen | 0.0204 | 0.0184 | 0.0161 | 0.0148 | 0.0140 |
| Hydrogen | 0.0193 | 0.0193 | 0.0191 | 0.0193 | 0.0193 |
| Oxygen | 0.049 | 0.0372 | 0.0325 | 0.0279 | 0.0284 |

TABLE XLI.—COMPRESSIBILITY OF LIQUIDS.*

| Temperature Degrees F. | Ammonia | Sulphur Dioxide | Carbon Dioxide |
|---------------------------|----------|--------------------|-------------------|
| 32 | 0.000111 | 0.000118 | 0.000824 |
| 59 | 0.000130 | 0.000134 | 0.002259 |
| 77 | 0.000148 | 0.000149 | 0.008400 |

*Kälte Industrie, March, 1915.

CHAPTER V

HEAT TRANSFER

Heat Transmission.—Heat is transmitted through a substance when there is a temperature difference, and is caused by the natural tendency of heat toward a temperature equilibrium. The heat flow is always from a region of higher temperature to a region of lower temperature, and may occur in three ways: Conduction, radiation and convection.

The rate of heat transfer from one region to another, depends on the amount of surface, the difference in temperature and the material through which the flow occurs. The rate of transfer through various materials has been determined experimentally by many scientists, the most reliable of which are given in Table XLII as compiled by the Bureau of Standards.

From this table it will be noted that a coefficient "C" is given, which is the overall transmission of heat based on a unit of time, surface, thickness and temperature difference or B.t.u. per hour per square foot per inch of thickness per degree F. As the heat transfer is practically proportional to the thickness, the fundamental law can be expressed in a very simple formula:

$$(1) \text{ Transmission in B.t.u./Hr.} = \frac{\text{"C"}}{\text{thickness}} \times \text{average sq. ft.} \times \text{temperature difference}$$

From the foregoing it will be noted, that if the temperature and area of a transmitting surface are known and held constant, the heat transfer depends upon conduction, radiation and convection.

HOUSEHOLD REFRIGERATION

TABLE XLII.—INTERNAL THERMAL CONDUCTIVITIES OF VARIOUS MATERIALS (C)*

| Material | Description | B.t.u. per 24 hours | B.t.u. per hour | Lb. per cu. ft. |
|-----------------------|--|------------------------|--------------------|--------------------|
| Air..... | Ideal air space..... | 4 2 | 0.175 | 0.08 |
| Air Cell, ½ inch..... | Asbestos paper and air spaces..... | 11.0 | 0.458 | 8.80 |
| Air Cell, 1 inch..... | Asbestos paper and air spaces..... | 12.0 | 0.500 | 8.80 |
| Aluminum..... | Cast..... | 24.000 | 1000.000 | .62 |
| Ammonia Vapor..... | 32° F..... | 3.19 | 0.133 | 0.21 |
| Aqua Ammonia..... | 64° F..... | 75.90 | 3.160 | 56.50 |
| Asbestos Mill Bd..... | Pressed asbestos—not very flexible..... | 20.00 | 0.830 | 61.00 |
| Asbestos Paper..... | Asbestos and organic bind- er..... | 12. | 0.500 | 31.0 |
| Asbestos Wood..... | Asbestos and cement..... | 65.0 | 3.700 | 123.0 |
| Balsa Wood..... | Very light and soft—across grain..... | 8.4 | 0.350 | 7.5 |
| Boiler Scale..... | ..... | 305 | 12.700 | ..... |
| Brass..... | ..... | 15.000 | 625.000 | 250. |
| Brick..... | Heavy..... | 120 | 5.000 | 131. |
| Brick..... | Light, dry..... | 84 | 3.500 | 115. |
| Brine..... | Salt..... | 27.1 | 1.130 | 73.4 |
| Cabot's Quilt..... | Eel grass enclosed in bur- lap..... | 7.7 | 0.321 | 16.0 |
| Calorax..... | Fluffy finely divided min- eral matter..... | 5.3 | 0.221 | 4.0 |
| Celite..... | Infusorial earth powder..... | 7.4 | 0.308 | 10.6 |
| Cement..... | Neat Portland, dry..... | 150.0 | 6.250 | 170. |
| Charcoal..... | Powdered..... | 10.0 | 0.417 | 11.8 |
| Charcoal..... | Flakes..... | 14.6 | 0.613 | 15.0 |
| Cinders..... | Anthracite, dry..... | 20.3 | 0.845 | 40.0 |
| Concrete..... | ..... | 125.0 | 5.200 | 136.0 |
| Concrete..... | Of fine gravel..... | 109.0 | 4.540 | 124.0 |
| Concrete..... | Of slag..... | 50.0 | 2.080 | 94.5 |
| Concrete..... | Of granulated cork..... | 43. | 1.790 | 7.5 |
| Copper..... | ..... | 50.000 | 2083.000 | 556.0 |
| Cork..... | Granulated ¼-3/16 inch..... | 8.1 | 0.337 | 5.3 |
| Cork..... | Regranulate 1/16-¼ inch..... | 8.0 | 0.333 | 10.0 |
| Corkboard..... | No artificial binder—low density..... | 6.7 | 0.279 | 6.9 |
| Corkboard..... | No artificial binder—high density..... | 7.4 | 0.308 | 11.3 |
| Cotton Wool..... | Loosely packed..... | 7.0 | 0.292 | ..... |
| Cypress..... | Across grain..... | 16.0 | 0.666 | 29.0 |
| Fibrofelt..... | Felted vegetable fibers..... | 7.9 | 0.329 | 11.3 |
| Fire Felt Roll..... | Asbestos sheet coated with cement..... | 15.0 | 0.625 | 43.0 |
| Fire Felt Sheet..... | Soft, flexible asbestos sheet..... | 14.0 | 0.583 | 26.0 |
| Flaxinum..... | Felted vegetable fibers..... | 7.9 | 0.329 | 11.3 |
| Fullers Earth..... | Argillaceous powder..... | 17.0 | 0.708 | 33.0 |
| Glass..... | ..... | 124.0 | 5.160 | 150.0 |
| Glass..... | ..... | 178.0 | 7.420 | 185.0 |
| Glass..... | ..... | 600 | 25.000 | 166.0 |
| Granite..... | ..... | ..... | 0.313 | 8.1 |
| Granulated Cork..... | About 3/16 inch..... | 7.5 | 0.282 | 115.0 |
| Gravel..... | Dry, coarse..... | 62.0 | 1.630 | 91.25 |
| Gravel..... | Dry, fine..... | 39.0 | 0.294 | 9.4 |
| Ground Cork..... | ..... | 7.1 | 0.250 | ..... |
| Gypsum Plaster..... | ..... | 54.0 | 0.246 | 17.0 |
| Hair Felt..... | ..... | 5.9 | 1.125 | 44.0 |
| Hard Maple..... | Across grain..... | 27.0 | 17.000 | 57.4 |
| Ice..... | ..... | 408 | 0.583 | 43.0 |
| Infusorial Earth..... | Natural blocks..... | 14.0 | ..... | ..... |
| Insulux..... | Asbestos and plaster blocks—porous..... | 22.0 | 0.916 | 29.0 |
| Insulite..... | Pressed wool pulp—rigid..... | 7.1 | 0.296 | 11.9 |
| Iron..... | Cast..... | 7.740 | 321.500 | 450.0 |
| Iron..... | Wrought..... | 11.600 | 483.000 | 485.0 |
| Kapok..... | Imp. vegetable fiber— loosely packed..... | 5.7 | 0.238 | 0.88 |
| Keystone Hair..... | Hair felt confined with building paper..... | 6.5 | 0.271 | 19.0 |
| Limestone..... | Close grain..... | 368 | 15.300 | 185.0 |
| Limestone..... | Hard..... | 214.0 | 9.330 | 159.0 |

*From "Principles of Refrigeration," Nickerson & Collins Co., Chicago.

TABLE XLII.—INTERNAL THERMAL CONDUCTIVITIES OF VARIOUS MATERIALS (C)—(CONTINUED)*

| Material | Description | B.t.u. per 24 hours | B.t.u. per hour | Lb. per cu. ft. |
|-------------------------|---|------------------------|--------------------|--------------------|
| Limestone..... | Soft..... | 100.0 | 4.167 | 113.0 |
| Linofelt..... | Vegetable fiber confined with paper..... | 7.2 | 0.300 | 11.3 |
| Lithboard..... | Mineral wool and vegeta- ble fibers..... | 9.1 | 0.379 | 12.5 |
| Mahogany..... | Across grain..... | 22.0 | 0.916 | 34.0 |
| Marble..... | Hard..... | 445 | 18.530 | 175.0 |
| Marble..... | Soft..... | 104 | 4.330 | 156.0 |
| Mineral Wool..... | Medium Packed..... | 6.6 | 0.275 | 12.5 |
| Mineral Wool..... | Felted in blocks..... | 6.9 | 0.288 | 18.0 |
| Oak..... | Across grain..... | 24.0 | 1.000 | 38.0 |
| Paraffin..... | "Parowax," melting point 52° C..... | 38.0 | 1.582 | 56.0 |
| Petroleum..... | 55° F..... | 24.7 | 1.030 | 50.0 |
| Plaster..... | ..... | 132.0 | 5.500 | 105.0 |
| Plaster..... | Ordinary mixed..... | 90 | 3.750 | 83.5 |
| Plaster..... | Board..... | 73 | 3.040 | 75.0 |
| Planer Shavings..... | Various..... | 10.0 | 0.417 | 8.8 |
| Pulp Board..... | Stiff pasteboard..... | 11.0 | 0.458 | ..... |
| Pumice..... | Powdered..... | 11.6 | 0.483 | 20.0 |
| Pure Wool..... | ..... | 5.9 | 0.246 | 6.9 |
| Pure Wool..... | ..... | 5.9 | 0.246 | 6.3 |
| Pure Wool..... | ..... | 6.3 | 0.263 | 5.0 |
| Pure Wool..... | ..... | 7.0 | 0.292 | 2.5 |
| Rice Chaff..... | ..... | 16.0 | 0.667 | 10.0 |
| Rock Cork..... | Mineral wool and binder— rigid..... | 8.3 | 0.346 | 21.0 |
| Rubber..... | Soft..... | 45 | 7.875 | 94.0 |
| Rubber..... | Hard, vulc..... | 16.0 | 0.667 | 59.0 |
| Sand..... | River, fine, normal..... | 188.0 | 7.830 | 102.0 |
| Sand..... | Dried by heating..... | 54.0 | 2.250 | 95.0 |
| Sandstone..... | ..... | 265 | 11.100 | 138.0 |
| Sawdust..... | Dry..... | 12.0 | 0.500 | 13.4 |
| Sawdust..... | Ordinary..... | 25.0 | 1.040 | 16.0 |
| Shavings..... | Ordinary..... | 17.0 | 0.707 | 8.0 |
| Silicate Cotton..... | ..... | 14.0 | 0.583 | 8.55 |
| Slag Wool..... | ..... | 18.0 | 0.750 | 15.0 |
| Snow on Ref. Coils..... | ..... | 75 | 3.130 | ..... |
| Tar Roofing..... | ..... | 17.0 | 0.707 | 55.0 |
| Vacuum..... | Silvered vacuum jacket..... | 0.1 | 0.004 | ..... |
| Virginia Pine..... | Across grain..... | 23.0 | 0.958 | 34.0 |
| Water..... | Still, 32° F..... | 100 | 4.166 | 62.4 |
| White Pine..... | Across grain..... | 19.0 | 0.791 | 32.0 |
| Wool Felt..... | Flexible paper stock..... | 8.7 | 0.363 | 21.0 |

Conduction.—Heat transfer by conduction occurs by means of molecular transmission due to the different intensities of irregular vibration of the molecules, causing the higher temperature or more rapid moving molecules to strike the lower temperature or slower moving molecules and cause them to move at the same rate. Due to friction, adhesion, etc., the intensity decreases as it passes from the faster to the slower molecules. The interchange of heat in this way may occur between different parts of the same body or between two separate bodies in actual contact.

When one end of a bar of iron is held in a fire the other end will soon become too hot to hold in the hand. The heat

has been transferred by conduction. One end of a wooden stick can be held in the fire without the other end becoming warm. In general, metals are good conductors, while lighter weight materials are poor conductors, so that comparative transmission can be made from their densities. A recent theory for the better insulating properties of substances containing air cells, is that there is a very intense atomic resistance at the junction of a solid and gas, thus offering greater retardation to the molecular activity transfer.

Radiation.—Radiation is the transfer of heat by means of continuous and irregular ether vibrations and the transformation, in whole or in part, of the energy of light into heat energy by impact upon the surface of a substance. It is an electromagnetic phenomenon, in which the longest heat waves are about 0.042 centimeters while the shortest solar waves that can pass through the atmosphere are 0.00003 c.m. The range of the radio waves is about 3 meters to 20,000 meters. When heat or solar radiation strikes a body it is in general partly reflected, partly absorbed and partly transmitted. The part which is transmitted is nil in case of metals, unless they are made into exceedingly thin almost transparent foils, it is very small in case of water and ice and large in case of quartz, rock salt, etc. Thus in most practical cases part of the radiation is absorbed and part of it reflected, the amount of which is smaller the more dull and black the surface is. In the ideal limiting case which is closely approached by lampblack, the entire amount of radiation is absorbed.

The amount of heat transferred by radiation depends upon the character of the radiating surfaces; whether hot or cold, dark or light, temperature difference, absorbing properties, etc.

The blacker an object the more heat it will lose by radiation. Stoves and radiators intended to give out heat should be black. Cooking utensils, coffee urns, etc., should be bright, (tinned or nickerled) in order to lose as little heat as possible. A stove nickel plated all over will give out only about half as much heat as the same stove at the same temperature if black. A brightly tinned hot air furnace pipe may lose less heat than when covered with one or two layers of asbestos paper, as the surface of the asbestos paper radiates heat much

more rapidly than the bright tin. The pipe should be black to prevent radiation to the inside surface of the asbestos paper, then the asbestos would be more effective. If asbestos paper of sufficient thickness is used, it will save heat, even on bright tin pipes.

Further it has been found experimentally that a body as it is heated radiates heat waves the amount of which is equal to the amount absorbed. The table below gives the radiating and absorbing power, and the reflecting power of a few common substances. It may be noted here that the radiating power is also called the emissivity.

TABLE XLIII.—HEAT ABSORBING, RADIATING, AND REFLECTING POWER OF SUBSTANCES

| Substances | Absorbing & Radiating Power | Reflecting Power |
|----------------------------|--------------------------------|---------------------|
| Black body | 1.00 | 0.00 |
| Glass | 0.90 | 0.10 |
| Ice | .85 | .15 |
| Polished Cast Iron..... | .25 | .75 |
| Polished Wrought Iron..... | .23 | .77 |
| Polished Brass | .07 | .93 |
| Copper Hammered | .07 | .93 |
| Silver Polished | .03 | .97 |

According to Prevost's theory of heat exchanges a warm body radiates more heat to the surrounding cold bodies than it receives from them and thus its temperature drops, while a cold body also radiates heat but it radiates less than it receives, and, therefore, its temperature rises. According to this theory, a body in a refrigerator placed near the ice radiates heat no faster than it would to a warmer body, but it receives less from the ice in return and, therefore, becomes colder.

It is well established that the heat exchange by radiation between two bodies is given by:

$$H = E (T_2^4 - T_1^4) \times 16 \times 10^{10}$$

Where H = B.t.u. per sq. ft. per hour.

T_1 & T_2 = Absolute Temperatures of the two bodies in degrees F.

E = An empirical constant called the emissivity of the surface considered: $E = 1$ for a black body.

Radiation Between the Sun and the Earth.—The heat and light from the sun come to us through space in a form of wave motion called radiation. The atmosphere offers considerable

obstruction to the passage of these waves. Even when the sky is very clear, rarely more than 65 per cent of the radiation penetrates to the surface of the earth, the part absorbed being expended in raising the temperature. The region near the upper limits of the atmosphere is one of intense cold. As the sun, having a much higher temperature than earth, radiates heat to the earth, so from the surface of the earth, heat is radiated to the much colder upper limits of the atmosphere.

The radiation of heat from the earth is continuous both day and night when there are no clouds or other obstruction between the earth and the upper atmosphere. During the day the amount of heat received from the sun is so much greater than the amount lost by radiation from the earth, that the temperature rises. After the sun sets, however, no heat is received to counterbalance the loss by outgoing radiation and the temperature falls.—(U. S. Department of Agriculture, Farmers' Bulletin, No. 1096).

Convection.—Convection is the transfer of heat by displacement of movable media; the heated medium moves and carries the heat energy with it. In other words heat is carried from one place or object to another by means of some outside agent, such as air or water or any moving gas or fluid. The hot air and hot water heating systems work on this principle. For example, in case of an ordinary household radiator, steam or hot water heats the radiator and it establishes a temperature differential between the metal and the adjacent layer of air, the layer of air is heated and consequently its density is reduced as compared to the cooler layers of air. Thus the denser and cooler particles of air begin to descend while the warmer and less dense particles begin to rise and a natural upward movement of heated particles sets in. If desired, however, the movement of these heated particles can be accelerated and the heat transfer greatly increased by means of a fan or blower. In the first instance we have natural convection and in the second forced convection. It is also clear that the increased heat transfer secured in the latter case is produced by the external mechanical work supplied and here as in all other engineering work we pay for what we receive.

The food and containers in a refrigerator are cooled mostly by convection. The circulating air is the medium used to transfer the heat from the food and walls of the food compartment to the ice. This process of heat transfer is continuous. The air in passing through the food compartment absorbs sufficient heat to increase its temperature about 10° F.

It is well known in a general qualitative way that heat flow by forced convection between a metal surface and a fluid depends upon the following:

- 1—The velocity of the fluid; the higher the velocity the higher the heat flow.
- 2—The temperature difference between the metal and the fluid; the higher this difference the higher is the heat flow.
- 3—The thermal conductivity of the fluid.
- 4—Diameter of the tubes around or in which the fluid is assumed to flow.
- 5—The density of the fluid.
- 6—The viscosity of the fluid.
- 7—The depth or length of the device measured along the path in which the fluid flows.
- 8—The temperature difference between fluid and body.
- 9—The character of the surface.

The values given in Table XLIV are for inside surface only, and are represented by the symbol K . Due to the more exposed outside surface and rapid movement of air, the coefficient for this is much larger, generally $2\frac{1}{2}$ to 3 times, so that K_2 can be used as 3 times K .

TABLE XLIV.—COEFFICIENTS OF RADIATION AND CONVECTION IN
B.T.U. PER HR. PER $^{\circ}$ F. SQ. FT.

University of Illinois Engineering Experimental Station.

| | | | |
|----------------------|------|--------------------------------|------|
| Brick Wall | 1.40 | Glass | 2.00 |
| Concrete | 1.30 | Tile plastered on both sides.. | 1.10 |
| Wood | 1.40 | Asbestos board | 1.60 |
| Corkboard | 1.25 | Sheet asbestos | 1.40 |
| Magnesia board | 1.45 | Roofing | 1.25 |

Comparison of Heat Insulators.—Table XLV gives a comparative idea of the thermal conductivity of insulators used in household cabinets. Air which cannot circulate and carry heat in that way (by convection) is one of the best heat insulators

to be found. Cotton, wool, feathers, cork, etc., are good insulators because they contain a large amount of air in the cells or in the spaces between the fibers. Clothing keeps in the heat of the body chiefly because it contains air between the lay-

TABLE XLV.—COMPARISON OF THERMAL CONDUCTIVITY OF HEAT INSULATING MATERIALS USED FOR INSULATING HOUSEHOLD REFRIGERATORS

| Material | Relative Thermal Conductivity |
|---|-------------------------------|
| Vacuum jacket silvered | 1 |
| Mineral wool (medium packed) | 66 |
| Corkboard (low density) | 67 |
| Ground cork (ordinary) | 71 |
| Vegetable fibre (Linofelt) | 72 |
| Granulated cork (about 3/16 inch) | 75 |
| Eel grass (enclosed in burlap) | 77 |
| Balsa wood (medium weight)..... | 92 |
| Planer shavings | 100 |
| White pine (across grain) | 190 |
| Oak (across grain) | 240 |

ers and in the meshes of the cloth. When the enclosed warm air is displaced and is replaced by colder air, as is the case in windy weather, the clothing no longer keeps one so warm.

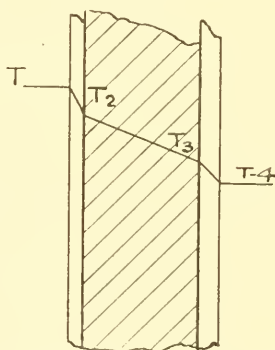


FIG. 4.—SHOWING RADIATION AND CONVECTION LOSSES.

If the clothing is close-fitting, there is less room for an air layer between the layers of the clothes and therefore, it is less warm.

To keep warm in cold, windy weather, the clothing should consist of loosely fitting garments, preferably of wool, with

some outside wrap which is nearly windproof, such as a very close woven cloth, or even leather or rubber. A fur coat is very much warmer if the fur is on the inside, where the wind cannot disturb the air which is held among the hairs.

Determination of Heat Loss Through a Wall or Refrigerator.—As shown in the previous paragraphs, heat is transmitted through a substance from higher regions to a lower region by means of conduction, radiation, and convection. Referring to Fig. 4 it can readily be seen that the drop from T_1 to T_2 is radiation and convection losses from the outer surface,

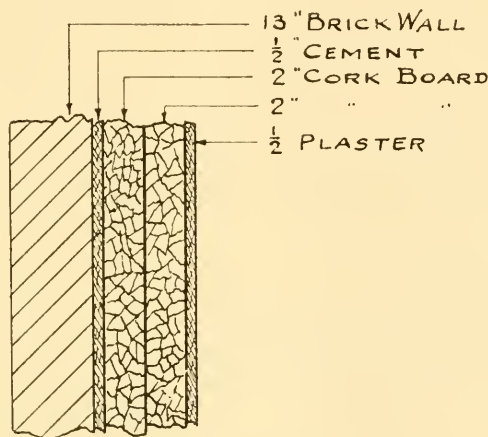


FIG. 5.—STANDARD WALL.

T_2 - T_3 the losses or transmission by conduction through the material, and T_3 - T_4 convection and radiation from the cold air in the box to the inner surface. The convection and radiation drop is caused by a very thin layer or surface film surrounding each surface.

Fig. 5 shows a standard wall as used in many cold storage buildings and ice storages. The unit transmission through the combination wall can very easily be determined from the following formula:

$$\text{B.t.u./ sq. ft./hr./}^\circ\text{MD} = \frac{1}{\frac{1}{K_1} + \frac{X}{C} + \frac{X}{C_1} + \frac{X}{C_2} + \frac{1}{C_2}}$$

X being the thickness of the material, C the unit coefficient for each material as in Table XLII, K_1 and K_2 surface coefficients for the inner and outer surfaces respectively.

$$\text{Substituting—B.t.u./sq.ft./hr./}^\circ\text{MD} = \frac{1}{\frac{1}{1.10} + \frac{13}{5} + \frac{4}{.279} + \frac{1}{6.25} + \frac{1}{4.2}}$$

“C”

If this value is now used as the factor $\frac{\text{“C”}}{\text{thickness}}$ in the fundamental formula (1) given on page 101 the total heat leakage through the walls can be obtained. It has been found that the resistance to heat flow at the surface, due to radia-

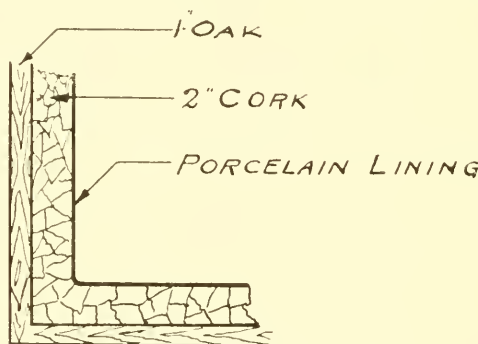


FIG. 6.—CROSS SECTION OF A STANDARD ICE BOX.

tion and convection is very small in comparison to internal thermal conductivity of the material itself, so that these two factors can be omitted, particularly when good insulation of normal thickness is used. This can be demonstrated by the omission of the factors K_1 and K_2 in the above formula resulting in a final value of .0585 instead of .0548 or $6\frac{3}{4}\%$ greater.

Referring to Fig. 6, a cross section of a standard ice box is given. Assuming this to be a 9 cu. ft. refrigerator the outside surface would be 54 sq. ft. and the inside surface 34.5 sq. ft. or an average of 44.25 sq. ft.

The unit heat transmission would be

$$\frac{1}{\frac{2}{.279} + \frac{1}{1}} = .1225 \text{ B.t.u./sq. ft./}^\circ\text{MD/ hr.}$$

Substituting in our fundamental formula for $\frac{\text{"C"}}{\text{thickness}}$

$$\text{B.t.u./hr.} = .1225 \times 44.25 \times 1^\circ = 5.42$$

Actual tests on this box gave 5.75.

For practical results to obtain the compressor load, 50% should be added for opening door, warm edibles, making ice, etc.

Insulation.—The most important factors entering into the choice of an insulator are as follows:

1. Thermal conductivity.
2. Odorless and sanitary.
3. Compact.
4. Vermin and fire resistant.
5. Not easy to disintegrate or settle.
6. Durable in service.
7. Reasonable in cost.
8. Structurally strong and easy to ship, handle, and install.
9. Conform to variation on surface of lining.

1. *Thermal Conductivity.*—The best insulator that could possibly be found would be one that was an absolute non-conductor of heat. Since this has not been discovered as yet we must content ourselves with insulation which are good non-conductors, or in other words, transmit heat at a very slow rate. As heat loss through an insulated wall is a continuous process, it must be the aim to reduce this loss to a minimum by increasing the thickness to a maximum commensurate with desired results. This is a question of first or initial cost.

2. *Odorless and Sanitary.*—Since ordinary food products are stored in the refrigerator, it is evident that the insulation should be absolutely free from mould, rot, or odor and perfectly sanitary. The interior surfaces should be so constructed that they can be washed with water without effecting the insulation.

3. *Compactness.*—An insulation in order to be favorably considered must be compact or occupy a small amount of space for the equivalent heat loss prevention. If it can be made very thin, but at the same time give as good insulating value as

another 2 to 3 times as thick, it would naturally be given preference.

4. *Vermin and Fire Resistant.*—A desirable insulation should be of such nature that it will exclude vermin of all kinds, and should lend itself to fireproof construction of buildings. It should be slow burning and fire retarding and should not support a flame.

5. and 6. *Not Easy to Disintegrate or Settle.*—The durability of insulating materials depends upon the life of the materials used in their manufacture, the mode of manufacture and the waterproofness.

The insulation of a refrigerator is called upon to withstand constant changes of temperature and humidity. The ordinary refrigerator using ice usually has a rather poor water insulating material to protect the insulation. The greatest trouble is experienced around the ice compartment where water vapor will condense on the outside surface of the lining or rather between the lining and the insulation. If the insulation is installed very tightly against the lining, this condition is not likely to cause trouble. Moisture not only causes the insulation to deteriorate rapidly, losing to a large extent in heat insulating properties, but also may rust the lining and absorb food odors which will make the refrigerator very insanitary.

The moisture problem is especially important on mechanical refrigerators where freezing temperature or temperature below 32° F. are maintained in part of the cabinet. In this case a much lower room humidity will deposit moisture on the lining. There are very few ice refrigerators constructed which are insulated in a suitable manner to be used for the lower temperatures as usually supplied by mechanical refrigerating machines.

7. *Reasonable in Cost.*—An insulation to be universally used depends on such factors as a reasonable initial cost of material, cheap installation cost, minimum of repair charges, as well as a minimum amount of space for maximum retardation of heat flow.

8. *Structurally Strong and Easy to Ship, Handle and Install.*—Insulation should be compact and structurally strong so that it may be used in walls, ceilings, and floors of any type of construction. It should have sufficient strength to allow for shipment and for installation by ordinary workmen. These factors determine to a large extent, its application commercially.

9. *Conform to Variations on Surface of Lining.*—Due to unevenness of surfaces on which insulation is to be placed it is essential that elasticity, to a certain extent, be embodied in the insulator, or otherwise there will be resultant breaks when the non-flexible insulation is jammed against an uneven surface.

Air Spaces.—Many refrigerators use air spaces for insulation. Heat may be transferred across an air space by all three methods of heat transfer: radiation, convection and conduction.

A very high vacuum is necessary to appreciably lower the rate of heat transfer by convection. The heat transfer by convection is greater when there is a large temperature drop, as the air will then circulate more rapidly, carrying heat from one wall to the other.

Air is a very poor conductor of heat when compared with the usual insulating materials used in refrigerators. The conductivity B.t.u. per day per sq. ft. per deg. F. per inch thickness for various materials is given as follows:

| | |
|--|------|
| Air, if radiation and convection could be prevented..... | 4.2 |
| Mineral wool | 6.6 |
| Corkboard | 6.7 |
| Flaxlinum | 7.9 |
| White pine | 19.0 |
| Oak | 24.0 |

This tabulation shows that the amount of heat transferred across air space by conduction is relatively low.

The amount of heat passing over an air space by radiation is very large when there is a large temperature differential between the two walls. The rate of heat transfer by radiation is proportional to the fourth power of the absolute temperature of the surface, enclosing the air space, providing the surfaces

are perfect radiators or absorbers. The blacker the object the more heat it will lose by radiation. Bright tinned or nickered objects lose very little heat by radiation. The vacuum bottle usually has bright polished surfaces to prevent heat entering the walls by radiation.

The United States Bureau of Standards gives the following tabulation on the heat conduction of air spaces, in which A is the width of the air space in inches, B is the heat conduction expressed in B.t.u. per square foot per degree F. per 24 hours for the corresponding thickness stated, and C, the heat conduction expressed in B.t.u. per square foot per degree per 24 hours per inch thickness:

| A | B | C |
|---------------------|---------|------|
| $\frac{1}{8}$ | 50..... | 6.3 |
| $\frac{1}{4}$ | 32..... | 8.1 |
| $\frac{3}{8}$ | 26..... | 9.8 |
| $\frac{1}{2}$ | 23..... | 11.6 |
| $\frac{5}{8}$ | 22..... | 13.6 |
| $\frac{3}{4}$ | 22..... | 16.4 |
| $\frac{7}{8}$ | 22..... | 20 |
| 1..... | 22..... | 22 |
| 2..... | 21..... | 43 |
| 3..... | 21..... | 62 |

The insulating value of air spaces is not proportional to the thickness of the spaces.

The heat loss between walls of materials such as wood, paper, etc., by radiation alone, is about 20 B.t.u. per day per square foot per degree F. for ordinary temperatures. At higher temperatures, the radiation loss is still larger. Air spaces are not good insulators on account of this radiation loss. This large heat loss by radiation may be greatly reduced by using polished surfaces for the walls between the air spaces. Perhaps the best way to reduce this loss is to use an insulating material such as cork, which eliminates the heat loss by radiation almost entirely.

One authority describes the use of a heat insulating material such as corkboard, as an air space insulation composed of an almost perfect heat radiation screen. Each air cell in the cork must radiate heat from one wall to another and as the temperature differential is small, the amount of heat transferred by radiation is nearly negligible.

Insulating Effect of Air Spaces.—The insulating effects of air spaces, according to various authorities are given in Table XLVI. The effects are given in conductivities, expressed in B.t.u. per square foot per twenty-four hours per degree of temperature difference for various thicknesses of air spaces. It will be noted that the increasing of the thickness of the air space above a certain amount does not proportionately decrease the total conductivity.

TABLE XLVI.—INSULATING EFFECT OF AIR SPACES

| Authority | Thickness Inches | Conductivity B.t.u. per sq. ft. per 24 hrs. per Deg. Fahr. Temp. Diff. | Remarks |
|--|------------------------|--|--|
| Prof. L. A. Harding, Pennsylvania State College | 1 to 6 | 39.8 | |
| Refrigerating World | 1 | 30.0 | |
| Prof. A. C. Willard, Railway Age Gazette | 4 | 38.2 | |
| Nusselt | $\frac{3}{4}$ | | Spaces greater give no additional value. |
| Willard & Lichty | | | Single and double box test. |
| University of Illinois | $\frac{1}{2}$ | 42.5 | |
| U. S. Bureau of Standards | $\frac{1}{2}$ | 11.0 | Corrugated asbestos paper enclosing air space. |
| U. S. Bureau of Standards | $\frac{1}{8}$ | 50 | Air spaces bounded by sheets of insulating paper. |
| | $\frac{1}{4}$ | 32 | Air spaces not wider than $\frac{3}{4}$ inch retard heat about as well as an equal thickness of sawdust. |
| | $\frac{3}{8}$ | 26 | |
| | $\frac{1}{2}$ | 23 | |
| | $\frac{5}{8}$ | 22 | |
| | $\frac{3}{4}$ | 22 | A 3 inch air space has nearly the same value as a 1 inch space. |
| | $\frac{7}{8}$ | 22 | |
| | 1 | 22 | |
| | 2 | 21 | |
| | 3 | 21 | |
| U. S. Bureau of Standards | 1 | 4.2 | No heat transferred by radiation or conduction |
| Pennsylvania State College | 3 in. spaces | 5.36 | Three air spaces. |
| Wood & Grundhofer | $\frac{1}{2}$ in. each | 7.68 | |
| | 3 spaces | 5.28 | |
| | 1 in. each | 5.29 | Three air spaces. |
| | | 4.26 | |

Comparison, if 3 air spaces $\frac{1}{2}$ in. each = 100%
 Then 2 air spaces $\frac{1}{2}$ in. each = 79%
 and 1 air space $\frac{1}{2}$ in. each = 59%
 Comparison, if 3 air spaces $1\frac{1}{2}$ in. each = 100%
 Then 3 air spaces 1 in. each = 88%
 and 3 air spaces $\frac{1}{2}$ in. each = 70%

Types of Insulating Material.—As can be noted in Table XLII, many kinds of materials can be used for insulation. The most commonly used materials are corkboard, granulated cork, ground cork, mineral wool, rock cork, hair felt, kapok, lith-board, sawdust and shavings.

Cork.—Cork is the outer bark of a tree growing on the Spanish Peninsula and in Northern Africa. In its natural state, it is composed of a large number of minute air cells, separated by thin walls.

Corkboard is made by compressing pure granulated cork in molds and baking. The baking process improves the insulating value, first by driving off the sap, thus increasing the volume of confined air; second, by coating the surface of each separate granule with a thin film of the natural waterproof gum or rosin, which cements the whole mass together firmly. After the baking process, the boards are trimmed to size. Pure cork contains 43% wood fibre and 57% entrapped air.

A cheaper and inferior grade of corkboard may also be manufactured. In this process, granulated cork is mixed with hot asphalt and pressed into sheets.

The boards are 12"x36" and are supplied in thicknesses 1-1½-2-2½-3-4-6". The weight varies from 7 to 12 lbs. per cubic foot, depending on the process. Regranulated cork of 8-20 mesh or fineness weighs 11 lbs. per cubic foot, and coarse granulated weighs 5 to 6 lbs. per cubic foot. The regranulated is baked and is made from savings trimmed from corkboard.

Because of its cellular structure, cork has little capillary attraction, which together with the coating of waterproof gum for binder, makes it practically impervious to moisture. It possesses essentially all of the requirements previously cited for a good commercial insulator and is therefore the most universally used.

Mineral Wool.—Mineral wool is a vitreous substance made of limestone which is melted at 3000° F. and then blown into fine fibres by high pressure steam. It is a soft, pliable and elastic material resembling wool or cotton, and due to the fibres crossing and interlacing in every direction small air spaces are formed which produce its insulating properties. Mineral wool boards are made by mixing the wool with a paraffin wax binder and other ingredients and then compressing it into sheets. These are usually 16x36 inches and are made from ½ to 3 inches in thickness. The weight is approximately 18 lbs. per cubic foot in boards, but only 12½ lbs. when loosely

packed. The board contains about 90 per cent mineral wool and 10 per cent binder and consists of approximately 80 per cent entrapped air. Mineral wool board possesses many of the essentials of a good insulator but is inferior to corkboard as to structural strength, fire retardation and installation cost.

Flaxlinum or Linofelt.—This is a flax fiber product pressed into a continuous sheet and covered with a waterproof charcoal sheathing. It is customary to use two sheets of flaxlinum with a dead air space between them. This insulation is also made in quilted sheets which are held in place by wooden strips.

Mineral Felt.—Mineral felt is a combination of mineral wool, asbestos, and hair felt. It is claimed that this material will not settle like other loose feltings.

Balsa Wood.—Balsa wood is being used to some extent for insulation on refrigerators. Its peculiar structure and qualities which make it suitable for this purpose were first realized about 1915.

The tree grows in certain parts of South America and the West Indies. It grows very rapidly to a height of from thirty to sixty feet and a diameter of from twelve to fifteen inches in four or five years. This rapid growth is probably the cause of the peculiar structure of the wood. The cells are large and remote from one another, and the cell walls are exceedingly thin, while in most other woods the cells are small, close together and have fairly thick walls. The balsa tree is now being cultivated in artificial groves. Balsa is a second growth wood which is always found in clearings. The trees seldom grow closely together.

In the natural state, balsa wood is not suitable for insulating material. Colonel Marr discovered a method of treating the wood which renders it waterproof, prevents rot and keeps it from changing shape. This process is a bath composed mostly of paraffin, performed in such a way that the interior cells are coated without clogging up the porous structure.

Lithboard.—Lithboard consists of mineral wool and vegetable fibers. It is made into boards by using a waterproofing

binder and compressing. These boards have a composition of approximately 40 per cent vegetable fibres (flax) and 60 per cent mineral wool, and are generally 18"x48" with a thickness of $\frac{1}{2}$ to 3". It weighs about 12½ lbs. per cubic foot.

Rock Cork.—Indiana limestone with a certain specified content is heated up to 2800° F. and passed through a "V" shaped steam jet. The heavier particles of blown rock drop off right at the nozzle and are separated from the rock wool that is picked up from the blowing chamber. This rock wool still has some very small particles of blown rock in it. The rock wool is taken to an agitator and here the rest of the particles are removed. The rock wool now is mixed with an oil asphalt and some paper stock, at approximately 200° F. Water is introduced and acts as a carrier agent for the mixture. The mixture is poured into moulds, that have screens in the bottom through which it drains, and the mixture is allowed to settle. After the water has drained off the mould goes to a drying kiln and stays there for about 72 hours.

Rock cork does not undergo any sort of compression during the moulding process other than that due to its own weight. The rock cork now is in slabs and is planed down to any required thickness as desired. Rock cork weighs approximately 16 to 20 lbs. per cubic foot and possesses many of the requirements of a good insulator.

Selection.—In selecting an insulation for a proposed installation a number of factors must be taken into consideration:

1. Type of construction
2. Character of refrigerated products
3. Temperatures to be maintained
4. Thickness of walls
5. Location of plant.

The following table gives the most economic thickness of corkboard and other insulation of same unit transmission:

| | | |
|---------------|-------|----|
| —20° to —10° | ..... | 8" |
| —10° to — 0° | ..... | 6" |
| 0° to 15° | ..... | 5" |
| 15° to 35° | ..... | 4" |
| 35° to 45° | ..... | 3" |
| 45° and above | ..... | 2" |

Heat Transfer in Apparatus.—The heat transfer taking place in a refrigerating apparatus is similar to that occurring through insulation, in that the flow occurs from a region of high temperature to a region of low temperature. Whereas, a very slow rate of infiltration through insulation was desired just the reverse is true in the apparatus; the fastest possible transfer is wanted. Generally this transfer of heat is accomplished between two fluids separated by a solid wall of good conductivity.

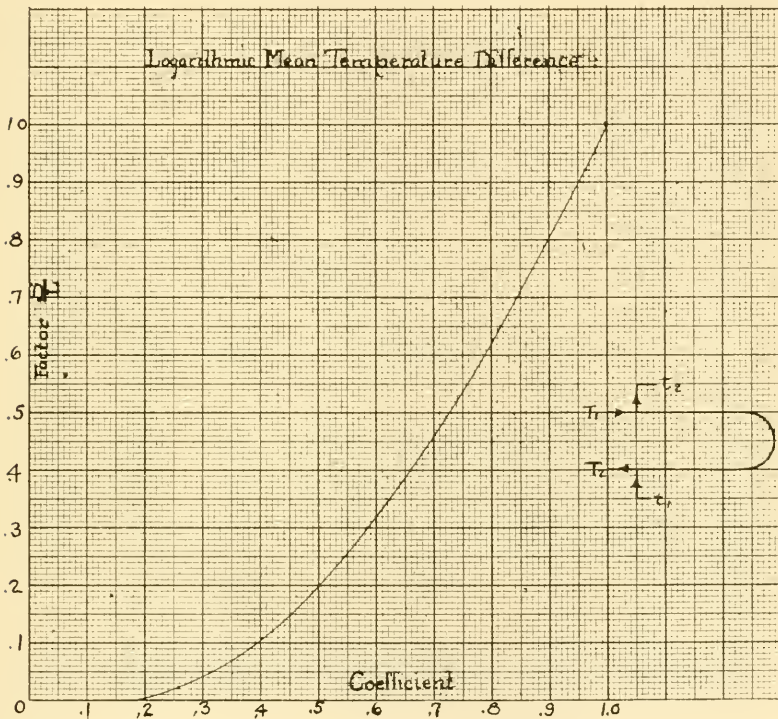


FIG. 7.—MEAN TEMPERATURE DIFFERENCE CURVE.

Since the heat transfer may occur by means of conduction, radiation or convection, the fundamental law of heat transfer holds, the same as for insulation; although the unit transmission as determined by experiment combines all three methods, as well as the kind of material and thickness of separating wall. The formula then becomes—(2).

B.t.u./hr. = "C" \times sq. ft. of surface \times temperature difference.
(C is given in Table XLVIII.)

The *mean* temperature difference for apparatus is somewhat different than for insulation due to the fact that the temperatures on both sides of the insulation are comparatively constant, whereas in the apparatus they are changing constantly. Therefore in the first case an arithmetic degree mean difference can be used but a logarithmic mean temperature difference must be found in the latter case.

Due to the character of the formula as given by Hausbrand and its attendant higher mathematics this logarithmic degree mean difference method has been put in a simple curve form, making it available to everyone.

TABLE XLVII.—THICKNESS OF INSULATION FOR COLD PIPES

| Thickness of Cork | For Use With | For Temperatures |
|-------------------|--|------------------|
| 1½ in. | Ice water, liquid ammonia, brine and other cold lines. | Above 25° F. |
| 2 in. to 3 in. | Brine, ammonia and other cold lines. | 0° to 25° F. |
| 3 in. to 4 in. | Brine, ammonia and other cold lines. | Below 0° F. |

T_1 = Inlet temperature of substance to be cooled

T_2 = Outlet temperature of substance to be cooled

t_1 = Inlet temperature of cooling substance

t_2 = Outlet temperature of cooling substance

$T_1 - t_2$ and $T_2 - t_1$ = Differences

S = Smallest difference

L = Largest difference

Factor $\frac{S}{L}$ = Ordinate

Coefficient obtained from Curve = Abcissa

Coefficient \times largest difference = Mean temperature difference.

Example: To cool milk from 120° to 80° with 72° water heated to 80° during the process.

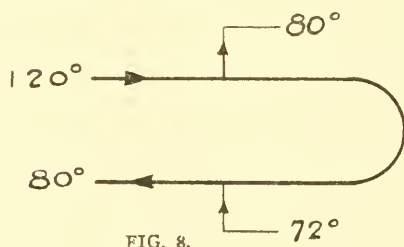


FIG. 8.

$$\frac{S}{L} = \frac{8}{40} = .2$$

Running across on the .2 factor line to the curve and then projecting down at right angles the coefficient .5 is obtained. Then the mean temperature difference is $.5 \times 40 = 20$.

If an arithmetical degree *mean* difference had been used the result would have been the difference of average temperatures of

$$\frac{(120 + 80)}{(2)} - \frac{(80 + 72)}{(2)} = 24$$

which would have been a 20 per cent error.

It has been found that for all practical purposes if $\frac{S}{L}$ is greater than .5 an arithmetic degree *mean* difference can be used.

Coefficients of Heat Transfer in Apparatus.—In table XLVIII is given overall unit heat transfer coefficients, as determined by experiments. They hold good for the general wall thicknesses found in refrigerating apparatus and when the surface is comparatively free from frost scale, oil and other foreign matter.

The best heat transfer is obtained from liquid to liquid followed by liquid to gas and the worst transfer is from gas to gas. Copper has a considerably higher rate of transfer than steel while lead is very much worse than either. Some important factors on which the rate of heat transfer depends are:

1. Velocity of fluids
2. Density and kinds of fluids
3. Temperatures at which they are handled
4. Thickness and material of separating wall
5. Smoothness and cleanliness of wall as regards foreign substances, material, as well as gases.

As an example to show the amount of steel pipe to be installed in a small storage box having a load factor of 3000 B.t.u. hr. and held at a temperature of 40° with 15° average expansion through the coil, using the fundamental formula (2):—

$$3000 = 2.5 \times \text{sq. ft.} \times (40 - 15) \\ \text{sq. ft.} = 48.$$

TABLE XLVIII.—HEAT TRANSFER COEFFICIENTS, IN B.T.U. PER HOUR PER SQ. FT. PER DEGREE TEMP. DIFF.*

| Heat Transfer | | Apparatus | Heat Transfer Coefficient | Mean Temperature Difference | Conditions |
|-------------------|-------------------|--------------------------|---------------------------|-----------------------------|---|
| From | To | | | | |
| Gas Cooling..... | Liq. Boiling..... | Direct Exp. Coils..... | 2.5 | 20° F. up | Gravity Air Circulation—About 180' per min. |
| Gas Cooling..... | Liq. Boiling..... | Direct Exp. Coils..... | 2.0 | 15° 10° | Gravity Air Circulation—About 120' per min. |
| Gas Cooling..... | Liq. Boiling..... | Direct Exp. Coils..... | 1.5 | 10° 14° | Gravity Air Circulation—About 90' per min. |
| Gas Cooling..... | Liq. Warming..... | Brine Coils..... | 3.5 | 20° 14° | Gravity Air Circulation—About 180' per min. |
| Gas Cooling..... | Liq. Warming..... | Brine Coils..... | 3.0 | 15° 10° | Gravity Air Circulation—About 120' per min. |
| Gas Cooling..... | Liq. Warming..... | Brine Coils..... | 2.5 | 10° 14° | Gravity Air Circulation—About 90' per min. |
| Liq. Cooling..... | Liq. Boiling..... | Holdover Brine Tank..... | 1.25 | 20° 14° | Direct Expansion |
| Liq. Cooling..... | Liq. Boiling..... | Holdover Brine Tank..... | 1.0 | 15° 10° | Direct Expansion |
| Liq. Cooling..... | Liq. Boiling..... | Holdover Brine Tank..... | 0.75 | 10° 14° | Direct Expansion |
| Gas Cooling..... | Liq. Boiling..... | Direct Exp. Coils..... | 3.0 | 10° 20° | Forced Air Circulation, 600' per min. |
| Gas Cooling..... | Liq. Warming..... | Brine Coils..... | 4.5 | 14° 18° | No. Brine Agitation |
| Liq. Cooling..... | Liq. Boiling..... | Ice Tank Coils..... | 13.0 | 14° 18° | Med. Brine Agitation—1 change in 10 min. |
| Liq. Cooling..... | Liq. Boiling..... | Ice Tank Coils..... | 13.0 | 14° 18° | Rapid Brine Agitation—1 change in 5 min. |
| Liq. Cooling..... | Liq. Boiling..... | Ice Tank Coils..... | 15.0 | 14° 18° | Brine Coils on Submerged Expansion Coils |
| Liq. Cooling..... | Liq. Boiling..... | Brine Tank..... | 18.0 | 10° 15° | Velocity of Brine = 3' to 4' per second |
| Liq. Cooling..... | Liq. Boiling..... | Com. Tank..... | 80.0 | 10° | Water Circulated Over Subm. Expan. Coils |
| Liq. Cooling..... | Liq. Boiling..... | D. Brine Cooler..... | 80.0 | 10° | Water Circulated Over Subm. Expan. Coils |
| Liq. Cooling..... | Liq. Boiling..... | Shell Brine Cooler..... | 80.0 | 10° | Water Circulated Over Subm. Expan. Coils |
| Liq. Cooling..... | Liq. Boiling..... | Water Cooler..... | 20.0 | 30° | Water Flowing Over Pipes (Armonia, 32° F.) |
| Liq. Cooling..... | Liq. Boiling..... | Water Cooler..... | 40.0 to 60.0 | | Counter-Current Flow Armonia Condenser |
| Vapor Cond..... | Liq. Warming..... | D. P. Condenser..... | 135.0 | | Counter-Current Flow Armonia Condenser |
| Vapor Cond..... | Liq. Warming..... | Atmos. Condenser..... | 125.0 | | Parallel Current Flow Armonia Condenser |
| Vapor Cond..... | Liq. Warming..... | Atmos. Condenser..... | 40.0 to 60.0 | | Counter-Current Flow Armonia Condenser |
| Liq. Cooling..... | Liq. Warming..... | Submerged Cond..... | 30.0 | | Counter-Current Flow Armonia Condenser |
| Liq. Cooling..... | Liq. Warming..... | D. P. Exchanger..... | 30.0 | | Brine Coils in Circulated Water |
| Liq. Cooling..... | Liq. Warming..... | Water Cooler..... | 30.0 | | Water Flowing Over Brine Coils |

*From "Principles of Refrigeration," Nickerson & Collins Co., Chicago.

Since it takes 2.3 ft. of $1\frac{1}{4}$ " pipe to make 1 square foot of surface, it will be necessary to use $48 \times 2.3 = 110$ ft.

From the foregoing it can readily be seen that many refrigerating problems are really heat transfer problems, and can be solved by either formula—1 or 2.

CHAPTER VI

REFRIGERATING SYSTEMS.

History and Principles of Refrigerating Systems.—The following chapter is devoted to historical data and the general principles underlying the operation of the principal refrigerating systems. The air refrigerating machine works on a principle of cooling by the absorption of sensible heat, and was one of the first types given consideration. Absorption refrigerating machines were also given early consideration.

The inherent advantages of the compression refrigerating machine, in which advantage is taken of the latent heat of evaporation, were early recognized and this type of system, consequently, was subjected to development and perfection at an early date. A chemical method for producing refrigerating effects has been used for centuries, but of course, the commercial application of such methods is limited, on account of the high cost of producing such refrigerating effects.

Following a discussion of the refrigerating systems, attention is given to the requirements of a household system, in which special attention is devoted to the design and construction of the different component parts of such systems.

Gorrie Air Machine.—The first air refrigerating machine was invented by Doctor Gorrie at New Orleans about 1850. Air was compressed in a cylinder and delivered to a chamber which was immersed in the cooling water. The pressure in the chamber was maintained at about 15 pounds per square inch above the pressure of the atmosphere. Water injection

was used to partly cool the air during compression. Both air and water were delivered to the receiver. The air in the receiver was further cooled by the water on the outside. Then the air was expanded in another cylinder discharging at about atmospheric pressure. The expanding air was mixed with a quantity of brine which was injected into the expansion cylinder. The expanding air cooled the brine to about 20° F. This cold brine was used for ice making or refrigeration.

Kirk Air Machine.—Dr. Alexander Kirk invented a closed cycle air machine about 1861. This machine used a confined mass of air, operating always at pressure considerably above atmospheric pressure. Machines of this same type were made by Allen, an American, and Windhausen, a German.

Open Cycle Air Machine.—The open cycle air machine consists of two cylinders called a compression cylinder and an expansion cylinder. Air from the room which is to be cooled is taken in the compression cylinder. It is compressed and therefore warmed. This compressed air is then cooled by circulating water. This air is then made very cold by expansion to atmospheric pressure. Upon reaching this condition it is returned to the cold room.

Open cycle air machines of this type were proposed by Lord Kelvin and Professor Rankin about 1852. The first actual machine operating on this principle was made by Giffard in 1873. At a later date, machines of this type were made, namely the Bell-Coleman and other improved designs by Mr. Lightfoot, Messrs. Haslam and Hall.

The air machine has a relatively large power consumption and is only used to any large extent on ships.

Allen Dense Air Machine.—The dense air machine is used to some extent on boat installations.

In this system air is compressed to about 250 pounds and then cooled by the cooling water. This cooling is usually performed by a copper coil immersed in water.

The air is then passed through a moisture separator, after which it is conducted to the expansion cylinder. In this

cylinder the air is expanded to about 60 to 70 lbs. pressure and a very low temperature.

The 70 lbs. air is then passed through an oil separator before being returned to the compressor to start another cycle. A primer pump is used to automatically supply make up air.

Machines of this type require considerable attention to eliminate trouble from ice forming within the evaporator, due to freezing the water vapor supplied by the make up air. Lubrication is rather difficult on a machine of this type.

This system of refrigeration has not proven successful for small household machines, although the use of air as a refrigerant has some important advantages in this particular field of refrigeration.

Low Pressure Air Refrigeration System.—A recent development in household refrigerating machines operates on the principle of accelerating the evaporation of ammonia or alcohol by blowing air through the liquid.

The air is compressed by a blower to a pressure of 10 to 15 lbs. gauge. The blower is usually direct-connected to the motor and operates at motor speed.

This process is claimed to operate at efficiencies better than those obtained in the usual compression system.

Water Vapor Absorption Machines.—In the absorption type machine, two substances are used which have an affinity for one another so that one unites or dissolves in the other when they are cold, but they separate readily when heated. Sulphuric acid when cold has a great affinity for water. Heating a sulphuric acid and water mixture drives off water vapor. This vapor is condensed by the cooling water. The acid is then cooled and reabsorbs the water vapor at a low temperature and a very low pressure. There is a very low vacuum during both parts of the cycle. The absorbing substance acts like a pump and maintains a low pressure during the cooling cycle. This principle was first used by Professor Leslie in 1810. A small machine of this type was made by M. E. Carré in 1875 for household work. It consisted of an air pump, and a chamber to contain the acid. A rod on the pump handle served to agitate the surface of the sulphuric acid. Mr. Wind-

hausen made a large machine of this type in 1878. A small machine of this type is on the market at the present time, being manufactured by the Pulsometer Co., of Reading, Eng., and others.

Machines of this type have an overall thermal efficiency of about fifteen per cent which is lower than the compression type.

Ammonia Absorption Machines.—The ammonia absorption machine works on the principle of ammonia dissolving in water. One quart of water will dissolve about 500 quarts of ammonia gas. Ammonia has a higher vapor pressure than water and the absorbing is accomplished under a pressure considerably above atmospheric. Heating a water and liquid ammonia mixture drives off ammonia gas. This gas is condensed by the cooling water. The water is then cooled and reabsorbs the gas at a low temperature. In actual practice only part of the ammonia is driven off from the aqua solution.

The ammonia absorption machine was invented by F. Carré about 1858-1860. The original machine was a very crude affair, consisting merely of two vessels—one surrounded by cold water, the other containing the ammonia and water. The original patent in the United States was issued October 2, 1860, the reissue being dated February 18, 1873. The Carré machine, subsequently improved by Mignon and Rouart in France, Vass and Littmann in Germany, Reece, Mort, Nicolle, and others in England and Australia, marked a great era in mechanical refrigeration.

The Carré machine was the first one to obtain a foothold in the ice making industry in the United States. The first machine was shipped through the blockade in 1863 to Augusta, Ga., by Mr. Bujac of New Orleans. It was supposed to have a capacity of 500 pounds per day. Due, mainly, to the parties who had it in charge, the machine was not a success, and in 1866 it was shipped to Gretna, La., where it was run for exhibition and experiniental purposes. Three other Carré machines, purchased by the firm of Bujac & Girarde, New Orleans, La., and installed in that city, also proved unsuccessful in operation.

In the fall of 1865, the firm of Mepes, Holden, Montgomery & Co. purchased the first of these machines and shipped it to San Antonio, Tex., and put it in operation under the supervision of D. L. Holden.

The absorption refrigerating machine is now manufactured by the Carbondale Machine Co., Columbus Iron Works, Henry Vogt Machine Co., York Manufacturing Co., and others in the United States. Messrs. Haslam and Hall now manufacture a machine of this type formerly developed by Messrs. Pontifex and Wood, in England. The overall thermal efficiency of the ammonia absorption system is about 25 per cent.

History of the Vapor Compression Machine.—The first machine of the vapor compression type was invented by Jacob Perkins, an American, and patented in England in August, 1834. It was further developed by Twining, who took out his English patent in 1850. This machine was not a commercial success.

It was not until 1857 that James Harrison of Geelong, Australia, made a compression machine using sulphuric ether which was of commercial value. Messrs. Siebe and Gorman later manufactured these machines in England. This refrigerant is not used today.

In April, 1867, Prof. P. H. Van der Weyde of Philadelphia, Pa., obtained patents for the use of naphtha, gasoline, petroleum, ether and condensed petroleum gas (chimogene) as refrigerants, and obtained patent on his compression refrigerating machine.

Mr. D. L. Holden, after his successful experience in San Antonio with the Carré ammonia absorption machine in 1865, purchased the patent rights of Prof. Van der Weyde and built his first compression machine at the Novelty Iron Works in New York City. Several other compression refrigerating machines using ammonia were built and installed by Mr. Holden in New Orleans, La., Bonham, Houston and Galveston, Tex.; Mobile, Ala.; Thibodauxville, La.; Selma, Ala., and Charleston, S. C. In September, 1869, and April 1870, and at various later dates, Mr. Holden obtained patents on his "regaled" ice making system.

In 1868, Charles Tellier, of Passy, near Paris, took out patents on his compression apparatus, whose refrigerating agent was methylic ether, and which was designed to make ice and to refrigerate air and liquids. The date of his letters patent in the United States was June 5, 1869, and one of his machines was erected in the Old Canal Brewery, New Orleans, by George Metz, with the object of producing cold, dry air, and making ale and lager beer without the use of ice.

In the seventies appeared the inventions of Francis D. Coppet of New Orleans; Franz Windhausen, Germany; Prof. C. P. G. Linde of Munich, Bavaria; Raoul P. Pictet, Geneva, Switzerland; Thos. L. Rankin of Ohio; Martin & Beath, San Francisco; A. T. Ballentine of Maine; James Boyle of Texas, and David Boyle of Chicago.

In 1877 Mr. Enright designed and built a machine having a vertical double-acting compressor, and in the fall of the year one of this type was installed in the brewery of A. Ziegele of Buffalo, N. Y. In 1878 patents were issued to the inventor, not only for his double-acting compressor, but for the pipe joint commonly known as the Arctic.

Vincent constructed a chloride of methyl compression machine in 1878. M. Raoul Pictet invented a sulphurous acid machine about 1875. This machine is used in France and Switzerland. Dr. Carl Linde, of Munich, introduced the ammonia machine in 1876.

In 1878, the first compression machine made by C. J. Ball was erected at Dallas, Tex. Upon his retirement he was succeeded by his son, P. D. C. Ball, who conducted the business under the name of the Ice & Cold Machine Co., until 1920, at which time the name of the company was changed to the Ball Ice Machine Co.

The first De La Vergne refrigerating machine was placed in the Hermann Brewery, New York City, in 1879. One of the inventors of the original apparatus, John C. De La Vergne, was engaged in the brewing industry in 1876, and in 1881 he formed the De La Vergne Refrigerating Machine Co., for the manufacture of the so-called De La Vergne-Mixer Machine, the second patentee being William M. Mixer of New York.

The refrigerating department of the Frick Co. originated about 1881, when either Mr. Jariman or Mr. Ferguson of Baltimore, Md., submitted plans of machinery to George Frick, and plants were subsequently erected for several parties in that city.

About 1882 Peter Weisel, the founder of the business now conducted by the Vilter Manufacturing Co., Milwaukee, Wis., designed a double-acting horizontal refrigerating machine which the firm of Weisel & Vilter commenced to build in that year. The first machine was installed in the Cream City Brewery, Milwaukee.

In 1885 W. G. Lock, an engineer of Sidney, Australia, patented a compound compressor for ammonia consisting of two single-acting high and low-pressure pumps, side by side. Patents covering the idea were issued as early as 1867, and the Lock improvements, together with the St. Clair compound machine, manufactured by the York Manufacturing Co., were great improvements on the originals. Thomas Shipley, vice-president and general manager of the company, made a number of most important changes and improvements on the originals, and also patented other improvements on ice making and refrigerating plants.

The compression refrigerating machine is now produced by a number of the leading manufacturers in the United States.

The carbonic acid machine was patented by Raydt in 1881 and later by Windhausen in 1886. This type machine is made by Messrs. J. and E. Hall of Dartford, Eng., The Linde Co., Messrs. Haslam and Hall and the Pulsometer Co.

The carbonic acid machine was introduced in the United States in the early eighties, and is now manufactured by American Carbonic Co., Brunswick-Kroeschell Co., Frick Co., Norwalk Iron Works, Wittenmeier Machinery Co., and others.

Vapor Compression Machines.—Most of the mechanical refrigeration of today is performed by vapor compression machines. In this process, a liquid is used which can be alternately liquefied and vaporized.

The liquids in common use are ammonia, sulphur dioxide, methyl chloride, ethyl chloride, ether, and carbon dioxide. The refrigerating cycle may be divided into four different phases:

1. Throttling effect through expansion valve.
2. Vaporization process in cooling coils.
3. Compression of vapor in compressor.
4. Cooling and condensing of vapor in condenser.

Refrigeration is produced by the latent heat of vaporization of these substances, all of which have a relatively low boiling point. The vapor resulting from the vaporization of the liquid in the cooling element is conducted to the suction side of the compressor. This vapor usually reaches the compressor in a slightly superheated condition. The compressor then forces the gas into the condensing element, where it is liquefied by cooling, usually by means of water or air. The liquid refrigerant is then allowed to return to the cooling element through an expansion valve or a restricted orifice. This cycle is continuous.

The restricted orifice must always be sealed on the condensing or high pressure side with liquid refrigerant, in order to function properly.

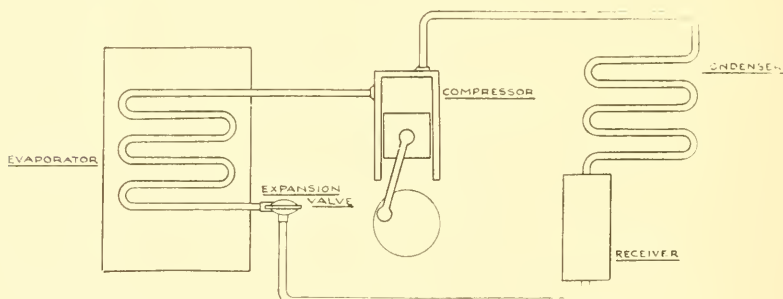


FIG. 9.—COMPRESSION REFRIGERATING SYSTEM.

The cooling element may operate either on a flooded or dry system. In the flooded system, a relatively large amount of the liquid is stored in the cooling element and a regulation of the restricted orifice keeps this amount nearly constant. In the dry system, the regulation of this orifice is usually controlled by the pressure of the low or evaporating side.

Statistics show that more than 90 per cent of all the refrigerating and ice making plants in the United States today are operated on the ammonia compression system. This is only true of the commercial or larger size plants as the household systems favor sulphur dioxide compression machines.

The compression refrigerating system is shown diagrammatically by Fig. 9. The five essential parts shown are the compressor, condenser, receiver, expansion valve, and evaporator. An ordinary piston type of compressor is illustrated.

Chemical Methods.—It is a well known fact that when ice melts the temperature remains constantly at 32° F. Heat is supplied to cause this physical change of state from a solid to a liquid, and if the rate of heat supply be increased or decreased there will be no change in the temperature of the ice but simply a change in the rate of melting. Mixtures of some salts with ice and of certain salts with water or acids do not follow this same rule. For example, if salt is mixed with ice the rate of melting will tend to increase more rapidly than the heat is absorbed and the temperature will fall below that of melting ice. The temperature will be depressed a certain amount depending upon the per cent of salt used.

United States Department of Agriculture Bulletin No. 98 gives the temperature resulting from mixtures of ice and salt as follows:

| Per Cent Salt | Degrees F. |
|---------------|------------|
| 0..... | 32 |
| 5..... | 27 |
| 10..... | 20 |
| 15..... | 11 |
| 20..... | 1.5 |
| 25..... | —10. |

The temperature of water may be lowered as much as 40° F. by dissolving ammonium nitrate in it. Ice may be formed in this way.

The lowering of temperature by means of ice and salt mixtures is shown graphically in Fig. 10. This figure illustrates how the temperature is reduced as the percentage of salt is increased. This chart is for ordinary salt, sodium chloride.

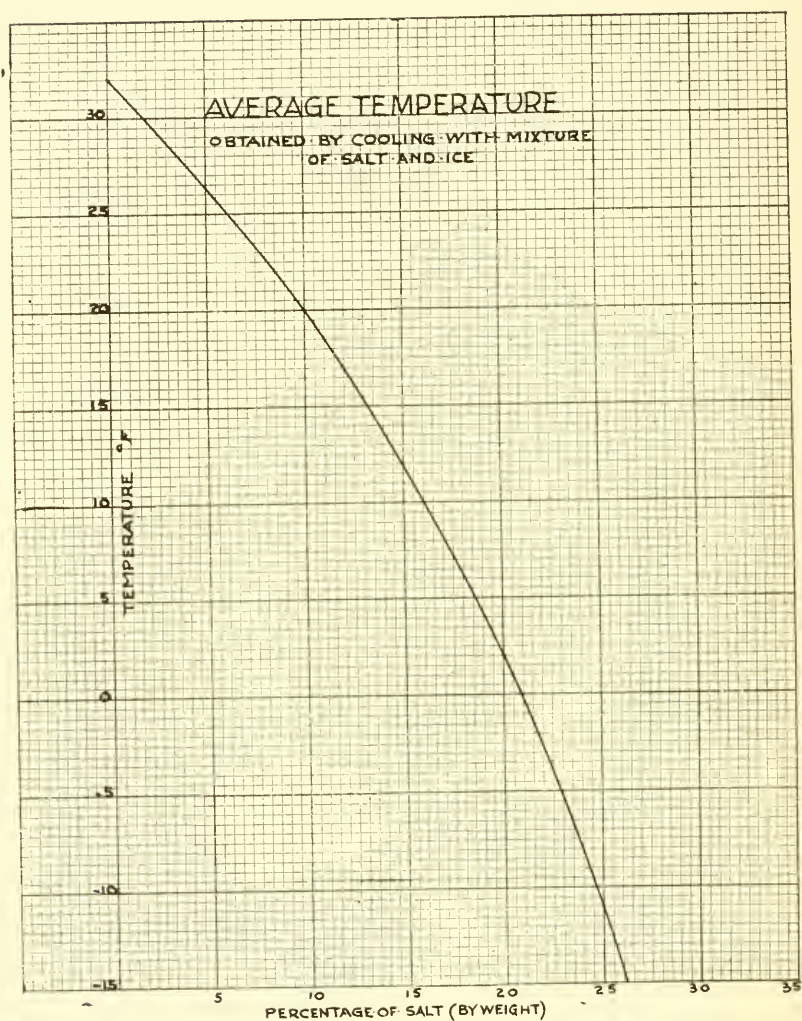


FIG. 10.—TEMPERATURES OBTAINED BY ICE AND SALT MIXTURES.

Water for Cooling Food.—Farmers' Bulletin No. 375 of the United States Department of Agriculture gives the following, in reference to cooling of foods, by means of water:

There are many ways of lowering temperature by utilizing the fact that water when evaporating draws off heat from surrounding objects. If a pitcher of water be wrapped with a cloth which is kept saturated and exposed to a draft of air, the temperatures of the water in the pitcher will be lowered by several degrees.

A receptacle in which food is placed may be cooled in the same way. Take a wooden box with a sound bottom made of one piece and invert it. Tack a layer of cotton batting over it and cover with some coarse cloth. It is now to be kept wet by some contrivance that will furnish an automatic drip. The writer used for this purpose an old aluminum pan which had in it a half dozen very tiny holes, and when filled with water it supplied just enough water to keep the cloth saturated. Under this box lettuce in cold water, a cold pudding, a pat of butter, and other food were placed and kept in good condition. A pan of milk lowered into another of cold water is kept from souring many hours longer than if it was unprotected from the surrounding air. Spring water of low temperature is used by many farmers' wives to keep milk and butter cool, and a "spring house" is a common thing on many farms, though less depended upon than was the case before ice houses, refrigerators and ice chests became so common.

It is also an old-fashioned practice to lower foods in covered pails into the well and suspend them not far above the surface of the water.

Requirements.—The requirements of a household refrigerating machine may be summarized as follows:

1. Maintain food compartments between 40—50° F. automatically.
2. Freeze water and desserts in reasonable length of time.
3. Low initial cost.
4. Dependable operation without adjustments, hand controls, or service.
5. Simplicity of design.
6. Simplicity of operation.
7. Efficiency of operation.
8. Quietness of operation.
9. Prevent leakage at stuffing box
10. Accessibility for repairs.
11. Safety of operation of exterior moving parts, of electrical apparatus or fuel burners.
12. Adaptability for installing as a single unit with cabinet.
13. Freedom from wear of moving parts.

14. Positive operation of valves.
15. Insure necessary lubrication under all conditions of service.
16. Prevent misplacement of lubricant.
17. Limit the number of gasket and pipe connections whereby refrigerating gas might escape.
18. Protect compressor from damage of pumping liquid refrigerant or lubricant.
19. Insure necessary cooling of compressor and motor.
20. Protect metals from rust and corrosion.

The household refrigerating machine has been under development for the past forty years. This work includes problems in mechanical, electrical, and chemical engineering. It has proven very difficult to construct a machine which will start and stop itself at required intervals, which will be self-regulating and self-oiling under all conditions, and which will be fool-proof and of such simplicity that a servant can operate it.

The machine should be entirely automatic as the advantages gained over the use of ice are not sufficient to compensate for a manually controlled system. Machines have been proposed which would be started manually and stopped automatically. Other plants have been proposed which would operate all of the time, varying the speed of the compressor according to the temperature in the food compartment. These experiments have not proven successful commercially.

The machines should make ice in small quantities or freeze desserts for table use. This feature assures the user that it is functioning properly. Experience shows that thermometers placed in food compartments are seldom understood, but the fact that ice is frozen and stored in the brine tank or cooling element is convincing proof that the machine is operating satisfactorily. The time required to freeze ices or desserts should not be longer than five hours, the usual time between meals, unless there is a large ice storing capacity insuring a reserve supply.

A large amount of work has been done on compressor design and development. It has been estimated that 90 per cent of the experimental work performed on household refrigerating machines has been on compressor development. Many concerns have met with financial difficulties before emerging

from the compressor development stage, while others have placed their machines on the market without taking time to develop the other important parts of the refrigerating system. Some very satisfactory compressors have been built and efforts are now being made to better the condensing, evaporating, ice making, and automatic control features.

In Europe and the tropics where labor is cheap and electricity is not available, there is a demand for hand operated machines. These are produced in large quantities, usually of a small refrigerating capacity, just sufficient to cool a carafe of water in a few minutes and make several pounds of ice in a half hour. The larger sizes will make 20 to 30 pounds of ice per hour. These are vacuum systems using sulphuric acid to absorb the water vapor, an improved form of the Carré sulphuric acid freezing machine.

Household refrigerating machines will not be used in large quantities until the mechanical features have been perfected, and until they operate at a cost comparable with that of buying ice. It is merely an improvement on existing conditions.

The initial cost must be low as the average family uses between 100 and 200 lbs. of ice weekly. The average yearly cost of ice would be about \$40.00.

The Compressor.—The reciprocating type of compressor is in general use with refrigerants such as sulphur dioxide, ammonia, methyl chloride, carbon dioxide, and high pressure air.

Blowers and turbine compressors are mostly used with refrigerants such as ethyl chloride, ether, formic-aldehyde, and low pressure air. With these gases, a relatively large amount of gas must be handled.

Herringbone gear compressors have been used to some extent on sulphur dioxide machines, but they have not as yet met with success commercially.

Sulphur dioxide compressors are used most extensively on household refrigerating machines. These compressors are usually of the single-acting type with two vertical cylinders, although some machines on the market today have one and

others three vertical single-acting cylinders. They operate at from 250 to 500 r.p.m., the speed being limited mostly by noise and efficiency of the valves. The multi-cylinder compressors are favored in order to reduce the starting torque.

Some progress has been made with sulphur dioxide compressors operating at motor speed or about 1750 r.p.m. The cylinder on a machine of this type is usually less than one inch in diameter, for use with a $\frac{1}{4}$ -hp. motor. Most machines using these compressors have been of the double-acting single cylinder design. One manufacturer uses a four-cylinder compressor operating at motor speed.

The displacement in cu. in. per min. for a compressor of average efficiency necessary to produce the refrigerating effect equivalent to 100 lbs. of ice melting per day is approximately as follows:

| | |
|-----------------------|----------------|
| Ethyl chloride | 3,450 to 5,100 |
| Sulphur dioxide | 1,200 to 1,800 |
| Ammonia | 450 to 670 |
| Carbon dioxide | 90 to 130 |
| Methyl chloride | 900 to 1,340 |

An important part of the compressor design is the packing gland which seals the drive shaft. Most of the first models used a packing of fiber, asbestos, and graphite, forced against the shaft by means of a spring acting against a metal gland. The spring automatically compensates for wear. It is advantageous to have oil on both sides of a packing gland of this type.

A later development is to use a ring of metal containing graphite. This ring is forced by means of a spring against a collar turned on the shaft. This ring may be attached to one end of a metal bellows, thus having only one surface to seal instead of two if the metal bellows is not used.

It is a decided advantage to have the packing gland on the slower speed shaft when a reduced speed drive is used. Some machines are entirely or partly enclosed, thus eliminating the packing gland.

The design of a compressor includes a system of lubrication which should function under many different operating conditions. The lubricant usually has a tendency to locate

and stay in the evaporating coils. This condition lowers the rate of heat transmission in the evaporator. The return of lubricant to the compressor through the suction line is usually the result of some temporary unusual working condition. It is difficult to design a refrigerating system in which the lubricant returns regularly from the evaporation element to the compressor.

The piston type compressor usually has surplus lubrication of the pistons and cylinders.

In the herringbone gear type compressor, it is necessary to have generous lubrication of the gears in order to pump gas. Small holes feed lubricant to the gears during part of their rotation. If too much lubricant is supplied it decreases the amount of gas pumped. Lubrication is one of the most difficult problems in the gear type compressor.

The rotary compressor presents a difficult lubricating problem as the blades usually wear rapidly when forced against a surface.

TABLE XLIX.—AIR PUMPING TEST ON A STANDARD TWO-CYLINDER AIR-COOLED SULPHUR DIOXIDE COMPRESSOR.

| Discharge Pressure Pounds Gauge | Volumetric Efficiency Percent | Watt-minutes per cu. ft. Free Air Delivered per Minute |
|--|-------------------------------------|---|
| 0 | 72.5 | 253 |
| 20 | 65.8 | 330 |
| 40 | 58.7 | 402 |
| 60 | 52.1 | 481 |
| 80 | 45.1 | 573 |

Using $\frac{1}{4}$ -hp., 110-volt, a. c. R. I. Standard Motor.

Table XLIX gives the results of an air pumping test on a standard two-cylinder air-cooled sulphur dioxide compressor. The test results give the volumetric efficiencies as the discharge pressure is increased from 0 to 80 pounds per square inch gauge. The resulting watt-minutes per cubic foot of free air delivered per minute are given also.

Table L gives similar results for an air pumping test on a standard three-cylinder air-cooled sulphur dioxide compressor.

TABLE L.—AIR PUMPING TEST ON A STANDARD THREE-CYLINDER AIR-COOLED SULPHUR DIOXIDE COMPRESSOR.

| Discharge Pressure Pounds Gauge | Volumetric Efficiency Percent | Watt-minutes per cu. ft. Free Air Delivered per Minute |
|--|-------------------------------------|---|
| 0 | 70.8 | 238 |
| 20 | 61.3 | 342 |
| 40 | 56.6 | 432 |
| 60 | 52.5 | 526 |
| 80 | 49.7 | 620 |

Using 1/6-hp., 110-volt, a. c. R. I. Motor.

Table LI gives similar results for an air-pumped test on a herringbone-gear type compressor.

TABLE LI.—AIR PUMPING TEST ON HERRINGBONE GEAR TYPE COMPRESSOR.

| Discharge Pressure Pounds Gauge | Cu. Ft. Free Air Delivered Per Minute | Watt-minutes per cu. ft. Free Air Delivered per Min. |
|---------------------------------------|---|--|
| 0 | 0.87 | 150 |
| 10 | 0.857 | 187 |
| 20 | 0.833 | 240 |
| 30 | 0.78 | 302 |
| 40 | 0.75 | 367 |
| 50 | 0.75 | 413 |
| 60 | 0.74 | 440 |
| 70 | 0.732 | 512 |
| 80 | 0.69 | 610 |

Used 1/4-hp., 110-volt a. c. R. I. Standard Motor (1,775 r.p.m.).

The Condenser.—The condenser is used to cool and liquefy the refrigerant gas as it leaves the compressor or blower. The customary cooling medium is either water or air.

Some systems use tap water from the city mains. A sufficient quantity of water should be used so that its outlet temperature is not more than 15° or 20° F. higher than the inlet or tap water temperature. If less water is used, an excessive condensing pressure will likely result. On large plants it is customary to use sufficient water for a 10° F. water inlet and outlet differential.

Some household systems use the same water over and over again. In a system of this kind, it is an advantage to conduct the warm water leaving the condenser to a well or

tank which is in the ground. In this way the water is cooled during the periods when the machine is not in operation.

The water supply is sometimes regulated by a valve which opens automatically at a certain predetermined condensing pressure. Then as the condensing pressure increases, the valve opens wider allowing more water to flow through the condensing coil. This system compensates for different temperatures and pressure of condensing water and to some extent, for other variations in operating conditions. A machine operating on this principle requires still another control to prevent operation when water is not available, even though this water-regulating valve functions properly.

Another water control system in use is a valve which opens automatically when the machine is operating and closes during the inoperative periods. This valve does not regulate the amount of water used so that any change in pressure or temperature of the water supply is not compensated for automatically. This system may waste considerable water or may cause the plant to operate inefficiently at times.

The packing on automatic regulating water valves has given some trouble in service. This difficulty has been met by using a copper bellows or rubber diaphragm to seal the valve stem and eliminate the packing troubles.

There are three general types of water-cooled condensers in use: The submerged type, in which the pipe containing the refrigerant gas is submerged in the water, and the double-pipe condenser in which one pipe is inside a larger one. The refrigerant gas flows through the annular space and the water through the inside pipe. This gives the advantage of some cooling by the atmosphere. A condenser of this type is usually arranged to have counter-current heat flow, the cold water entering the liquid outlet at the end of the condenser. The other method is to submerge the cooling water pipe in the gas space itself. The refrigerant gas condenses on the pipe and drops into a sump or receiver.

When copper tubing is used for water-cooled condensers, the usual practice is to use from two to three square feet of cooling surface per 100 lbs. ice melting effect.

On a small household plant, the average cost of water is less than two per cent of the total operating cost, so that it is usually practical to use tap water which wastes to the drain.

Air-cooled condensers are rapidly gaining favor for small household machines. Some of the more important advantages of the air-cooled condenser are: Lower initial cost, reduced cost of installation, simplified apparatus, no danger of water lines freezing in winter, and water cooling limits location of mechanical unit.

Air-cooled machines usually operate at condensing pressures, twenty-five to thirty per cent higher than on water-cooled systems. This of course lowers the efficiency of the system, however the increased simplicity may compensate for this loss in efficiency.

There are two systems of air cooling in common use. In the dead air system a relatively large amount of condenser cooling surface is used. With the forced air system a smaller amount of condenser surface is used. A fan or blower forces the air over all or part of the condenser, thus procuring more efficient use of the cooling surface and permitting the use of less surface.

Machines using the dead air type condenser have been used mostly on installations where the mechanical unit is placed in the cellar. This assures a relatively low condenser temperature, averaging between 7° and 10° F. lower than the refrigerating cabinet environment temperature.

The usual practice on dead air-cooled condensers is to use from ten to twelve square feet condenser surface for each one hundred pounds ice melting refrigerating capacity. Less than half this surface is needed with forced air cooling, the exact amount depending upon the amount of air used and the efficiency with which it is used.

Some air-cooled systems use a large capacity condenser so that it also serves as a receiver for the liquid refrigerant. This feature eliminates pipe connections and adds to the simplicity of the machine.

Table LII gives capacities and horsepower for different sizes of Sirocco blowers. This table gives the cubic feet of air delivered per minute r.p.m. and brake hp., at various suction

pressures, expressed in inches of water for some of the small blowers.

TABLE LII. — SIROCCO BLOWER DATA, CAPACITIES AND HORSE POWER.

| Number of Fan | Diameter of Wheel, Inches | Suction Pressure Inches of Water | Cubic Feet Air Delivered per Minute | R. P. M. | Brake Horse Power |
|----------------|---------------------------|----------------------------------|-------------------------------------|----------|-------------------|
| 00 | 3 | $\frac{1}{4}$ | 40 | 2220 | 0.004 |
| 00 | 3 | $\frac{1}{2}$ | 57 | 3160 | 0.0115 |
| 00 | 3 | $\frac{3}{4}$ | 69 | 3885 | 0.0208 |
| 0 | $4\frac{1}{2}$ | $\frac{1}{4}$ | 90 | 1480 | 0.0087 |
| 0 | $4\frac{1}{2}$ | $\frac{1}{2}$ | 127 | 2110 | 0.0258 |
| 0 | $4\frac{1}{2}$ | $\frac{3}{4}$ | 155 | 2590 | 0.0466 |
| 0 | $4\frac{1}{2}$ | 1 | 182 | 3025 | 0.0745 |
| 0 | $4\frac{1}{2}$ | $1\frac{1}{2}$ | 222 | 3700 | 0.137 |
| 1 | 6 | $\frac{1}{4}$ | 160 | 1110 | 0.0155 |
| 1 | 6 | $\frac{1}{2}$ | 226 | 1580 | 0.046 |
| 1 | 6 | $\frac{3}{4}$ | 276 | 1940 | 0.083 |
| 1 | 6 | 1 | 325 | 2270 | 0.1325 |
| 1 | 6 | $1\frac{1}{2}$ | 394 | 2770 | 0.244 |
| 1 | 6 | 2 | 464 | 3240 | 0.381 |
| $1\frac{1}{4}$ | $7\frac{1}{2}$ | $\frac{1}{4}$ | 250 | 885 | 0.0242 |
| $1\frac{1}{4}$ | $7\frac{1}{2}$ | $\frac{1}{2}$ | 354 | 1265 | 0.072 |
| $1\frac{1}{4}$ | $7\frac{1}{2}$ | $\frac{3}{4}$ | 431 | 1555 | 0.1295 |
| $1\frac{1}{4}$ | $7\frac{1}{2}$ | 1 | 507 | 1813 | 0.207 |
| $1\frac{1}{4}$ | $7\frac{1}{2}$ | $1\frac{1}{2}$ | 616 | 2220 | 0.381 |
| $1\frac{1}{4}$ | $7\frac{1}{2}$ | 2 | 725 | 2585 | 0.595 |

The following are some of the leading characteristics of fans:

Capacity varies as speed

Pressure varies as (speed)²

Horsepower varies as (speed)³

Horsepower varies as (capacity)³

Horsepower varies as (pressure)^{3/2}

Horsepower varies as (diameter)²

Speed varies inversely as diameter.

Speed varies as density.

Capacity varies as $\sqrt{\text{absolute temperature}}$.

Horsepower varies as $\sqrt{\text{absolute temperature}}$.

Table LIII gives the results of some tests of exhaust fans. In this table, it will be observed that the size of the fan varies from three inches to sixteen inches, and the corresponding data are given for r.p.m, watts consumed, air velocity in feet per minute, air delivered in cubic feet per minute, cubic feet delivered per watt of electrical energy consumed, and characteristic of electric current.

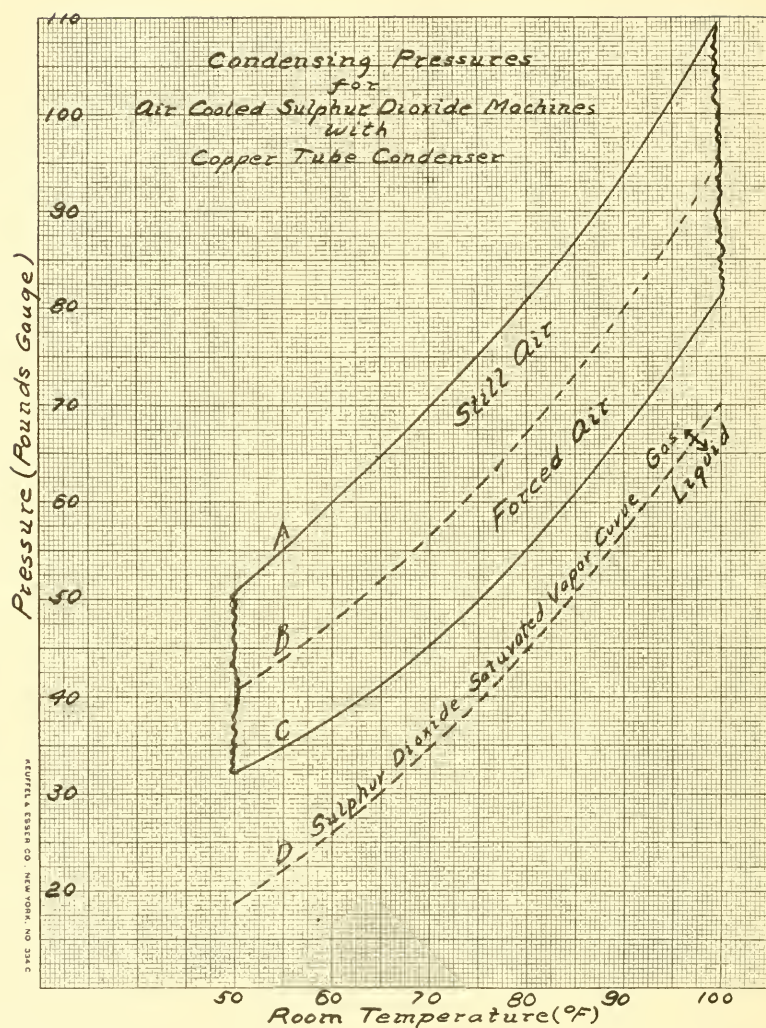


FIG. 11.—CONDENSING PRESSURE FOR AIR-COOLED SULPHUR DIOXIDE MACHINE.

TABLE LIH.—TESTS ON EXHAUST FANS.

| Diameter Fan | Discharge Outlet | R.P.M. | Watts | Air Velocity per Minute | Air Delivered Cu. Ft. per Minute | Cu. Ft. per Watt | 110 Volt |
|--------------|------------------|--------|-------|-------------------------|----------------------------------|------------------|----------|
| 3 in. | 2½ in. | 2660 | 37 | 2355 | 80.1 | 2.16 | D.C. |
| 3 in. | 2½ in. | 2075 | 29 | 1775 | 80.3 | 2.08 | D.C. |
| 4½ in. | 3⅝ in. | 1730 | 66 | 1780 | 125 | 1.89 | A.C. |
| 6 in. | 4⅞ in. | 1100 | 111 | 1680 | 201 | 1.82 | A.C. |
| 9 in. | 9 in. | 1610 | 38 | 815 | 360 | 9.48 | D.C. |
| 9 in. | 9 in. | 1550 | 66 | 1185 | 523 | 7.93 | A.C. |
| 12 in. | 12 in. | 1140 | 58 | 818 | 643 | 11.08 | D.C. |
| 12 in. | 12 in. | 1620 | 48 | 520 | 489 | 10.18 | A.C. |
| 12 in. | 12 in. | 1400 | 67 | 1170 | 921 | 13.7 | A.C. |
| 16 in. | 16 in. | 1030 | 81.5 | 518 | 805 | 9.88 | A.C. |

Condensing Pressure for Air Cooled Compressors.—Fig. 11 shows the condensing pressure in pounds per square inch gauge for air-cooled sulphur dioxide refrigerating machines, equipped with copper tube condensers. The curves show graphically how the condensing pressure increases with the increase of the room temperature. The space between curves A and B shows the result when the proper tube condensers are exposed to still air, while the space between curves B and C shows the results when forced air circulation over the condenser is used. The curve D is the saturated vapor curve for sulphur dioxide and represents the corresponding condensing temperatures for the pressures shown on the left-hand side of the diagram. The relative distances between curve D and the curves A, B, and C show how nearly the condenser pressure approaches the theoretical possibilities.

Flintlock Condensers.—Fig. 12 shows a new type condenser developed for air-cooled electric refrigerators by Flintlock Corporation of Detroit, Michigan.

One lineal foot of this finned tubing has been found to have the equivalent cooling capacity of ten feet of copper tubing of equal size, when air is drawn through at an average velocity of 500 feet per minute.

Tests have proven that draw fans are more efficient than blow fans. Only that amount of air which can be drawn through the free area of the condenser need be handled by the fan.

Fig. 13 shows a cross section of tubes also the internal fins. The construction is of brass tinned inside and out. The

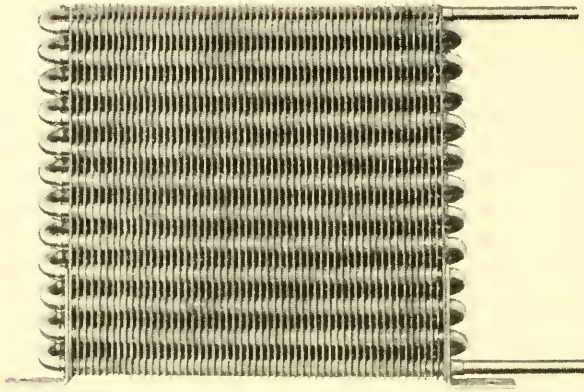


FIG. 12.—FLINTLOCK AIR COOLED CONDENSER.

tubes are an integral part of the fins. Heat transmission does not pass through a soldered joint.

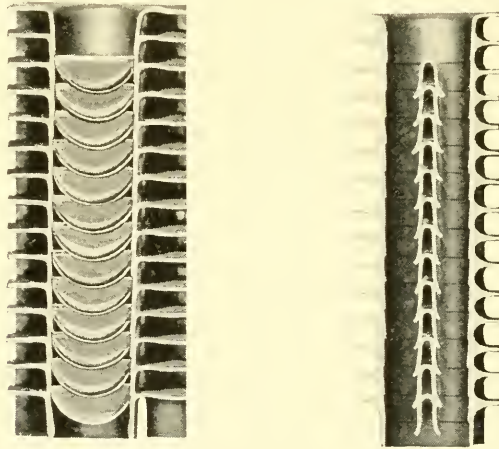


FIG. 13.—CROSS SECTION OF TUBES—SHOWING INTERNAL FINIS.

Fig. 14 is a typical installation of this type condenser on a compressor unit.

Tubes and Spiral Fin Tubes.—The use of drawn seamless tubes or coils made into simple, or sometimes fairly compli-

cated forms, is very extensive throughout the refrigerating industry. Considering household machines, the conventional condenser and evaporator consists of many feet of seamless copper tubes, or steel tubes in case ammonia is used as the refrigerant. The copper tubes used ordinarily are $\frac{1}{4}$ inch outside diameter, $\frac{5}{16}$ inch up to $\frac{1}{2}$ inch outside diameter with a wall thickness of about 0.015 to 0.032 inch. These tubes

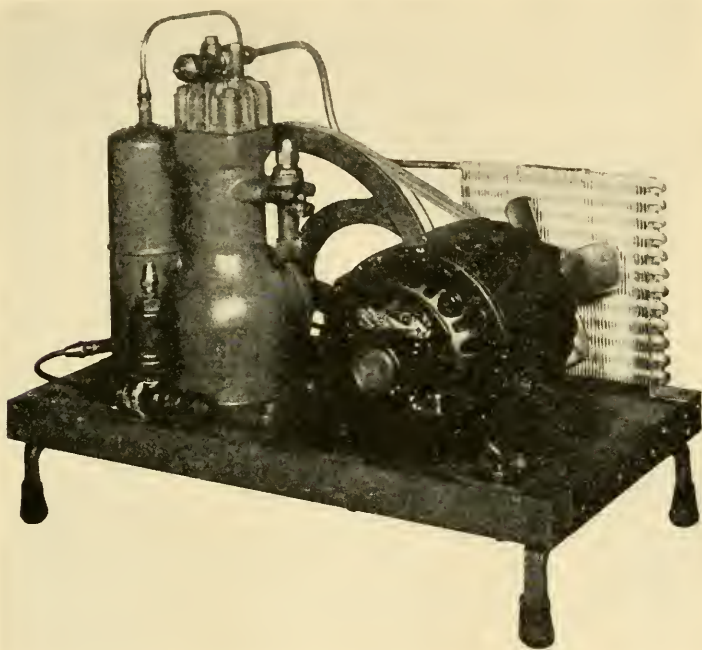


FIG. 14.—TYPICAL INSTALLATION OF FLINTLOCK CONDENSER.

have ample bursting strength, are soft, easy to work with and when formed into coils present an attractive appearance.

In some designs the tubing is flattened before or while it is being formed into a coil; the object in flattening the tubes is, of course, for a given tube spacing to increase the area of the air passages between the tubes. For example, if a coil is formed with $\frac{3}{8}$ inch tubes the center lines of which are $\frac{5}{8}$ inch apart, the air passage between the tubes will be $\frac{2}{8}$ or

1/4 inch. However, if the same tubes are flattened to a thickness of 3/16 inch the air passage will be increased from 1/4 inch to 7/16 inch. Further, if desired, the tubes can be placed closer together so that the air passage is still 1/4 inch as before, but the overall dimensions of the coil, consisting of a

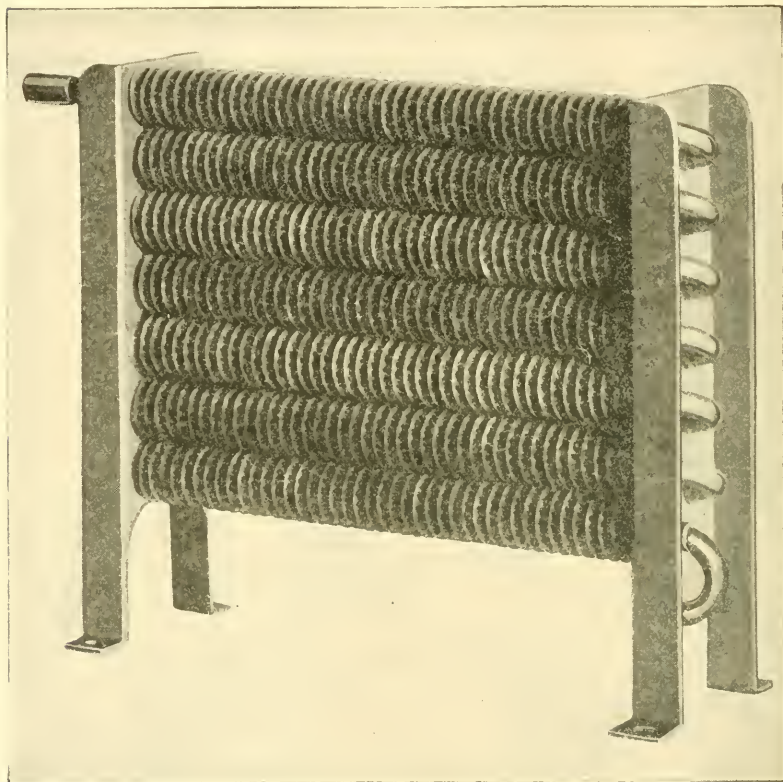


FIG. 15.—SPIRAL FIN TUBE CONDENSER.

given number of feet of tubing, will obviously be reduced. In any case it is clear that there is a definite gain in the use of flat tubes and whether or not this gain is sufficient to warrant the expense of flattening the tubes should be decided in each case.

Instead of using plain tubing for condensers, evaporators, etc., it is possible and very advisable under certain conditions

to use so-called spiral fin tubes. As the name indicates, a spiral fin, about $\frac{1}{4}$ inch wide and 0.006 to 0.008 inches thick, is wound spirally around the tube and attached to it securely

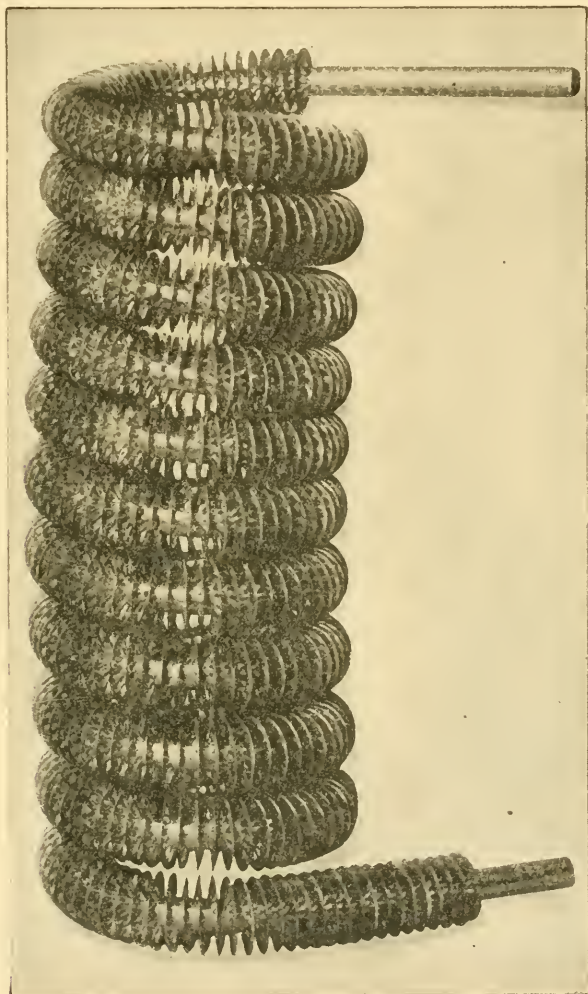


FIG. 16.—SHOWING HOW SPIRAL FIN TUBE CAN BE SHAPED.

by means of solder. The finished product is known as a spiral fin tube. Such a tube can be wound and formed into various shapes as shown in Figs. 15, 16 and 17 showing typical con-

densers made by the McCord Radiator Company of Detroit, Mich.

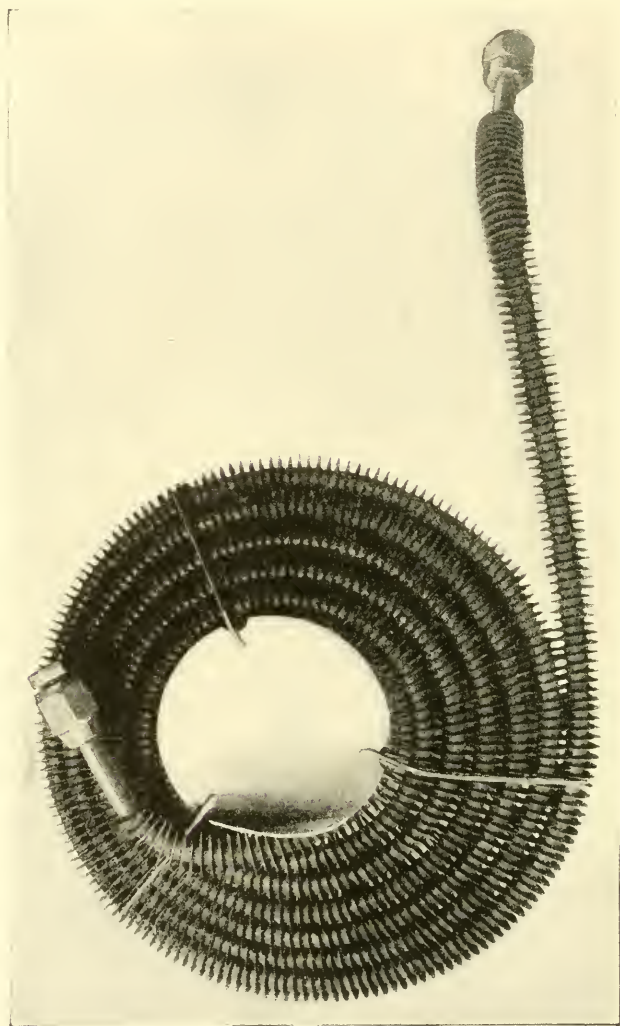


FIG. 17.—SPIRAL FIN TUBE.

A glance at Table LIV will show that the total outside surface of the spiral fin tubes is nearly seven times as large as the surface of the plain tubes from which they are made.

Since heat transfer from metal to a fluid such as air or brine depends upon the surface, it is clear that the spiral fin tube should have some advantage over the plain tube. This advantage is particularly large in such cases as that of condensing a refrigerant inside of a tube, over which a blast of air is directed by means of a fan or a blower. In a case of this kind the heat absorbed by the air per square foot of tube surface is very small compared to the heat transferred by the refrigerant to the tube. For example, if the latter is 20 times as large as the former it is clear that the factor limiting the overall heat transfer is the rate at which heat is absorbed by the air. However, suppose we increase the surface exposed to the air, while the surface in contact with the refrigerant is maintained the same; then one square foot of the inner surface of the tube will furnish heat to seven square feet of the outer surface of the tube, instead of one square foot of the outer surface, and conditions will evidently be greatly improved.

TABLE LIV—STANDARD SIZES OF FLINTLOCK CONDENSERS

| Size | Width | No. Tubes | I. D. Tubes | No. Fins | Square Inch Radiating Surface |
|-----------|--------|-----------|-------------|----------|-------------------------------|
| 6" x 6" | 1 1/4" | 18 | 1 1/32" | 43 | 609 |
| 7" x 7" | 1 1/4" | 20 | 1 1/32" | 50 | 814 |
| 8" x 8" | 1 1/4" | 24 | 1 1/32" | 57 | 1114 |
| 9" x 9" | 1 1/4" | 26 | 1 1/32" | 64 | 1364 |
| 10" x 10" | 1 1/4" | 30 | 1 1/32" | 71 | 1682 |
| 10" x 12" | 1 1/4" | 36 | 1 1/32" | 71 | 2016 |
| 12" x 12" | 1 1/4" | 36 | 1 1/32" | 85 | 2415 |
| 14" x 14" | 1 1/2" | 32 | 7/16" | 99 | 3778 |
| 16" x 18" | 1 1/2" | 36 | 7/16" | 113 | 4937 |

The heat transfer from the condensing refrigerant to the tube can very aptly be compared to a boulevard 140 feet wide, terminating at a large square which would correspond to the tube which has a high conductivity; if this square connects only with one pavement, say 20 or 30 feet wide, we shall have the case of the plain tube, but if we have seven such streets radiating from the square, we shall have the case of a spiral fin tube.

If the temperature of the fin surface were the same as the temperature of the tube surface then a square foot of the fin surface would be equivalent to a square foot of the tube surface. But this is not the case, and therefore, a spiral fin tube having one square foot of tube surface and six square feet of fin surface will have an effective heat transfer capacity of $1 + (0.60 \times 6) = (1 + 3.6) 4.6$ instead of a capacity of $(1 + 6) = 7$, assuming that the efficiency of the fin surface is 60 per cent of that of the tube, while the plain tube would have a heat transfer capacity of one.

Another advantage of the spiral fin tube is the adaptability to compact designs. If 30 feet of spiral fin tubing replace 120 feet of plain tubing, as it has been done in practice, then it is clear that there will result compactness of design, and economy of space.

Further this compactness of design makes possible the improvement and control of the air flow through the coils. A very good example of this is Fig. 18 where the round condenser can be made to cover the fan and thus use its air blast very efficiently.

Calculation of the Surface of a Spiral Fin Tube.—Consider a $3/8$ inch outside diameter tube wound spirally with a fin $1/4$ inch wide and $1/6$ inch pitch. The surface per foot length will be:

$\pi 3/8 \times 12 = 14.18$ square inches per foot length of tube. Suppose that in winding the ribbon around the tube the outside diameter is maintained at $(1/4 + 3/8 + 1/4) = 7/8$ inch, and the excess material next to the tube is crimped. Then, the length of the ribbon, per turn will be practically, $\pi (7/8)$ and its area, facing upward, $\pi (7/8) (1/4)$. Thus the total fin or indirect surface, as it is sometimes called will be:

$\pi 7/8 \times 1/4 \times 2 \times 6 \times 12 = 99$ square inches per foot length of tube. Where the factor 2 is introduced because there are two surfaces, one facing upward and the other facing downward; the factor 6 is used because we have 6 turns per inch length of tube and 12 in order to get the surface per foot

length of tube. Adding the direct and indirect or fin surface we have

$$\begin{aligned} 14.18 + 99 &= 113.18 \text{ square inches per foot length.} \\ &= 0.785 \text{ square feet per foot length.} \end{aligned}$$

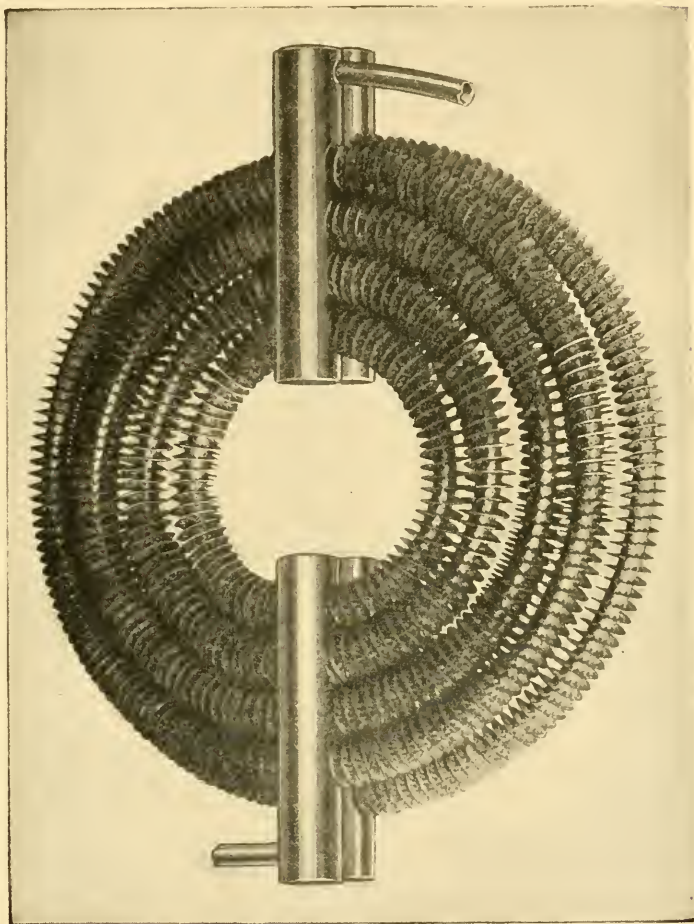


FIG. 18.—ROUND CONDENSER, DESIGNED TO COVER THE FAN.

Next suppose that instead of crimping the fin on the inside, we draw it through a die, and force it to assume a flat ring-like shape around the tube. The surface of the ring will be

$$\begin{aligned} &\pi (7/8)^2 (1/4) - \pi (3/8)^2 (1/4) \text{ or} \\ &\text{Approximately } \pi (5/8) (1/4) \end{aligned}$$

Where $5/8$ is the average diameter of the ring and $1/4$ its width. Thus the total indirect surface will be

$\pi 5/8 \times 1/4 \times 2 \times 6 \times 12 = 70.7$ square inches per foot length.

The total surface of the spiral fin tube will be $70.7 + 14.18 = 84.88$ square inches per foot length. Thus the total surface

TABLE LV—DATA ON COMMERCIAL FIN TUBES

| | Tube Sizes | | | | |
|--|------------|--------|--------|--------|--------|
| | $5/16$ | $3/8$ | $7/16$ | $1/2$ | $5/8$ |
| Outside Diameter of Tubes, inches..... | 0.312 | 0.375 | 0.437 | 0.500 | 0.625 |
| Outside surface of tubes, square inches per foot length..... | 11.78 | 14.18 | 16.49 | 18.85 | 23.56 |
| Fins per inch length of tube | 6 | 6 | 6 | 6 | 6 |
| Width of fins, inches..... | 0.187 | 0.250 | 0.250 | 0.250 | 0.250 |
| Outside surface of fins when crimped, square inches per foot length..... | 58.31 | 99.0 | 106.0 | 113.1 | 127.2 |
| Total outside surface (crimped fins), square inches per foot length.... | 70.09 | 113.18 | 122.49 | 131.95 | 150.76 |
| Square feet per foot length.. | 4.85 | 7.87 | 8.50 | 9.15 | 10.46 |
| Outside surface of fins when not crimped, square inches per foot length..... | 42.3 | 70.7 | 77.7 | 85 | 99 |
| Total outside surface (fins not crimped), square inches per foot length..... | 54.08 | 84.98 | 94.19 | 103.85 | 122.56 |
| Square feet per foot length.. | 3.76 | 5.9 | 6.54 | 7.21 | 8.72 |

of the crimped spiral fin tube is 113.2 square inches per foot length of tube, while that of the uncrimped spiral fin tube is 84.9 square inches or 75 per cent of the former.

Table LV gives in detail data on commercial spiral fin tubes, which were calculated as those outlined above.

The Evaporator.—There are two types of evaporator or cooling elements in general use. The type operating with an expansion valve is sometimes called the “dry” system. The

other type, in which a relatively larger amount of liquid refrigerant is retained in the evaporator, is the "flooded" system.

The "flooded" system has several important advantages. Heat transfer is more rapid through surfaces contacting with liquid than through surfaces contacting with a gas or a mixture of a gas and a liquid. The additional liquid refrigerant in the evaporator has a certain heat storage capacity which may prove advantageous.

A direct expansion system for a household machine usually requires a much smaller quantity of refrigerant. This is an advantage, if any danger is involved should the gas escape in the home. The direct expansion system has an advantage in giving an easier starting load when the machine is first placed in operation. This condition is very important when an air-cooled condenser is used. This system usually operates with a more uniform suction pressure, thus automatically regulating the refrigerating load more closely than with the flooded system.

It is customary to control the supply of liquid refrigerant to the flooded system by a float valve. A float on the liquid refrigerant surface drops when the liquid refrigerant is vaporized and removed by the compressor. This opens a valve, allowing sufficient liquid to enter the evaporator to maintain the liquid level required by the float to close the valve.

This valve may be placed in a reservoir forming part of the flooded evaporator, or in the liquid sump or reservoir below the condenser. When the valve is placed outside of the refrigerator, it is necessary to insulate the liquid line to the evaporator. In order to avoid this insulated line, most designs show this valve located in a header forming part of the cooling unit.

An evaporator in common use consists of pipes or tubes immersed in a solution of calcium or salt brine contained in a sheet-metal tank. This tank is placed in the ice compartment of a refrigerator and usually functions at a surface temperature colder than ice.

The average brine temperature found to be suitable for household refrigerators is about 20° F. The temperature may vary as much as 10° above or below this amount during the

operating period without any objectionable results in operation. It has been found that with a 20° F. average brine temperature, ice and desserts can be frozen in quantities sufficient for household use within the shortest time intervals between meals, that is, five or six hours.

Experience has indicated that the food compartment of the average ice refrigerator will accommodate a large enough brine tank for the cooling with a 20° brine tank surface.

There are three principal factors involved in determining the amount of cooling performed by the evaporator:

1. Amount of effective evaporator surface.
2. Temperature of evaporator surface.
3. Rate of air circulation in the cabinet.

A brine tank will usually maintain a food compartment temperature under 50° F. under usual service conditions. If the brine tank has a surface equivalent to the average ice surface, it should, of course, produce lower food compartment temperatures, as the 20° F. brine tank surface is 12° colder than ice.

Some manufacturers use an evaporator made of pipes or tubing directly exposed to the air. This system eliminates the brine. Much difficulty has been experienced in making tanks to hold the brine solution, as there is a chemical and electrolytic action which frequently causes tanks to leak. This effect is especially bad with copper and solder exposed to the action of calcium chloride brine.

The brineless evaporator usually has a smaller heat storage capacity. However, with an automatic machine, this is not considered so important, as frequent operation is not objectionable. Sometimes this heat storage condition is improved by the addition of a heavy cast-iron sleeve to contain the ice trays and to also serve as a heat storage element.

A large amount of refrigerant is stored in the evaporator by some manufacturers to function as a heat storage capacity. When the heat storage capacity of the evaporator is relatively low, the cycles of operation are usually lengthened by increasing the temperature differential of the evaporating unit. A brine system might operate with a brine differential temperature of 4° (22°—18°). Nearly the same results would

be obtained on a brineless evaporator, say of half the heat storage capacity, but with a temperature differential of 8° (24°—16°). There would be some loss in efficiency in the latter case, as the compressor operates at lower efficiency at the lower suction pressure required to cool to 16° F. rather than 18° F.

It is very important to properly place the evaporator in the ice compartment. It should not project above or block the warm air flues. The warm air entering these flues should pass over the top of the evaporator with little or no restriction, so that it can drop along the four sides of the brine tank to replace the cold air passing out of the compartment. The sides of the evaporator should clear all side walls by at least two and, preferably, three inches. The clearance at the bottom should be at least three inches and preferably more.

The frost collecting on the evaporator sometimes interferes with the normal operating of the refrigerating system. As the evaporating surface is usually below 32°, moisture from the circulating air is deposited and freezes to the cold surfaces of the evaporator. This frost will gradually build up unless the evaporating surface temperature reaches 32° F. during the inoperative period of the cycle. This layer of frost acts as a heat insulator and increases the temperature in the food compartments. It is customary to stop the mechanical unit for certain periods every few weeks to permit this frost to melt off the evaporating surface.

It is an advantage to have an evaporator which will function so that the surface will have a high enough temperature to defrost each inoperative period of the refrigerating cycle. Some of the most important advantages are:

1. Eliminates food odors from cabinet.
2. Cooling element operates more efficiently.
3. Cooling effect more uniform.

The water vapor in the circulating air absorbs large quantities of gases and odors from the foods. Some of this water vapor is constantly being condensed on the surface of the cooling element. It is preferable to discharge this water to the drain as soon as possible. Freezing the water liberates a large per cent of the gases. Therefore the circulating air

will be greatly benefited if the condensed water vapor is discharged to the drain each inoperative period.

| | B.t.u. per pound water vapor |
|--|---------------------------------|
| 1. To cool water vapor (50° to 32°)..... | 18 |
| 2. To condense water vapor..... | 970 |
| 3. To freeze water vapor..... | 144 |
| 4. To cool ice or frost (32°—20°)..... | 6 |
| Total | <u>1,138</u> |

It requires a relatively large quantity of heat to condense, freeze, and cool the water vapor deposited on the evaporator surface, as shown in the table on the preceding page.

The heat loss under Items 1 and 2 are necessary in order to have a dry food compartment with a relative humidity of approximately 60 to 80 per cent.

The heat loss under Items 3 and 4 could be saved by operating the evaporator at a surface temperature so that it will automatically defrost during the inoperative part of the cycle.

The efficiency of the evaporator surface for cooling the circulating air gradually decreases as the thickness of the layer of frost on it increases. The ice acts as a heat insulator. It is estimated that a layer of frost $\frac{1}{2}$ inch in thickness will decrease the effectiveness of the cooling surface about twenty per cent.

Much difficulty has been experienced in returning lubricant from the evaporator to the compressor. In the usual household system there is a tendency for the lubricant to enter the evaporator, while if no special method is used for its return to the compressor it may collect in excessive quantities in the evaporator. An excessive amount of lubricant in the evaporator will reduce its heat-absorbing efficiency. Some household plants have a special oil return system, while others use oil traps to prevent this condition. It is an advantage to have the evaporator located above the compressor so that any oil in the suction line will drain to the compressor.

The rate of heat transmission between the coil and the brine in a direct expansion type of brine tank is from ten to fifteen B.t.u. per square foot per degree F. per hour. In a

flooded type tank the rate of heat transfer is about double this amount.

When direct expansion coils are used to cool unagitated air the rate of heat transmission is $1\frac{1}{2}$ to 2 B.t.u. per square foot per degree F. per hour. With brine pipes the rate is 2 to $2\frac{1}{2}$ B.t.u.

In designing an evaporator it is of importance to note the relative thermal conductivity of the following materials:

| | | |
|--------------------------------|---|-------|
| Corkboard | = | 1. |
| Half inch air space..... | = | 1.54 |
| One inch air space..... | = | 1.56 |
| Water | = | 13. |
| Brine (calcium or sodium)..... | = | 15. |
| Ice | = | 54. |
| Iron | = | 1400. |
| Copper | = | 8600. |

Brine Tank Data.—Table LVI gives the properties of solution of calcium chloride in water. The gravity expressed in degrees Beaumé and in degrees salometer, per cent of calcium chloride, freezing point in degrees F., and the corresponding ammonia gauge pressure in pounds per square inch (corresponding to the freezing point) are given.

Table LVII gives data on the properties of solutions of common salt (sodium chloride) in water.

Table LVIII gives interesting brine tank data, relative to the heat-storing capacity and cost of various materials, which might be used to replace calcium chloride or sodium chloride brine. Specific gravity, specific heat, B.t.u. heat-storing capacity per pound of material in cents, and B.t.u. stored for each cent cost of material are given for some common substances, such as calcium and salt brine, water, cast iron, lead, copper, aluminum, concrete, sandstone, paraffin, oil, and kerosene. In reference to the heat stored per pound of material, it will be noted that water has the highest value. This is, of course, due to the high specific heat. Oil and kerosene are lowest, with approximately 0.4 B.t.u. per pound of material. In reference to the cost of material, it will be observed that the sandstone has the smallest cost, with sodium and calcium chloride brine next, and with aluminum as the highest cost. In reference to the B.t.u. stored for each cent cost of materials,

it will be noted that lead has the lowest value, this being 0.006, and that sandstone is the highest, with the value of 4.4 B.t.u.

TABLE LVI.—PROPERTIES OF SOLUTION OF CALCIUM CHLORIDE IN WATER

| Specific Gravity at 60°F. | Per Cent Pure Calcium Chloride | Freezing Temp. Degree F. | Lbs. of Calcium Chloride Crystals (73 to 75%) in one Gal. of Brine | Weight, lbs. per Gal. at 60°F. |
|------------------------------|-----------------------------------|-----------------------------|---|-----------------------------------|
| 1.000 | 0.00 | 32.00 | .... | 8.33 |
| 1.010 | 1.40 | 31.50 | .... | 8.44 |
| 1.020 | 2.30 | 30.50 | .... | 8.50 |
| 1.030 | 3.80 | 29.50 | .... | 8.59 |
| 1.040 | 5.00 | 27.50 | .... | 8.67 |
| 1.050 | 6.20 | 26.00 | .... | 8.76 |
| 1.060 | 7.20 | 24.75 | .... | 8.84 |
| 1.070 | 8.20 | 23.75 | .... | 8.92 |
| 1.080 | 9.60 | 22.50 | .... | 9.00 |
| 1.090 | 10.60 | 21.00 | .... | 9.10 |
| 1.100 | 11.80 | 18.50 | 1.43 | 9.18 |
| 1.110 | 12.80 | 16.50 | 1.60 | 9.25 |
| 1.120 | 13.80 | 14.50 | 1.75 | 9.34 |
| 1.130 | 15.00 | 12.00 | 1.88 | 9.42 |
| 1.140 | 16.00 | 10.30 | 2.05 | 9.49 |
| 1.150 | 17.20 | + 7.52 | 2.18 | 9.58 |
| 1.160 | 18.30 | + 3.75 | 2.35 | 9.67 |
| 1.170 | 19.20 | + 1.50 | 2.50 | 9.77 |
| 1.175 | 19.85 | - 1.50 | 2.56 | 9.80 |
| 1.180 | 20.20 | - 2.50 | 2.65 | 9.85 |
| 1.190 | 21.20 | - 5.50 | 2.80 | 9.93 |
| 1.200 | 22.20 | - 9.50 | 2.95 | 10.00 |
| 1.210 | 23.20 | -14.00 | 3.10 | 10.09 |
| 1.220 | 24.20 | -18.00 | 3.30 | 10.16 |
| 1.230 | 25.10 | -23.50 | 3.45 | 10.22 |
| 1.240 | 26.00 | -27.04 | 3.60 | 10.34 |
| 1.250 | 27.00 | -32.62 | 3.76 | 10.42 |
| 1.260 | 27.85 | -39.00 | 4.00 | 10.52 |
| 1.270 | 28.80 | -44.50 | 4.10 | 10.60 |
| 1.280 | 29.70 | -52.50 | 4.35 | 10.68 |
| 1.290 | 30.60 | -54.40 | 4.50 | 10.76 |
| 1.300 | 31.60 | -42.50 | 4.70 | 10.84 |
| 1.310 | 32.40 | -32.50 | 4.90 | 10.92 |
| 1.320 | 33.40 | -17.00 | 5.10 | 11.00 |
| 1.330 | 34.20 | - 4.00 | 5.25 | 11.08 |
| 1.340 | 34.50 | + 3.50 | 5.40 | 11.16 |
| 1.350 | 36.10 | +14.37 | 5.60 | 11.23 |

From "Practical Refrigerating Engineers' Pocketbook," Nickerson & Collins Co.

The freezing points of some brine tank solutions are given by Fig. 8. Curves showing the freezing points as the percentage by volume of solute are given for glycerin, denatured alcohol, calcium chloride, and one-half wood alcohol and one-half glycerin.

Prime Mover.—Electric motors are used to drive practically all household refrigerating machines. Most of the machines

TABLE LVII.—PROPERTIES OF SALT (SODIUM CHLORIDE) SOLUTIONS
IN WATER

| Specific Gravity at 39°F. | Pct Cent of Sodium Chloride | Freezing Temp. Degree F. | Weight, Lbs. per Gallon | Specific Heat |
|------------------------------|--------------------------------|-----------------------------|----------------------------|---------------|
| 1.010 | 1.5 | 30.25 | 8.44 | 0.986 |
| 1.020 | 2.6 | 28.40 | 8.50 | 0.979 |
| 1.030 | 4.0 | 26.60 | 8.59 | 0.968 |
| 1.040 | 5.2 | 25.20 | 8.67 | 0.958 |
| 1.050 | 6.5 | 23.40 | 8.76 | 0.945 |
| 1.060 | 7.8 | 21.60 | 8.84 | 0.936 |
| 1.070 | 9.1 | 19.90 | 8.92 | 0.922 |
| 1.080 | 10.4 | 18.40 | 9.00 | 0.912 |
| 1.090 | 11.8 | 16.40 | 9.10 | 0.902 |
| 1.100 | 13.0 | 14.60 | 9.18 | 0.886 |
| 1.110 | 14.1 | 13.4 | 9.25 | 0.876 |
| 1.120 | 15.5 | 11.6 | 9.34 | 0.865 |
| 1.130 | 16.8 | 10.0 | 9.42 | 0.856 |
| 1.140 | 18.0 | 8.6 | 9.49 | 0.846 |
| 1.150 | 19.2 | 7.0 | 9.58 | 0.832 |
| 1.160 | 20.5 | 5.9 | 9.67 | 0.824 |
| 1.170 | 21.8 | 3.8 | 9.77 | 0.817 |
| 1.180 | 23.0 | 2.4 | 9.85 | 0.806 |
| 1.190 | 24.3 | 1.0 | 9.93 | 0.794 |
| 1.191 | 24.5 | + 0.8 | 9.94 | 0.792 |
| 1.200 | 25.6 | + 0.2 | 10.00 | 0.776 |
| 1.204 | 26.0 | - 1.1 | 10.04 | 0.771 |

This table varies slightly from 4°F. to 20°F. from those usually published, which are considered more correct. The differences would affect only calculations on congealing tanks, as it is customary in ice making to make the brine as strong as possible, or near 25% or 26%.

From "Practical Refrigerating Engineers' Pocketbook," Nickerson & Collins Co.

TABLE LVIII.—BRINE TANK DATA

Relative heat storing capacity and cost of various materials which might replace calcium or salt brine.

| Material | Specific Gravity | Specific Heat | B.t.u. Heat Storing Capacity per Pound of Material | Cost per Pound of Material Cents | B.t.u. Stored for Each Cent Cost of Materials |
|---------------|---------------------|------------------|--|---|--|
| Salt brine | 1.2 | 0.78 | 0.93 | 0.5 | 1.9 |
| Calcium Brine | 1.2 | 0.70 | 0.84 | 0.5 | 1.68 |
| Water | 1.0 | 1.00 | 1.00 | ..... | ..... |
| Cast Iron | 7.1 | 0.13 | 0.92 | 5.0 | 0.18 |
| Lead | 11.4 | 0.03 | 0.34 | 6.0 | 0.006 |
| Copper | 8.9 | 0.093 | 0.83 | 20.0 | 0.041 |
| Aluminum | 2.6 | 0.22 | 0.57 | 30.0 | 0.019 |
| Concrete | 2.2 | 0.25 | 0.55 | 0.14 | 3.9 |
| Sandstone | 2.2 | 0.20 | 0.44 | 0.1 | 4.4 |
| Paraffin | 0.9 | 0.69 | 0.62 | 10.0 | 0.062 |
| Oil | 0.9 | 0.4 | 0.36 | 6.0 | 0.06 |
| Kerosene | 0.8 | 0.5 | 0.40 | 2.0 | 0.20 |

on the market today use $\frac{1}{4}$ horse power motors. This size motor with a reasonably efficient refrigerating system should be capable of refrigerating properly fifty cubic feet of food storage space. Refrigerating systems of this capacity in use today require from three to six times the amount of current necessary to perform this duty on a large commercial plant. More efficient machines should be developed; however, it is not necessary to very closely approach the efficiency of the large plant.

Some machines have been placed on the market using $\frac{1}{6}$ horse power motors. This size has now proven successful for the smaller units up to twenty cubic feet of food storage space.

It is assumed that the food storage spaces are properly insulated. For food compartment temperatures of 40° - 50° F., the insulation should be at least 3 inches thickness of cork-board or its equivalent.

The starting torque and the overload capacity are important features in the choice or design of the motor. The overload may be double the normal operating load and it may be necessary to operate at this overload for several hours. This condition usually occurs when the machine is placed in operation in a warm environment temperature. The starting torque is high when the unit is first placed in operation on account of the high pressure on the evaporating side of the system. In normal operation the starting torque may be greatly increased if either the expansion valve or the compressor discharge valve leaks. Air-cooled machines have a more severe starting condition than water-cooled machines especially when a dead air condenser is used.

It is customary to use repulsion-induction type of a.c. motors for driving household refrigerating machines because of their relatively high starting torque. Split-phase motors have been used to a very limited extent on some of the smaller machines.

Some machines have been made with the entire motor housed inside a gas tight metal casing, thus eliminating the packing of a drive shaft. Considerable difficulty has been experienced, however, in operating a motor enclosed with the

refrigerant gas. A later design has the stator outside a thin metal casing, the rotor being inside, thus eliminating packing a drive shaft.

Lubrication of the motor is an important feature as it usually operates from six to twelve hours a day. With this service condition, the motor should be oiled at least once a month. Some motors are oiled automatically through copper tube lines from a gear case pump; the oil is forced or splashed into the tube by the rotating gear. This method is only applicable on a direct-connected motor compressor unit.

The efficiencies of fractional horsepower alternating current motors of the repulsion-induction type at full rated load are usually within the following limits:

| Horsepower | Efficiency per cent |
|---------------------|---------------------|
| $\frac{1}{6}$ | 50-60 |
| $\frac{1}{4}$ | 60-75 |
| $\frac{1}{2}$ | 65-80 |

Direct current motors should have efficiencies considerably higher than given in this table.

It is customary to limit the normal operating load to 300 watts on the $\frac{1}{4}$ hp. and to 200 watts on the $\frac{1}{6}$ hp. size. These motors will usually stand 100 per cent overload for short periods of operation.

Table LIX gives the ampere ratings of alternating current motors of capacities ranging from $\frac{1}{4}$ to 5 hp. on both single and three-phase current, at 110 and 120 volts.

TABLE LIX—AMPERE RATING OF ALTERNATING CURRENT MOTORS

| SINGLE PHASE | | | THREE PHASE | |
|----------------|-----------|-----------|-------------|-----------|
| Horsepower | 110 Volts | 220 Volts | 110 Volts | 220 Volts |
| $\frac{1}{4}$ | 4 | 2 | ..... | ..... |
| $\frac{1}{2}$ | 7.5 | 3.75 | 4.4 | 2.2 |
| $\frac{3}{4}$ | 10 | 5 | ..... | ..... |
| 1 | 12.5 | 6.25 | 8 | 4 |
| $1\frac{1}{2}$ | 18 | 9 | 10.3 | 5.1 |
| 2 | 24 | 12 | 12.5 | 6.25 |
| 3 | 34 | 17 | 18 | 9 |
| 4 | 43 | 22 | 24 | 12 |
| 5 | 55 | 28 | 30 | 15 |

The Drive.—Some of the more important types of drives in use are: belt, gear, and direct.

The belt drive has several important advantages. It gives an easier starting torque than a direct-connected or gear drive. Some motors operate at a rather small load and therefore at a low efficiency, simply because they must be large enough to insure starting under all conditions of service. The belt also gives a certain protection to the motor, as it will sometimes slip or come off the pulleys with an excessive overload on the motor. Another important advantage of a belt drive is that it can be easily repaired or replaced without the services of an expert mechanic.

A belt drive generally costs less than a gear drive. The belt drive is easier to manufacture and assemble as it does not require such close limits on lining up the motor.

Some machines use a series of from two to five small belts. If one breaks it does not greatly affect operation. This multiple belt system has not proven very satisfactory in actual use, probably because one of the belts is usually driving more than its share of the load.

A belt drive is ordinarily from 95 to 98 per cent efficient. This is a much higher efficiency than is usually obtained with a gear drive.

An exposed belt drive is dangerous on a machine which starts automatically, and every precaution should be taken to safeguard it. One method of obtaining this result is to make the condenser coil of tubing and arranging it so as to form a guard around the belt and its pulleys.

Flat belts have been used on a large number of successful machines. They are generally made of either leather, canvas, or fabric.

An idler is generally used with a flat belt drive. It is necessary in order to increase the angle of contact on the motor pulley. The idler is usually operated by a spring or a weight. It also serves another purpose in automatically keeping the belt tight by compensating for any stretching of the belt in service. One cannot depend upon attention being given to a belt by the user, especially in the way of making adjustments. One of the difficult features on a flat belt drive is to insure necessary lubrication of the idler pulley.

The V-type rubber or fabric belt as developed for use in driving the radiator fan on automobiles is being used with success on household plants. It has most of the features of a flat belt with the added advantage of not requiring an idler pulley. A belt of this type drives by means of friction on the side of the V-shaped groove. The inside face of the belt should not touch the pulley. These belts are generally of the endless type, they run quite loose and do not stretch enough in service to require any adjustment of pulley centers.

Spiral gear drives are used on compressors both with parallel and right angle shafts.

Spiral gears have an advantage over worm gears in that they do not require as close limits on shaft centers and can be made without a hob.

Gear drives produce end thrust on the shafts which is usually carried on a thrust or ball bearing. It is difficult to keep the end clearance on shafts, subjected to a thrust load, to a small enough limit so that the noise from end play on the shafts will not be objectionable.

The thrust bearings should be well lubricated. The starting torque may sometimes be greatly increased when the thrust bearings have not received instant lubrication on starting. This may occur when the thrust bearings are lubricated by a splash system which does not function until the machine has started to operate.

It has been difficult to build gear drives for the reciprocating type compressors so that excessive noise would not result on account of backlash caused by the necessary clearance between the teeth.

Gear drives usually operate at an efficiency of 70 to 90 per cent.

The direct-connected drive is in common use on machines having a gear or rotary pump and on machines with the moving parts enclosed in the refrigerant gas space. Most of the designers have placed the packing gland on the relatively slow-speed compressor shaft, as it is more difficult to pack the motor shaft which rotates at a much higher speed. When the motor or the moving part of the motor is enclosed in the gas space, this packing gland trouble is eliminated. Difficulties have been experienced in starting machines which have

a thin metal shell between the rotor and field of the motor, especially on three-phase, alternating-current motors.

The direct-connected unit has proven more successful commercially in Europe than in the United States.

Valves.—The suction and discharge valves should be designed for service, quietness, positive opening and closing action, and efficiency.

The suction valve is usually simply a port or slot in the cylinder wall which is uncovered by the piston during its relatively slow rate of travel at the end of the stroke. This type of valve has a relatively low efficiency but is free from service troubles, operates quietly, and is positive in action.

The port valve has a loss in efficiency due to the necessity of producing a vacuum in the cylinder, as the top of the piston returns on the suction stroke. The gas rushes in the cylinder at the end of the stroke during the short interval of time that the port is uncovered by the piston sometimes causing wire drawing, a further loss in efficiency.

The port valve can be used to good advantage on compressors with lapped pistons, as some difficulty has been experienced in using piston rings which must pass over ports in the cylinder walls.

A floating valve of the poppet type is used in the pistons of some of the larger compressors. These valves have not proven so successful as the port type, as a small particle of scale, sand, carbon or dirt can be deposited on the seat and will prevent the valve closing tightly. This frequently happens on a new machine and is prevented to a certain extent by placing a fine mesh screen in the suction line of the compressor.

Some designs use a slight rotating movement of the cylinder itself to uncover ports.

Many varieties of discharge valves are used. These are simply check valves permitting low-pressure gas to enter the cylinder on the suction stroke.

The poppet type valve has proven successful with a light spring to assist in closing. Disc steel valves are also used. These are more difficult to manufacture than the poppet type, however they make less noise.

The steel spring flapper valve is used to a considerable extent. These valves require very close limits in manufacture. They give good service once they are assembled properly, and are not easily affected by corrosion or dirt.

The discharge valve should be capable of opening more than the normal lift, in order to discharge liquid refrigerant or lubricant which is sometimes pumped by the compressor.

An important feature to be considered in valve design, is to construct a valve which will give service for years without requiring adjustments or service of any kind. A service call is quite expensive and with most of the refrigerating gases in common use, such repairs can only be made by a trained service man. This is probably the fundamental reason for using port suction valves even at large loss in efficiency, by some of the most successful manufacturers.

Shut-off valves are very important in order to facilitate repairs to a certain part of the refrigerating system. It is customary to use three of these valves, one on the suction or inlet line to the compressor, one on the discharge line between the compressor and condenser, and the third between the condenser and expansion valve. The valves near the compressor usually have double seats so that they may be closed against a gauge or charging connection.

It is important to have the valve stem opening limited by a stop to prevent backing out the stem and thus losing some of the refrigerant. When the refrigerating system is not used for a period of weeks, it is sometimes advisable to close the two valves on the compressor, suction, and discharge lines, to prevent loss of refrigerant through the packing gland.

Alco Liquid Control Valve.—Fig. 19 is a cross-section of the automatic liquid control valve manufactured by the Alco Valve Company, at St. Louis, Mo.

The liquid refrigerant enters at F. In operation the valve needle J opens from the valve seat G and the liquid refrigerant discharges through tube K.

These discharge tubes are furnished in different sizes for different capacity machines.

Expansion of the refrigerant is prevented in the valve body by using the small discharge tube K. It is claimed that this

feature eliminates the following troubles experienced with the regular type expansion valve.

1. Frost forming on the valve.
2. Water freezing on the diaphragm.
3. Oil congealing in the valve.
4. Scoring of pin or seat.

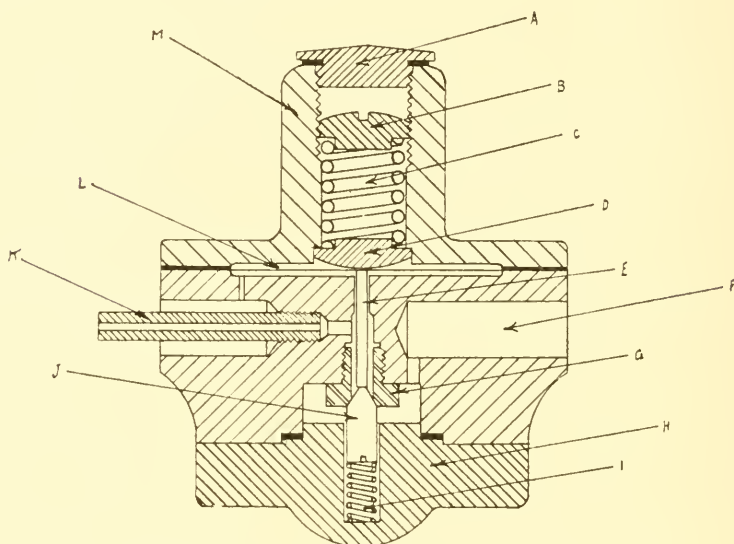


FIG. 19.—CROSS SECTION ALCO LIQUID CONTROL VALVE.

American Automatic Expansion Valve.—Fig. 20 shows the automatic expansion valve made by the American Radiator Company of Buffalo, N. Y.

These valves are designed for use with the following refrigerants: Methyl chloride, sulphur dioxide, ethyl chloride, or any refrigerant not having a detrimental effect on brass.

Fig. 21 is a sectional view of this valve. Adjustment is made by turning the adjusting screw, regulating the spring pressure against the bellows.

The valve closes against pressure, thereby eliminating chattering and wire drawing, and making the valve seat self-cleaning.

Pressure is on the outside of the bellows, a desirable construction feature.

Valves are supplied with 3/8-inch pipe thread or flanged connections.

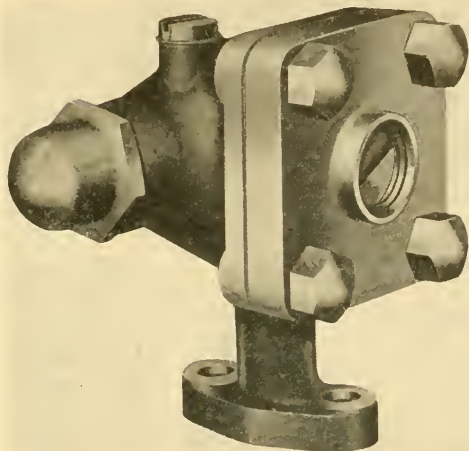


FIG. 20.—AMERICAN AUTOMATIC EXPANSION VALVE.

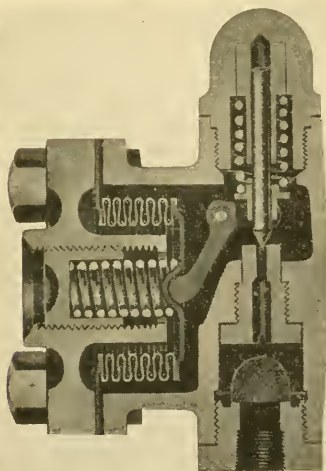


FIG. 21.—SECTIONAL VIEW OF AMERICAN AUTOMATIC EXPANSION VALVE.

American Float Valve and Refrigerating Section.—Fig. 22 shows the float valve which may be used either as a low or high pressure float.

The float is cylindrical, thereby making the valve more compact than is the case when the usual bulb type is used.

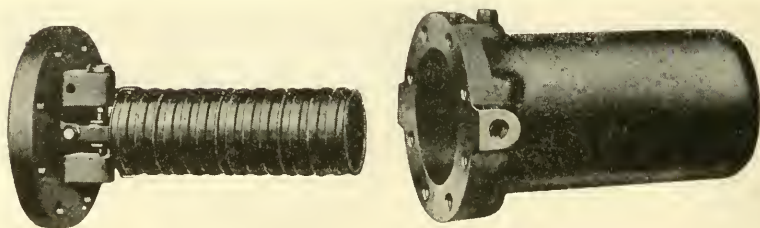


FIG. 22.—AMERICAN FLOAT VALVE.

A new style of domestic refrigerating section is now manufactured as in Fig. 23. This section is made in two types, one as illustrated, containing the float chamber, and a similar type

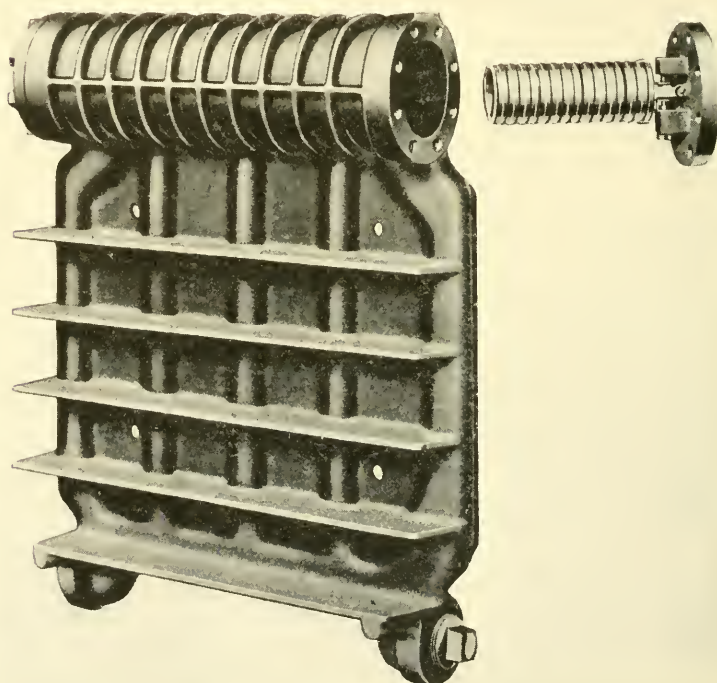


FIG. 23.—AMERICAN REFRIGERATING SECTION

without the float chamber. These are made for five or seven ice trays, each tray containing eight cubes, one cube wide and eight cubes deep.

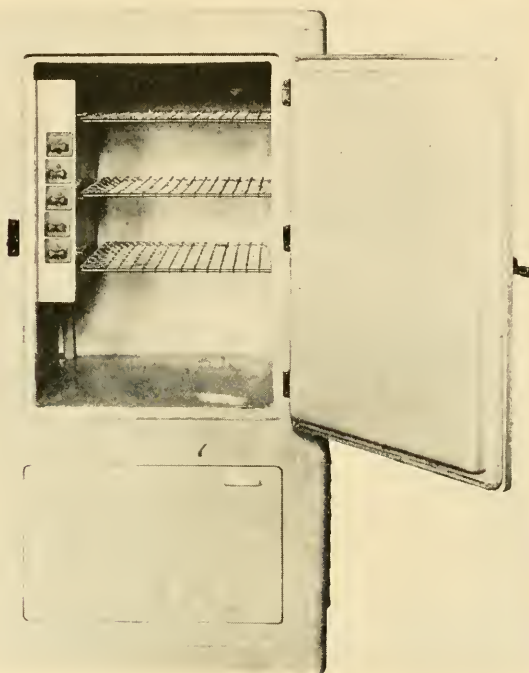


FIG. 24.—AMERICAN REFRIGERATING SECTION INSTALLED.

Fig. 24. shows one of these refrigerating sections installed in a cabinet. This design gives more space in the refrigerator for the storage of food than cooling units of conventional design.

Flow of Air Through Orifices.—Table LX gives the amount of free air in cubic feet which will flow through circular orifices in a receiver into air at atmospheric pressure, corresponding to various air gauge pressures in pounds per square inch in the receiver. The diameter of the orifices varies from $1/64$ in. to 2 ins.

HOUSEHOLD REFRIGERATION

TABLE LX.—CUBIC FEET OF FREE AIR FLOWING THROUGH A CIRCULAR ORIFICE FROM RECEIVER INTO ATMOSPHERE PER MINUTE (Cox)

| Diameter of Orifice—Inches | Air Gauge Pressure in Pounds | | | | | | | | | |
|----------------------------|------------------------------|-------|-------|-------|-------|------|------|------|--|--|
| | 2 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | | |
| $\frac{1}{64}$ | .038 | .0597 | .0842 | .103 | .119 | .133 | .156 | .173 | | |
| $\frac{1}{32}$ | .153 | .242 | .342 | .418 | .485 | .54 | .632 | .71 | | |
| $\frac{1}{16}$ | .647 | .965 | 1.360 | 1.67 | 1.93 | 2.16 | 2.52 | 2.80 | | |
| $\frac{1}{8}$ | 2.435 | 3.86 | 5.45 | 6.65 | 7.70 | 8.60 | 10.0 | 11.2 | | |
| $\frac{1}{4}$ | 9.74 | 15.40 | 21.8 | 26.70 | 30.80 | 34.5 | 40. | 44.7 | | |
| $\frac{3}{8}$ | 21.95 | 34.60 | 49. | 60. | 69. | 77. | 90. | 100. | | |
| $\frac{1}{2}$ | 39. | 61.60 | 87. | 107. | 123. | 138. | 161. | 179. | | |
| $\frac{5}{8}$ | 61. | 96.50 | 136. | 167. | 193. | 216. | 252. | 280. | | |
| $\frac{3}{4}$ | 87.60 | 139. | 196. | 240. | 277. | 310. | 362. | 400. | | |
| $\frac{7}{8}$ | 119.50 | 189. | 267. | 326. | 378. | 422. | 493. | 550. | | |
| 1 | 156. | 247. | 350. | 427. | 494. | 550. | 645. | 715. | | |
| $1\frac{1}{4}$ | 242. | 384. | 543. | 665. | 770. | 860. | 1000 | | | |
| $1\frac{1}{2}$ | 350. | 550. | 780. | 960. | | | | | | |
| 2 | 625. | 985. | | | | | | | | |

| Diameter of Orifice—Inches | Air Gauge Pressure in Pounds | | | | | | | | | |
|----------------------------|------------------------------|------|-------|------|------|--------|-------|------|------|--|
| | 40 | 45 | 50 | 60 | 70 | 80 | 90 | 100 | 125 | |
| $\frac{1}{64}$ | .190 | .208 | .225 | .26 | .295 | .33 | .364 | .40 | .486 | |
| $\frac{1}{32}$ | .77 | .843 | .914 | 1.05 | 1.19 | 1.33 | 1.47 | 1.61 | 1.97 | |
| $\frac{1}{16}$ | 3.07 | 3.36 | 3.64 | 4.20 | 4.76 | 5.32 | 5.87 | 6.45 | 7.85 | |
| $\frac{1}{8}$ | 12.27 | 13.4 | 14.50 | 16.8 | 19. | 21.2 | 23.50 | 25.8 | 31.4 | |
| $\frac{1}{4}$ | 49.09 | 53.8 | 58.2 | 67. | 76. | 85. | 94. | 103. | 125. | |
| $\frac{3}{8}$ | 110.45 | 121. | 130. | 151. | 171. | 191. | 211. | 231. | 282. | |
| $\frac{1}{2}$ | 196.35 | 215. | 232. | 268. | 304. | 340. | 376. | 412. | 502. | |
| $\frac{5}{8}$ | 306.80 | 336. | 364. | 420. | 476. | 532. | 587. | 645. | 785. | |
| $\frac{3}{4}$ | 441.79 | 482. | 522. | 604. | 685. | 765. | 843. | 925. | | |
| $\frac{7}{8}$ | 601.32 | 638. | 710. | 822. | 930. | 1,040. | | | | |
| 1 | 785.40 | 860. | 930. | | | | | | | |

Temperature Control.—The automatic temperature control is an important part of the refrigerating system.

The food compartments should be maintained at a temperature never warmer than 50° F. and never colder than 40° F. These temperature limits have been definitely established by experience. Perishable foods keep well at a temperature below 50° F. Food compartment temperatures below 40° F. will cause unnecessary heat losses even with a well-insulated cabinet, and the outside surface of the cabinet will frequently be damaged by sweating.

The automatic control should be arranged to freeze water or desserts in a reasonable length of time, and to constantly maintain the food compartment temperatures between 40° and 50° F.

It is desirable to freeze water or desserts in less than the shortest time interval between meals which is about six hours. An average brine temperature of 20° F. will freeze water in the ordinary cube form in from four to six hours. The temperature should not vary more than four degrees from this value. It is more difficult to freeze desserts than water, especially if the ice tray grids are removed.

Some of the first mechanical refrigerators sold had the liquid tube of the thermostat line suspended in the cold air flue. This liquid tube was connected by tubing to a diaphragm or metal bellows which operated the motor switch.

A 1/4-hp. motor was generally used and this required a quick make and break type of switch. This was called the food compartment temperature control system.

Some of the volatile liquids used in these thermostat systems were: Sulphur dioxide, methyl chloride, ethyl chloride, and ether.

The usual method of operating the switch is by means of a volatile liquid. This liquid is trapped in a closed gas system, so that the liquid tube itself is always immersed in the brine or in close contact with the place where the temperature is to be regulated. The diaphragm or metal bellows can be placed above or below this liquid trap. The gas pressure in the closed system is always definitely determined by the temperature of the volatile liquid. The switch can be adjusted

to operate at any desired temperature, within the working range of the liquid used.

An improvement in the brine temperature regulating system is to use an automatic damper in the cold air flue. This

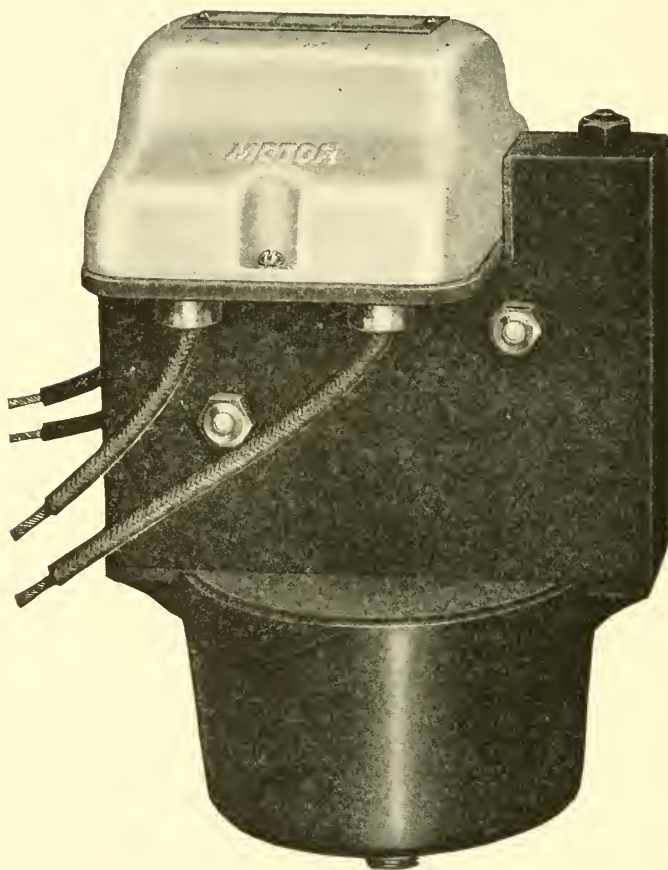


FIG. 25.—PENN ELECTRICAL CONTROL.

damper opens and increases the air circulation when the food compartment temperature increases.

Another method of improving this temperature control, is to have the liquid tube located close to the last turns of the evaporating coil. Then if the evaporating coil frosts through, the liquid controlling the temperature in the thermostat will be rapidly cooled, thus stopping the compressor.

Other manufacturers use a temperature control partly influenced by the temperature of the brine and partly by the temperature of the circulating air. This kind of regulation has advantages of both of the systems previously described.

Some machines are operated by a time clock. The clock operates a switch and can be set for a certain number of cycles per day. Usually this type of control is adjusted for a summer or winter condition. This system does not compensate for cold nights and gives rather unsatisfactory food compartment temperature regulation.

Some switches are operated by using a bimetallic thermostat. The small temperature differential, usually from 4° to 10° F., makes the design of a bimetallic thermostat a difficult problem. Switches of this type have not proven a success commercially.

An improvement in the bimetallic switch is being used now. It consists of mounting to a bimetallic member a glass tube, containing a small amount of mercury which flows from one end to the other. In this way a quick make and break contact is secured. These tubes have the air exhausted from them and contain an inert gas so that any arcing will not affect the mercury or terminal contact points.

Fig. 25 shows a switch made by the Penn Electric Machine Co., of Des Moines, Ia.

This switch is provided with a bellows type diaphragm, which can either be filled with a volatile fluid or attached to a bulb, which contains the volatile fluid and which causes the diaphragm to expand, closing the switch contacts when the temperature increases to the predetermined amount.

The switch may be placed inside or outside the refrigerator. When placed outside, the bulb containing the volatile fluid is inside at the desired location for proper temperature control. This installation simplifies the wiring connections.

The contacts are of the two-pole double break per line type. The switch is approved by Underwriters for use on motors up to 5 hp., 3-phase, 550-volts.

This type switch is compact, easily installed, and convenient for wiring.

Thermostat Operation.—Figs. 26 and 27 show the operation of a volatile liquid thermostat.

The volatile liquid is contained in a tube immersed in the brine. Sufficient liquid is placed in this tube so that at the highest operating temperature there will still be liquid in the thermostat bulb. In this way, the pressure in the thermostat line is always the corresponding pressure for the temperature of the liquid in the bulb.

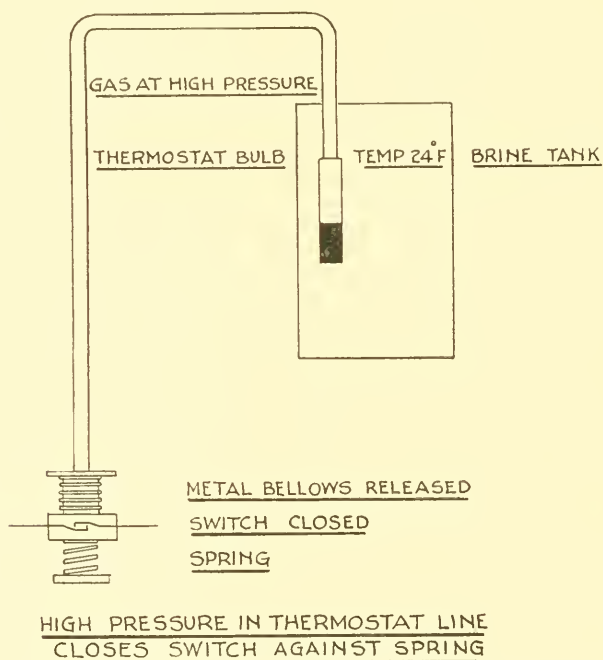


FIG. 26.—OPERATION OF VOLATILE LIQUID THERMOSTAT.

In Fig. 26 the brine temperature has increased to 24°, vaporizing some of the liquid in the thermostat bulb and increasing the gas pressure, until finally the metal bellows expands against the spring, closing the motor switch.

The motor then operates the compressor cooling the brine. The thermostat bulb is cooled decreasing the gas pressure in the thermostat system. The gas pressure is decreased as gas is condensed into liquid form in the thermostat bulb.

Finally the pressure is lowered to a pressure so that the spring will compress the metal bellows and open the motor switch.

By adjusting the compression of the spring, the motor may be started or stopped at any desired brine temperature.

When too much liquid is charged into a thermostat system of this kind, the pressure will be a function of the thermo-

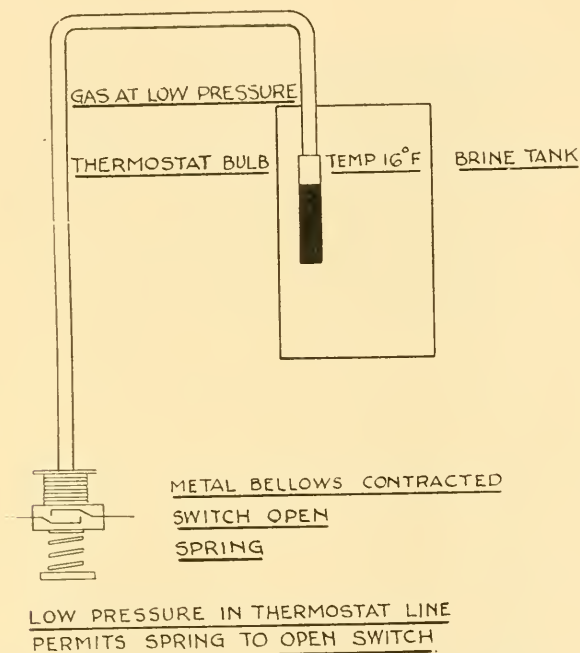


FIG. 27.—OPERATION OF VOLATILE LIQUID THERMOSTAT.

stat line temperature and the control will not operate satisfactorily.

If the volatile liquid charge is too small, all the liquid will vaporize at the higher brine temperature and the control will not function properly.

Air or foreign gases in the thermostat system will produce an abnormally high pressure at all times. Oil in the thermostat will cause a sluggish action.

Water Controls.—When a water-cooled condenser is used with the compression type household machine, it is desirable to have the following controls.

1. Open the water valve when the compressor starts to operate.
2. Close the water valve when the compressor shuts down.
3. Regulate the amount of water supplied to the condenser compensating for a warmer or colder tap water temperature.
4. Regulate the amount of water supplied to compensate for different loads on the compressor.
5. Compensate for different water supply line pressures.
6. Prevent the compressor from operating when the water supply fails.
7. Permit the compressor to function normally when the water supply is again available.

A method of water control in common use is to open, close, and regulate the water valve by means of a diaphragm or metal bellows responsive to the condensing pressure.

The valve is set to open at a certain pressure slightly higher than the pressure ever obtained in the condenser during the inoperative part of the cycle. An increase in condensing pressure will open the water valve still more. This increase in condensing pressure may be due to an increased load on the compressor or to a higher tap water temperature or to a decrease in the water supply line pressure.

Another system of water control is to use a water valve opened and closed by means of a solenoid coil. This coil is placed in the motor circuit and holds the valve open while the compressor is operating. This system does not compensate for differential water temperatures and changes in the refrigerating load.

A water cooling system used to some extent consists of a valve opened by the centrifugal force of weights mounted on the compressor or motor shaft. This gives a control functioning in a way similar to the electric valve but entirely mechanical in operation. This system does not regulate the amount of water supplied, in accordance with the requirements due to changes in temperature, pressure, and load.

A dead water tank has been used to some extent. The condenser is immersed in a rather large tank of water. During the inoperative part of the cycle, this water is cooled to a temperature approaching that of the room. As a household

machine usually operates about 25 per cent of the time, there is a sufficient time interval between runs for the condensing water to cool to nearly the room temperature.

Mercoïd Control.—Fig. 28 and 29 shows a special control for domestic refrigerating machines made by the American Radiator Company of Buffalo and the Federal Gauge Company of Chicago.

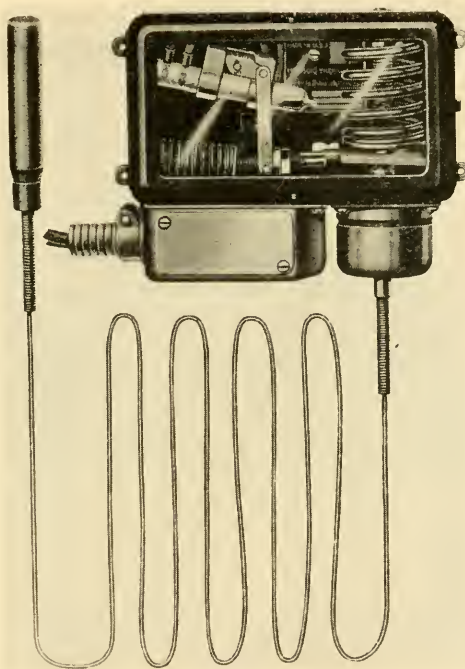


FIG. 28.—MERCOÏD CONTROL, FLEXIBLE TUBE TYPE.

The Mercoïd Switch consists of a glass tube in which are sealed leads of special material. A quantity of mercury makes or breaks the circuit when the tube is tilted. Hermetically sealed within the tube are inert gases which stifle the arc instantly. There is no oxidation or corrosion. The contact is permanently clean and instantaneous in operation.

Fig. 28 shows the remote control, flexible tube type. Fig. 29 shows the pressure type thermostat.

This control can be furnished to automatically open or close an electric circuit with a change in temperature. The circuit is controlled directly to the motor or other electric equipment.

Ordinary lighting or power current can be run through the control.

The operation of this control is very simple. A power element is expanded automatically by temperature, which in turn,

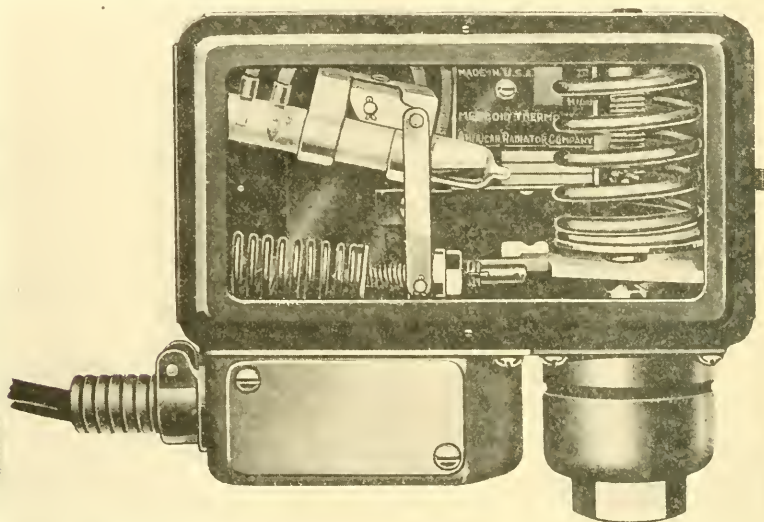


FIG. 29.—PRESSURE TYPE THERMOSTAT.

tilts the switch with a snap action. A spring throws the switch in the opposite direction as pressure or temperature decreases.

A special feature of the thermostatic power element is its dependability. The operation remains constant and does not change; years of service will not affect its power or sensitivity.

The power element consists of a seamless metallic bellows, the folds of which are so made that expansion and contraction will not affect the life of the metal. When used thermostatically the bellows contain liquids of various boiling points as determined by the desired operating temperatures.

Refrigerator Control Switch.—Fig. 30 is a sectional view of the electric refrigerator control unit made by the Automatic Reclosing Circuit Breaker Company of Columbus, Ohio.

The expansion bellows is filled with a freezing solution. When this solution freezes the bellows expand and close the

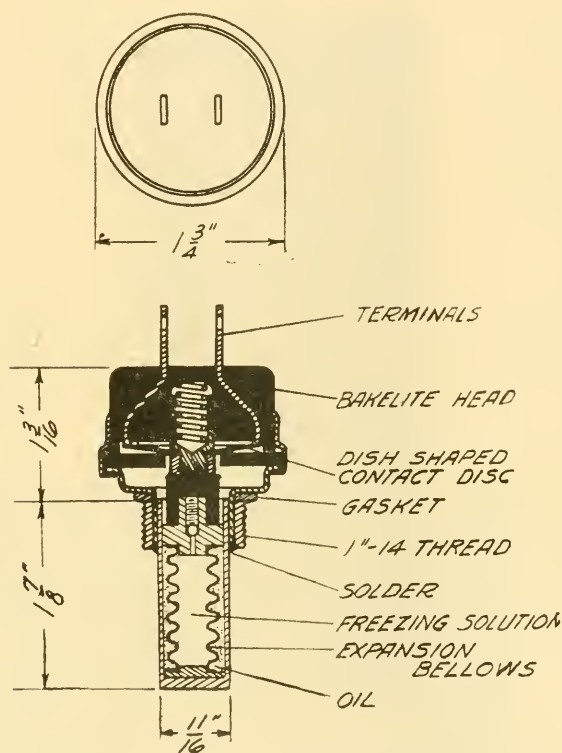


FIG. 30.—SECTIONAL VIEW OF ELECTRICAL REFRIGERATOR CONTROL.

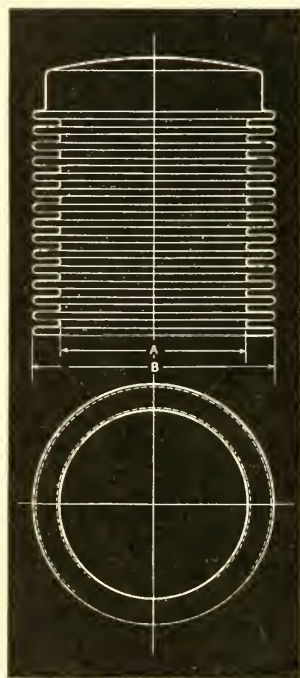
electric circuit by forcing the dish-shaped contact against the two electric terminal inserts.

There is no adjustment for temperature as this setting is obtained by changing the proportions of the materials used for making the freezing solution.

This design affords a control free from outside adjustments and of very simple construction.

Multiflex Bellows.—Fig. 31 shows the seamless one-piece multiflex metal bellows made by the Bishop & Babcock Sales Company.

These bellows are used in many different parts of electrical refrigerating systems, usually in connection with the thermostat while some manufacturers use them to seal the compressor shaft.



A—Inside Diameter

B—Outside Diameter.

FIG. 31.—SEAMLESS ONE-PIECE MULTIFLEX METAL BELLOWS.

Table LXI gives standard sizes of bellows. Wall thickness can be supplied for external or internal pressure to 500 pounds per square inch.

The Fedders Manufacturing Company of Buffalo, New York, make appliances for household refrigerating machines.

Fig. 32 shows a condenser and receiver unit. The condenser consists of coils of copper tubing with a special type of copper fins to increase the cooling efficiency.

TABLE LXI—STANDARD BELLOWS

| Outside Diameter | Inside Diameter | Free Movement | No. of Convolutions | Normal Length |
|---------------------|--------------------|--------------------|---------------------|--------------------|
| 1" | 3 $\frac{1}{4}$ " | 1 $\frac{1}{4}$ " | 18 | 11 $\frac{1}{8}$ " |
| 1 $\frac{1}{4}$ " | 3 $\frac{5}{16}$ " | 1 $\frac{5}{16}$ " | 16 | 1 $\frac{5}{16}$ " |
| 1 $\frac{3}{8}$ " | 1" | 3 $\frac{3}{8}$ " | 18 | 1 $\frac{3}{4}$ " |
| 1 $\frac{1}{2}$ " | 1 $\frac{1}{32}$ " | 3 $\frac{1}{8}$ " | 18 | 1 $\frac{3}{4}$ " |
| 1 $\frac{5}{8}$ " | 1 $\frac{3}{16}$ " | 3 $\frac{1}{8}$ " | 18 | 1 $\frac{3}{4}$ " |
| 1 $\frac{13}{16}$ " | 1 $\frac{3}{8}$ " | 3 $\frac{1}{8}$ " | 18 | 2" |
| 2" | 1 $\frac{7}{16}$ " | 7 $\frac{1}{16}$ " | 16 | 2 $\frac{1}{16}$ " |
| 2 $\frac{1}{16}$ " | 1 $\frac{1}{2}$ " | 3 $\frac{1}{8}$ " | 14 | 2 $\frac{1}{4}$ " |
| 2 $\frac{3}{8}$ " | 1 $\frac{3}{4}$ " | 7 $\frac{1}{16}$ " | 15 | 2 $\frac{1}{4}$ " |
| 2 $\frac{7}{8}$ " | 2 $\frac{1}{4}$ " | 3 $\frac{1}{4}$ " | 18 | 3 $\frac{1}{8}$ " |
| 4 $\frac{1}{8}$ " | 3 $\frac{3}{8}$ " | 3 $\frac{1}{4}$ " | 17 | 2 $\frac{5}{8}$ " |
| 7 $\frac{3}{4}$ " | 6 $\frac{7}{8}$ " | 1 $\frac{1}{2}$ " | 10 | 2 $\frac{3}{4}$ " |

Fig. 33 is a photograph of the expansion valve which may be used with any of the refrigerants in common use in household machines. A change of springs is necessary with very low pressure refrigerants.

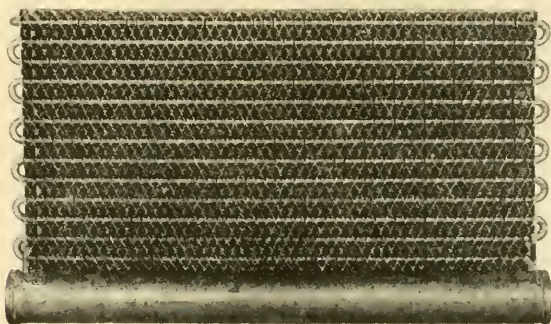


FIG. 32.—CONDENSER AND RECEIVER UNIT.

Fig. 34 is a tubular liquid strainer used in the inlet connection to the expansion valve. A liquid filter, Fig. 35, is used to filter out the small particles of scale or oxide which may accumulate in the refrigerating system. This filter contains two circular pieces of fine meshed screen with wool felt between them.

Fig. 36 shows a typical brine tank. These tanks are made of tinned copper with lock seams. The wall thickness of the copper is .028 inches. These tanks are made in standard sizes

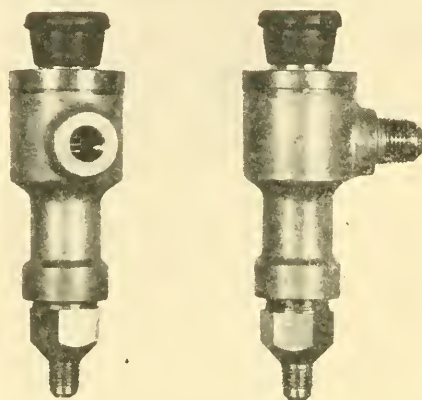


FIG. 33.—EXPANSION VALVE.

to suit the requirements of the different styles and types of refrigerators in use today.

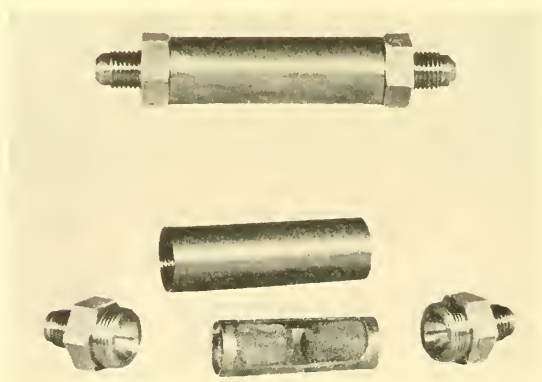


FIG. 34.—TUBULAR LIQUID STRAINER.



FIG. 35.—A LIQUID FILTER.

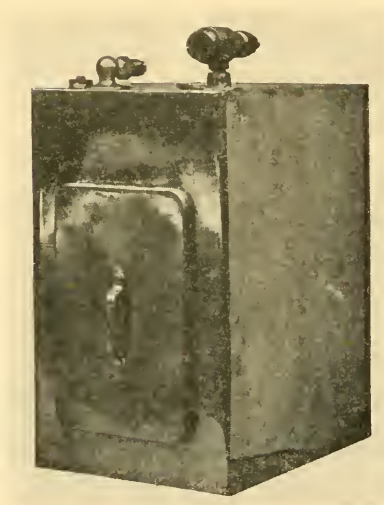


FIG. 36.—A TYPICAL BRINE TANK.

CHAPTER VII

HOUSEHOLD REFRIGERATING MACHINES COMPRESSION TYPE

Household Refrigerating Machines.—In this chapter, attention will be given to the general types and characteristic construction of a number of household compression refrigerating machines. The makes of the various household refrigerating machines which are described here have been selected promiscuously, and represent the characteristic design of the different classes of machines. It does not include descriptions of all of the different kinds of household machines, since, at present, there are several hundred different concerns producing or developing machines of this type.

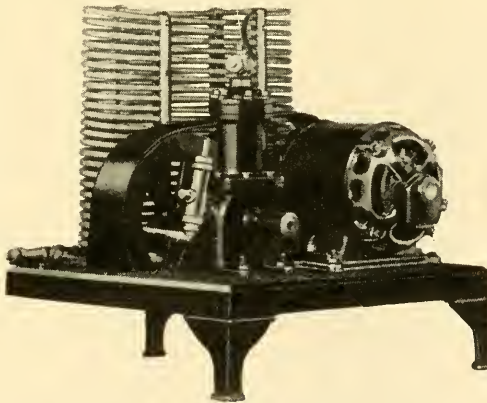


FIG. 37.—ABSOPURE AIR-COOLED MECHANICAL UNIT.

In the following, attention has been given to the mechanical design of the different parts of the compression type.

Absopure.—Fig. 37 shows a $\frac{1}{4}$ hp. air-cooled mechanical unit used on the household machine manufactured by the Gen-

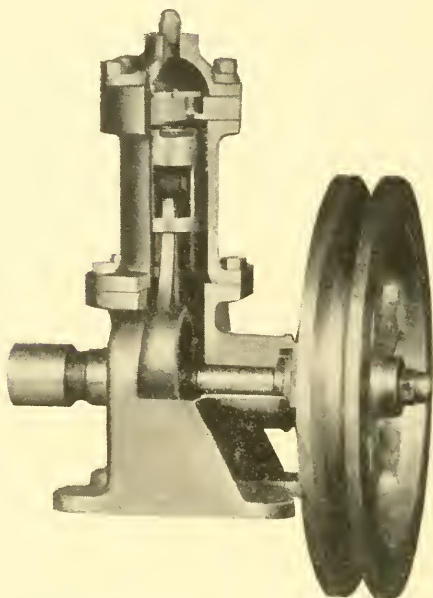


FIG. 38.—SECTIONAL VIEW OF ABSOPURE COMPRESSOR.

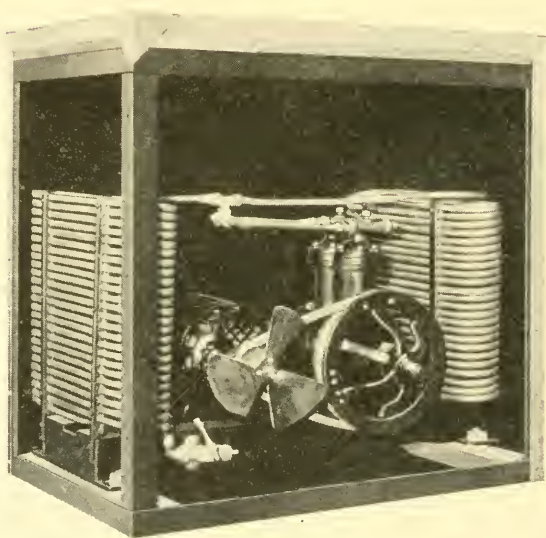


FIG. 39.—HALF-HORSEPOWER ABSOPURE CONDENSING UNIT FOR ICE CREAM CABINET.

eral Necessities Corporation of Detroit, Michigan. This machine uses methyl chloride as the refrigerant.

A sectional view of the compressor is shown in Fig. 38. The motor drives the compressor by means of a "V" type belt. The discharge valve is of a disk type. The shut-off valves are made of forged brass.

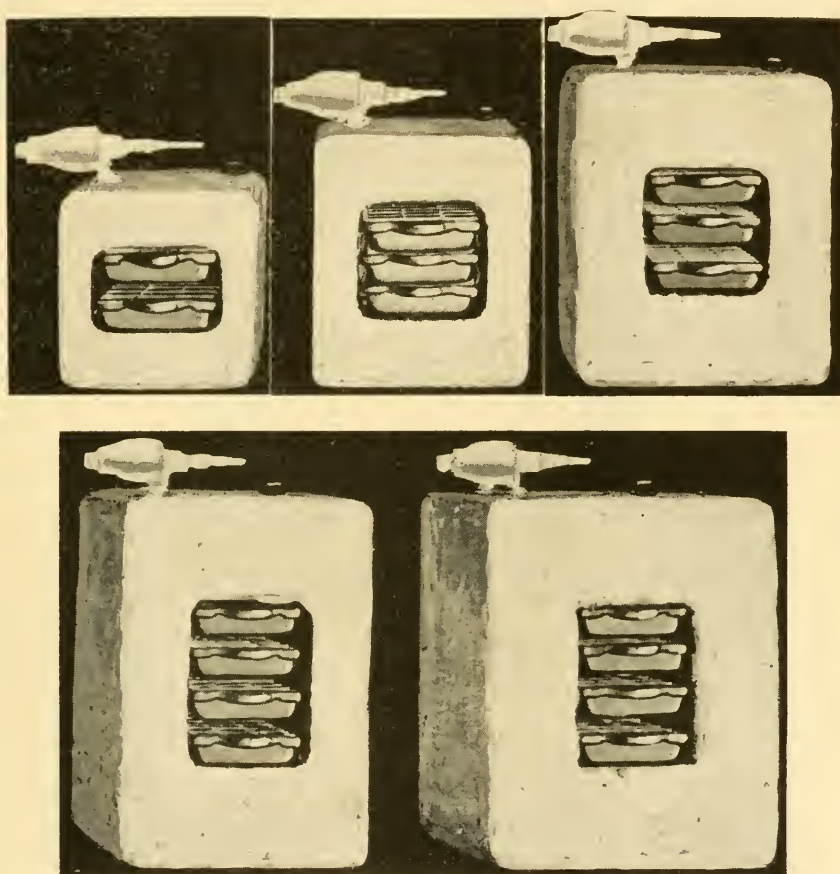


FIG. 40.—TYPICAL ABSOPURE FREEZING UNIT IN VARIOUS SIZES.

The $\frac{1}{2}$ hp. air-cooled mechanical unit is shown in Fig. 39. This is one of the condensing units used for ice cream cabinet work. The condensing unit is placed in a compartment which may be fastened to the ice cream cabinet.

Fig. 40 shows a typical freezing unit. These are made in sizes suitable for use in all types of household refrigerators.



FIG. 41.—TYPICAL ABSOPURE REFRIGERATOR.

Fig. 41 is a typical refrigerator in which the mechanism may be installed as a complete self-contained unit.

Audiffren.—Fig. 42 gives a sectional view of the household machine manufactured by the Audiffren Refrigerating Machine Company of New York City. A view of a cabinet equipment with this machine is shown in Fig. 43.

This machine has an enclosed sulphur dioxide compressor. All of the operating parts are sealed up within this revolving “dumbbell,” consisting of two bronze bells on a hollow shaft.

The Rotor consists of two hollow bronze bells connected by a hollow steel shaft. One bell containing the compressor also acts as the “condenser”; in the other the liquid boils off under reduced pressure and this is the “evaporator” where intense cold is produced. The hollow shaft contains a tube through which the liquid refrigerant is carried from the con-

denser to the evaporator, and an annular space around the tube through which the spent gas is drawn back by the compressor. Thus compressor, condensing surface, liquid receiver, oil separator, expansion valve and refrigerating surface are all represented in this hermetically sealed Rotor.

The compressor rides on the shaft inside of the spherical bell, being held in an approximately vertical position against the turning of the Rotor by means of a heavy lead counterweight. The compressor has two double acting, oscillating cylinders. The compressor pistons are driven by an eccentric secured to the shaft.

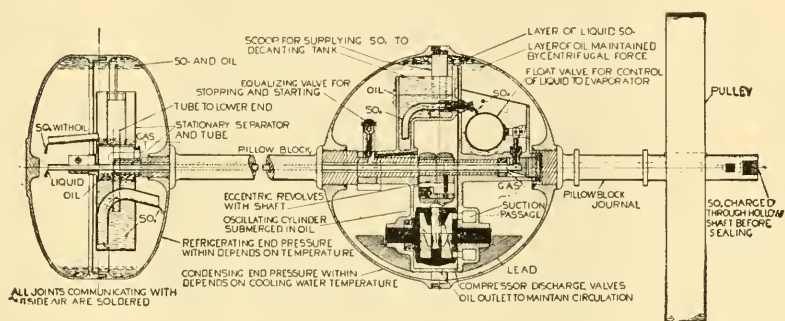


FIG. 42.—SECTIONAL VIEW OF AUDIFFREN HOUSEHOLD MACHINE.

As the Rotor revolves, this compressor, being held in position by the counterweight, draws gas from the evaporator, compresses and discharges it under pressure into the condenser bell within which the compressor is located.

The condenser bell runs partly immersed in cooling water and the compressed gas is cooled and condenses on the inner walls of this bell. The operating pressure is about 50 pounds per square inch, varying with the cooling water temperature.

The condensed refrigerant and the oil are held out against the shell of the condenser bell by centrifugal force and are finally caught by means of a small scoop mounted on top of the frame of the compressor and poured down into a decanting cup where the oil is separated and poured back over the compressor cylinders to lubricate and cool them. The refrigerant is then passed by means of a float valve, which serves for an

automatic "expansion valve," to the evaporator bell of the machine, again to boil off and continue its cycle.

The evaporator is a simple bell providing a chamber for the liquid to evaporate and produce cold. The lubricant that reaches the cold end of the machine is automatically separated and returned to the condenser end through the cylinders, providing internal lubrication for the cylinders and the pistons.

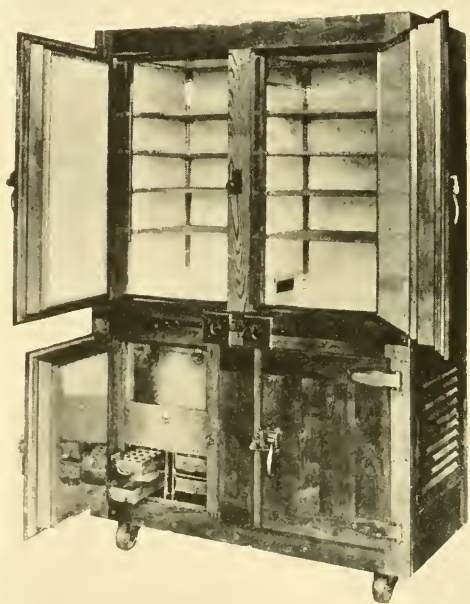


FIG. 43.—VIEW OF CABINET EQUIPPED WITH AUDIFFREN MACHINE.

The temperature and pressure in the condenser will, obviously, be dependent upon the temperature of the condensing water. Consequently the position assumed by the compressor under the control of the counterweight will be dependent upon the temperature of the condensing water. If the supply of condensing water gives out so that the temperature rises above the normal operating limit, the counterweight will finally rise to the horizontal position and any increase in pressure beyond this point will cause the counterweight to revolve with the machine, so that no increase of pressure beyond that for which

the counterweight is designed can be caused by the operation of the machine. This acts as a safety device absolutely protecting the machine from dangerous pressures as a result of failure of condensing water. Until the law of gravity fails, this machine is absolutely safe.

To freeze ice, the ice cans are placed directly in the brine tank. To cool refrigerators, this cold brine is circulated through pipe coils placed in the refrigerators.

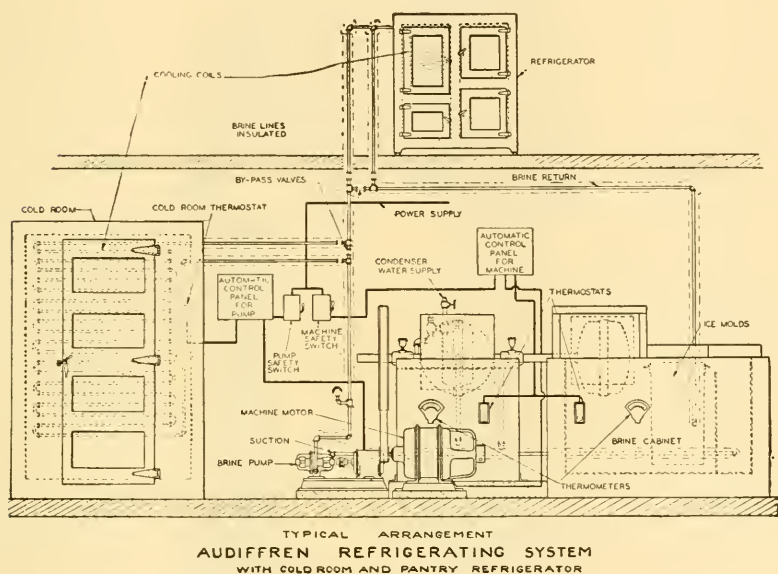


FIG. 44.

Fig. 44 shows a typical arrangement for cooling a large cold room, a pantry refrigerator and an ice making plant. A circulating brine system is used. During the last 15 years many systems similar to this have been used for large residences and country estates.

Autofrigor.—This machine, Fig. 45, is manufactured by Esher Wyss & Company of Zurich, Switzerland.

The refrigerant is methyl chloride. The compressor "5" is double-acting, operating at motor speed. Gas from the suction chamber "6" is compressed into the pressure chamber

"7." The compressed gas then passes through the vertical pipe to the high pressure gas chamber "8" and into the annular space surrounding the chamber. The condensed liquid collects in chamber "9." The gas is condensed by circulating water which enters by connection "11" and leaves by outlet "12." Nozzle "13" is used in place of an expansion valve to the evaporator "R."

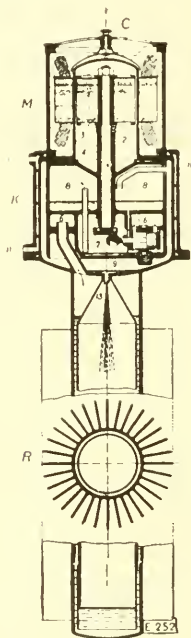


Abb. 2

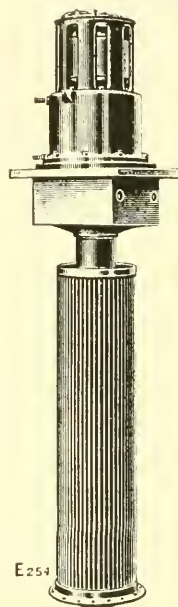


Abb. 3

FIG. 45.—AUTOFRIGOR.

The motor "M" has its rotor "3" enclosed by a steel shell "4," which seals the gas chamber "8." This machine is manufactured in several sizes.

Brunswick-Kroeschell.—Fig. 46 shows one of the small self-contained units made by the Brunswick-Kroeschell Company of New Brunswick, New Jersey, who have been making household refrigerating machines continuously for more than 25 years. Self-contained units are supplied for full automatic control, semi-automatic or manual operation.

The ammonia or carbon dioxide system can be supplied for either direct expansion of the refrigerant or cooling through brine circulation.

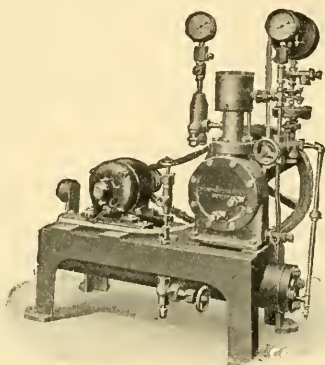


FIG. 46.—SMALL SELF-CONTAINED BRUNSWICK-KROESCHELL UNIT.

Fig. 47 shows a large self-contained unit. This consists of a compression side, electric motor with its starting equip-

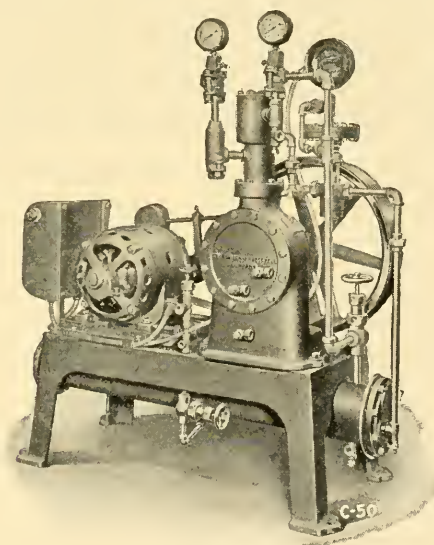


FIG. 47.—LARGE SELF-CONTAINED BRUNSWICK-KROESCHELL UNIT.

ment, special power transmission for short center operations, and interconnection for ammonia, water and electric supply;

these are all mounted on a cast iron pedestal and interconnected ready for service.

The compressor is of the enclosed, vertical, single acting type. Splash lubrication is used.

The condenser is of the shell and tube multi-pass type. Removable heads permit convenient cleaning of the condenser tubes when required in cases where the water leaves a sedi-

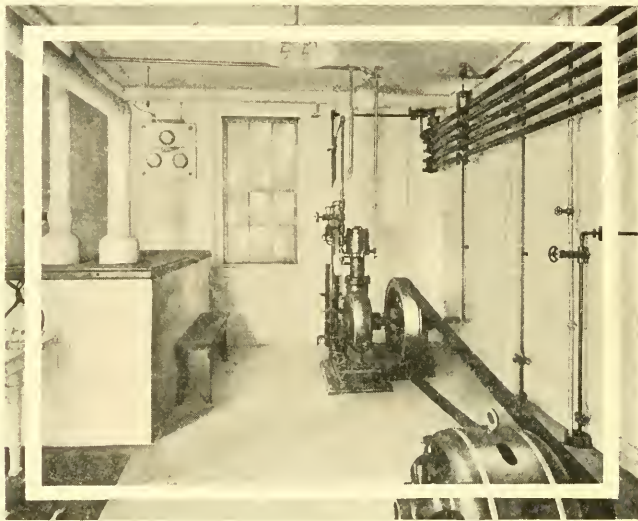


FIG. 48.—BRUNSWICK-KROESCHELL RESIDENCE INSTALLATION, INCLUDING ICE-MAKING SET.

ment. The shells are of ample size for the combined purpose of service as condenser and ammonia receiver.

Fig. 48 shows a typical residence installation including an ice-making set.

Carbondale.—Fig. 49 shows a self-contained unit made by the Carbondale Machine Company, Carbondale, Pa. Ammonia is the refrigerant used.

The compressor is of the vertical, single-acting type. Worthington feather valves are used in the compressor. The cylinder is ground and honed to size. All the bearings are of the die cast type and are interchangeable.

The condenser is of the horizontal, tubular type with removable heads and straight tubes, making it conveniently cleaned and inspected. The water passes through seamless drawn steel tubes, which are expanded into forge welded heads.

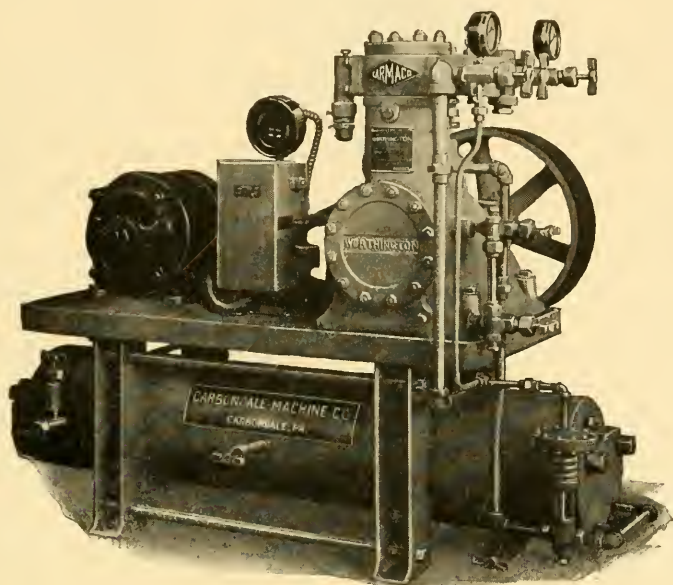


FIG. 49.—CARBONDALE REFRIGERATING UNIT.

The one ton unit is driven by a three horse power motor at 265 r.p.m. when operated at standard suction and discharge pressures. The same machine is rated at two tons when operated at 530 r.p.m. by a five hp. motor. This machine has a vertical compressor of $3\frac{1}{2}$ inch diameter and $3\frac{1}{2}$ inch stroke.

The unit is equipped with the following automatic devices:

- Automatic starting panel.
- High pressure cut out switch.
- Ammonia pressure water control valve.
- Automatic expansion valve, with strainer.

The high pressure cut out is arranged with hand reset, so that in case it acts, the machine will not start itself until the

cause for the high ammonia pressure is determined and corrected.

The thermostat operates at full voltage and is fitted for two connecting wires. The thermostat is very accurate, and with a properly designed room, or box, the temperature may be held within a few degrees of the desired temperature.

The water regulating valve is mounted on the front end of the condenser. It is of the pressure actuated type and controls the flow of water by the ammonia pressure of the condenser. When the ammonia pressure drops, the flow of water ceases; and as it rises, the flow is increased, thus obtaining maximum economy in the use of water.

The ammonia connections, both to this valve and to the high pressure cut out, are short and protected by other parts of this unit. Valves are provided in both connections, so that the appliance can be removed for repairs or adjustment.

The automatic expansion valve is of the spring and diaphragm controlled type, selected for the service that it has given hundreds of users, and of a type that will operate satisfactorily under the most adverse conditions.

Champion.—The Champion Electric Icer is made by the Champion Electric Company of St. Louis, Missouri, a division of the Champion Shoe Machinery Company.



FIG. 50.—“JUNIOR” MODEL, CHAMPION ELECTRIC ICER.

Fig. 50 shows the Junior Model. This compressor is of the single cylinder reciprocating type. A belt drive is used.

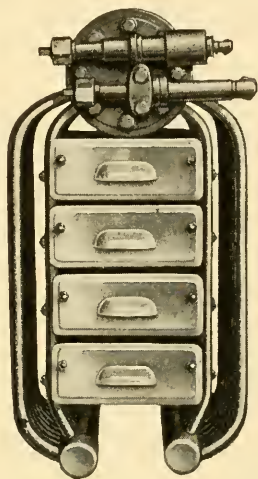


FIG. 51.—CHAMPION COOLING UNIT.

The cylinder block is lined with tool steel bushing hardened and ground. The pistons are semi-steel equipped with two piston rings. The crankshaft is drop forged in one piece.

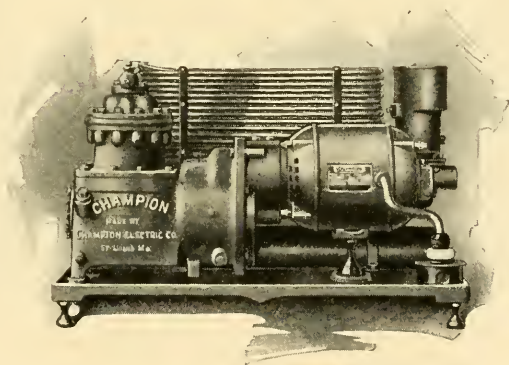


FIG. 52.—“SENIOR” MODEL, CHAMPION ELECTRIC ICER.

Large eccentric bearings are used which are of semi-steel. Model No. 6 Junior Compressor has $1\frac{1}{2}$ inch diameter cylinder, $1\frac{1}{6}$ inch stroke, and operates at 500 r.p.m. Model No. 8

Junior compressor has $1\frac{1}{2}$ inch diameter cylinder, $1\frac{1}{2}$ inch stroke, and operates at 500 r.p.m.

The condenser consists of a double coil of $\frac{1}{4}$ inch copper tubing. Natural air circulation is used for cooling the condenser.

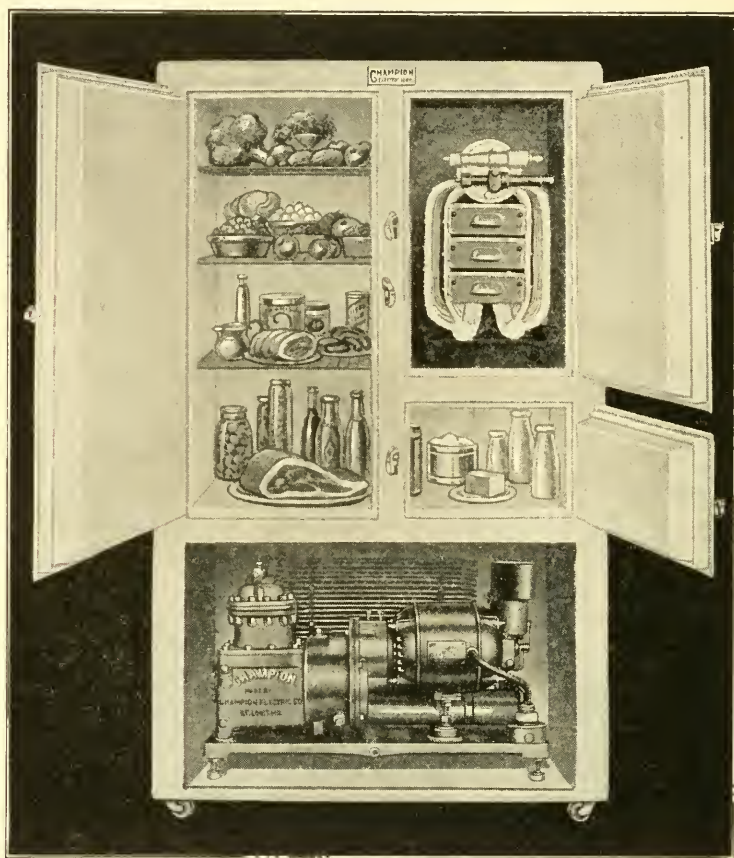


FIG. 53.—CHAMPION "SENIOR" MODEL WITH COOLING UNIT INSTALLED.

The automatic control is of the adjustable pressure type on the suction line.

The motor is $1\frac{1}{6}$ hp. and is of the induction-repulsion type.

Fig. 51 shows the cooling unit which operates on the

flooded system. This uses direct expansion in open type coils. The refrigerant is sulphur dioxide.

Fig. 52 shows the Senior Model which consists of a two-cylinder reciprocating type compressor gear-driven. The $\frac{1}{4}$ hp. motor drives the compressor by means of completely enclosed gears. The gear drive consists of a composition pinion on the motor shaft, driving a helical cut semi-steel gear on crank shaft. All moving parts are enclosed and run in oil. The compressor has a $1\frac{1}{2}$ inch bore, $1\frac{1}{16}$ inch stroke, and operates at 500 r.p.m.

The condenser, automatic control and cooling units are similar in type to those used on the Junior Model.

Fig. 53 shows the Senior Model and cooling unit complete with the cabinet.

Chilrite.—This machine, Fig. 54 is made by the Narragansett Machine Company in Pawtucket, R. I.

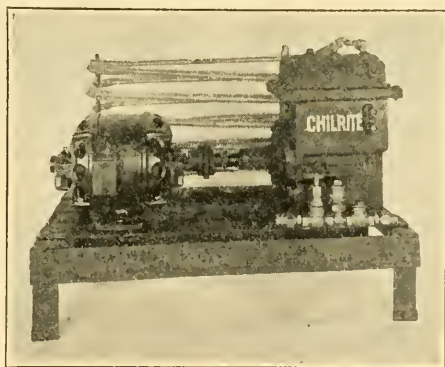


FIG. 54.—CHILRITE REFRIGERATING UNIT.

The compressor is of the multi-stage rotary gear type and uses sulphur dioxide as the refrigerant. The condenser consists of a coil of finned tubing.

The cooling unit is of the dry system consisting of a coil connected with an expansion valve and submerged in a tinned copper tank filled with alcohol and water. In some installations the tank is dispensed with and the open coil system is used.

The temperature is controlled by an immersion type of thermostat of the tilting tube variety.

The machine is made in three sizes using $\frac{1}{8}$, $\frac{1}{4}$ and $\frac{1}{3}$ hp. motors and is adapted to operate with any standard make of cabinet.

Climax.—Fig. 55 shows the self-contained refrigerating unit manufactured by the Climax Engineering Company of Clinton, Iowa. The refrigerant used is methyl chloride.

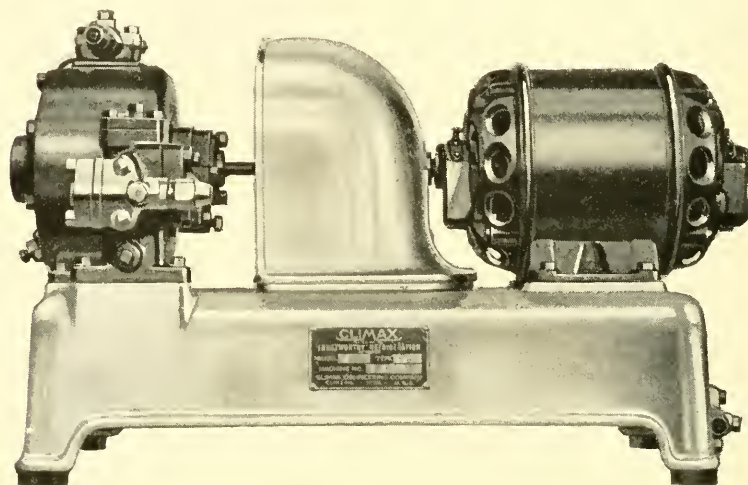


FIG. 55.—CLIMAX REFRIGERATING UNIT.

The condenser, compressor and motor are all mounted on the same base. The compressor is direct connected to the electric motor. A rotary type of compressor is used, consisting of only three moving parts. The rotating element operates on bronze bearings submerged in oil, thus providing positive lubrication.

The refrigerating unit is made in four different sizes:

| Model | Motor | Weight | Ice Melting Effect |
|---------|-------------------|----------|--------------------|
| Model G | $\frac{1}{8}$ hp. | 86 lbs. | 75 lbs. |
| Model F | $\frac{1}{4}$ hp. | 127 lbs. | 150 lbs. |
| Model E | $\frac{1}{3}$ hp. | 204 lbs. | 300 lbs. |
| Model D | $\frac{1}{2}$ hp. | 224 lbs. | 500 lbs. |

The condenser is of the radiator type and is mounted under the base. The air is drawn through the radiator and does dou-

ble duty by being blown against the compressor case. A float valve is used for the liquid control.

The operation of this unit is controlled by a thermostat or pressure control and is entirely automatic.

Coldmaker.—In Fig. 56 is illustrated the Coldmaker household refrigerating machine manufactured in Toledo, Ohio. The machine is installed in the basement or other out of the way place and the cooling coils are installed in the ice compartment of any box.

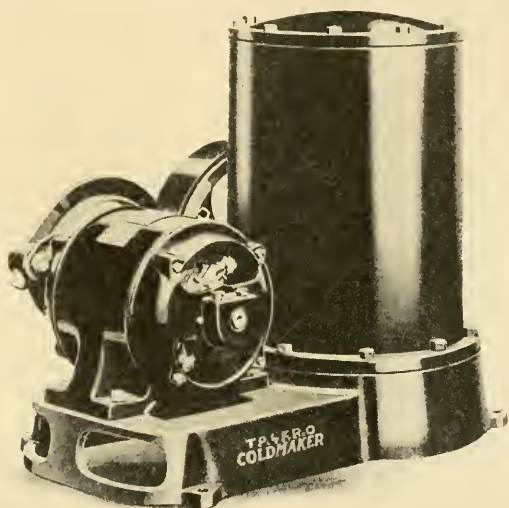


FIG. 56.—COLDMAKER REFRIGERATING MACHINE.

Coldmaker consists of a water cooled ammonia system of automatic refrigeration. The compressor is motor driven by means of a flat leather belt.

The compressor has two cylinders, $1\frac{1}{4}$ inches in diameter by $1\frac{1}{4}$ inch stroke made of a semi-steel casting. Suction port openings are located near the center of the cylinders.

The pistons have long ports on each side to admit the suction gas. The suction valve is located in the upper end of the piston. The top end of the piston has four piston rings

and the lower end three rings. The wrist pins are made of nickel steel. The eccentrics are made of gray iron castings and are cast integral at an angle of 180°. They are shrunk and pinned to the shaft. The shaft is made of forged steel and is ground to size after the eccentrics have been shrunk on.

The discharge valves are made of nickel steel, light in weight, and cup shaped. They give full area opening of the cylinder and permit the compressor to handle saturated gas or liquid without endangering the safety of the machine.

The suction valves, located in the head of the pistons, are made of nickel steel. They have a large suction area and operate with a minimum lift.

Both suction and discharge valves are provided with springs to hold the valves snugly to seats when the pressure is released.

The end plates containing the shaft bearings are made of semi-steel, bored and reamed accurately, and fitted with die cast bearings.

The stuffing box is provided with an oil gland, or ring, with soft packing on both sides. The gland has a direct connection with an oil reservoir, entirely separate from the oil in the crank case. This in reality, forms an oil storage in the center of the stuffing box, which keeps the packing soft and resilient, and effectively seals the stuffing box so that no gas can get past this oil seal. A threaded packing nut or gland forms the outer end of the stuffing box proper.

The rings are made of soft, close grained gray iron. Each ring is cast individually and the inner surface is left unfinished to give toughness and resiliency to the ring. The rings are cast eccentric.

The cylinder heads are made of semi-steel. The discharge port is located in the cylinder head. The water jacket surrounds the compressor, condenser and liquid receiver. Any leak which might occur will be absorbed by the water. The condenser is made of extra heavy $\frac{1}{2}$ inch steel pipe bent to shape and surrounding the compressor cylinders.

Some advantages of the water jacket surrounding the compressor, condenser and liquid receiver are:

1. It absolutely assures splendid operating conditions for the compressor, preventing any contraction or expansion of the metals.

2. It prevents the oil from vaporizing in the crank case.

3. The bearings are kept at a uniform temperature and prevented from overheating.

4. It keeps the stuffing box in excellent condition at all times.

5. It gives additional condensing surface on the receiver.

6. Provides a direct outlet to the sewer in case of leaks.

The expansion valve is of the diaphragm pressure type. It is screened to prevent dirt and scale from getting to the valve seat.

The automatic control consists of a small 1/50 hp. motor which is reduced in speed by worm gears. One of these is directly connected to a rotating shaft, which contains on one end the rotary switch with three terminals corresponding to the three terminals on the thermostat, and the two terminals for the power motor switch. On the one end is fixed the water cock for regulating the flow of water to the condenser shell. As both switches and water valve are firmly fastened to the same shaft and rotate at the same time, it is plainly evident that both water and current must be on or off at the same time.

If the water supply fails, a diaphragm pressure switch directly connected to the water line cuts off the motor instantly. If the pressure falls below a safe margin, the motor will not start again until the water pressure has been again restored to normal.

With alternating-current, a repulsion-induction motor is used, continuous duty type. With direct current, a compound wound continuous duty motor must be used. The size furnished is $\frac{1}{3}$ horse power, 1200 r.p.m.

The capacity of the Coldmaker with the usual allowances for compressor inefficiencies, plus an additional allowance because of the small size of the equipment, figures out approximately 279 pounds of refrigeration when operating 24 hours. The machine is rated at 250 pounds of refrigeration.

Cooke Refrigerating Machine.—The Cooke Household Refrigerating Machine is manufactured by Mr. George J. Cooke, Sr., of Chicago, Illinois.

The compressor is of the single cylinder, vertical, single-acting type. A cross-section and longitudinal section is shown in Fig. 57. The cylinder diameter is $1\frac{1}{2}$ inches and the stroke is $1\frac{1}{2}$ inches. The compressor operates at 450 r.p.m. normally. The suction valve is of the port type; the discharge valve is of the disc plate type. The compressor crank shaft and

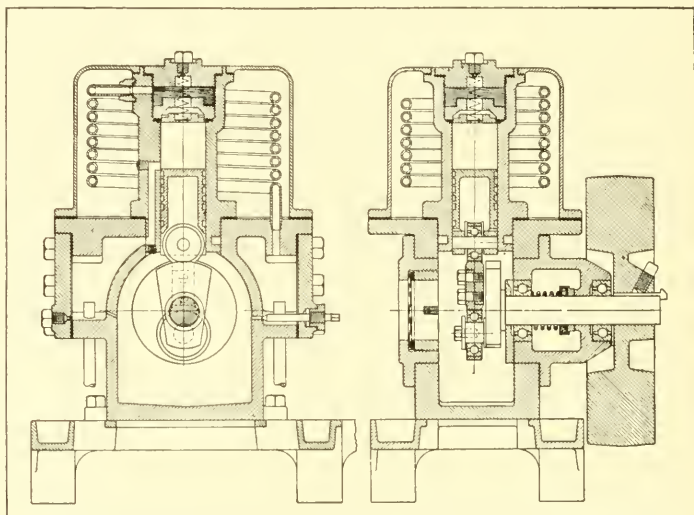


FIG. 57.—SECTIONAL VIEW OF COOKE REFRIGERATING MACHINE.

connecting rod are provided with ball bearings to reduce the friction losses to a minimum. The crank shaft is packed by means of the patented seal ring. The packing is submerged in oil while the machine is in operation. A small but heavy flywheel is keyed to the crankshaft. A glass-covered observation port is provided opposite the end of the crank shaft for observing the condition of the lubricating oil.

The condenser consists of a spiral pipe coil around the compressor cylinder, as shown by Fig. 57. An exterior casing encloses the water circulation for the condenser and water jacket for the compressor cylinder. The ammonia gas is **discharged**

into the top of the spiral condenser coil and the liquefied ammonia drains out of the bottom of the coil into a combined ammonia receiver and oil trap which is cast integral with the compressor frame. An automatic oil return valve is used.

The compressor is driven by means of a $\frac{1}{4}$ hp. electric motor running at 1,750 r.p.m. It is belted to the compressor by a "V" type belt. Proper belt tension is obtained by mounting the motor upon a hinged base. The compressor and motor are mounted upon a substantial cast-iron base. The compressor and motor unit is 20 inches long, 10 inches wide, and 15 inches high overall and weighs 150 pounds.

The cooling element consists of a brine tank containing direct expansion coils. Trays are provided for the freezing of seventy-two $1\frac{1}{2}$ inch ice cubes for table use. The expansion valve is of the angle standard orifice type, protected from foreign matter by a small strainer in the liquid line just ahead of the valve. It is located just above the brine tank.

The machine is self-contained, simple in construction, and all parts are readily accessible. The operation of the machine is positively and automatically controlled by means of a mercoïd electric switch which is actuated by a thermostatic element submerged in the brine of the main tank. The controls may be adjusted to maintain any reasonable temperature in the refrigerator. The condenser water supply is controlled by a diaphragm valve which is actuated by the condenser pressure.

The total charge of the ammonia in the system is said to be $3\frac{1}{2}$ ounces. The capacity of the machine, it is claimed, is 350 pounds of ice melting effect per day. It may be installed on or adjacent to any refrigerator having a maximum of 35 cubic feet.

The refrigerating machine has in connection with it an ice cream freezer of the domestic size. This is mounted on the side of the refrigerator. The ice cream freezer has a brine tank containing a submerged spiral direct expansion coil. Operation of the freezer requires only a one-quarter turn of a hand lever located just above the main brine tank. It is claimed that one gallon of ice cream may be frozen in ten to fifteen minutes.

Copeland.—Fig. 58 shows the household refrigerating machine made by Copeland Products, Incorporated, of Detroit, Michigan.

The compressor has one cylinder and is of the single-acting reciprocating piston type. The motor is $\frac{1}{6}$ hp. and drives the compressor by means of the "V" type belt.

The refrigerant used is Freezol or Iso-Butane, a hydrocarbon gas which is odorless, non-corrosive and non-poisonous.

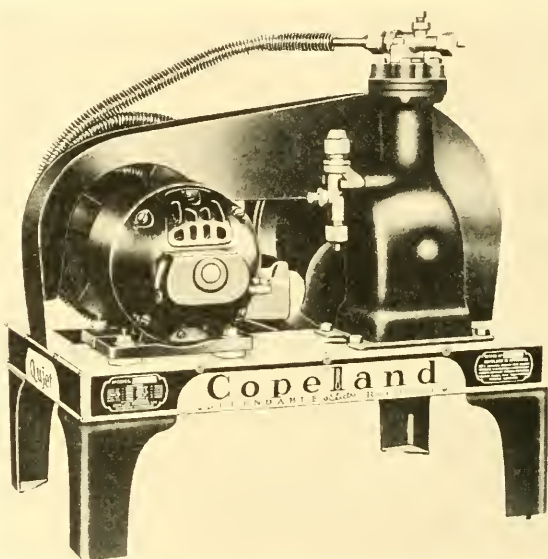


FIG. 58.—COPELAND REFRIGERATING UNIT.

The condenser is made of thin copper tubing and is cooled by forced air obtained by means of a fan attached to the motor shaft.

The cooling units are made entirely of copper and brass. Copper tubing is used for the expansion coils. This tubing encircles the ice tray sleeves, thus reducing the time required to freeze water or desserts. Cooling units are made in various sizes suitable for different sizes and types of refrigerating cabinets.

The expansion valve, Fig. 59, is located on top of the cooling unit and is of the balanced type using a diaphragm

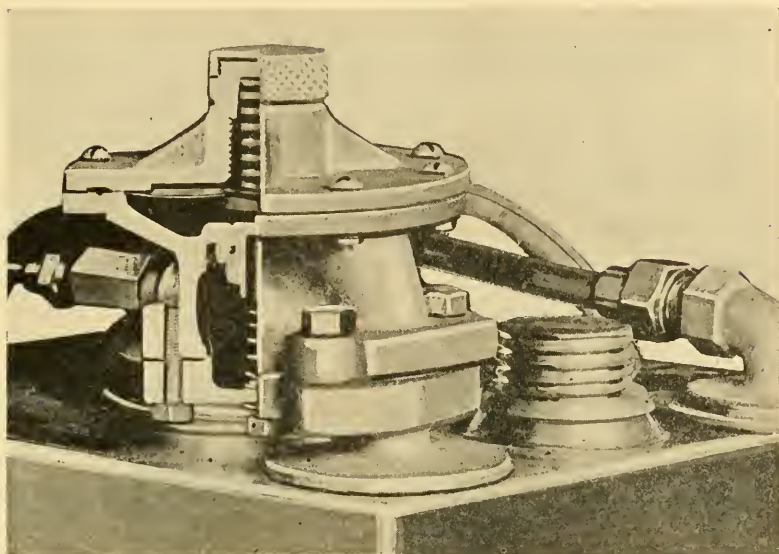


FIG. 59.—COPELAND EXPANSION VALVE.

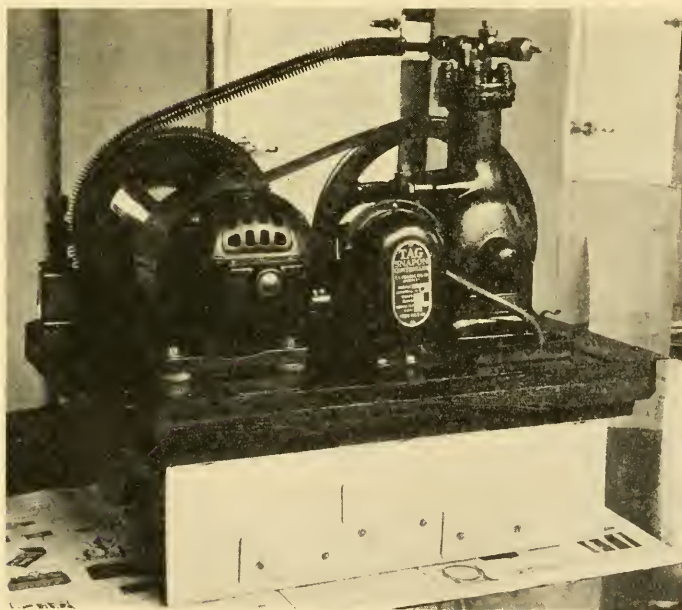


FIG. 60.—COPELAND ONE-PIECE FREEZING UNIT AND MACHINE.

between the outside adjusting spring and the regulating needle inside the valve.

The temperature control is automatic and is obtained by means of a thermostat responsive to the cooling unit temperature.

A line of all-metal cabinets is supplied.

Fig. 60 shows the freezing unit and machine all in one piece, mounted on an insulated base which forms the top of the refrigerator. This unit sets down into the top of the refrigerator, resting on an insulated base, and forms an air-tight seal with its own weight.

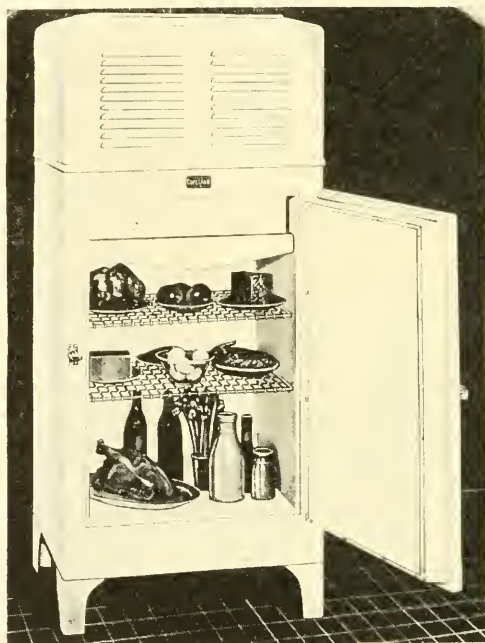


FIG. 61.—COPELAND CABINET AND REMOVABLE UNIT.

Fig. 61 shows the cabinet in which the removable unit operates. This cabinet is $62\frac{1}{2}$ inches high, $26\frac{1}{4}$ inches wide and 21 inches deep.

The exterior is covered with steel and the walls are insulated with $1\frac{1}{2}$ and 2 inches of solid cork. The exterior is of steel finished in white pyroxylin.

The cooling unit has an ice capacity of 6.6 pounds and a capacity of 108 cubes at one freezing. The food space is $5\frac{3}{4}$ cubic feet and the shelf area is 8 square feet.

CP Refrigerating Machine.—Fig. 62 shows the self-contained refrigerating machine made by the Creamery Package Manufacturing Company, Chicago, Illinois.

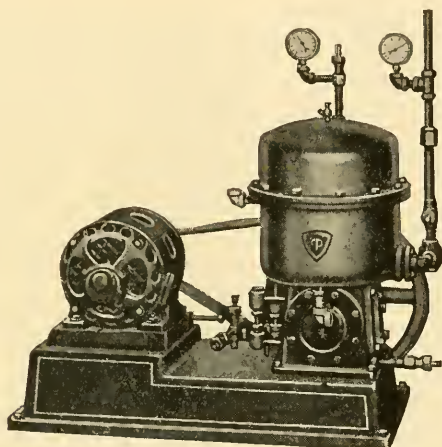


FIG. 62.—CREAMERY PACKAGE REFRIGERATING MACHINE.

The refrigerant used is ammonia. The compressor, liquid receiver, condenser, necessary valves, oil gauge and strainer are all mounted on one base. The compressor is of twin cylinder construction. The compressor has adjustable crank pin bearings, drop forged connecting rods and crankshafts, and improved type valves which are easily removable.

A $\frac{1}{2}$ hp. motor is used to drive the compressor. This machine has a capacity of $\frac{1}{4}$ ton refrigeration per day.

The machine is entirely automatic in operation. A thermostat is used to maintain any desired temperature.

Delphos.—Fig. 63 shows the complete self-contained refrigerating unit made by the Delphos Ice Machine Company, at Delphos, Ohio.

Ammonia is the refrigerant used. This unit consists of a complete high-side including a compressor, scale trap with

relief valve, oil trap, condenser, receiver, low and high pressure gauges, gauge and purge valves and electric motor. A cast iron base is used.

The compressor is of the enclosed crankcase type and all of the moving parts and bearings are lubricated by the splash of the eccentrics passing through the oil contained in the reservoir at the bottom.

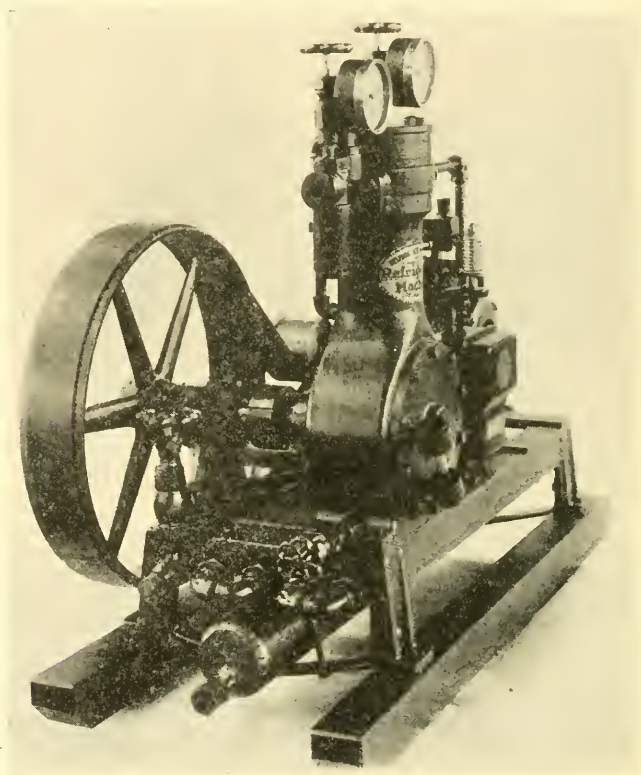


FIG. 63.—DELPHOS REFRIGERATING UNIT.

All the compressors are two cylinder with the exception of the three-fourths ton size which is single cylinder.

The ammonia condenser is of the double pipe, counter-current type with all ammonia joints welded. The water pipes are connected by means of return bends and lip unions to permit ready access for cleaning and removing water sedi-

ment. This can be done without disturbing the ammonia. The condenser is made up of black steel pipe with steel heads securely welded. The condenser and receiver are mounted integral with shut-off valve placed between condenser and receiver.

Electrical Refrigerating Co.—Fig. 64 shows a cross-section view of the compressor used in the machine manufactured by

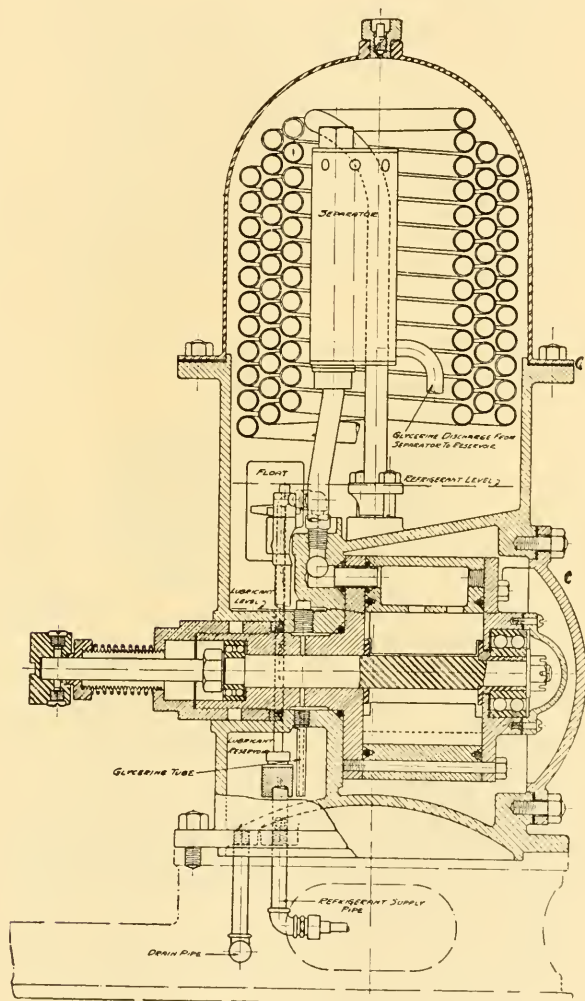


FIG. 64.—WILLIAMS REFRIGERATING MACHINE.

the Electrical Refrigerating Company at Brooklyn, New York.

This is a water-cooled type using ethyl chloride as the refrigerant. The flow of the refrigerant is controlled by means of a float valve.

Four sizes of this machine were developed including $\frac{1}{4}$, $\frac{1}{2}$, 1 and 2 hp. Most of the parts of all these sizes are interchangeable in the same housing, the outside diameter of all compressors being the same while the variations in their capacity is obtained by changing the bore and depth dimensions.

The capacity of the larger size condenser is provided by increasing the height of the dome.

ElectrICE.—Fig 65 shows the top view of the rotary compressor used on the household refrigerating machine made by the American ElectrICE Corporation at Belding, Michigan.

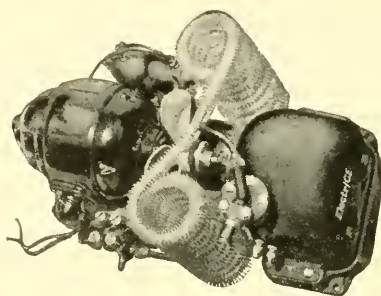


FIG. 65.—TOP VIEW OF ELECTRICE ROTARY COMPRESSOR.

The compressor is of the rotary type, using one set of gears operated at motor speed. The motor is direct connected to the compressor, eliminating the use of belts.

The compressor consists of two coils of thin tubing cooled by forced air obtained by means of a fan mounted on a motor shaft. The refrigerant control valve is mounted on the compressor base.

The motor control is responsive to a mercoid thermostat, starting and stopping the compressor, and is necessary to maintain a constant temperature in the refrigerator.

The ice-melting capacity of this unit is 125 pounds per twenty-four hours at 85° F. temperature.

Electro-Kold.—Figs. 66 and 67 show compressor units made by the Electro-Kold Corporation of Spokane, Wash. Compressor units are made in three sizes.

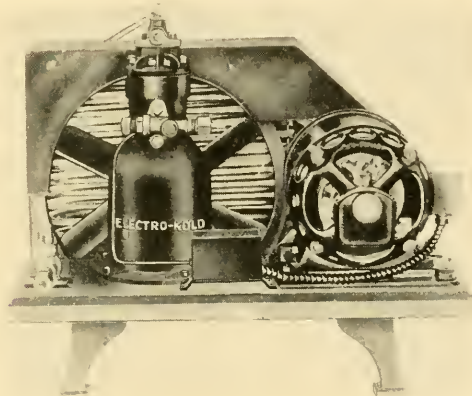


FIG. 66.—ELECTRO-KOLD COMPRESSOR UNIT.

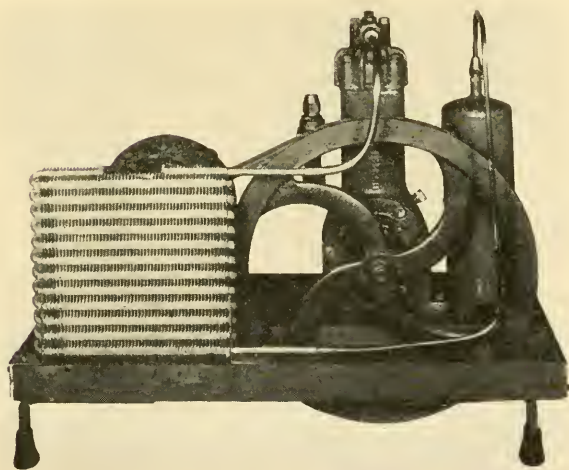


FIG. 67.—ELECTRO-KOLD COMPRESSOR UNIT.

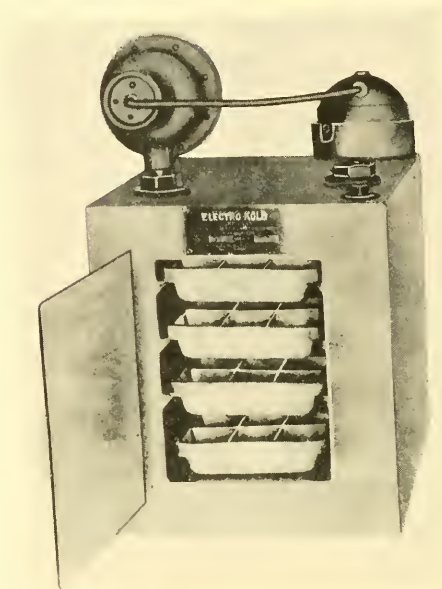


FIG. 68.—ELECTRO-KOLD FROST TANK.



FIG. 69.—COMPLETE ELECTRO-KOLD SELF-CONTAINED UNIT.

The refrigerating capacity and size of motors are as follows:

| Type | Size Motor | Number Cylinder | Refrigerating Capacity |
|------|-------------------|--------------------|---------------------------|
| C | $\frac{1}{4}$ hp. | 1 | 10 cu. ft. |
| F | $\frac{1}{2}$ hp. | 1 | 40 cu. ft. |
| A | $\frac{1}{2}$ hp. | | 60 cu. ft. |

Sulphur dioxide is the refrigerant used.

The condenser consists of copper tubing and it is cooled by forced air.

A pressure control is used instead of a thermostat to regulate the operation of the machines.

Fig. 68 is a view of a typical frost tank with a capacity for cooling ten cubic feet of food space. It has four ice trays of eighteen cubes each.

Fig. 69 shows a complete self-contained unit. The exterior is of steel with Duco finish. The insulation is of $1\frac{1}{2}$ inch corkboard. Several other larger self-contained models are produced.

Everite.—The Everite Products, Inc., Dayton, Ohio, manufactures the motor driven air cooled refrigerating machine, Fig. 70.

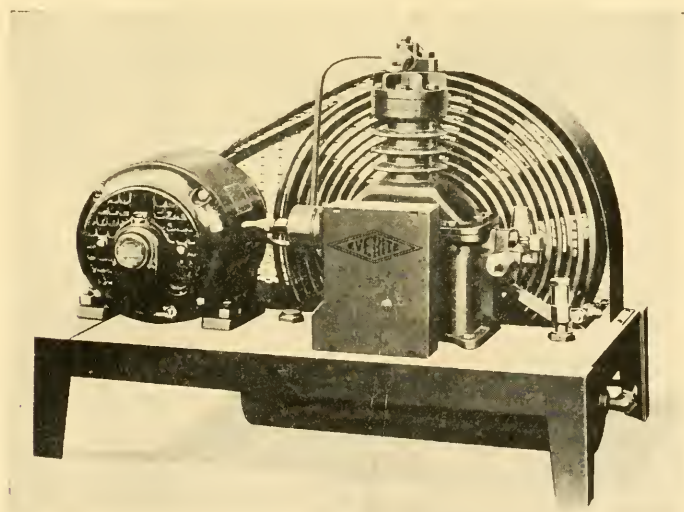


FIG. 70.—EVERITE REFRIGERATING MACHINE.

This machine may be used in the standard home refrigerator or in special all-steel, porcelain lined refrigerator cabinets furnished in five sizes from seven to twenty cubic feet food storage capacity.

Both single and double cylinder compressors operated by $\frac{1}{8}$ and $\frac{1}{4}$ hp. motors are manufactured. These have refrigerating capacity of twelve to twenty-five cubic feet respectively.

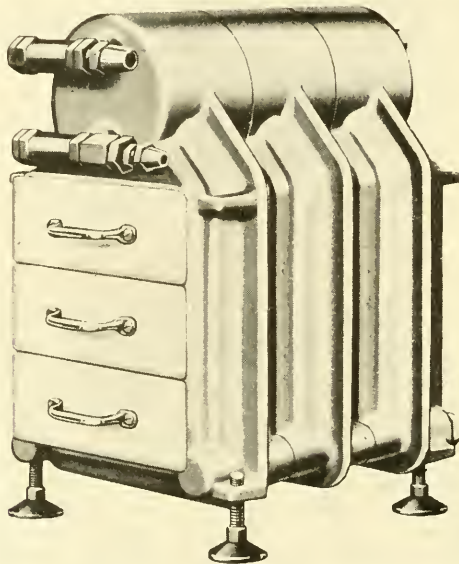


FIG. 71.—EVERITE FLOODED TYPE COOLING UNIT.

Commercial systems are also manufactured in $\frac{1}{4}$ and $\frac{1}{2}$ ton sizes.

Sulphur dioxide is the refrigerant used.

The Everite cooling unit, Fig. 71 is of the flooded type employing a float valve in its header. These are of cast construction built up in sections similar to a radiator which provides maximum cooling surface and permits the building up of suitable size cooling units for various size refrigerators from

the smallest to the largest within the capacity of the compressors.

The outstanding feature in this system is the condenser which is mounted directly in front of and covering the entire area of the fan pulley thus causing all the air drawn in by the fan to pass through the condenser rendering it very efficient and permitting neat and compact construction.

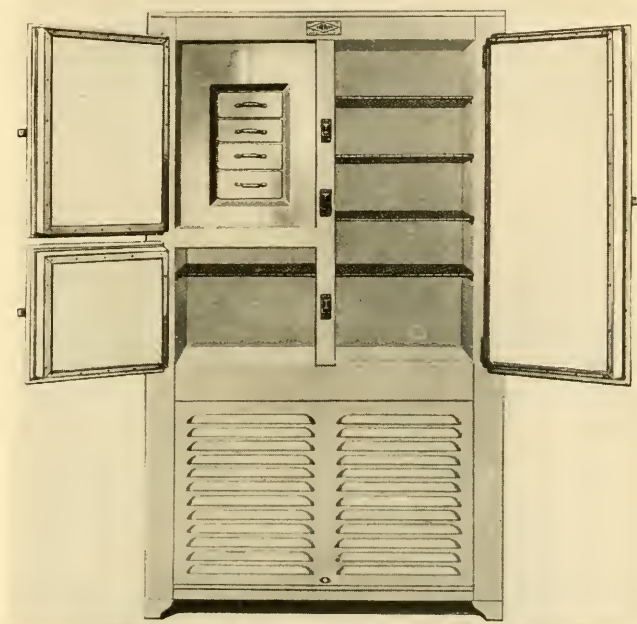


FIG. 72.—ALL-STEEL CABINET WITH EVERITE UNIT.

The control is the pressure type (no thermostat is used) thus eliminating difficulties usually experienced in this type of control.

Fig. 72 shows one of the all-steel cabinets supplied as a self-contained unit.

Frigidaire.—Two general types of Frigidaire household and commercial refrigerating machines are made by the Delco-Light Company at Dayton, Ohio. These are air-cooled and water-cooled units using sulphur dioxide as the refrigerant.

Fig. 73 shows the model "G" air-cooled condensing unit comprising the compressor, condenser, receiver, motor and automatic control, mounted on a steel base. The compressor

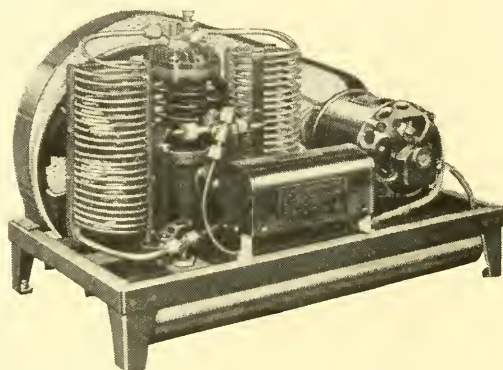


FIG. 73.—FRIGIDAIRE MODEL "G" AIR-COOLED UNIT.

is a two cylinder, vertical, single-acting type. The discharge valve is of the flapper valve construction. A disc suction valve is used in the top of the piston. An eccentric keyed to the shaft drives the pistons by means of the eccentric rods.

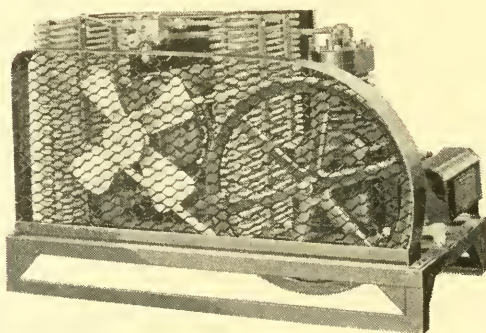


FIG. 74.—LARGER SIZE FRIGIDAIRE AIR-COOLED COMPRESSOR.

The compressor shaft is sealed by a special metal ring which automatically compensates for wear. The compressor pulley contains fan blades which force air over the copper condenser coils located on opposite sides of the compressor. The condenser coils are made of flattened copper tubing. The $\frac{1}{4}$ hp.

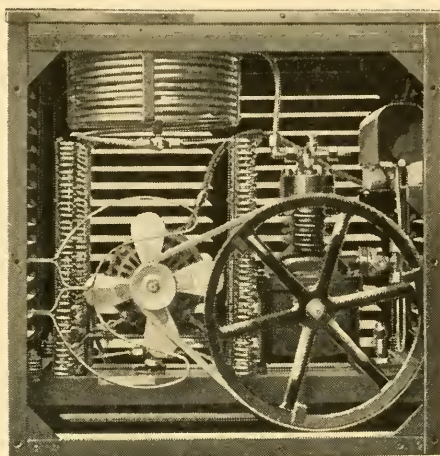


FIG. 75.—FRIGIDAIRE AIR-COOLED COMPRESSOR FOR HOUSEHOLD AND COMMERCIAL INSTALLATIONS.

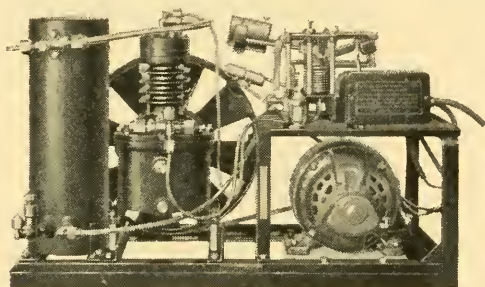


FIG. 76.—FRIGIDAIRE WATER-COOLED CONDENSING UNIT FOR COMMERCIAL INSTALLATION.

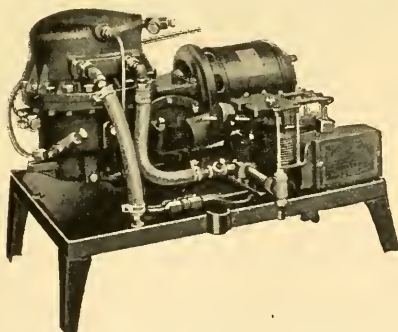


FIG. 77.—FRIGIDAIRE WATER-COOLED CONDENSING UNIT FOR COMMERCIAL INSTALLATION.

motor drives the compressor by means of a "V" type belt. The automatic control switch is actuated by a change of pressure on the low side of the refrigerating system.

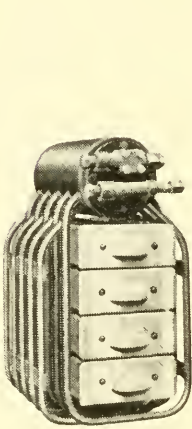


FIG. 78.—TYPICAL FRIGIDAIRE COOLING UNIT, FLOODED PRINCIPLE.

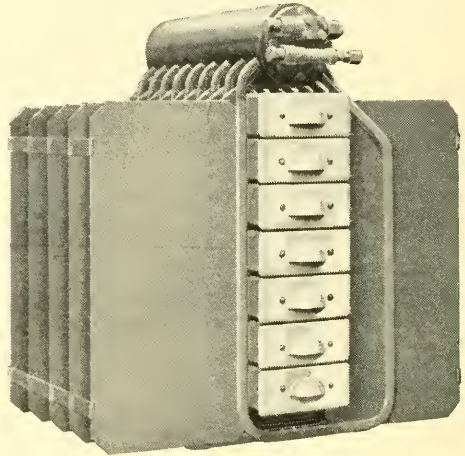


FIG. 79.—TYPICAL FRIGIDAIRE COMMERCIAL SIZE COOLING COIL, COPPER FINNS.

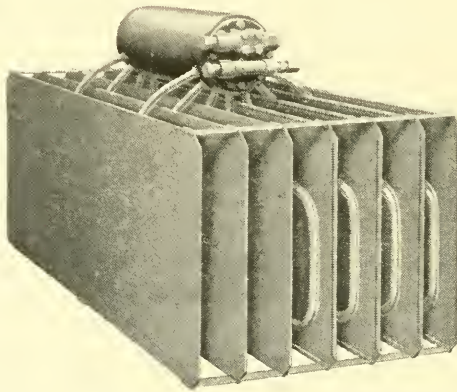


FIG. 80.—TYPICAL FRIGIDAIRE COMMERCIAL SIZE COOLING COILS, COPPER FINNS.

Figs. 74 and 75 show larger sizes of air-cooled compressors used on household and commercial installations.

Fig. 76 and 77 are water-cooled condensing units used mostly for commercial work.

Fig. 78 shows a typical cooling unit which operates on the flooded principle. The header contains a float valve which controls the supply of liquid refrigerant to the cooling unit. A series of copper coils terminate in the header. Copper

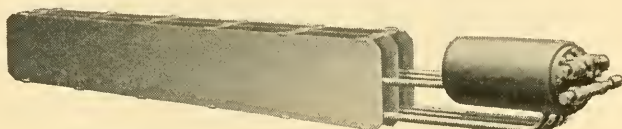


FIG. 81.—TYPICAL FRIGIDAIRE COMMERCIAL SIZE COOLING COILS, COPPER FINES.

sleeves are used inside the coils to accommodate the ice trays. This provides direct frost-coil cooling and the ice containers are of the self-sealing tray front type. Cooling coils are made

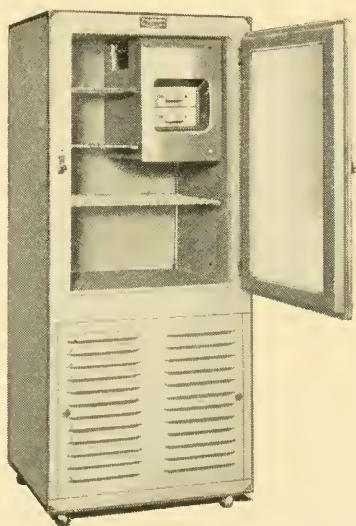


FIG. 82.—FRIGIDAIRE METAL CABINET.

in various sizes to fit in any household or commercial refrigerator.

Figs. 79, 80 and 81 show typical commercial size cooling coils with copper fins. The copper fins greatly increase the effective cooling surface. The copper tube is soldered to the fins and in some cases the copper tubes are flattened.

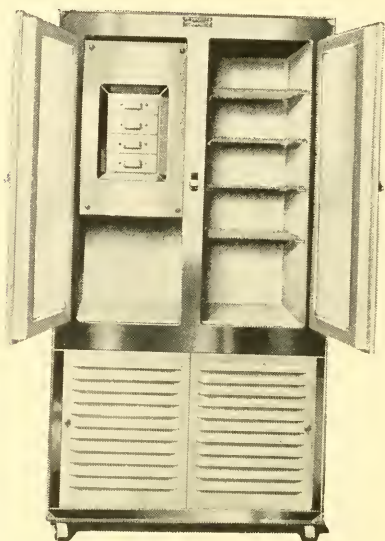


FIG. 83.—FRIGIDAIRE METAL CABINET.

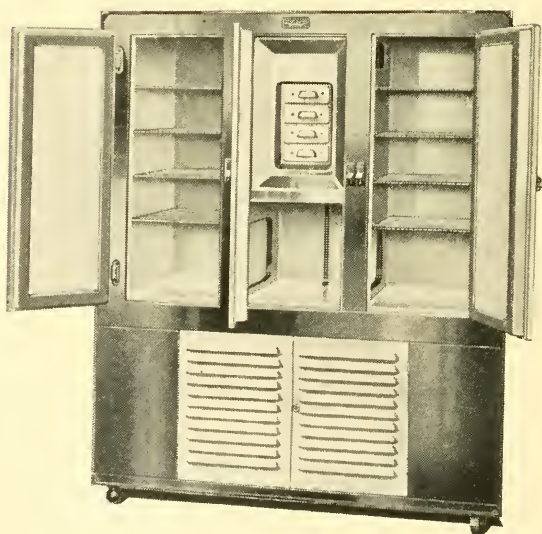


FIG. 84.—FRIGIDAIRE METAL CABINET.

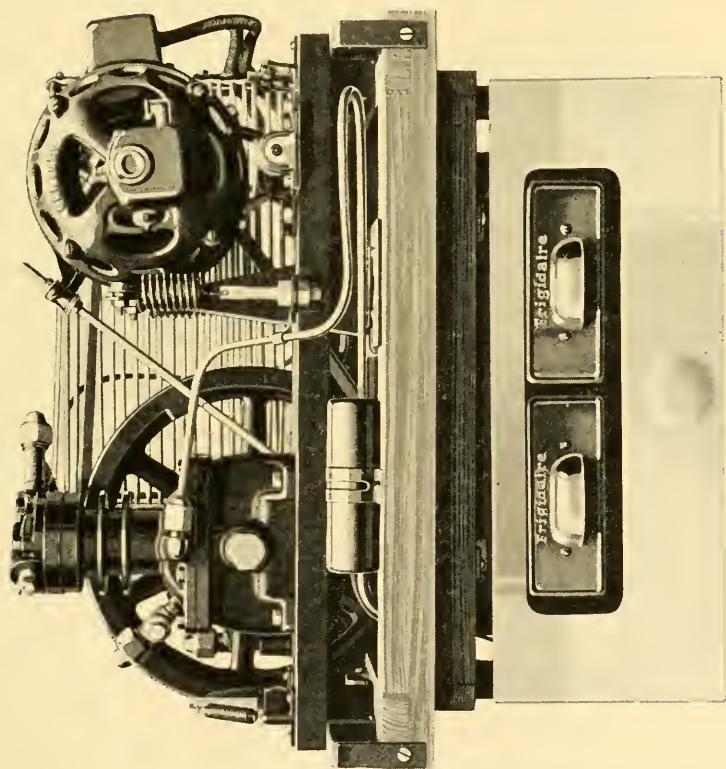


FIG. 86.—SPECIALLY DESIGNED FRIGIDAIRE MODEL

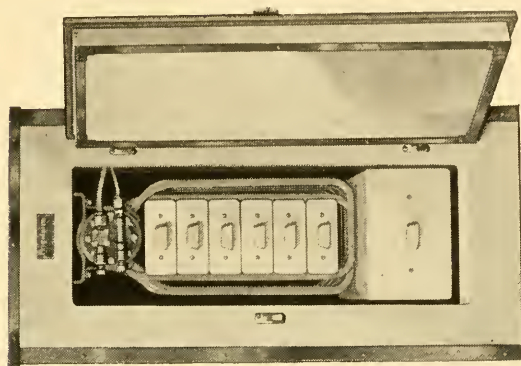


FIG. 85.—FRIGIDAIRE ICE MAKER.

Figs. 82, 83 and 84 show typical metal cabinets. The refrigerating mechanism may be placed in the bottom of any of these cabinets. These are made with 5, 7, 9, 12 and 15 cubic feet of food compartment space. One line of cabinets is made with the exterior finished in white Duco on steel.

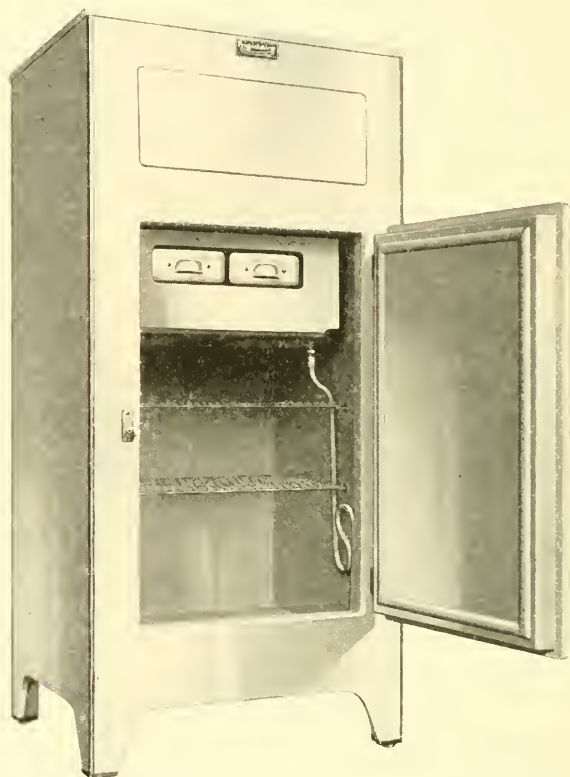


FIG. 87.—FRIGIDAIRE CABINET FOR SELF-CONTAINED UNIT.

Another complete line has the exterior of porcelain on steel, trimmed with monel metal. The front is of highly polished monel metal. These cabinets are insulated with corkboard and the linings, with the exception of one model, are made of porcelain on steel. The linings are of the one piece construction with rounded corners fitting flush above the door sills.

Fig. 85 shows the ice-maker which is used where a greater amount of ice is required than is provided by the cooling coil

installed in a regular refrigerator. The ice-maker contains six large capacity freezing trays and a storage compartment underneath.

Fig. 86 shows the specially designed model including the motor, compressor, condenser, and cooling coils arranged as a self-contained unit. A copper finned cooling coil is used. The compressor is mounted on a special spring suspension to eliminate vibration and afford quietness in operation.

Fig. 87 shows the cabinet in which the self-contained unit is used.

General Electric.—The General Electric Refrigerator is made by the General Electric Company of Schenectady, N. Y. Fig. 88 shows the complete refrigerating unit installed in a refrigerator cabinet.

The refrigerant used is sulphur dioxide. All moving parts are hermetically sealed in a drawn steel case containing the refrigerant—sulphur dioxide—and the lubricant. The condenser and evaporator coils are brazed to the steel casing. Specially developed insulated leads, similar to spark plugs, are used for the electrical connection to the motor. This construction permits complete enclosure and the elimination of the stuffing box through which gas or oil might leak. There is no external piping, cooling fan, belt or other external moving part.

The essential operating parts consist of:

1. A $\frac{1}{6}$ -hp., 110-volt, 60-cycle, split-phase motor mounted vertically. This motor is exceedingly simple in design and sturdy in construction—without brushes or other moving contacts.
2. A two-cylinder, single-acting compressor having oscillating cylinders.
3. A discharge valve of spring steel so arranged as to eliminate noise.
4. A copper tube condenser coil of circular cross section.
5. A float valve to regulate the amount of refrigerant passing to the evaporator coils.
6. An evaporator coil of copper tubing immersed in the brine tank.
7. An automatic regulating control.

The cooling tank, which is suspended within the cabinet itself, is covered inside and out with white, fused-on vitreous

porcelain—long wearing and easy to clean. The freezing trays, having a capacity of seven pounds of ice cubes, can be slipped into compartment in the tank. These trays are

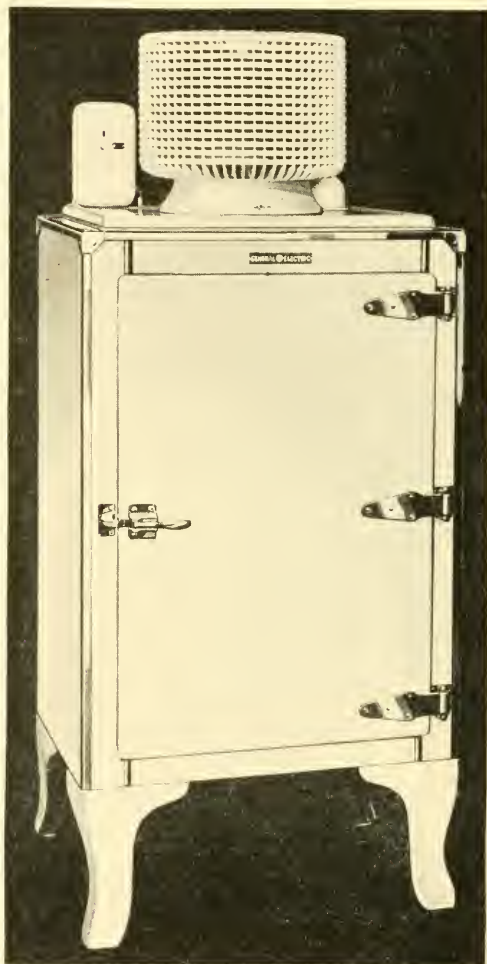


FIG. 88.—GENERAL ELECTRIC REFRIGERATOR.

of heavily tinned copper and are furnished with removable dividers to provide twenty-one cubes for each tray, or a total of sixty-three cubes for the three trays.

Complete automatic temperature and current control are provided. A control box on the front of the unit contains a manually-operated switch for disconnecting the machine, for defrosting or any other purpose.

The control box also contains an automatic thermostatic switch for starting and stopping the machine in response to temperature changes, a relay for transferring motor connections from starting to running position and a thermal, time-limit relay for protecting the motor from overload damage, also a reset button for a resumption of operation.

The automatic control is so adjusted that a brine temperature is maintained between 16° and 24° F., thereby maintaining a continuous cabinet temperature of from 40° to 50° F., which is admittedly the most satisfactory temperature for food preservation.

Installation is extremely simple as the refrigerator need only be moved to the desired position and attached to the nearest electric outlet. It can be installed wherever it will prove most convenient as there is no special plumbing or permanent fixtures to be connected to it. The cooling tank is placed in the cabinet, filled with a solution of salt brine and the refrigerating unit set into place. It is thoroughly portable and can readily be moved.

Fig. 88 shows the Model P-5-2 installed in a 5 cu. ft. refrigerator. This cabinet is of white porcelain exterior and interior. The exterior has flat polished metal trim strips. The exterior dimensions are height overall, 65¾ inches; width over hardware, 28¾ inches; depth over hardware, 22¾ inches. (Legs may be removed and the height reduced 11¾ inches.)

The cooling unit contains one small tray for making ice cubes and one large tray for making cubes or frozen dessert. The total ice-making capacity is 56 cubes or approximately 7 pounds of ice. The food storage capacity is 5.37 cubic feet and the food shelf area is 7.9 square feet.

Hall Refrigerating Machine.—Fig. 89 shows the compressor of the ammonia machine manufactured by Thomas Hall & Son, Ltd., Rotherham, England.

The piston is of the truncated type and contains the suc-

tion valve. The discharge valve is of a special type. It is not affected by the heat of the compression. The valve is contained in a safety head which allows any liquid ammonia or oil to pass without damage.

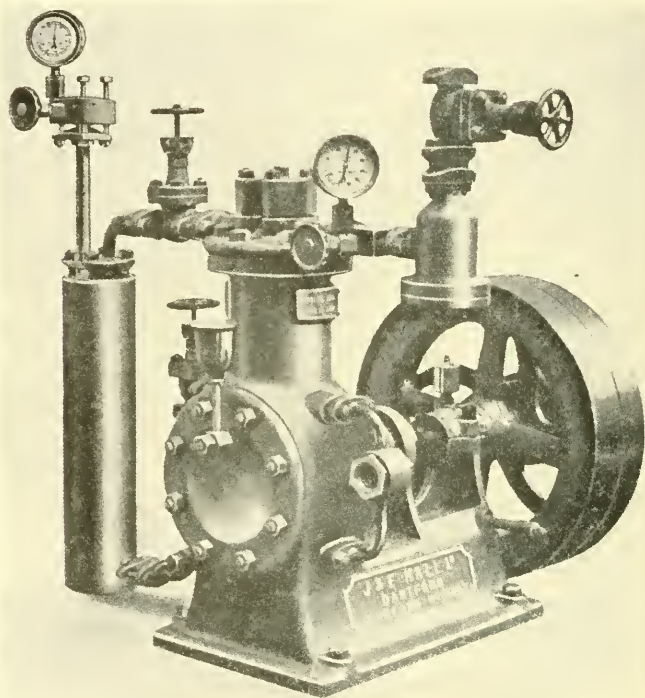


FIG. 89.—HALL REFRIGERATING MACHINE.

The crank case gland screws up like a nut, which prevents the gland from being pulled on one side and thus scoring the shaft. Metallic packing is used. The connecting rod is of forged steel. The dirt separator is fitted on the suction pipe, thus preventing any scale which may become loosened in the room coils from entering the machine and interfering with the working of the valves.

An oil sight glass is fitted in the end cover, which enables the level of the oil to be seen at a glance.

The stop valves are double seating, allowing the valves to be packed while the machine is running. The machine is fitted with a purge valve on the cylinder head to enable air and foul gases to be purged out of the system.

An oil trap is fitted on the discharge and is equipped with an oil return valve which enables the oil carried over through the valve, to be returned to the crank case, thus preventing it from going into the system.

A liquid ammonia receiver is fitted underneath the condenser making a compact unit.

The method of cooling usually adopted is by means of direct expansion coils immersed in a brine accumulator tank, which acts as a reservoir of cold and keeps the room down in temperature after the plant has been stopped. For some requirements air circulation is added. For frozen meat, direct-expansion coils are placed on the ceiling or on the walls.

This small size machine is capable of cooling a properly insulated cold room of 400 to 500 cubic feet to a temperature of 35° to 38° F.

Ice Maid.—The household refrigerating unit, Fig. 90, is made by the Lamson Company, Inc., at Syracuse, New York.

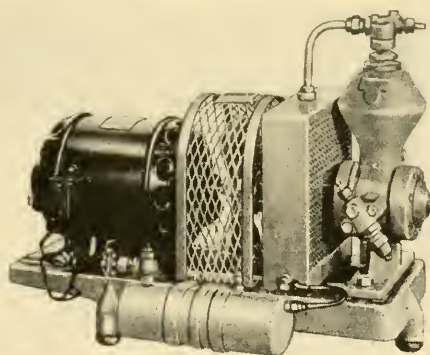


FIG. 90.—ICE MAID HOUSEHOLD REFRIGERATING UNIT.

The compressor is a direct connected rotary type running at motor speed and using ethyl chloride as a refrigerant. The compressor has a 2-bladed rotor mounted eccentric to the bore and is carried on annular ball bearings. The stuffing

box is of the syphon bellows type, the bellows revolving with the shaft thereby carrying away any heat that may be generated by the seal.

The discharge valve is of the flapper valve type and consists of two flat steel discs riveted to the seat on one side. An efficient oil separator is an integral part of the oil reservoir, it is located in the dome of the pump and oil is fed by the pressure of the gas through holes drilled in the pump casting to the bearings and the rotor. This gives the effect of a full pressure system and is fully automatic, as the load on the pump increases the quantity of oil fed to the bearing also is increased. Oil is used as a lubricant increasing the efficiency of the pump considerably.

Suction and discharge shut-off valves are of the double-seated type permitting removal of pump without losing the charge of refrigerant. A check valve of the flat disc type is located on the suction side of the pump to obviate the possibility of oil running back into the suction line.

The compressor is driven through a flexible coupling of the fabric disc type which is self-aligning. Coupling and fan hub are integral.

The motor is of the induction repulsion type, both $\frac{1}{3}$ and $\frac{1}{4}$ hp. being used. For remote control the motors run at 1750 r.p.m. and for self-contained installation they run at 1165 r.p.m. The motor is directly connected to the compressor by means of the fan and coupling assembly.

The condenser is of the Honeycomb Radiator type and has a cooling capacity equal to about 120 feet of $\frac{1}{2}$ -inch copper tubing. This is mounted between the pump and the fan. The fan running at motor speed throws a current of air directly through the radiator and thence around the pump. This direct positive cooling system is so effective that the machine usually operates under several pounds less head pressure than ordinary ethyl chloride systems using a copper tube condenser.

The compressor, radiator and motor are mounted as a unit on a rigid cast iron base. The base is drilled in such a manner that any standard motor that may be used can be mounted upon it readily. The base rides on sponge rubber balls which effectively absorb any slight noise or vibration.

Attached to the side of the base is a receiving tank of a capacity sufficient to hold the entire charge of refrigerant, thus making the entire condenser available for condensing purposes.

The dimensions of the entire unit are 24 inches long, 18 inches high and 12 inches wide. Due to this extreme compactness, the standard unit may be mounted in much less space than that occupied by the average machine and this can be installed in the base of a comparatively small refrigerator,

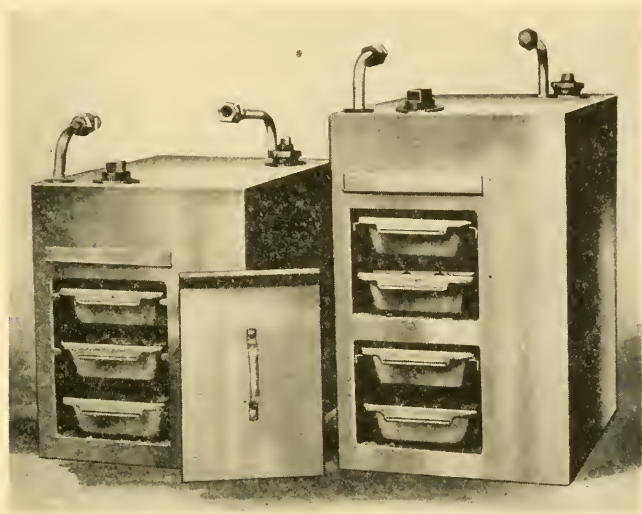


FIG. 91.—ICE MAID FREEZING UNIT.

without any changes whatsoever. The weight of the entire mechanical unit is approximately 100 pounds.

The freezing unit, Fig. 91, is of the brine tank type having a copper expansion coil of ell-shaped form and is equipped with compartment for ice trays. The tanks are nickel plated and are furnished in a variety of sizes sufficient to accommodate all standard refrigerators. The ice trays have a capacity of 24 cubes of ice.

The tray compartment is equipped with a cover which is so designed that it will not freeze to the tank and thus make it difficult to remove the ice tray.

The expansion valve is of the balanced type having only one spring which is the adjusting spring. It is constructed with a sylphon bellows and is fully automatic in its action. It is readily adjustable from the outside and is provided with an efficient means preventing moisture freezing and interfering with the operation of the bellows.

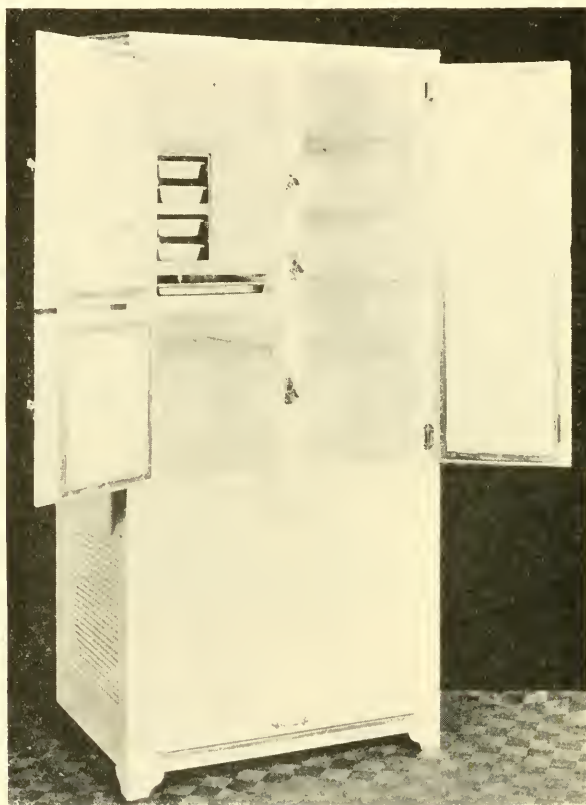


FIG. 92.—ONE OF THE TWELVE ICE MAID MODELS.

Control of the machine is effected by means of a mercoid switch located outside the refrigerator. It is connected to the refrigerator by means of a capillary tube which is attached to a bulb immersed in the brine, the other end of the tube being connected to a sylphon bellows actuating a tilting glass

tube containing mercury, which makes or breaks the circuit as the bulb is tilted back and forth. A brine temperature of 16° or 20° is maintained.

This method of control gives uniform brine temperature regardless of outside temperature. Only one size compressor is furnished, but by substitution of butane for ethyl chloride comparatively large restaurant, butcher boxes and other commercial applications can be handled.

A complete line of refrigerators with self-contained units are furnished in both wood and all metal comprising twelve different models from 5 to 20 cu. ft. food storage capacity. Fig. 92 shows one of these models.

Installation is simple as there are no electric wires entering the refrigerator and the standard mechanical unit is readily installed either as a remote or self-contained unit.

Iroquois.—Fig. 93 shows the compressor-condenser unit, made by the Iroquois Refrigeration Company, associate of the

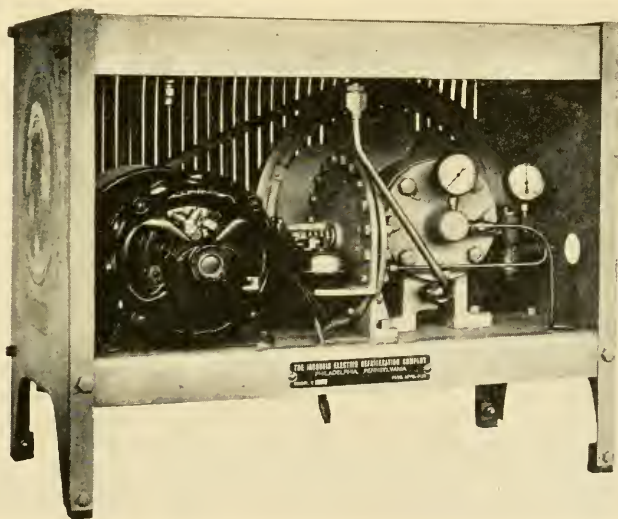


FIG. 93.—FRONT VIEW, IROQUOIS COMPRESSOR-CONDENSER UNIT.

Barber Asphalt Company of Philadelphia, Pennsylvania. Ethyl chloride is used as the refrigerant.

Fig. 94 shows the rotary type compressor used with this

unit. The condenser, Fig. 96, is of the double header type consisting of a series of copper tubes arranged so as to form a guard for the compressor. The condenser is cooled by two

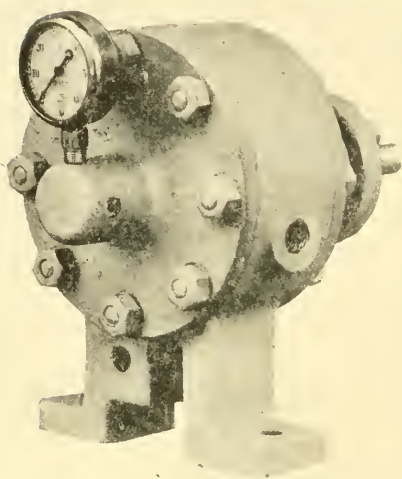


FIG. 94.—IROQUOIS ROTARY TYPE COMPRESSOR.

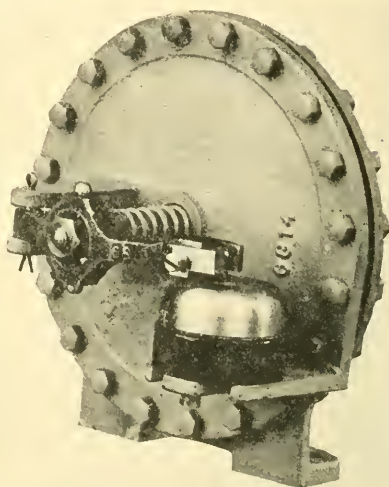


FIG. 95.—IROQUOIS PRESSURE CONTROLLED SWITCH.

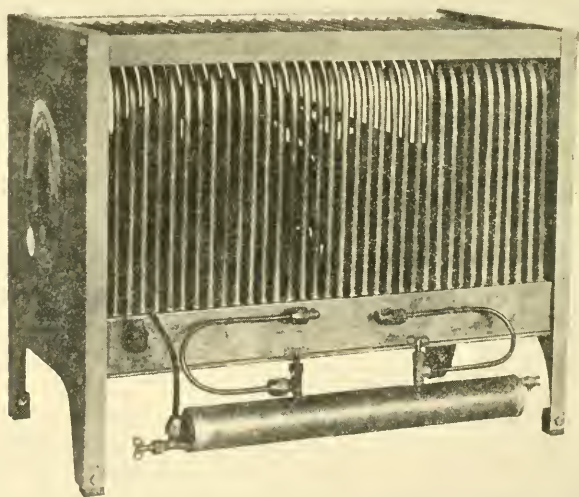


FIG. 96.—REAR VIEW, IROQUOIS COMPRESSOR-CONDENSER.

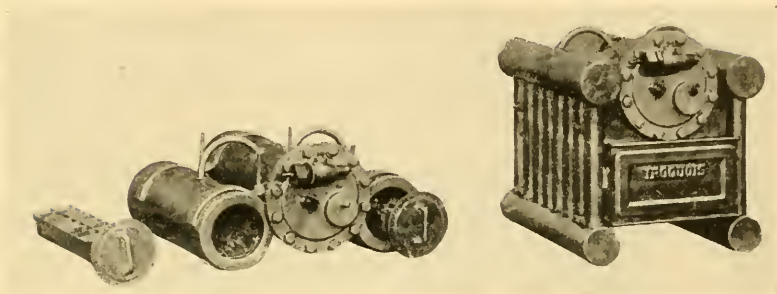


FIG. 97.—IROQUOIS COOLING UNITS. APARTMENT HOUSE UNIT AT LEFT.

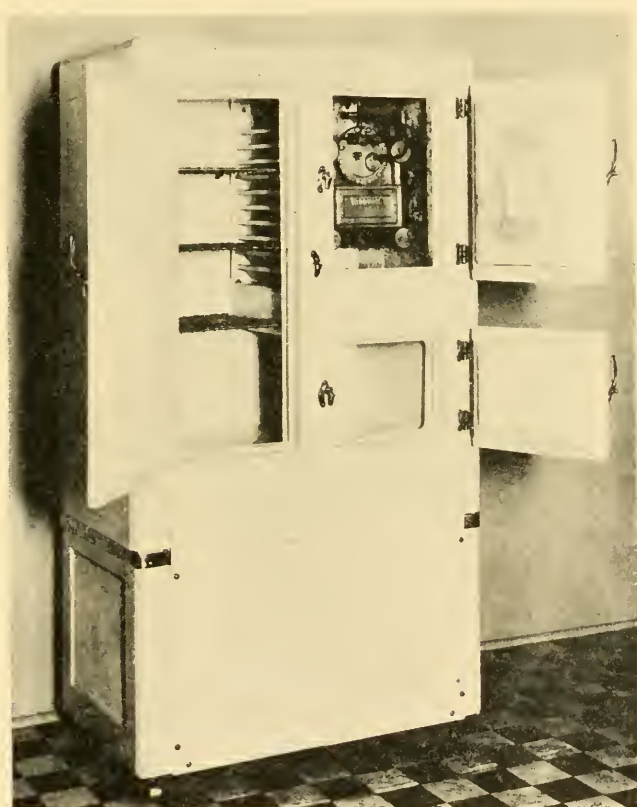


FIG. 98.—IROQUOIS SYPHON ALL-METAL CABINET EQUIPPED WITH COMPLETE SELF-CONTAINED REFRIGERATING UNIT.

fans, one on the motor shaft and the other on the compressor flywheel.

The automatic pressure controlled switch is shown in Fig. 95. This device consists of the powerful snap switch actuated

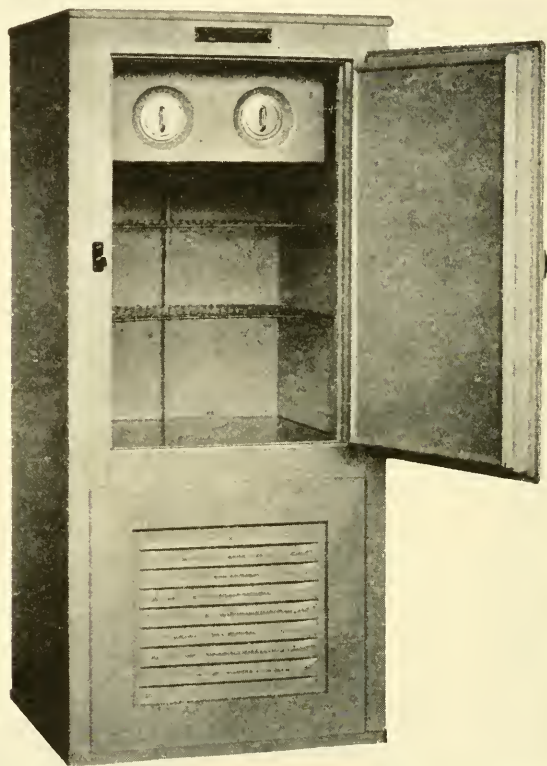


FIG 99.—IROQUOIS ELECTRICAL REFRIGERATOR, APARTMENT HOUSE TYPE.

by a diaphragm subjected to a pre-determined pressure in the cooling unit.

The cooling units, as Fig. 97, are constructed of heavy tinned copper and brass material. A float valve is used to control the flow of liquid refrigerant to the cooling unit.

Figs. 98 and 99 show a typical cabinet equipped with the refrigerating unit forming a complete self-contained model.

Isko—First Model.—The first model Isko machine is described as follows:

The motor operates the compressor and is controlled through the thermostat and the circuit breaker. When the refrigerator gets warm the thermostat starts the motor, which runs until a predetermined low temperature is attained and then stops. The thermostat is located in the cooling coil where the greatest variation of temperature is, there being nearly 32° of variation under average conditions. The thermostat alternates on from 2° to 4° of variation.

Isko cools the refrigerator by abstracting the heat through the tinned copper ice-making coils in which liquid sulphur dioxide is being boiled by the heat extracted from the refrigerator.

This sulphur dioxide steam, unlike the steam with which we are most familiar, is cold (14° F.). This is sucked into the compressor at atmospheric pressure and elevated in both temperature and pressure to the corresponding temperature of the room.

In the condenser (which is a coil of pipe surrounding the apparatus as a guard), this warm sulphur dioxide steam loses its heat by radiation to the surrounding atmosphere, causing it to liquefy because it is under pressure.

The liquid coming out of the bottom of the condenser is fed automatically into the tinned coil inside the refrigerator by means of an expansion valve, which works intermittently to step down these condenser pressures to a pressure above atmospheric pressure.

Moisture abstracted from the refrigerator is deposited on the coil, and freezes because the coil is at 14° F. The machine operates intermittently so that this frost does not accumulate. On the stand-still period the frost will melt and run off through the drain pipe of the refrigerator.

In the ice-making compartment it is possible in warm weather to make 32 cubes of ice in a day of twenty-four hours, automatically. Ice can be made in winter only when the refrigerator is in a well-heated room; otherwise the machine will run too small a percentage of the time.

The complete machine is supplied as a unit ready to run when connected to an electric light socket. The number 1

size will take care of an ordinary refrigerator not to exceed fifty-five square feet of internal exposed area when set over a hole thirteen inches by thirteen inches in the top of the refrigerator. The actual weight of the apparatus is 175 pounds.

Isko—Present Model.—The present model of the Isko ma-

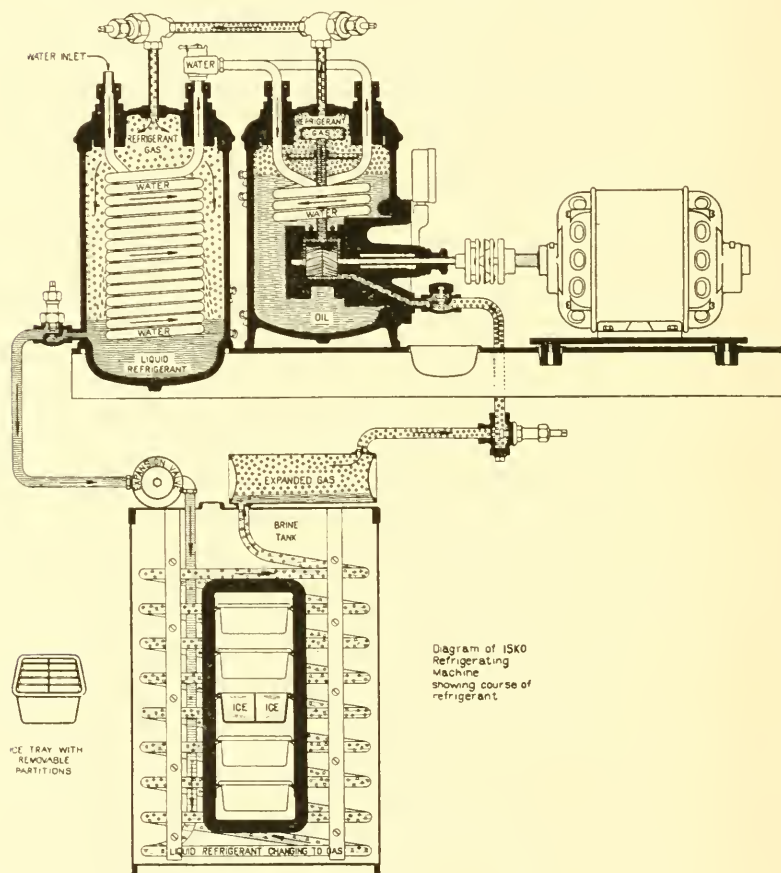


FIG. 100.—ISKO REFRIGERATING MACHINE.

chine is shown in Fig. 100. This machine was formerly manufactured in large quantities by the Isko Company at Chicago.

The compressor was of the herringbone gear type, operating at motor speed submerged in a sealed chamber of oil.

The gears were supplied with a small amount of oil to seal them so that they would compress the sulphur dioxide gas, this being the refrigerant used.

The cylinder and motor were mounted on a single base to be placed on the top of the refrigerator or in the basement, if desired. The motor was directly connected to the gear shaft through a flexible coupling.

Brine tanks were made in various sizes. An expansion valve was used, expanding into a copper tube immersed in the brine.

A small header was used on the suction line between the evaporating coil and the compressor to prevent frosting back to the machine.

The condenser was water-cooled by means of a copper coil inside the condenser cylinder. Part of the cooling water circulated through a coil in the compressor cylinder, in order to cool the oil in which the gears operate.

Full automatic controls were used to maintain a uniform temperature inside the refrigerator.

Kelvinator.—Fig. 101 shows the Model Senior (2 cylinder) refrigerating machine made by the Kelvinator Corporation, Detroit, Michigan. This is a motor-driven refrigerating machine designed for installation with any refrigerator of standard construction of not over 70 cubic feet contents.

The condensing unit consists of the motor, compressor, and condensing coil mounted on a single base and is installed in the basement or other out-of-the-way place.

The compressor is of the reciprocating, single-acting type. Piston valves and discharge valves are of the disc type. The pistons slide in steel sleeves. Instead of a stuffing box a sylphon gas seal of self-aligning, self-lubricating, anti-friction metal is used. It is driven through a combined flywheel and fan by a "V" belt. The motor is of the repulsion induction type, $\frac{1}{4}$ hp.

The condenser is a continuous coil of $\frac{1}{2}$ inch seamless copper tubing wound spirally and charged with sulphur dioxide. It is air-cooled and therefore is not dependant on any water supply for its proper operation.

Fig. 102 shows the Model Junior (1 cylinder) refrigerating machine. This is similar to the Model Senior except that it is installed with refrigerators of not over 20 cubic feet contents.

The refrigerating element consists of the brine tank, the expansion coils inside the brine tank, the expansion valve, the thermo-coil and the thermostat. Eighteen standard sizes of brine tanks are made, one of which is shown in Fig. 103 and fit practically all ice chambers.

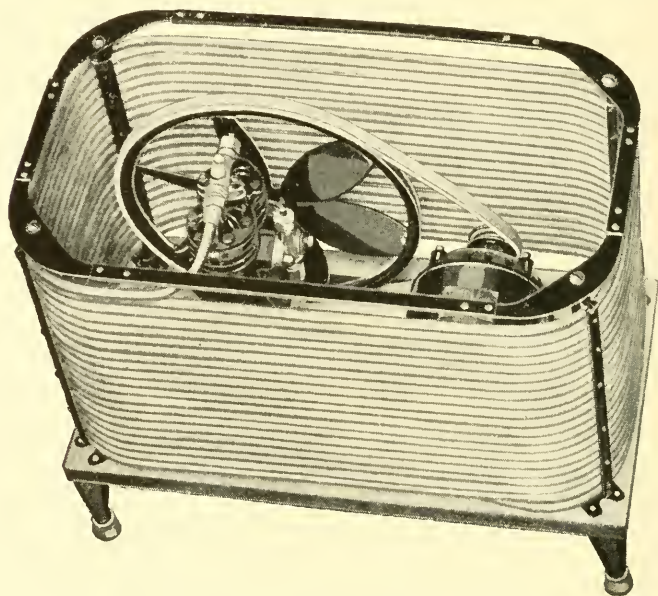


FIG. 101.—KELVINATOR TWO-CYLINDER REFRIGERATING MACHINE.

The brine tank is of sheet copper tinned on the outside. It has two to four freezing compartments, according to the tank size. Each 21-cube tray will freeze two and one-half pounds of ice, while the large tray will freeze an eight and one-half pound cake of ice. The tank is filled with a solution of calcium chloride. Expansion coils are placed in the tank in such a way as to surround each freezing compartment.

The liquid refrigerant is admitted to the expansion coils through an automatic expansion valve which lowers its pres-

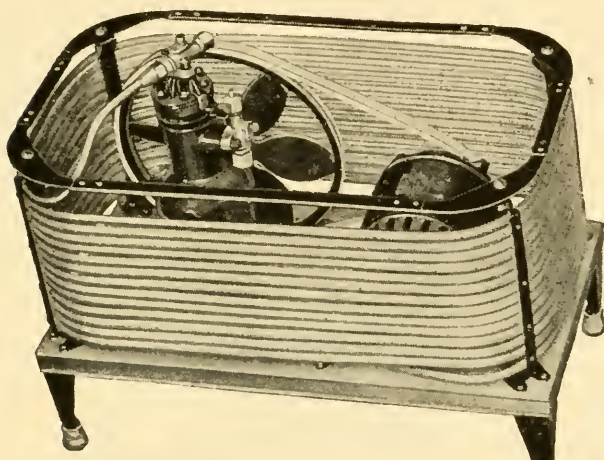


FIG. 102.—KELVINATOR SINGLE-CYLINDER MACHINE.

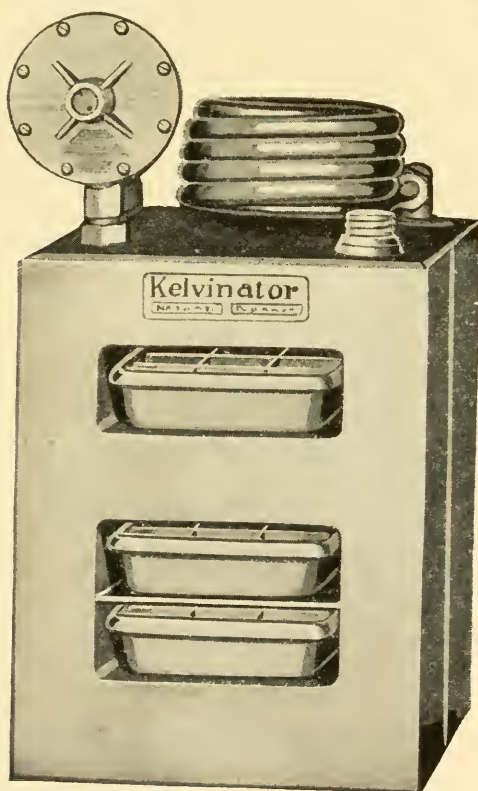


FIG. 103.—KELVINATOR COOLING UNIT.

sure from two inches of vacuum to three pounds per square inch, depending on the size of brine tank and number of feet of tubing in the expansion coil. The valve is of the balanced pressure type. Increasing pressure on the low side caused by the boiling refrigerant, acts against the pressure on the liquid side and automatically shuts off the supply of liquid when sufficient has been admitted. The valve automatically opens when the suction of the compressor sufficiently reduces the pressure on the low side.

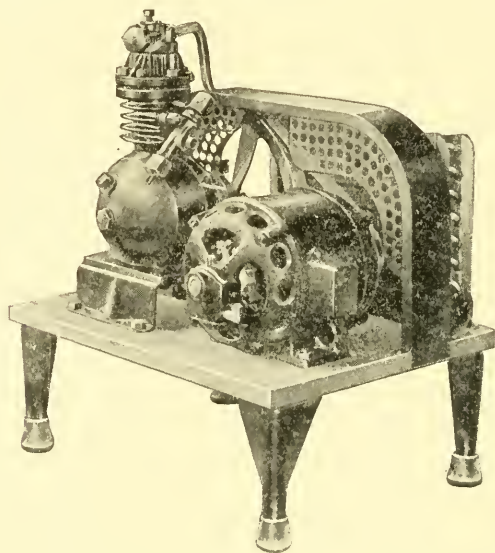


FIG. 104.—KELVINATOR CONDENSING UNIT.

The system is automatically controlled by the thermostat placed within the thermo-coil on top of the brine tank. The thermostat opens and closes the motor circuit as the temperature within the refrigerator falls and rises. It is of the syphon type, a corrugated metal bellows filled with sulphur dioxide, which by the contraction and expansion caused by changing temperatures operates the quick make and break switch.

The actual running time of Kelvinator will vary, of course, with the room temperature, the quality and degree of refrigerator insulation, the size of refrigerator, etc. Under ordinary conditions, however, the machine will run 6 or 7 hours a day.

The box temperatures will be at least 10° colder than ice would keep the same box. The reason for this is that the surface of the brine tank is kept constantly at 20° to 22° while the surface of a cake of ice is 32° F.

Fig. 104 shows the condensing unit Model 12800. This unit includes a $\frac{1}{6}$ hp. motor driving a reciprocating type.

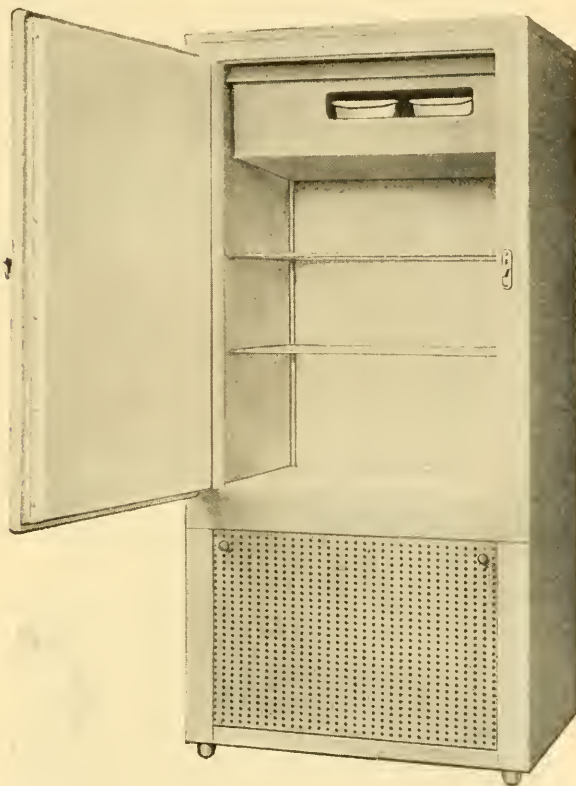


FIG. 105.—SPECIAL STEEL CABINET EQUIPPED WITH CONDENSING UNIT SHOWN IN FIG. 104.

single-cylinder compressor by means of a "V" type belt. The condenser is made of finned tubing. It is cooled with forced air circulation. A small receiver is used. The weight of this unit is 80 pounds.

This unit is supplied with a special steel cabinet, Fig. 105. The food storage space is 4.7 cubic feet and 7 square feet shelf area. The exterior is gray lacquer on steel. The lining

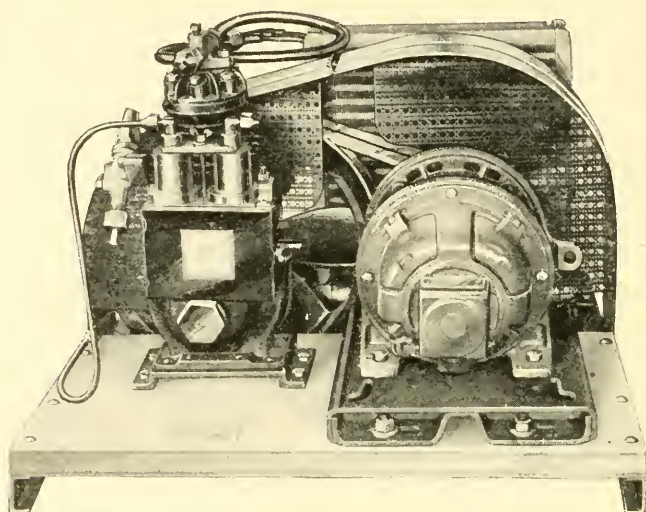


FIG. 106.—KELVINATOR TYPE "LB" LARGE CAPACITY AIR-COOLED CONDENSING UNIT.

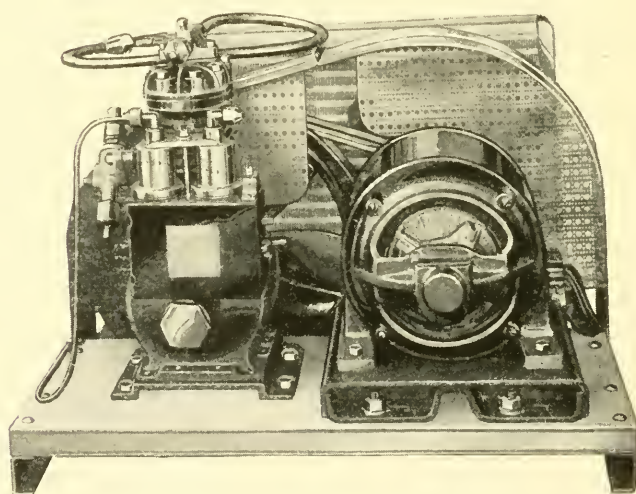


FIG. 107.—KELVINATOR, TYPE "BB".—COMPRESSOR HAS TWO CYLINDERS.

is white enamel on galvanized iron. The hardware is nickel-plated brass. The insulation is corkboard. The dimensions of the cabinet are:

| | Width | Depth | Height |
|----------------------------------|---------|---------|---------|
| Overall | 26½ in. | 22½ in. | 56⅛ in. |
| Food Compartment | 22 in. | 15½ in. | 24⅛ in. |
| Condensing Unit Compartment..... | 26¼ in. | 19½ in. | 16½ in. |

The cooling unit has two 15-cube ice trays. The shipping weight of this unit is 300 pounds.

Fig. 106 shows the type LB large capacity air-cooled condensing unit.

The compressor has one cylinder and is of the vertical, reciprocating, single-acting type. A $\frac{3}{4}$ hp. motor drives the compressor by means of a "V" type belt. The condenser is of the radiator type. It is cooled by forced air circulation, from the fanned motor pulley. The wattage is approximately 800 at rated capacity.

A similar larger type BB, Fig. 107, is manufactured. The compressor has two cylinders. A $1\frac{1}{2}$ hp. motor is used. The wattage of this model is approximately 1200 at rated capacity. Both of these units have extensive use for apartment house installations.

Kold King.—Fig. 108 shows the household refrigerating machine manufactured by the Kold King Corporation at Detroit, Mich. It is reported this company is out of business.

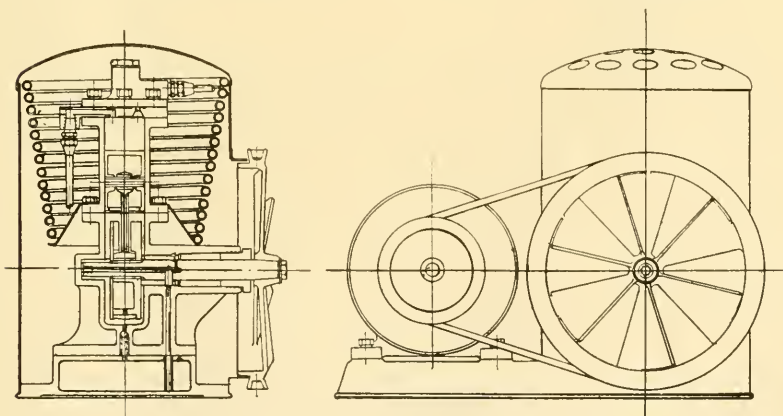


FIG. 108.—KOLD KING REFRIGERATING MACHINE.

A single-cylinder, sulphur dioxide compressor is used. The condenser is air-cooled and consists of sixty feet of copper tubing, forming a spiral coil around the compressor. A fan in the compressor fly wheel forces air over the condenser coil. The suction and discharge valves are of the flat steel flapper type. They are both located in the cylinder head plate. The compressor is driven by a $\frac{1}{8}$ hp. phase, repulsion-induction motor. A "V" type belt is used for the means of driving.

A float valve system of expansion has been developed for regulating the cooling compartment. The thermostat is attached to the crank case and is controlled by pressure. A brine tank is used which is placed in the ice compartment of the refrigerator.

The mechanical unit is supplied to refrigerate any standard cabinet.

Lipman Refrigerating Machine.—Fig. 109 shows the household size refrigerating machine, which is made by the Lipman Refrigerator Car & Mfg. Company, Beloit, Wis.

This company has specialized for years in producing refrigerating machines using ammonia as a refrigerant and operating with full automatic controls.

The motor, compressor, condenser, water valve, and high pressure cut-out, are mounted on a simple base to form a compact unit. A "V" belt drive is used, thus eliminating the need of an idler pulley.

The condenser is water-cooled. The water valve is automatically opened when the machine is operating, by an attachment on the outer end of the compressor shaft. A safety feature is included so that the machine will not operate should the supply of cooling water fail.

The operation of the machine is controlled by a thermostat placed in the food compartment. The motor starts or stops automatically when the temperature in this compartment varies only a few degrees.

An expansion valve is used to control the supply of refrigerant to the cooling coil. The household model uses only a few ounces of liquid ammonia in the entire system.

This machine is supplied with a cooling element to be placed in the ice compartment of the customer's refrigerator. This cooling element consists of a direct-expansion coil and a sharp freezer of steel pipe in which ice cubes or frozen desserts may be made. A cast iron sleeve is inserted in the horizontal part of this direct-expansion coil to form the sharp freezer.

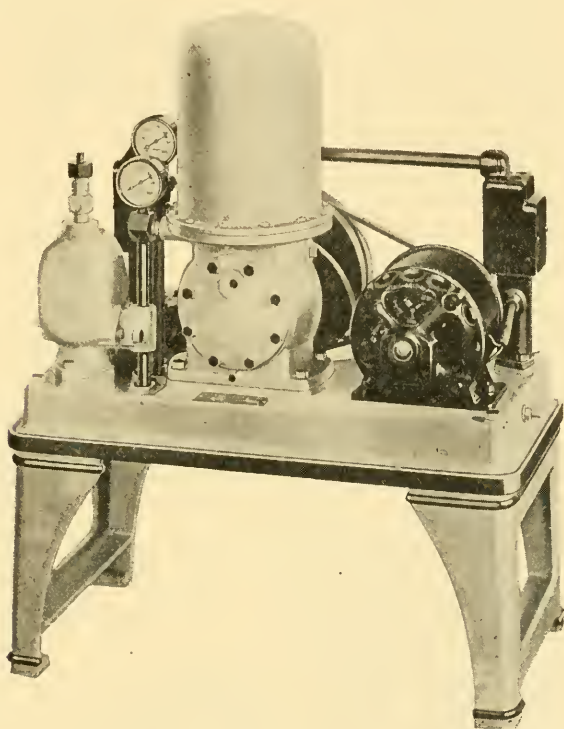


FIG. 109.—LIPMAN REFRIGERATING MACHINE.

Larger automatic machines are built for installations requiring a larger capacity machine.

Merchant and Evans.—Fig. 110 shows the electrical refrigerating system manufactured by Merchant and Evans Company of Philadelphia, Pa.

A low temperature liquefying gas is compressed (G), into coils (C), which are cooled by a fan on the pulley and thus

becomes a liquid which flows into the freezing chamber (F) through the Control Valve (V).

Here the liquid boils by absorbing heat from the interior of the box, cooling it to a temperature of 45° F. The thermostat

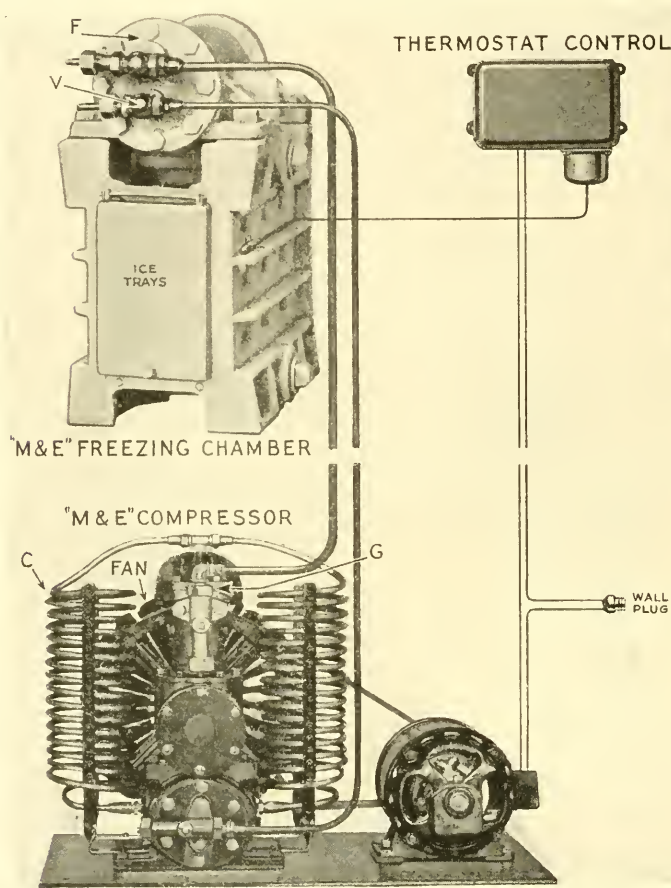


FIG. 110.—MERCHANT & EVANS ELECTRICAL REFRIGERATING SYSTEM.

then turns off the current automatically until the box temperature rises to 50° F. The thermostat then again starts the motor and the whole process is repeated until the box temperature again drops to 45° F.

The compressor is a single cylinder of the single-acting vertical reciprocating type, with long stroke.

The condenser consists of two coils of copper tubing placed on opposite sides of the compressor. Fan blades in the compressor flywheel are used to force air over the two condenser coils.

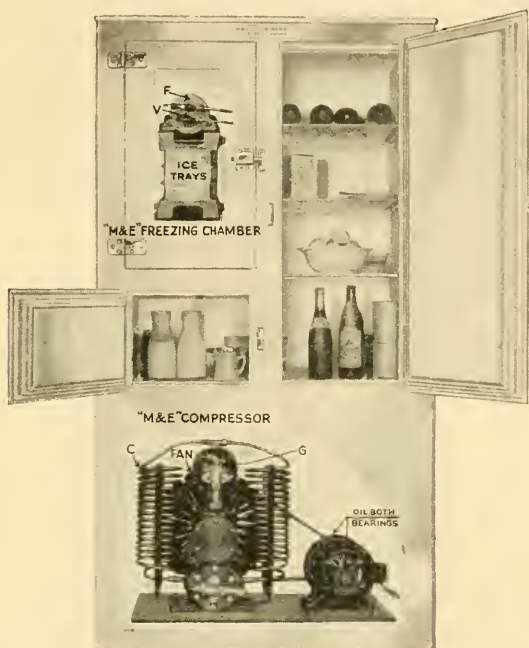


FIG. 111.—MERCHANT & EVANS REFRIGERATING SYSTEM INSTALLED.

The freezing chamber is made of galvanized cast iron and tested to 350 pounds pressure per square inch.

Fig. 111 shows a typical installation in a cabinet. Steel cabinets are supplied in sizes from 7 to 20 cubic feet inside capacity.

Norge.—The Detroit Gear & Machine Company manufacture an electric refrigerating machine for the Norge Corporation, Detroit, Michigan. This machine has been adopted for domestic use by McCray Refrigerator Company of Kendalville, Ind. The refrigerant used is sulphur dioxide.

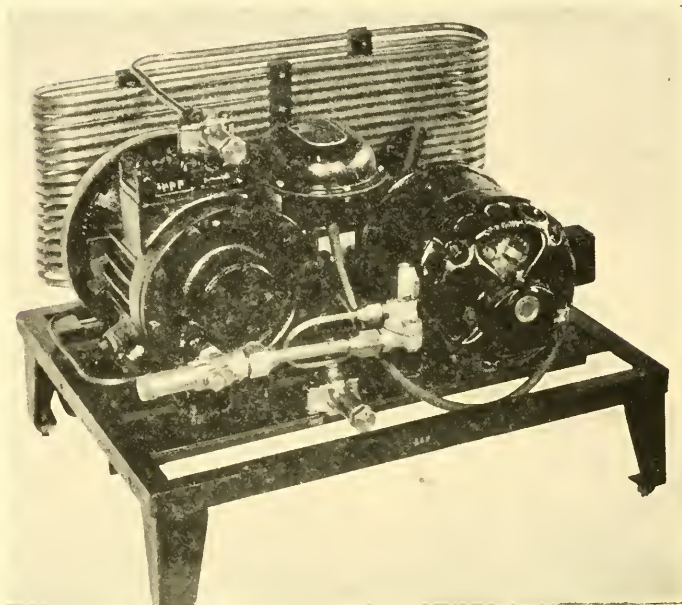


FIG. 112.—NORGE UNIT MOUNTED ON STEEL BASE.

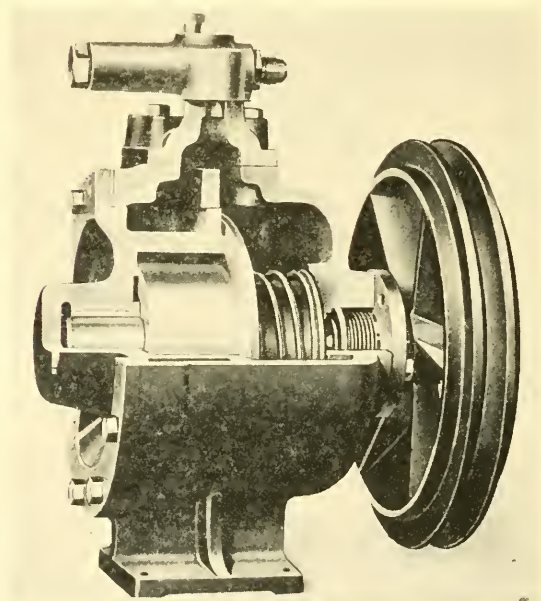


FIG. 113.—NORGE ROTARY TYPE COMPRESSOR.

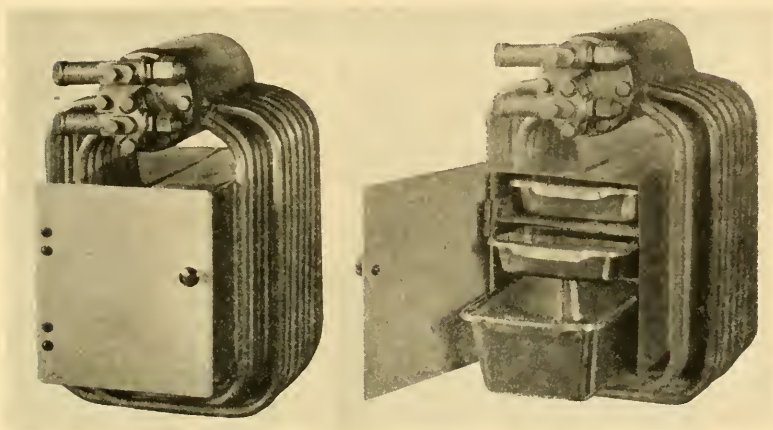


FIG. 114.—NORGE FREEZER COILS.

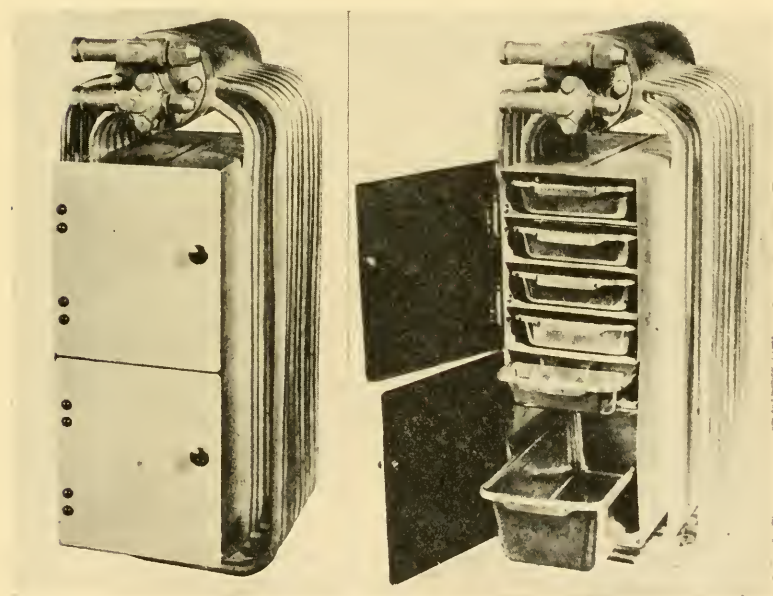


FIG. 115.—NORGE FREEZER COILS.

Fig. 112 shows the condensing unit consisting of the compressor, motor, condenser and automatic control mounted on a steel base.

The compressor, Fig. 113, is of the rotary type. The rotor is driven by an eccentric on the crank-shaft. It moves with a gyratory motion, opening the intake and permitting entrance

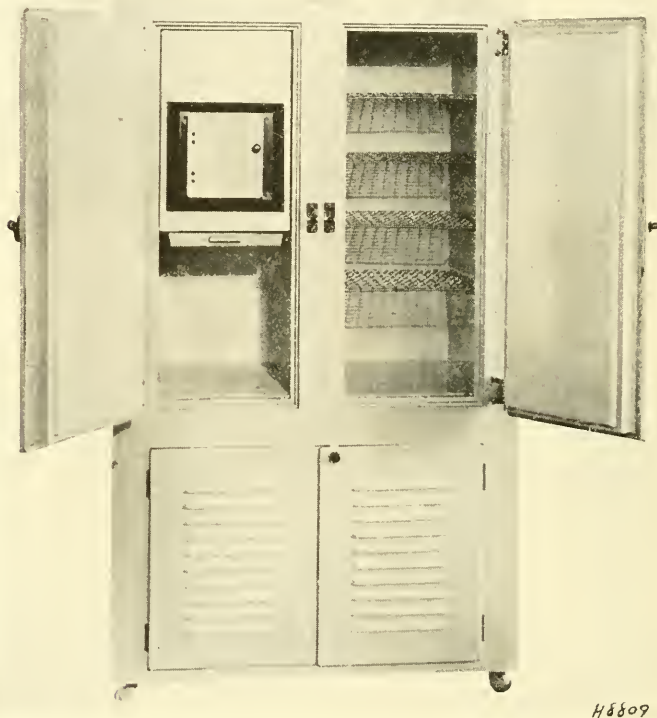


FIG. 116.—NORGE ELECTRICAL UNIT IN McCRAY REFRIGERATOR.

of the Sulphur Dioxide gas into the compression space. The gas escapes through the discharge valve. An oscillating blade always maintains contact with the rotor, and separates the suction chamber from the discharge chamber. This blade, as well as all other moving parts, is submerged in oil under pressure. The rotor fits into the cylinder in such a way that it automatically adjusts and takes up whatever wear may occur.

Figs. 114 and 115 show freezer coils of various sizes. These are equipped with white enameled swing doors which cover the ice tray openings. This prevents frost forming in the trays and eliminates food odors from the freezing pans.

Fig. 116 shows an electrical unit installed in a McCray refrigerator.

Odin.—The Odin refrigerating machine is made by the Automatic Refrigerating Company of Hartford, Conn.



FIG. 117.—ODIN REFRIGERATING UNIT.

This machine uses air under very low pressure for a refrigerating medium. The machine is entirely automatic. A thermostat in the food compartment automatically starts and

stops the refrigerating machine. This system is air-cooled, thus eliminating cooling water connections.

The cabinet, Fig. 117, has fifteen cubic feet of food compartment space. An ice making compartment is included. This box has a gray enamel finish on the outside and porcelain fused on a metal lining.

Rice.—A complete line of fourteen distinct models of refrigerating units for domestic use are manufactured by Rice Products, Inc., of New York City.

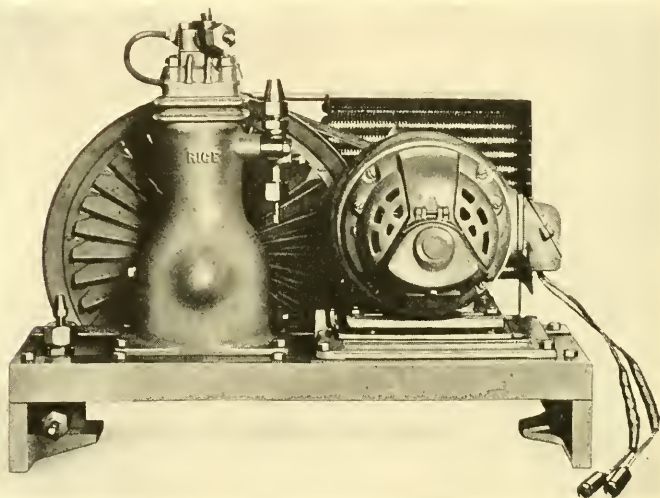


FIG. 118.—RICE COMPRESSOR UNIT.

Nine of these are designed for installation in conjunction with refrigerators ranging from five to sixty cubic feet in size, and consist of a compressor unit and a cooling unit. The latter is placed in the ice compartment of the refrigerator to be cooled and the compressor unit can be placed in the basement immediately beneath the refrigerator or other convenient location. The compressor and cooling units are connected by two small copper tubes. Five models known as D-5, D-7, D-9, D-12, and D-15 are complete self-contained electrical refrigerators ready for electrical connection to the lighting mains.

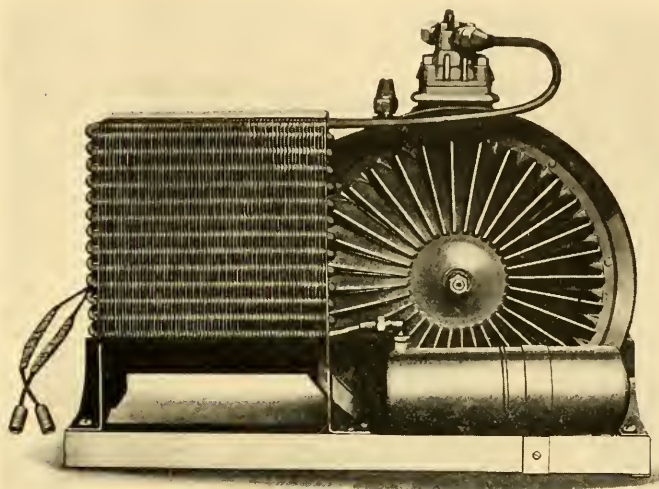


FIG. 119. ANOTHER VIEW OF THE RICE COMPRESSOR UNIT.

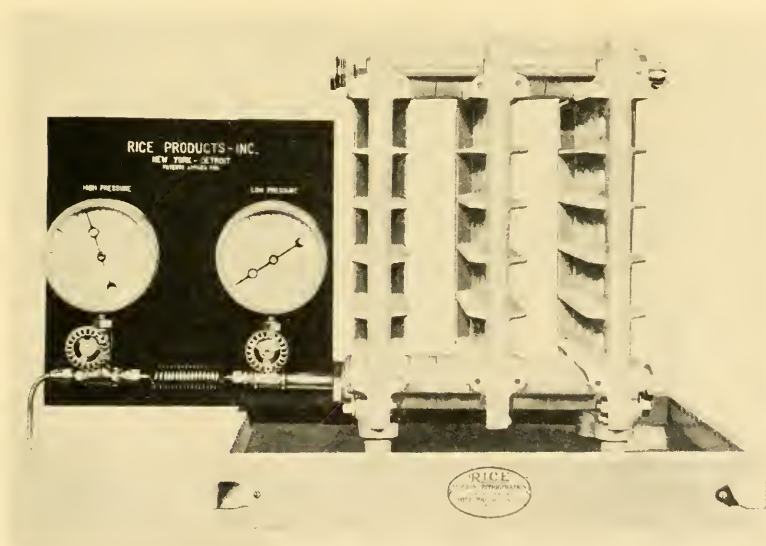


FIG. 120.—RICE GRID SECTIONS, MADE OF SEMI-STEEL CASTINGS, TONGUE AND GROOVE CONNECTED.

Fig. 118 and 119 show two views of the compressor unit. This consists of a compressor, motor, fly-wheel, fan pulley, belt, condenser, receiver with the necessary shut-off valves

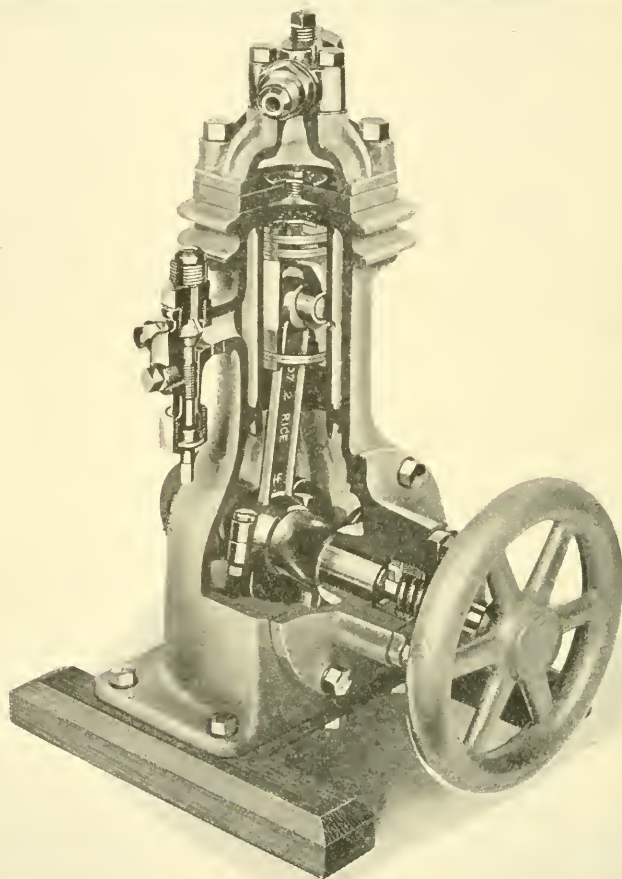


FIG. 121.—SECTIONAL VIEW OF RICE COMPRESSOR.

and strainer, all mounted on a substantial iron base. Both single and double cylinder compressors are furnished. The former is driven by $\frac{1}{4}$ hp. motor at 360 r.p.m. and the latter by a $\frac{1}{2}$ hp. motor at the same speed.

Fig. 121 is a sectional view of the compressor. Compressors are of the single-acting, vertical reciprocating type, air-cooled and lubricated by splash from the crankcase. They are belt driven by means of a moulded rubber and canvas "V" belt passing over the compressor fly-wheel which is $14\frac{3}{4}$ inches in diameter. Crank shafts are of forged steel, heat treated and ground and are $1\frac{1}{4}$ inches in diameter on both types. Main bearings are of cast iron $1\frac{3}{8}$ inches x $1\frac{1}{4}$ inches. An approved ball thrust bearing, to take the thrust of the seal spring is provided. Connecting rod bearings are babbitt broached to size and measure $1\frac{3}{16}$ inches x $1\frac{1}{4}$ inches. Bunting (bronze) bushings are used in the wristpin bearings.

Pistons are of cast iron with suction valve mounted flush with the head. They are fitted with six piston rings; two in each of the three ring slots. Both suction and discharge valves are of the feather type, of new and improved design. Valves are individually lapped to their seats and are noiseless in operation. The discharge valve plate is a die casting.

A metallic stuffing box of special design has been provided. The seal ring is lapped to a seat formed by a shoulder on the crankshaft and is kept in contact by means of a sixty-pound spring. The bar and stroke on both compressors is $1\frac{1}{16}$ inches x $1\frac{1}{16}$ inches.

Motors are regularly supplied for either 110 or 220 volt, 60 cycle, single phase alternating or 110 or 220 volt direct current. Motors wound for other voltages, frequencies or phases can be furnished to order at additional cost. Motors, as regularly supplied, are furnished with sliding bases to facilitate belt adjustment and dispense with idlers.

Condensers are of the Flint-lock type and are mounted at the back of the compressor unit. They are cooled by a fan mounted directly on the motor-shaft. The condenser assembly is self-supporting and mounted on the base. Condensers furnished with the Type "A" Compressor Unit measure 9 inches x 9 inches. Those furnished with the Type "B" measure 12 inches x 12 inches.

HOUSEHOLD REFRIGERATION

Compressor Units are finished in dark blue Duco. Dimensions are as follows, overall:

Type "A"
25 in. long
17½ in. deep
19¼ in. high

Type "B"
29 in. long
18¾ in. deep
19¼ in. high

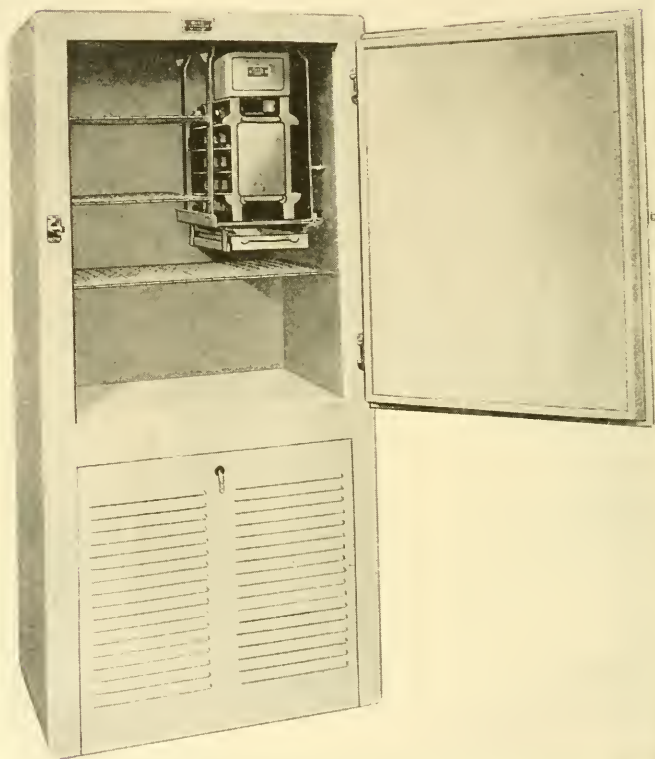


FIG.—122.—RICE METAL CABINET.

Net Weights: Type "A" 140 lbs. Type "B" 185 lbs.

The cooling unit, Fig. 121 consists of a series of grid sections made of semi-steel castings, tongue and groove con-

nected. These various sections can be assembled in grids to meet any domestic requirement.

Grids are galvanized both inside and out and are tested to 300 pounds air pressure under water and 350 pounds hydro-



FIG. 123.—RICE METAL CABINET.

static pressure. Grids are dehydrated under a vacuum at the factory and sealed prior to shipment.

Ice trays are of tinned copper and measure $10\frac{5}{8} \times 3\frac{5}{8} \times 1\frac{9}{16}$ inches deep and hold approximately one pound of water. Each tray is provided with a removable grid for forming cubes.

There are twelve $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{3}{8}$ inch cubes per tray. This is the standard ice tray furnished with all cooling units.

A particularly interesting feature consists in the elimination of the float or expansion valve, and the substitution therefor of a capillary tube, having no moving parts and no adjustment.

The thermostat is a Mercoid Control manufactured by the American Radiator Company. It is temperature controlled and is provided with both temperature and differential range adjustments. The circuit is controlled direct to the motor and accordingly no relays, transformers or other intermediate controls are required. Contacts are sealed within a glass tube containing an inert gas which prevents oxidation or corrosion, a common fault with most thermostatic controls.

Figs. 122 and 123 show typical metal cabinets. The standard construction is an exterior of steel finished in white Duco and an interior of porcelain on steel. Doors are provided with double gaskets. The insulation is of corkboard two inches thick sealed between interior and exterior metal with hydrolenc cement. The cabinet specifications of the five self-contained models are as follows:

CABINET SPECIFICATIONS

| Model | D-5 | D-7 | D-9 | D-12 | D-15 |
|--------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Width | 27 $\frac{3}{4}$ in. | 34 $\frac{1}{2}$ in. | 34 $\frac{1}{2}$ in. | 45 in. | 54 $\frac{1}{2}$ in. |
| Depth | 24 $\frac{3}{4}$ in. | 28 $\frac{1}{2}$ in. | 28 $\frac{1}{2}$ in. | 28 $\frac{1}{2}$ in. | 28 $\frac{1}{2}$ in. |
| Height | 60 in. | 63 in. | 69 in. | 69 in. | 69 in. |
| Weight | 460 lbs. | 530 lbs. | 612 lbs. | 665 lbs. | 781 lbs. |
| Gr. Capacity | 6.5 | 10.3 | 12 | 16 | 19.3 |
| Food Storage | 5 | 7 | 9 | 12 | 15 |
| Shelf Space | 8.3 | 9.2 | 12.2 | 17 | 23.2 |
| No. Cubes | 36 | 48 | 60 | 72 | 120 |
| Compr. Unit | Type "A" | Type "A" | Type "A" | Type "A" | Type "A" |
| Cool. Unit | No. 6 | No. 10 | No. 15 | No. 25 | No. 30 |

Sanat.—The Sanat machine, Fig. 124, is made by Sanat Refrigerating Co., Inc., 331 Madison Avenue, New York City.

The machine consists of a motor, a worm and worm gear drive, a compressor, a condenser, an expansion valve, a cooling tank, a temperature control, and the necessary piping and wiring to connect the units. The other elements are the refrigerant and the brine.

The refrigerant is chloric ether, a solution of ethyl chloride and alcohol. The pressure of condensation is relatively low, 16 to 20 pounds gauge.

A $\frac{1}{4}$ hp. motor is used to drive the compressor by means of a worm and worm gear drive. Radial and thrust ball bearings are used for mounting the worm, and friction is thereby greatly reduced.

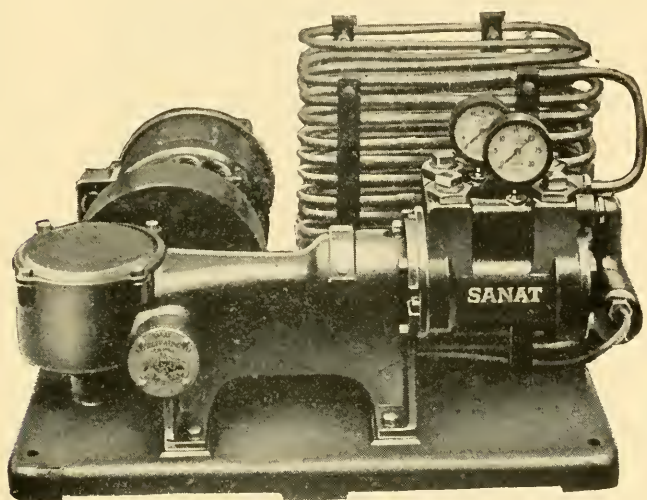


FIG. 124.—SANAT REFRIGERATING UNIT.

The compressor is a single cylinder, double acting, slow speed machine operating at forty strokes per minute, or eighty compressions. Poppet valves are used throughout—bakelite operating on brass seats, eliminating metal to metal contact with its attendant sticking. The bearings on the crank shaft and connecting rod are of hardened steel and amply large. The stuffing box is of the double gland type. The compressor is lubricated automatically by the mineral oil which is formed when the refrigerant is expanded into the brine.

The condenser is air cooled and consists of a hundred feet of $\frac{3}{8}$ -inch copper tubing. No forced draught is required over these coils to condense the refrigerant, therefore, the need for a fan is eliminated.

The expansion valve is a simple device which runs into the brine within a few inches of the bottom of the tank. This valve releases the chloric ether into the brine from the high to low pressures. The expansion member of this mechanism is a sylphon bellows, which expands or contracts through very narrow limits, thus eliminating or keeping adjustments to a minimum.

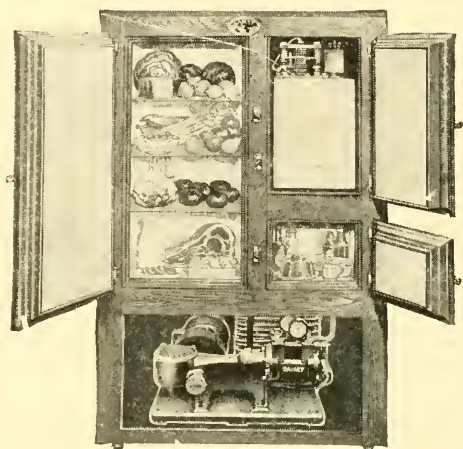


FIG. 125.—COMPLETE SANAT UNIT INCLUDING CABINET.

The cooling tank, made of $\frac{1}{8}$ -inch steel, occupies the space in the ice compartment of the refrigerator and contains the solution of calcium chloride brine and alcohol. The refrigerant is expanded directly into the brine causing an agitation which produces an even temperature throughout the brine and results in a constant crisp dry-cold in the refrigerator. A marked advantage of this system lies in the fact that the agitation resulting from the direct expansion of the refrigerant into the brine produces an emulsion, which is equivalent to a medium grade mineral lubricating oil. This lubricant is formed in small but sufficient quantities and is drawn back into the compressor and automatically solves the lubricating problem.

The temperature control operates on a ten volt circuit; a relay mounted in a convenient location being used to reduce the voltage from the usual home pressures. This arrangement

requires the minimum of attention. The thermostat is governed by the temperature of the brine and can be set to operate accurately between small variations of temperature.

Fig. 125 shows a complete unit including the cabinet. Fig. 126 shows the cabinet with vegetable storage space at bottom as arranged when the machine is located in the basement.

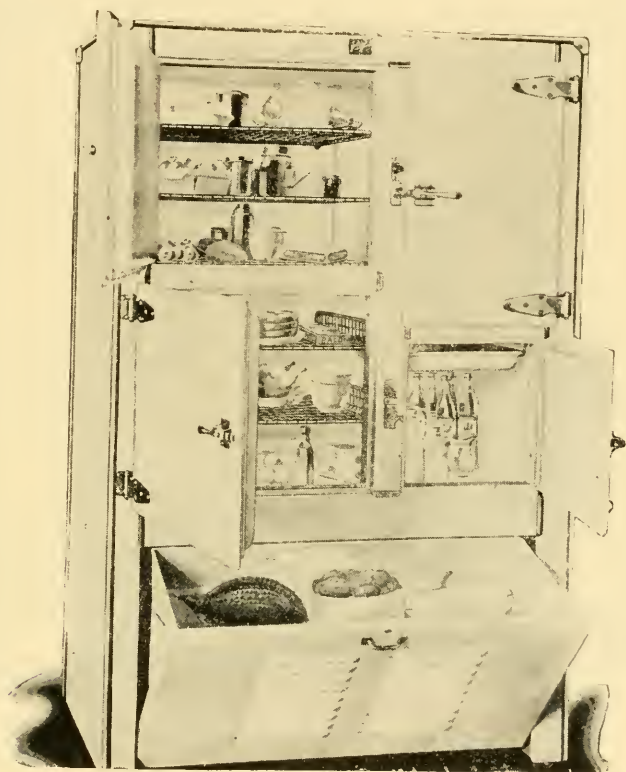


FIG. 126.—SANAT METAL CABINET WITH VEGETABLE STORAGE.

Savage.—Fig. 127 shows the mercury refrigerating machine made by the Savage Arms Corporation, Utica, New York, suitable for ice cream cabinet and household fields.

Fig. 128 shows the machine with the condenser removed. This machine operates on a new system of mercury compression.

The screw pump, invented by Archimedes about 250 B. C.,

using mercury as the compressing fluid, is the basis of the design. Following are the most important advantages:

There are no internal moving parts. There is no lubricant within the refrigerating cycle.

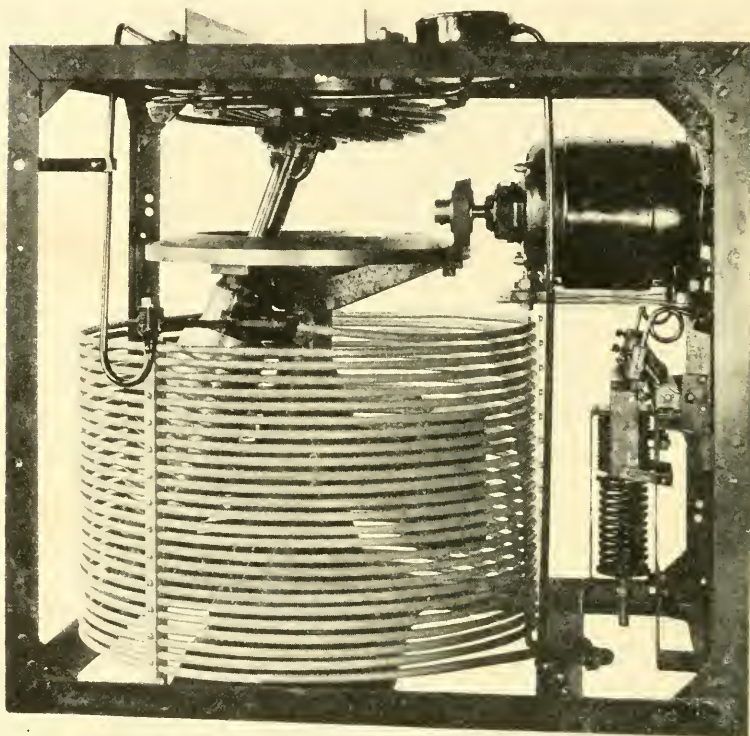


FIG. 127.—SAVAGE MERCURY REFRIGERATING MACHINE.

The drive is external to the refrigeration cycle, requiring no stuffing box or gland joint. The system is sealed by welding, and is leak proof.

The machine is exceptionally quiet in operation, due to purely rotary motion at relatively low speeds.

Mercury compression, because of its inherent freedom from power losses, makes possible an exceedingly low power consumption per unit of refrigeration.

Excessive pressures cannot be generated, since the critical point of the mercury compressor is reached only a few pounds above the working pressure of the machine. It then blows back, short circuiting itself.

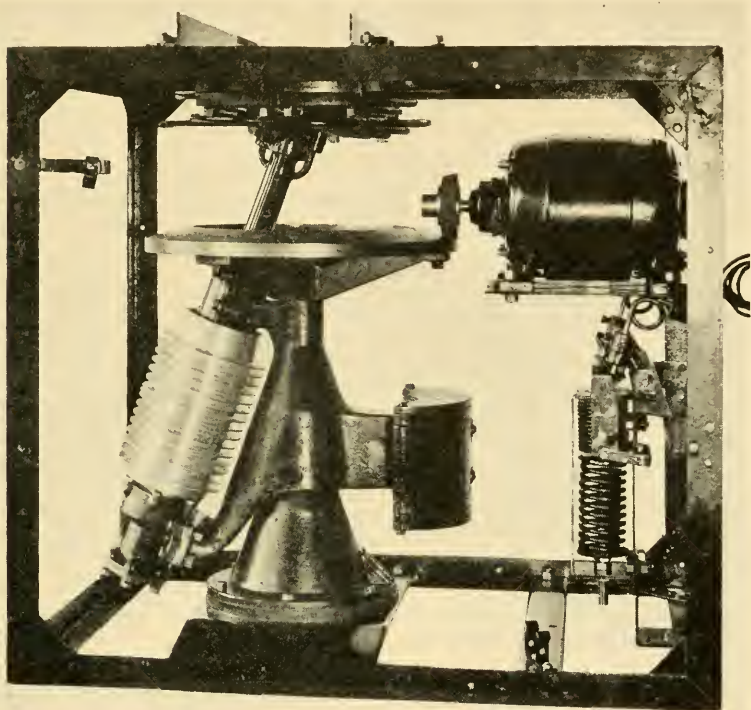


FIG. 128.—SAVAGE MERCURY REFRIGERATING MACHINE WITH CONDENSER REMOVED.

A force feed oiling system provides adequate lubrication to the four external bearings with oil storage capacity sufficient for many years of operation.

An automatic temperature speed control gives the machine added refrigerating capacity as the room temperature rises. The machine automatically operates at the most efficient speed for all room temperatures, an exclusive feature.

Service may be performed upon any mechanical or electrical part of the machine without disconnecting or disturbing the refrigeration system, and without losing any refrigerant.

It is obvious that there can be no piston leakage, since each mercury piston seals itself in the helical passageway. Neither can there be any clearance or re-expansion loss, since each gas volume is pushed completely through from the low to the high pressure chamber. There is no internal wear.

Fig. 129 is a typical cabinet for preserving ice cream. This cabinet is of angle iron frame construction with tongue and groove spruce flooring.

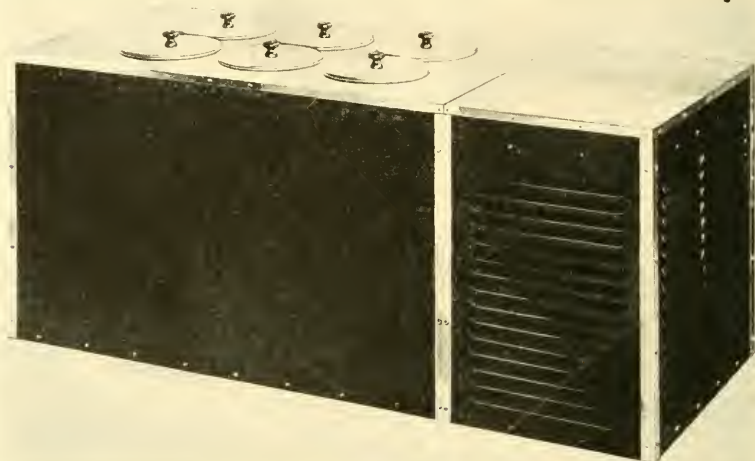


FIG. 129.—SAVAGE ICE CREAM CABINET.

Cork insulation is used and all joints flooded with sealing compound. Two thicknesses of waterproof paper are used as an additional protection against air leakage. The lining is of heavy galvanized sheet steel. The top is of laminated wood, covered with non-corrosive metal. The sides are of black-enameled sheet steel, bound in by metal corner angles.

The cabinets may be installed either as a unit with the compressor or as a remote system. In the latter case the compressor unit is generally installed in the basement or in some other convenient place separate from the cabinet.

Servel.—Figs. 130 and 131 shows the Model 21-A refrigerating machine manufactured by the Servel Corporation

whose main offices are at 51 East 42nd Street, New York City.

Methyl Chloride is the refrigerant used in this system.

The compressor, condenser, pressure control and $\frac{1}{4}$ hp. motor are mounted on a pressed steel base. The 21-A is used in all complete Servel refrigerators, as well as all remote

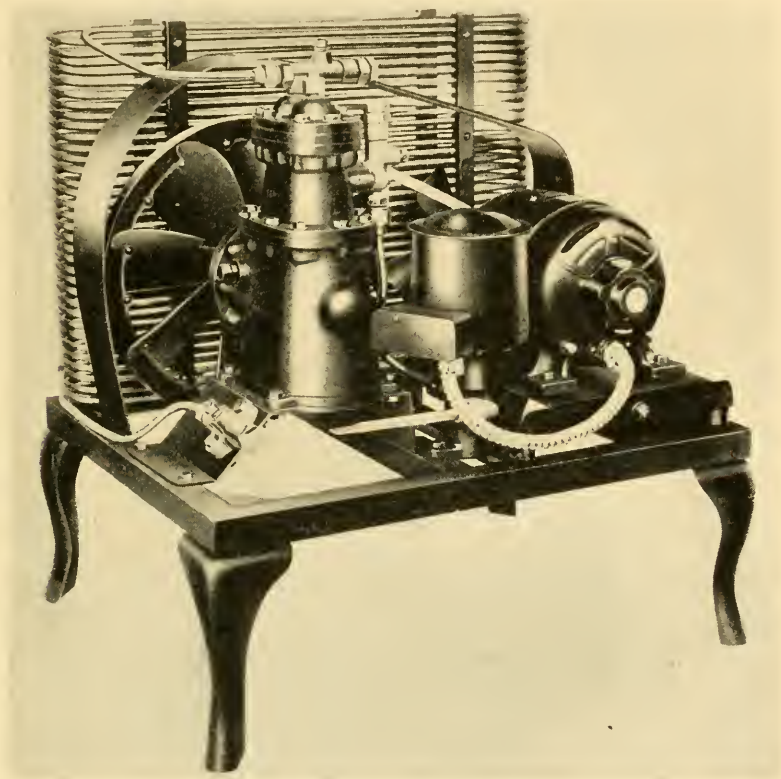


FIG. 130.—SERVEL MODEL 21-A REFRIGERATING UNIT.

household installations. The compressor is of the vertical, twin cylinder, single acting, reciprocating type. It is free from vibration and practically noiseless. The bore is $1\frac{1}{2}$ inch and the stroke $1\frac{1}{4}$ inch. The compressor runs at a comparatively low speed—375 r.p.m. The drive is accomplished through a "V" belt. Both the inlet and outlet valves are flapper valves.

Leakage around the compressor shaft is prevented by use of a special syphon seal of the rotating type.

The temperature control, Fig. 132, is accomplished by means of the action of the copper bellows connected to the low

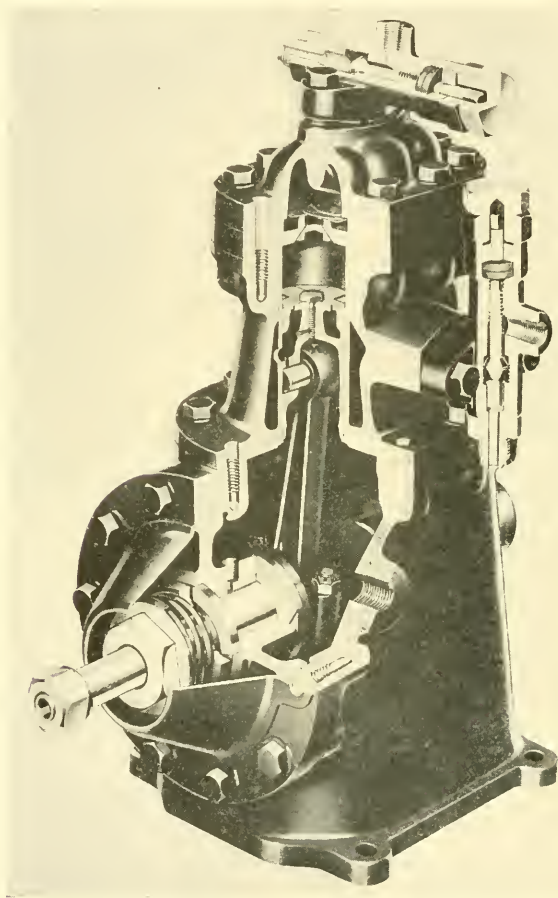


FIG. 131.—CUTAWAY VIEW OF SERVEL COMPRESSOR SHOWING MOVING PARTS AND SYLPHON PACKING.

pressure side of the system. The inflation and deflation of the bellows operates a quick make and break switch, opening and closing the motor circuit, and is adjustable for different pres-

sure to give any desired temperature. A special feature of the control device is that it limits the pressure of the suction gas to the compressor at the time of start so that no overload is placed on the motor.

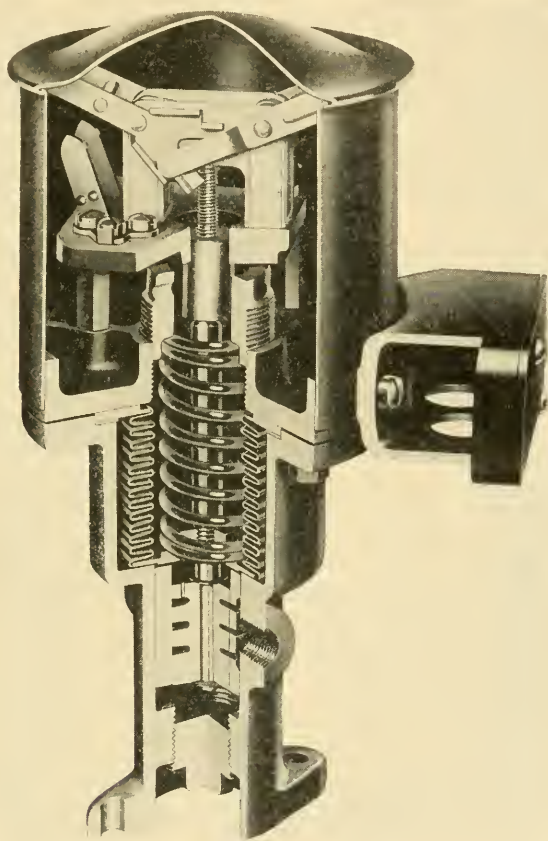


FIG. 132.—SERVEL PRESSURE CONTROL CUT OPEN TO SHOW OPERATION OF PISTON.

The condenser is trombone shaped, cooled by two fans running in opposite directions. The four bladed fan on the motor pulley blows directly into and across the condenser. The large fan on the compressor flywheel draws the air out of the condenser. Exhaustive tests show conclusively that

this arrangement is superior to two fans operating in the same direction and materially reduces the head pressure where boxes are so located as to make air circulation difficult. The motor mounting plate is of pressed steel and adapted to Gen-

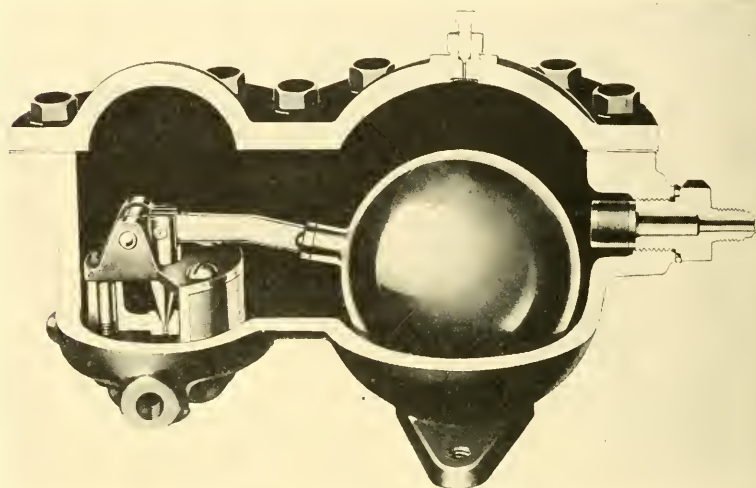


FIG. 133.—FLOAT VALVE, SERVEL REFRIGERATING UNIT.

eral Electric, Century, Emerson and Westinghouse motors. The adjusting of the motor for belt tension is controlled by one nut, making this a very simple operation.

In the complete refrigerator the float valve is placed in the machine compartment. The sturdy construction of this float is clearly shown in Fig. 133. When sufficient liquid methyl chloride has accumulated in the float it raises the ball, opens the needle valve and enters the expansion coils. A cylindrical screen is used as a strainer both on the inlet to the float and as a cage surrounding the needle valve. This prevents any foreign matter clogging the needle valve.

All shutoff valves are made from bronze forgings and are provided with caps which completely inclose the valve stem, thus eliminating leaks through the valve packing.

Fig. 134 shows the Model S-7, suitable for the family of medium size, one of the three all steel models now being man-

ufactured by Servel. The other two models are the S-5, for the small family, and the S-10, suitable for the more pretentious household. (Fig. 135 and 136.)

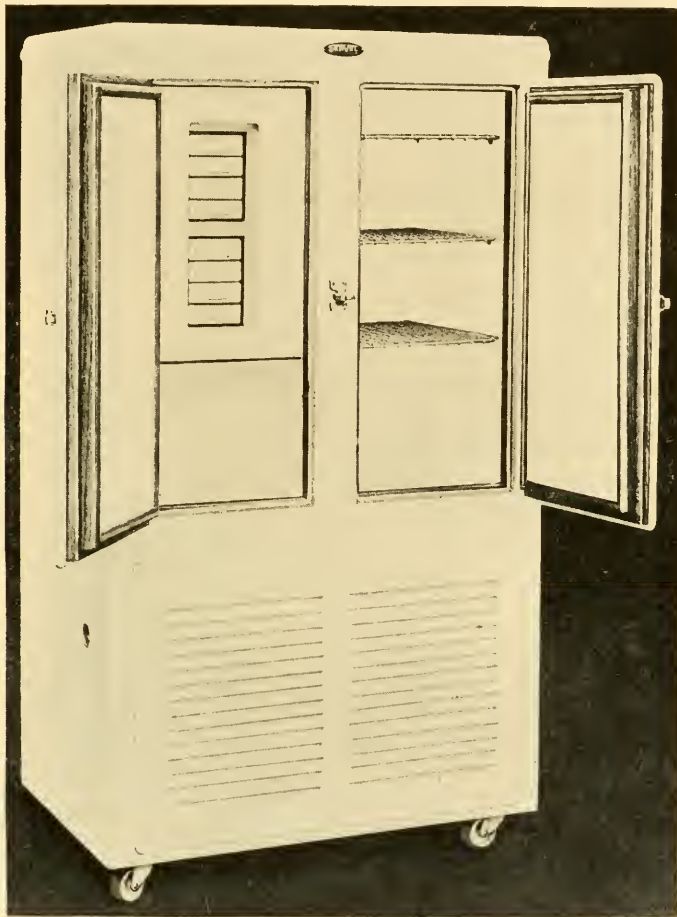


FIG. 134.—SERVEL ALL-STEEL REFRIGERATOR FOR MEDIUM SIZED FAMILY.

The cabinets are constructed of especially selected "Armco" Ingot Iron carefully lead-coated as a positive protection against rust. The metal shell is given an application of oil base primer coat, after which this coat is slowly and carefully baked on under a low temperature, producing a

finish which will neither peel nor scale. Next, several coats of surfacer and two coats of genuine Du Pont White Duco Lacquer are applied and allowed to air dry. The slow process of air drying, while it creates an additional factory cost, pro-

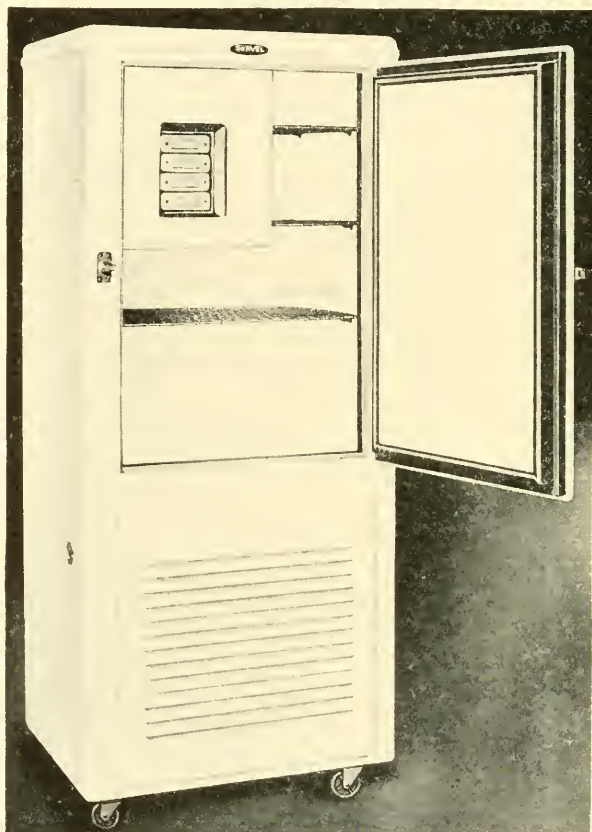


FIG. 135.—SERVEL ALL-STEEL REFRIGERATOR FOR SMALL FAMILY USE.

duces a much better appearing and more lasting finish than can ever be expected under artificial or forced drying.

The porcelian liners are of the box type, and are so constructed, with double lock flanges, that bolt holes or screw holes are entirely eliminated except those required for tank and shelf supports. This produces an absolutely sanitary liner and eliminates all chance of flaking of the porcelain finish, due

to uneven strain such as results from the use of screws or bolts.

The chilling units are of tinned copper and have front

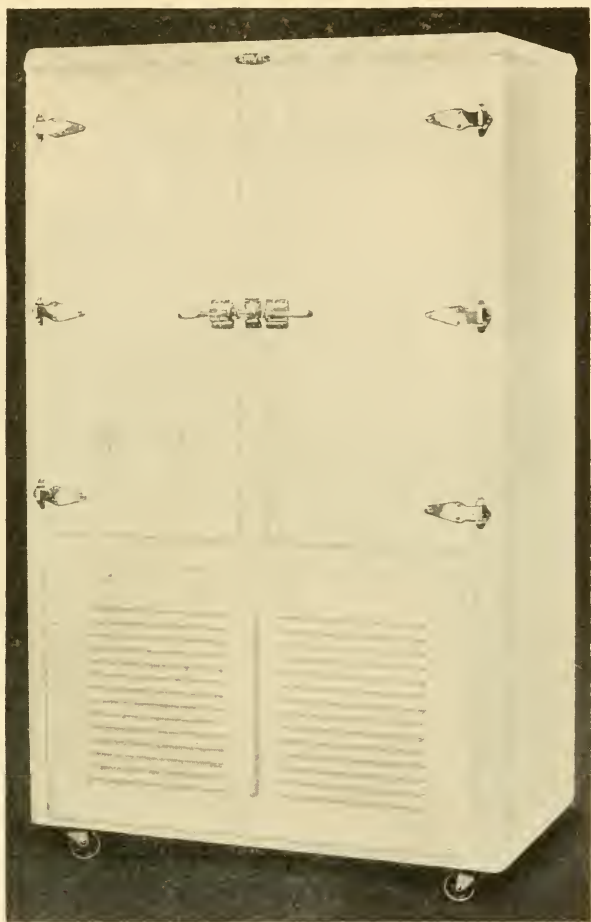


FIG. 136.—SERVEL ALL-STEEL REFRIGERATOR FOR LARGE SIZED FAMILY.

panels and ice-cube-tray fronts of genuine porcelain. Each ice-cube-tray holds 12 cubes.

The insulation is pure compressed corkboard thoroughly impregnated with hydrolene, $1\frac{1}{2}$ -inch thick on top and sides

on the S-5, 2-inch thick top and sides on the S-7 and S-10; with a 3-inch bottom thickness on all models.

All seams in the corkboard are filled with Hydrolene. Waterproof paper is then applied over the corkboard as added

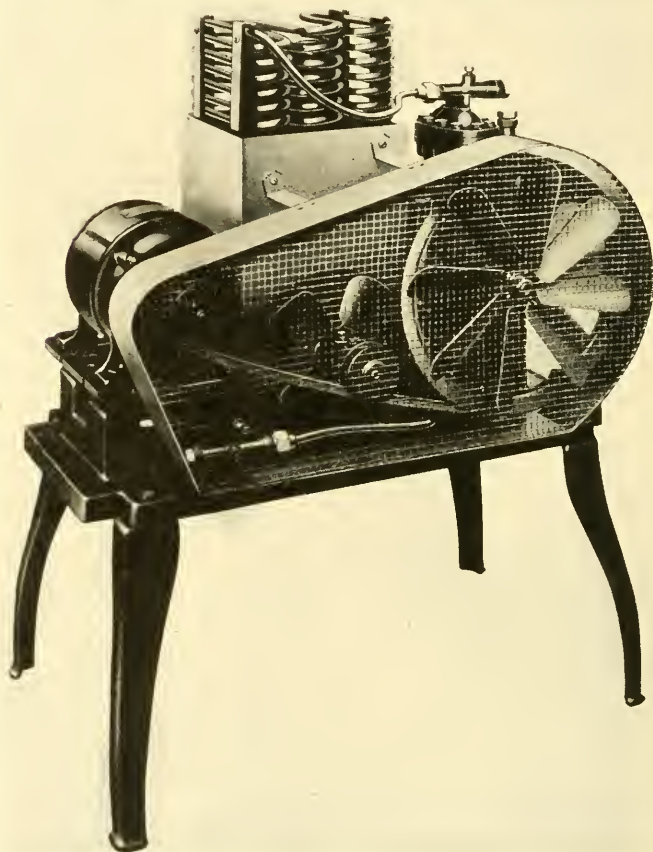


FIG. 137.—SERVEL SEMI-COMMERCIAL REFRIGERATING UNIT.

seal against air leaks. An air space of $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch is used between the outer metal shell and the insulation surrounding the liner.

The semi-commercial machines are shown in Figs. 137

and 138. The 15-A is particularly adapted for ice cream cabinets and low temperature work. The rated capacity of the

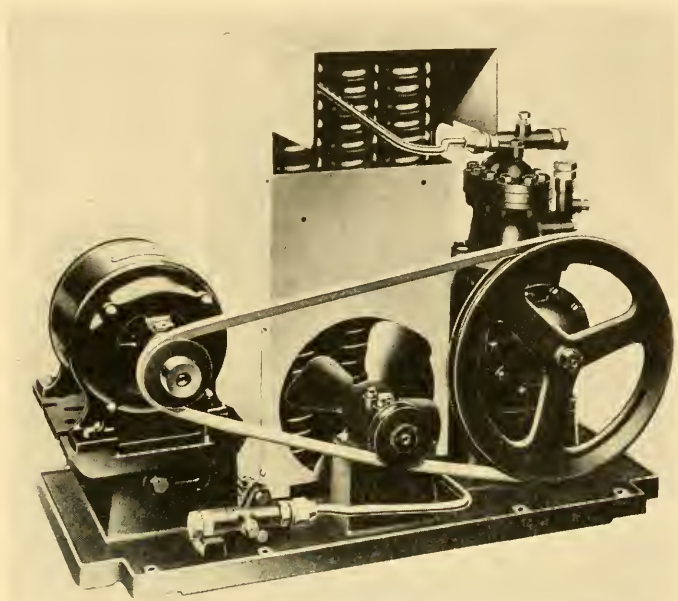


FIG. 138.—SERVEL SEMI-COMMERCIAL REFRIGERATING UNIT.

15-A is 350 lbs. The 18-A has a rated capacity of 300 lbs., and is used on large household or small commercial boxes.

Socold.—Fig. 139 shows the compressor unit used in the electric refrigerator manufactured by the Socold Refrigerating Corporation of Boston, Massachusetts. The refrigerant used is sulphur dioxide.

The compressor has two vertical cylinders. The pistons are driven by connecting rods operated by a walking beam. The drive shaft oscillates on an arc of 12 to 15 degrees each side of center at slow speed. A plate of special metal seals against a shoulder on this shaft. Thus the wear on the packing is very slight. The discharge valves are in the cylinder head and are made of three monel discs. The suction valves are single parts in the cylinder walls.

The condenser consists of a coil of one tube mounted on the same base with the compressor. Forced air cooling is obtained by a fan in front of the motor and in the compressor drive wheel.

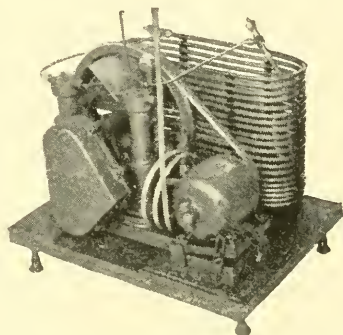


FIG 139.—SOCOLD REFRIGERATING UNIT.

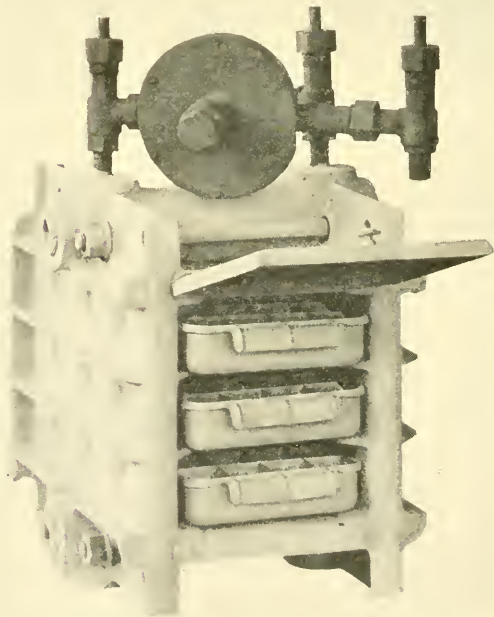


FIG. 140.—SOCOLD FROST UNIT OF HEAVY SEMI-STEEL CONSTRUCTION.

Fig. 140 shows the frost unit which is of heavy galvanized semi-steel construction and operates on the direct expansion system. An expansion valve of single construction is used to reduce the pressure of the liquid refrigerant.

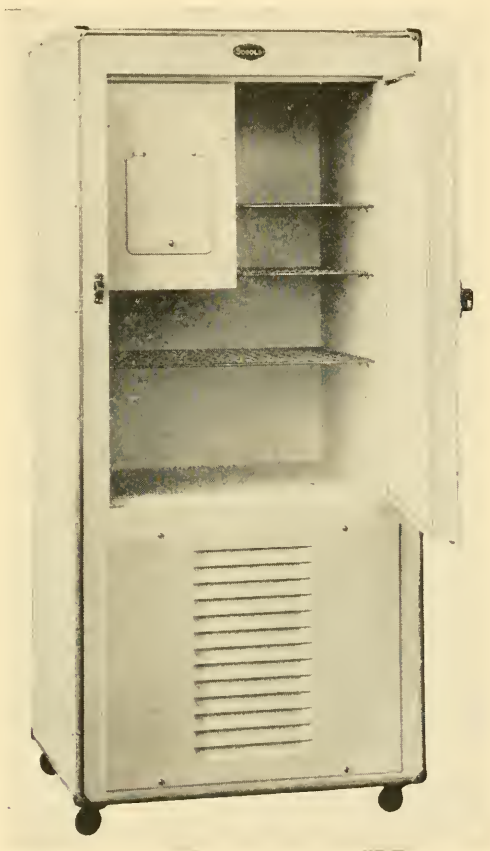


FIG. 141.—SOCOLD TYPICAL STEEL CABINET.

A Mercoid thermostat is used for temperature control. It is responsive to the temperature of the frost unit and not by temperature of the food compartments, which issues a constant supply of ice cubes without making seasonal adjustments necessary. The thermostat is set to maintain a temperature in the frost unit of from 20 to 24 degrees F. This

produces a temperature of from 45 to 50 degrees F. in the food compartment.

Fig. 141 and 142 show typical steel cabinets.

The construction provides one air and moisture tight steel

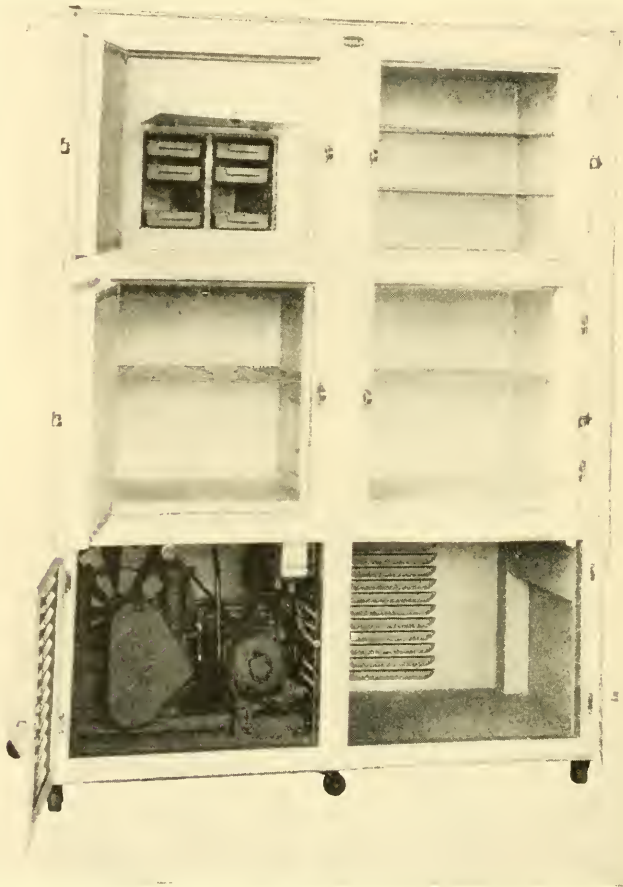


FIG. 142.—SOCOLD STEEL CABINET SHOWING REFRIGERATING AND FROST UNITS INSTALLED.

case inside another which will not permit the penetration of moisture and odors into the insulation.

Balsam-wool is used to insulate the cabinets. This material is manufactured from the fibers of northern coniferous woods. The process is somewhat similar to that employed in

pulp making, as the wood is first reduced by mechanical means and then chemically treated so the wood fibers are separated from one another. The individual fibers are fine, hairlike, hollow tubes, and at this stage are saturated with chemicals that render them non-inflammable and proof against decay. These fibers are handled by air and felted into a fleecy mat bound together with cement. An important feature of this mat is that its fibers extend in all three cubical dimensions, with the result that the blanket is remarkably light in weight and contains millions of dead-air cells.

To increase the mechanical strength of the fibrous blanket, a layer of water-proofed Kraft paper is cemented to each side of the blanket with asphalt. This method of applying the liner does away with stitching and leaves the surface of the material impervious to water and air.

The cold storage type of balsam-wool is particularly adapted for these small boxes because it is easily fitted in around the corners, is odorless either wet or dry, and will not support mildew or mold. A complete line of cabinets in porcelain or white baked enamel are manufactured.

Universal Refrigerating Machine.—Fig. 143 shows the household compressor unit manufactured by the Universal Ice Machine Company of Detroit.

The refrigerant used is ammonia. A $\frac{1}{2}$ hp. motor drives the compressor by means of a "V" type leather belt and idler pulley. The compressor has a special type aluminum piston, designed to assure good lubrication and eliminate wear on the sides of the cylinders.

Disc plate suction and discharge valves are used. These are located in the head of the compressor and are easily accessible. The cylinder head is water jacketed. Metallic packing is used on the compressor crankshaft. The condenser is made of a double spiral coil with welded ends. Water flows through the inner coil.

Utility Refrigerating Unit.—Fig. 144 shows the mechanical unit used in the Utility Electric Refrigerator which is manufactured at Adrian, Michigan by the Utility Compressor Company. It is reported this company is now out of business.

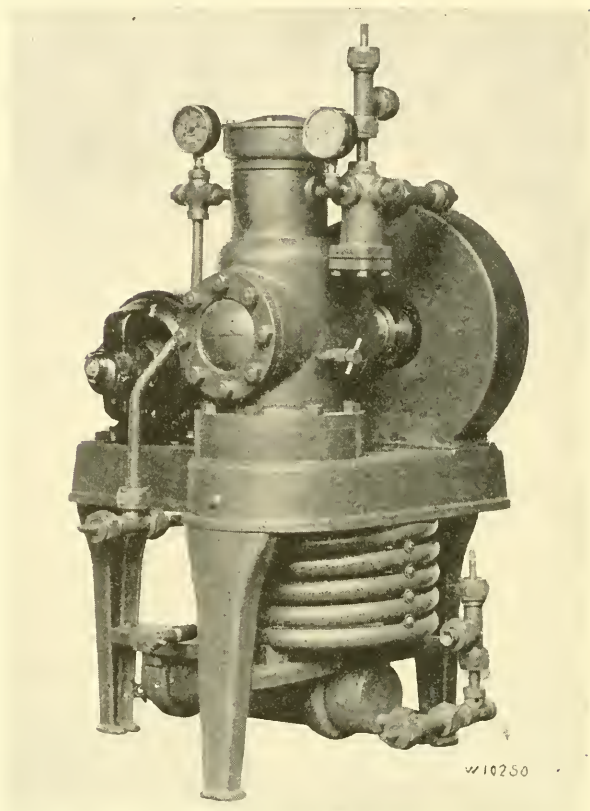


FIG. 143.—UNIVERSAL REFRIGERATING MACHINE.

The electric motor and pump are enclosed in the dome at the right, hermetically sealed. This eliminates a packing gland for the shaft of the compressor.

The thermostat and the cooling coils, which absorb the heat from the atmosphere in the refrigerator are situated in the chamber at the left.

The condenser is of the radiator type and is located behind the dome and coil chamber. This condenser is air-cooled. The complete mechanical unit is interchangeable and easily removed from the cabinet.

In case service is required, it is claimed that the complete mechanical unit can be removed and another put in place in

fifteen minutes. This eliminates the need of mechanics working on repairs in the home. The small door is for the ice freezing chamber.

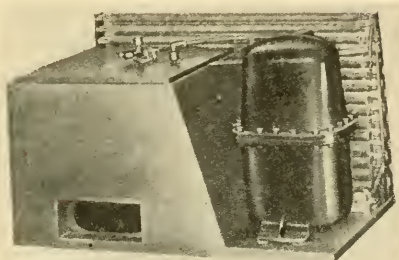


FIG. 144.—UTILITY REFRIGERATING UNIT.

The mechanical unit is placed in the upper part of a special cabinet. The cabinets are of white porcelain or natural wood exteriors. A one-piece porcelain lining is used. The cabinets are seventy inches high, thirty-eight inches wide, and twenty-three inches deep.

Ward.—Fig. 145 shows the condensing system of the household refrigerating machine made by the Ward Electric Refrigerator Corporation of Buchanan, Michigan.

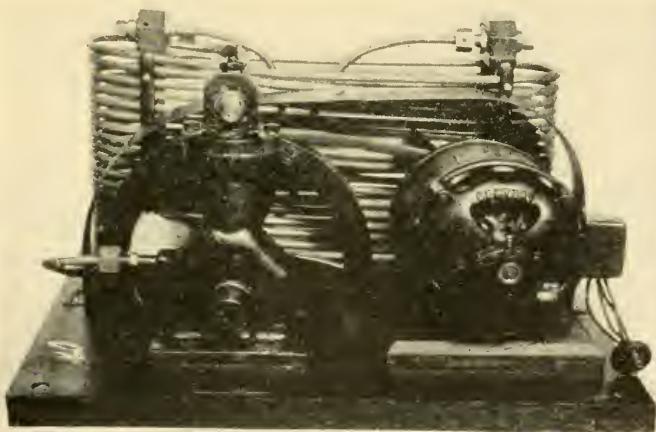


FIG. 145.—WARD HOUSEHOLD REFRIGERATING SYSTEM.

A $\frac{1}{6}$ hp. motor drives the compressor by means of a "V" type belt. The condenser consists of a coil of copper tubing. Air is forced over the condenser by a fan on the motor shaft.

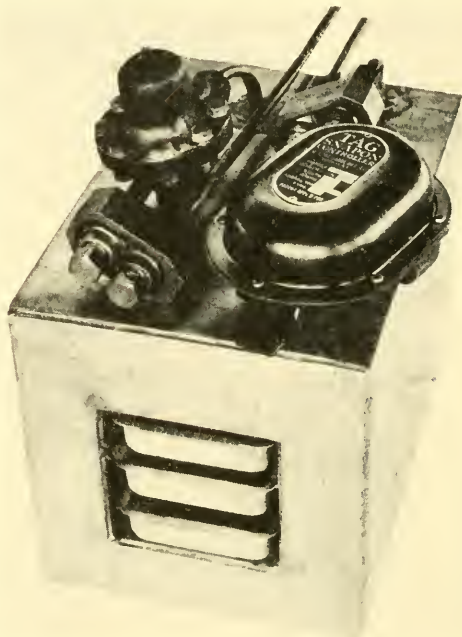


FIG. 146.—WARD EVAPORATING SYSTEM.

Fig. 146 shows a typical evaporating system consisting of a brine tank, expansion valve and necessary connections. The thermostat control is mounted on the brine tank.

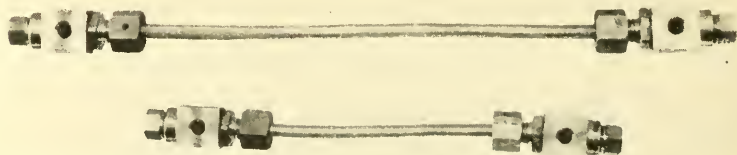


FIG. 147.—SHOWING SPLIT-VALVE CONNECTIONS, WARD REFRIGERATING SYSTEM.

The system is connected together by means of tubing containing split-valves on each end as in Fig. 147. This arrange-

ment eliminates the need to dehydrate, pull a vacuum or charge the machine when making an installation. The valves on each end of the tubing are shut off when charged at the factory and after dealer has connected up same with machine, they are then turned on by a ratchet wrench which operates on the end of each valve and thus the dealer does not lose the charge when installing unit.



FIG. 148.—WARD STEEL HOUSEHOLD CABINET.

One of the cabinets is shown in Fig. 148. The cabinet has a steel exterior and is insulated with corkboard. Various sizes and types of cabinets can be supplied.

Warner.—Fig. 149 and 150 show compressor units made by the Warner Stacold Corporation of Ottawa, Kansas.

Air-cooled sulphur dioxide compressors are made in the

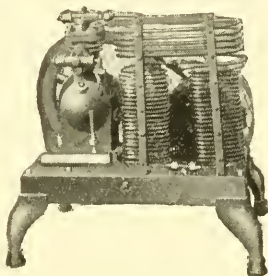


FIG. 149.—WARNER STACOLD COMPRESSOR UNIT.

following sizes: 1-cylinder compressors driven by $\frac{1}{8}$ and $\frac{1}{4}$ hp. motors; 2-cylinder compressors driven by $\frac{1}{4}$ and $\frac{1}{3}$ hp. motors; 3-cylinder compressors driven by $\frac{1}{2}$, $\frac{3}{4}$ and 1 hp. motors.

These compressors are of the slow speed reciprocating type. A special “V” belt is used. The compressors have crank shafts which operate with less friction than eccentrics.

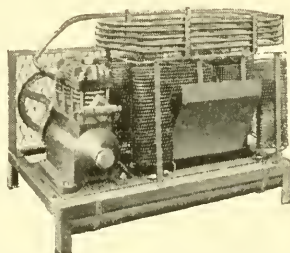


FIG. 150.—WARNER STACOLD COMPRESSOR UNIT.

Ground removable cylinder sleeves are used. The commercial compressors have pistons equipped with 4 rings.

A series of 8 sizes of cooling tanks are made suitable for the various refrigerators.

Flooded type cooling coils are also made. These coils are used in apartment houses and commercial installations where

it is necessary to have more than one cooling coil connected to one compressor.

Metal cabinets are manufactured from 4.6 to 10.5 cubic feet food storage space. These cabinets are insulated with cork. The exterior has a lacquer finish. The interior is of white enamel or porcelain.

Welsbach.—This machine, Fig. 151, is manufactured by the Welsbach Company at Gloucester, N. J.

The refrigerant used is "Alcozol," which has been developed in the Welsbach chemical laboratories. "Welcolub,"

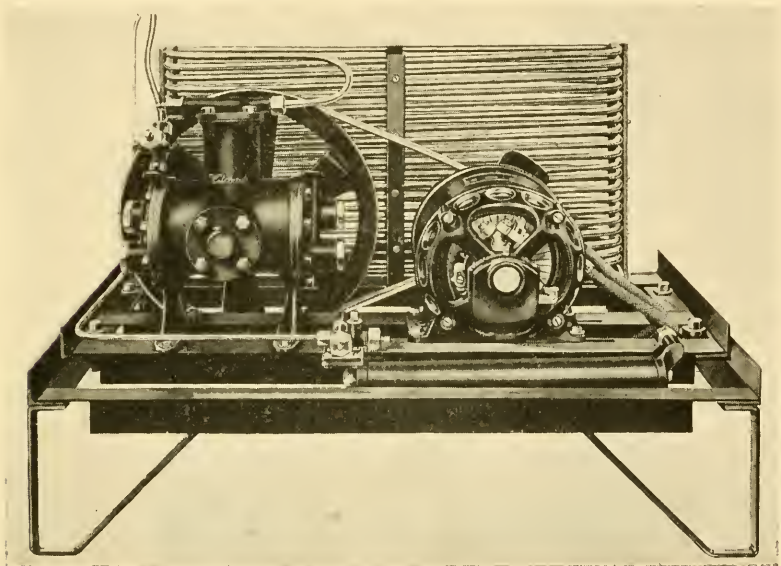


FIG. 151.—WELSBACH COMPRESSOR UNIT.

another product of the Welsbach laboratories, is used as the lubricant.

The compressor is of the horizontal, double acting type. The compressor cylinder has a bore of 3 inches, with a stroke of 1 inch. It operates at low speed—280 revolutions per minute. In normal operation in a 90° F. room the condensing pressure is 20 to 25 lbs., while the suction pressure is a vacuum.

General Electric and Century $\frac{1}{4}$ hp. motors are used, operating at 1750 revolutions per minute, with an average

connected load of 210 watts. The motor drives the compressor by means of a rubber-fabric "V" type belt.

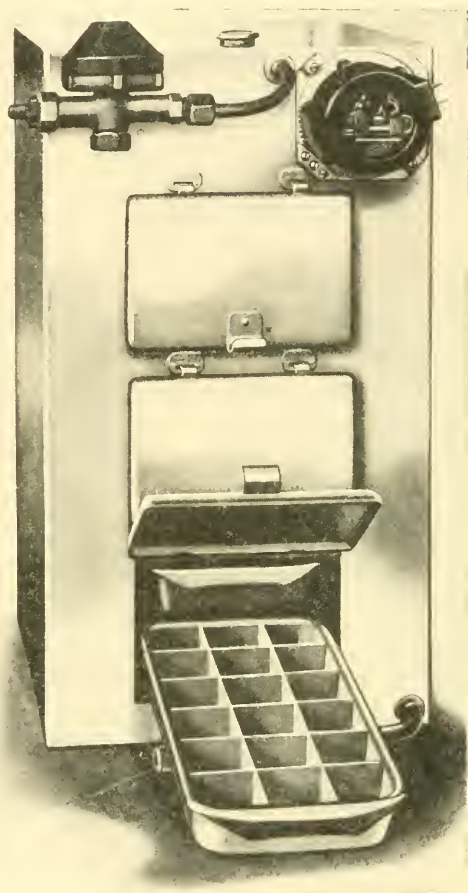


FIG. 152. WELSBACH FREEZING UNIT.

The condenser is made of $\frac{3}{8}$ -inch copper tubing. Forced air cooling is obtained by means of a two-blade fan on a motor pulley, and fan blades in the compressor pulley. The condenser supplies liquid refrigerant to a receiver of sufficient size to hold the entire charge.

Fig. 152 shows the freezing unit made of tinned copper, containing a non-freezing solution of glycerine and water.

The expansion coils are made of $\frac{3}{8}$ -inch copper tubing, pancake winding. A downward pitch in the evaporator permits the drainage of circulated lubricant back to the compressor.

An expansion valve is used and automatically maintains a predetermined vacuum, regardless of the condensing pressure.

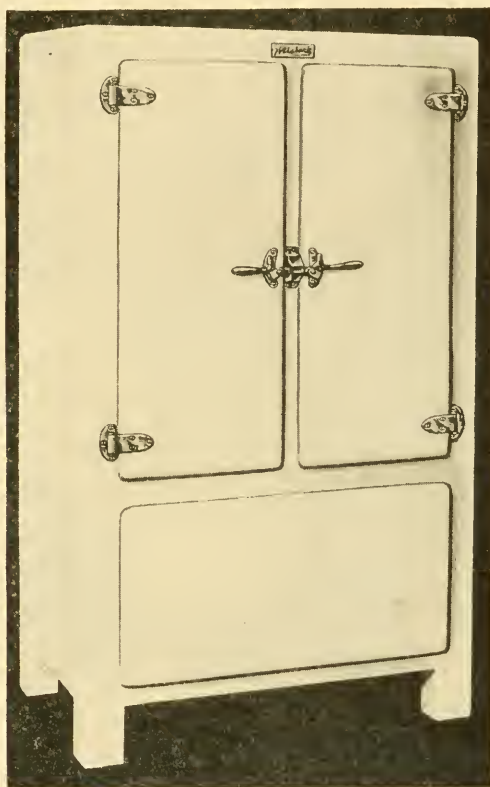


FIG. 153.—WELSBACH STEEL CABINET.

The automatic temperature control consists of a mercury switch mounted on a bi-metallic coil sealed in a bakelite case. The control is mounted on the upper right-hand corner of the cooling tank.

Fig. 153 shows a typical steel cabinet as manufactured by the Welsbach Company. Fig. 154 shows a typical hardwood cabinet made of 5-ply laminated wood, using flush panel con-

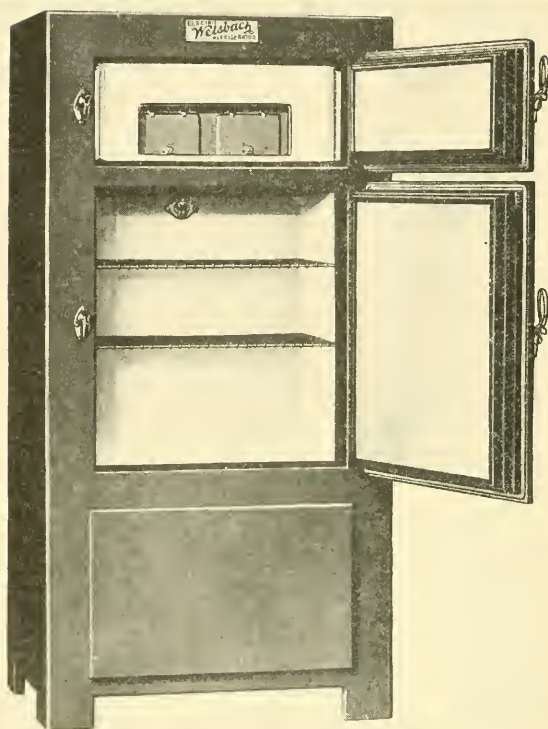


FIG. 154.—WELSBACH HARDWOOD CABINET.

struction. Both the steel and wood cabinets are supplied in various models. The dimensions, food storage space, number of trays and number of ice cubes vary with different models.

Whitehead.—Fig. 155 shows the compressor unit used with the household refrigerating machine manufactured by the Whitehead Refrigeration Company of Detroit, Michigan.

The compressor is of the reciprocating type. It is connected directly to the motor shaft and operates at motor speed, thus eliminating belts or gears. A flexible coupling is used to connect the motor and compressor shafts.

The condenser is made of finned tubing and is cooled by forced air. The fan is mounted on the compressor motor shaft.

Methyl chloride is used as the refrigerant. The receiver



FIG. 155.—WHITEHEAD COMPRESSOR UNIT.



FIG. 156.—WHITEHEAD COOLING UNIT.

contains a visible gauge showing the amount of refrigerant contained in the receiver.

The temperature control is of the mercury tube type.

Fig. 156 shows a typical cooling unit. This is made in five sizes as follows:

| Tank Size | Width | Depth | Height | Ice Box Capacity | Maximum Cube Capacity per Freezing |
|-----------|--------|--------|--------|------------------|------------------------------------|
| 1 | 10 in. | 11 in. | 10 in. | 5-7 cu. ft. | 96 |
| 2 | 10 in. | 11 in. | 13 in. | 8-10 cu. ft. | 96 |
| 3 | 10 in. | 11 in. | 16 in. | 11-15 cu. ft. | 144 |
| 4 | 11 in. | 11 in. | 19 in. | 16-20 cu. ft. | 144 |
| 5 | 11 in. | 11 in. | 23 in. | 20-30 cu. ft. | 192 |

Williams Simplex.—An air cooled refrigerating machine was developed for household use called the Williams Simplex. Ethyl chloride is used as the refrigerant.

The compressor is of the rotary type, directly connected to the motor shaft without employment of intermediary gearing or belting. The compressor has a volumetric efficiency ranging from 82 per cent to 85 per cent, and a mechanical efficiency comparing favorably with the best reciprocating types of many times greater capacity.

A ground steel collar is used to seal the drive shaft. This collar is self-aligning and automatically takes up wear, as it is attached to the compressor by means of a corrugated metallic tube. A spring, assisted by the condensing pressure, holds these members in firm contact. This forms a tight joint, which will run indefinitely without a tendency to wear or break down.

The compressor is mounted integrally with and supported by the motor. Positive pressure feed of lubricant is maintained to all moving elements of the compressor while in operation.

The compressor and condenser are cooled entirely by maintaining a current of air over their surfaces. The air is circulated by means of a Sirocco type of blower mounted between the motor and the compressor, the blower casing forming the supporting bracket for the compressor.

The air is first drawn through the condenser chamber which contains a continuous coil of copper tubing into which

the refrigerant vapor is compressed, taking up the latent heat of vaporization; it then passes over the heat radiating fins of the compressor, from which it discharges through a flue extending through the top of the machine cover. Air is also simultaneously drawn from the opposite direction through and around the motor and discharged from the fan as above described.

The so-called flooded system is employed, in which the expansion or cooling coils are filled with liquid refrigerant. These coils connect into a vertical header from the top of which the vaporized refrigerant is drawn. This vapor, after being liquefied in the condenser, is discharged into a small chamber fitted with a float valve, which permits it to feed back into the expansion coils at the same rate at which it is being condensed.

These features are important, in that the radiating surfaces of the cooling coil have a much higher heat transmitting capacity when full of liquid. The ratio to the usual method of gas expansion at constant pressure is about 1.56 to 1.

A still more important advantage is that the expansion pressure is automatically varied to maintain constant balance between the compressor capacity and the radiating surfaces as the temperature changes. This provides maximum efficiency operating conditions throughout any range of temperature, while in the usual gas expansion method the pressure is necessarily set and held for the lowest temperature required, which is always the condition of lowest efficiency.

The machine is controlled by means of a thermostat, arranged to operate responsive to the temperature of the brine surrounding the coils in the brine tank. The switching apparatus and its actuating motor are located on the machine base, while the bulb of the instrument only is located in the tank. The advantage of placing the thermostat bulb in the brine tank is due to the fact that the maximum temperature change occurs in the brine.

A safety pressure switch is also used, which is operated directly responsive to the refrigerant condensing pressure.

The machine has a capacity when operating at 15° F. of about 150 lbs. ice equivalent per 24 hours. The power con-

sumption, including motor losses, is from 190 to 200 watts with direct current, and from 260 to 300 watts with alternating current, the difference being due to the larger losses in the alternating current motor.

Zerozone.—The Zerozone Household Electrical Refrigerating Unit is manufactured by the Iron Mountain Company of Chicago, Illinois.

This is an air-cooled compressor type unit using a cooling unit of the indirect type. The refrigerant used is sulphur dioxide.

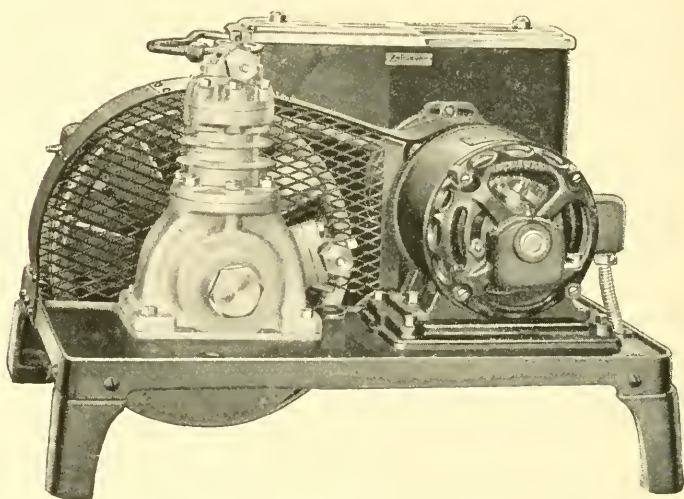


FIG. 157.—ZEROZONE ELECTRICAL REFRIGERATING UNIT.

The compressor unit consists of a one-cylinder reciprocating type compressor which is used on all well insulated refrigerators up to 20 cu. ft. and is shown in Fig. 157. The bore and stroke is $1\frac{3}{4}$ inch and the compressor operates at 330 r.p.m. The compressor is driven by a $\frac{1}{4}$ hp. repulsion induction electric motor by means of a "V" type belt.

A two cylinder type compressor is used on all refrigerators from 20 to 50 cu. ft. and is shown in Fig. 158. The bore and stroke is $1\frac{3}{4}$ inch and the compressor operates at 265 r.p.m. driven by a $\frac{1}{3}$ hp. repulsion induction electric motor by means of a "V" type belt.

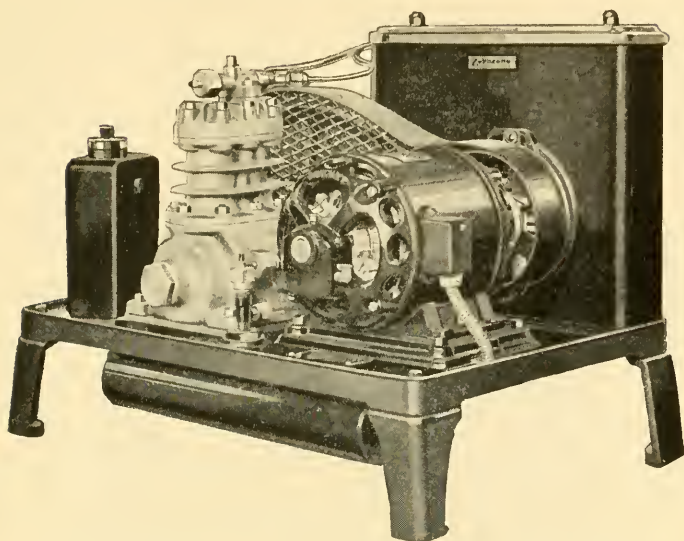


FIG. 158.—ZEROZONE TWO-CYLINDER TYPE COMPRESSOR.

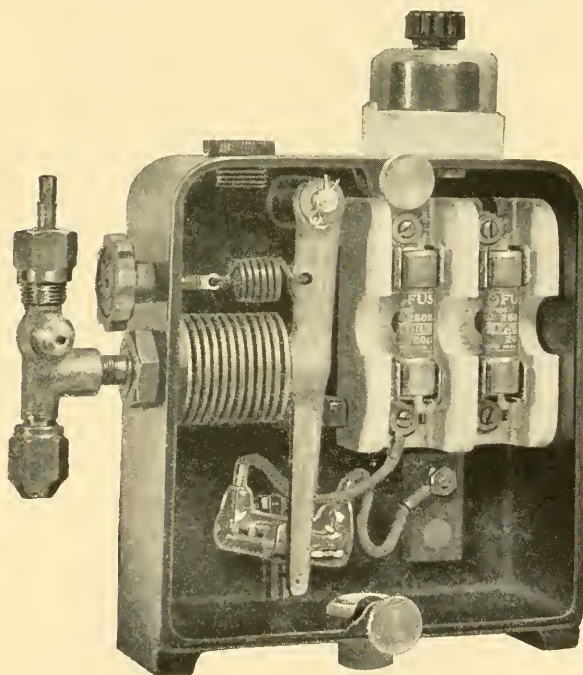


FIG. 159.—ZEROZONE AUTOMATIC CONTROL.

The condenser in each case is a double copper coil cooled by forced air by means of a fan attached to pulley end of the motor shaft.

The control used on the individual installation is an automatic thermostat, Fig. 159, and is responsive to the tempera-

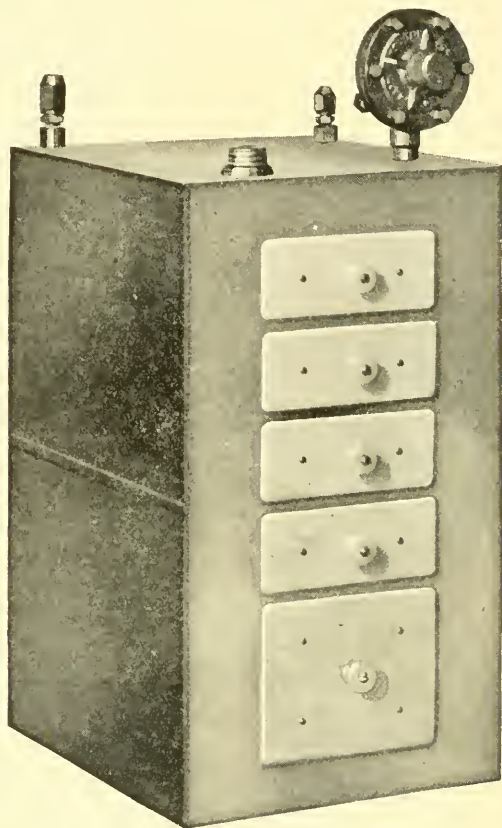


FIG. 160.—ZEROZONE COOLING UNIT.

ture in the cooling unit. The thermostat tube in the cooling unit connects to a siphon which operates a mercury tube switch, by means of a suitable lever mechanism.

The control used on the Multiple installation is of the low pressure type, and is responsive to the pressures in the low side of the refrigerant system. This low pressure control,

controls the operation of the compression unit itself, the temperature of each cooling unit in the multiple installation being controlled individually by a low side, thermostatic actuated valve, commonly referred to as a temperature governor.

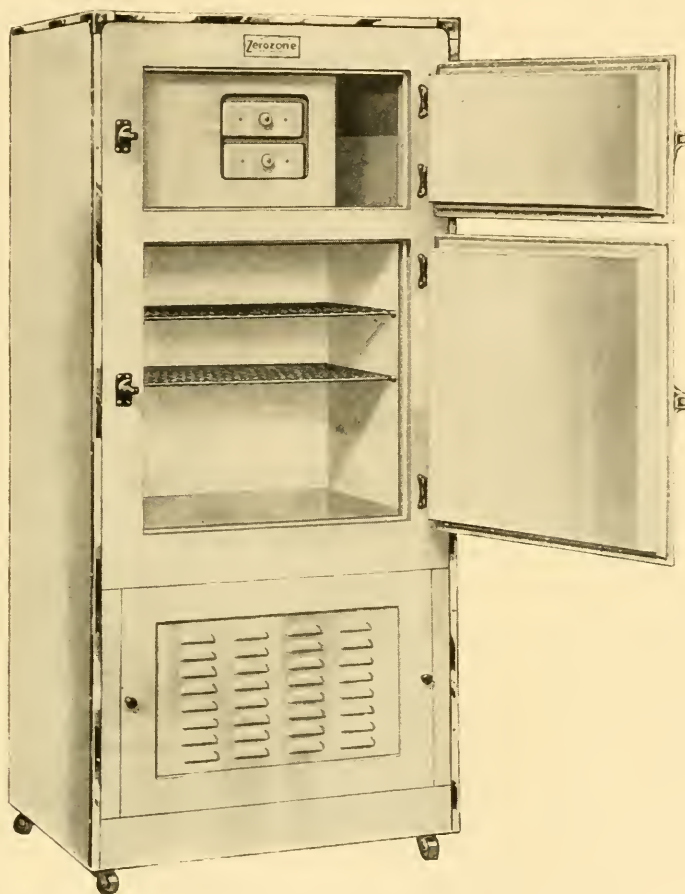


FIG. 161.—ZEROZONE SELF-CONTAINED METAL CABINET.

A diaphragm type expansion valve is used to automatically meter the correct supply of liquid refrigerant to the expansion coils.

The cooling units are made of 20 ounce sheet copper, made in various sizes, one of which is shown in Fig. 160, and con-

tains $\frac{3}{8}$ -inch copper tubing for the expansion coil. The non-freeze solution is calcium chloride.

Fig. 161 shows a typical self-contained cabinet, the exterior of which is metal, finished with white lacquer. Cork-board is used to insulate the walls and doors. The lining is of the one piece porcelain on steel type. The cabinets are made in various styles and sizes.

CHAPTER VIII

HOUSEHOLD REFRIGERATING MACHINES ABSORPTION TYPE

Household Absorption Refrigerating Machines.—In this chapter, attention will be given to the general types and characteristic construction of a number of household absorption refrigerating machines.

Ice-O-Lator.—Fig. 162 shows an absorption type refrigerating machine manufactured by the Winchester Repeating Arms Company for the National Refrigerating Company at New Haven, Conn.

The "absorbent" which was the result of so many years of research by Prof. Keyes is the basis of the machine. Other absorbents have been known. Charcoal is an efficient absorbent and is frequently employed to absorb gases of various kinds. A good example is in gas masks. But charcoal cannot be employed in refrigeration because it is such a poor conductor of heat that no practical degree of efficiency can be obtained in the operation of a machine using it. You can get the gas into it well enough, but you can't get it out again without the expenditure of a prohibitive amount of energy. This absorbent combines the highest known absorbing qualities together with the quality of high heat conductivity.

Following are the qualities which the inventors set out to embody in their absorbent. They are the properties of an ideal material:

1. Cheapness and unlimited supply.
2. Should absorb at least 100 per cent of its own weight of refrigerant.

3. Should have a high heat conductivity in order to facilitate the removal of heat of absorption and also the application of heat for driving off the refrigerant.

4. Cellular, or porous structure, in order to present necessary working surface.

5. Stability. There should be no diminution of operating efficiency, or no disintegration or decomposition after continued use.

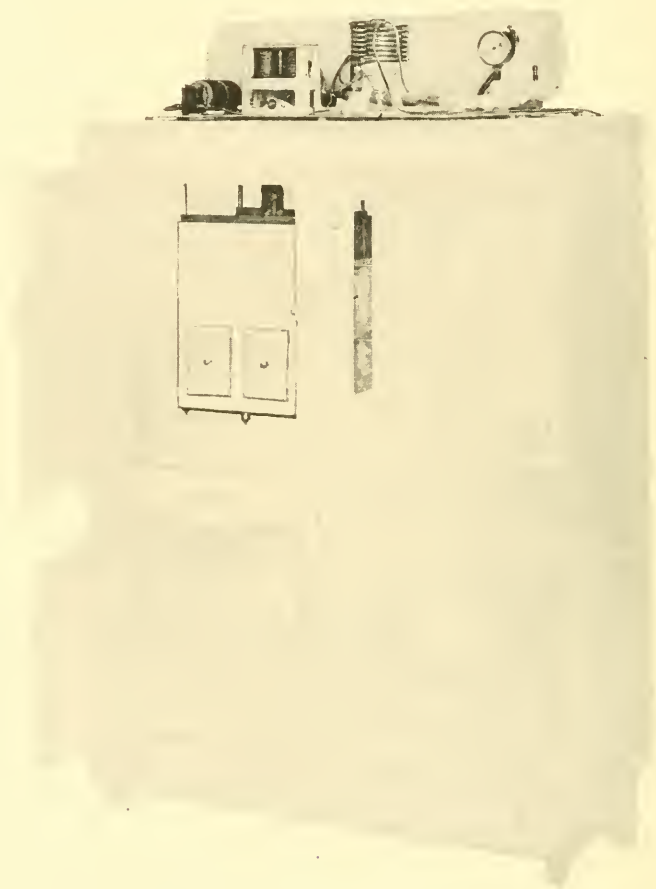


FIG. 162.—NATIONAL REFRIGERATING MACHINE.

In three years of continuous operation, no sign of decreased efficiency has developed.

A brief comparison with water, the best known absorbent, forms a favorable basis for comparison. Water compels the

use of aqueous ammonia. This material is absolutely dry, making possible the use of pure anhydrous ammonia. Water absorbs 40 per cent of its own weight of ammonia. This material absorbs approximately 110 per cent of its own weight of ammonia gas and in addition loses its working charge on the application of about half the amount of heat necessary to drive the much smaller charge from water. Result—much less bulk and much more economical operation.

As the efficiency of the material has been steadily increased by constant scientific research since its discovery, there is considerable possibility that it may be still further increased.

The small household machine operates as follows: A steel tube is filled with a material which will absorb a large quantity of ammonia gas. When heat is applied the pressure is increased and the NH_3 gas is liberated and passes through a filter and check valve to the condenser. When the pressure reaches a point that corresponds to the temperature of the cooling water, condensation takes place and liquid NH_3 is delivered to the liquid valve float chamber. The purpose of this chamber is to insure complete condensation by the cooling water. The liquid NH_3 is then delivered through a small orifice and tube to the refrigerating chamber and coils. The heating continues until enough liquid NH_3 has collected in the refrigerating chamber and coils to make a contact by means of the float contacting mechanism at the top of the refrigerating chamber. When this contact is made the relay switching system is tipped to the opposite position, the heating circuit is broken, and the water is shifted by means of the valve from the condenser to the generator. As soon as the pressure over the material in the generator has dropped to the point which is less than the vapor pressure of the liquid ammonia in the refrigerating chamber and coils, boiling in this chamber commences and continues until all the liquid has evaporated. This evaporation may require from one hour to five hours depending upon the temperature in the refrigerator. When the temperature is high, the evaporation is very rapid and when it is low the boiling requires a much longer period of time. The temperature in the refrigerator, then is regulated by the rate of evaporation of the liquid. The brine tank maintains the

low temperature during the heat period when no refrigeration is taking place so that the temperature in the refrigerator is practically constant. When the entire quantity of liquid has evaporated a contact is made at the bottom of the refrigerating chamber which tips the relay to the heating position, the heating circuit is made, the water is shifted back to the condenser, and the cycle repeats.

Fig. 163 shows a diagrammatic drawing of the gas-fired Ice-O-Lator. This model has electrical controls and is water-

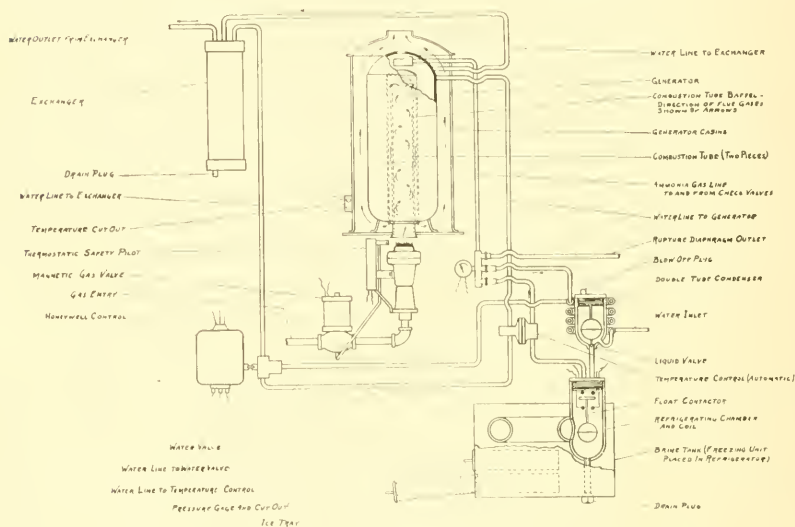


FIG. 163.—DIAGRAMMATIC DRAWING OF THE GAS-FIRED ICE-O-LATOR.

cooled. The unit is placed in the cellar or any convenient place outside of the refrigerator cabinet.

The following information concerning the cost of operating this unit is of interest.

Illuminating or coal gas delivers 520 B.t.u. per cubic foot and natural gas an average of 1100 B.t.u. per cubic foot. One kw-hr. of electricity at 110 volts delivers 3415 B.t.u. Taking coal gas for comparison, 6.56 cu. ft. of gas is equivalent to one kw-hr. of electricity for heating purposes.

The cost of gas per 1000 cu. ft. ranges from \$0.40 to \$1.50 in various localities. Many cities have a rate under \$1.00.

Natural gas, with about double the B.t.u. of coal gas, can be purchased for as low as \$0.40 per 1000 cu. ft. in some localities. As against this, the cost of electricity averages about \$0.55 per kw-hr.

Heat for heat, the difference will readily be seen. At \$1.00 per thousand cu. ft. for coal gas the same number of B.t.u. can be obtained for three-fifths of a cent as from five and one-half cents' worth of electricity at the above rate.

The following table shows the approximate cost of operation, for the equivalent of 100 lbs. of ice refrigeration, of a machine using gas at the various rates.

| Cost of Gas Per 1000 Cu. Ft. | Cost Per 100 Lbs. of Refrigeration |
|---------------------------------|---------------------------------------|
| \$0.40 | \$0.05 |
| .80 | .10 |
| 1.00 | .125 |
| 1.50 | .187 |
| 2.00 | .25 |
| 2.80 | .35 |

It will probably have been observed that the small household machine is cyclic and subject to peaks. Whereas this has not proven an objection in any of the machines at present in operation, still in the event that continuous refrigeration should be desired to meet some special conditions, such can easily be obtained by the use of two generators, one absorbing while the other distills.

Keith.—Fig. 164 shows an ammonia absorption type household refrigerating machine made by the Keith Electric Refrigerator Division of the Canada Wire and Cable Company, Ltd., at Leaside, Ontario, Canada.

Referring to Fig. 164, which shows the unit in the cooling position, on the left hand side in the generator, is about two quarts of ordinary "ammonia" as used in the home. Within the tank there is also a small electric heater. When the heater is started the gas is driven out of the water, just as you can see gas or bubbles of air driven out of the water in your tea kettle as it begins to boil. This gas is not very warm, as ammonia is easily driven off, and when it flows over into the pipes shown on the right hand of the illustration, it is chilled by a trickle of cold water which is flowing over the pipes of

the condenser. When it is chilled, the gas is deposited on the inside of the condenser, about the same as dew is deposited by the chill of the morning air. This deposit is pure liquid ammonia.

When the condenser is nearly full of pure liquid ammonia, in approximately one hour's time, it begins to weigh more than the generator, and swings down, pulling the generator up and shutting off the electric heater. Almost immediately the pure liquid ammonia begins to evaporate and chills the

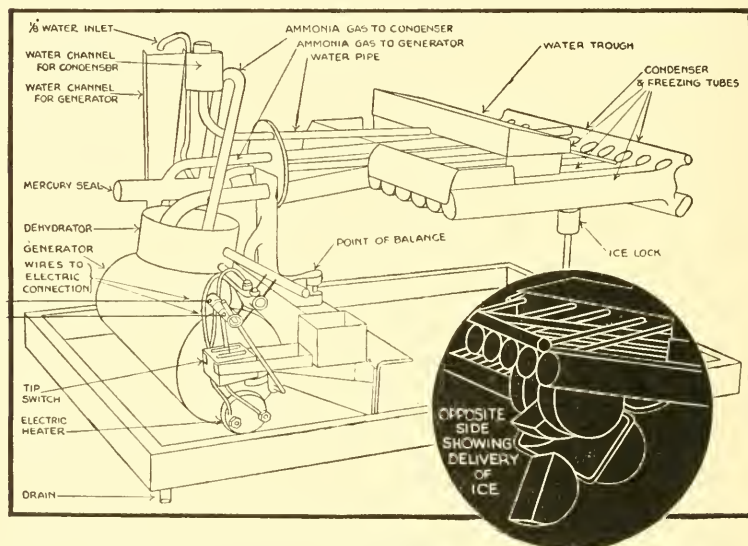


FIG. 164.—KEITH AMMONIA ABSORPTION TYPE REFRIGERATING MACHINE.

pipes to approximately zero temperature. This chills the surrounding air, which flows down into the food compartment of the refrigerator.

As the pure liquid ammonia evaporates, it flows back as a gas into the tank of water, where it is once more quickly absorbed. As soon as all the ammonia is returned to the generator, the pipes of the condenser naturally become lighter and the tank (or generator) heavier, and the unit gently tilts back to the original position, the electric heater starts and the operation commences all over again.

The operation, as has been explained is purely automatic, requiring no attention and maintains an even cold temperature at all times, ideal for the preservation of food. The amount of electrical energy consumed averages about $3\frac{1}{2}$ kilowatt hours per day for continuous operation, depending on the weather and other conditions.

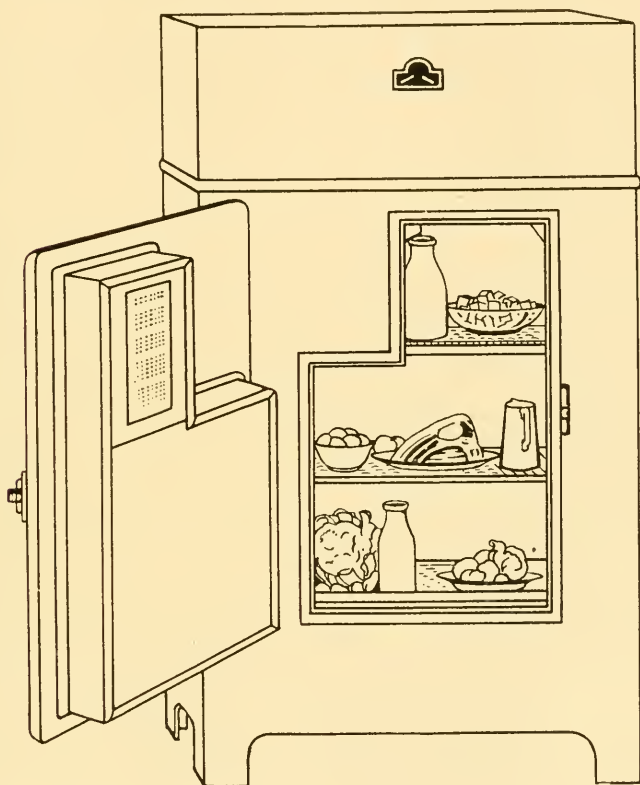


FIG. 165.—KEITH REFRIGERATING UNIT INSTALLED IN COMPARTMENT ON CABINET.

Heater—900 watt resistance coil, porcelain core, inserted in steel tube through generator.

Ice lock—Holds the condenser down until all ammonia is in the generator. Is released by temperature rising above freezing point.

Tip switch—A safety device to disconnect the electricity should the water be shut off.

Mercury seal—Contains mercury, which runs to lowest point with the tilting of the unit opening and closing the ammonia pipe to condenser.

Dehydrator—Eliminates water vapor from ammonia gas as it rises to the condenser.

The cabinet, Fig. 165, shows a complete self-contained unit with the machine in the compartment at the top.

Master.—An absorption machine of simple design is made by the Master Domestic Refrigerating Company, Inc., at Flushing, N. Y. It comprises a cylindrical generator, water cooled condenser and evaporator, connected by a single pipe to form the complete machine. It is made entirely from steel pipe and sheet steel.

Only water and ammonia are used as the means of producing refrigeration. These substances are charged in the generator in the correct proportions. Ammonia in the form of gas is released by applying heat to the generator. The gas is then cooled and liquefied in the condenser from which it flows by gravity to the evaporator in the cooling compartment of the refrigerator. By the subsequent cooling of the generator a reduction in the pressure is produced and the ammonia slowly evaporates thus producing the required refrigeration. The gas is re-absorbed by the cooled water in the generator. When the evaporation of the ammonia is practically completed a new cycle automatically begins.

The necessary reduction of the pressure is attained solely by the cooling of the generator, no check, float, or expansion valve, restricted orifice or other device is used in the machine and the pressure is always the same at any given time in all parts of the machine. The generator, condenser and evaporator freely communicate with each other at all times with pipe of full orifice.

The machine requires no attention as it is completely automatic. The automatic control consists of a power element actuated by the temperature of the generator, and a further power element which is placed in contact with the evaporator. The cooperation of these two power elements, by means of a simple mechanical principle, which is novel in its application to this machine, regulates and establishes the heating and cool-

ing periods and assures the proper and continual functioning of the machine in a simple and positive maner.

Should for any reason the supply of water to the condenser be interrupted, the heating means is automatically cut off. Simple and effective means are provided for automatically returning to the generator any water which may be carried over by the ammonia gas to the evaporator.

The machine and refrigerator are built as a complete self-contained unit, but, if desired, the machine may be installed outside of the refrigerator. Defrosting of the evaporator is automatic. Provision is made for an ample supply of ice cubes for table use.

The present machine is used to cool refrigerators of any size up to eight cubic feet inside capacity.

The Electrolux Servel.—The first practical continuous operating absorption refrigerating machine was made about the year 1860 by a Frenchman named Carre. His apparatus consisted first of a source of heat, generator, condenser cooling water, expansion valves, evaporator, absorber and pump. The heat liberated the ammonia gas from the aqua ammonia, so called "rich solution or strong liquid" leaving a weak liquid or water in the generator. The gas passing to the condenser is cooled off by the cooling water and condensed into a liquid. The liquid ammonia flows through the throttle or expansion valve into the evaporator, where the liquid ammonia is vaporized into a gas. During the evaporation heat is withdrawn from the surroundings, and thus cold is produced. The cold vapor passes into the absorber where it is sprayed by weak liquid from the generator. By the expulsion of the ammonia from the aqua-ammonia solution in the generator, the remaining liquid is to a large extent water. This poor solution being exposed to the high pressure passes through an expansion valve into the absorber. In this way the poor solution, meeting the ammonia vapors, absorbs them, so that in the bottom of the absorber a mixture collects as a "rich or strong solution." This solution is continually forced into the generator by the pump, which is operated by outside mechanical forces. A line drawn from the expansion valves through the pump

separates the machine into a high pressure side and a low pressure side.

In the apparatus of Carre's there are two cycles. The ammonia circulates from the generator through the condenser, the vaporizer and the absorber back to the generator. It therefore passes through all four receptacles. The water circulates from the generator to the absorber and vice versa. The water therefore only passes through these two receptacles.

The Carre machine was built in great numbers, being used in breweries, distilleries and similar plants where large amounts of heat vapor was available for which at that time no particular use was made.

However as the steam technique further developed and afforded numerous uses for exhaust steam for other purposes, the employment of the absorption machine became less and less. This was further augmented by the high efficiency of the newly developed compressor system. Mechanical difficulties also played a role as with small units as were used, the expansion valves were necessarily small and the orifice was continually clogging up with dirt; then too the pumps were a source of constant maintenance and had to be operated by auxiliary power, independent of this source of heat used in evaporating the aqua-ammonia.

There therefore arose a demand for small continually operating absorption machines, from which the above said defects of the machine of Carre were eliminated, said machines to have neither expansion valves nor pump, but which could be operated merely by the heat supply.

This was the aim of Geppert. In order to reach this aim he dispensed with the difference of the total pressure for the purpose of vaporization. With the same total pressure in the entire apparatus he tried to effect the vaporization necessary for refrigeration, as well as the reuniting of the ammonia gases with the water, and returning the mixture to the boiler without a pump or other mechanical energy. To this end, Geppert, in addition to the cooling medium (ammonia) and the absorbing liquid (water) used in the vaporizer a third medium, to wit, a gas, in the presence of which according to physical laws (due to the difference of so called partial pressures of

the gases) liquid ammonia evaporates without a drop of the total pressure being required.

In the year 1899, Geppert built such an apparatus. In the boiler the ammonia gas is expelled as in the Carre machine. After being liquified in the condenser the liquid ammonia flows through a conduit into the upper pan of the evaporator. In this liquid is immersed a porous material which is so placed as to extend over the rim of the inner opening and extending completely under the pan. The porous material with its large exposed surface facilitates the evaporation of ammonia in the presence of the second gas contained in the receptacle. The second gas used by Geppert was air. At a slight distance below the porous pad on the bottom of the upper pan is a bath of poor solution, which flows from the boiler, being cooled by passing through a cooler on its way to the absorber. It will thus be seen that Geppert combined the evaporator and absorber into one vessel. The ammonia gases resulting from the evaporation at the surface of the porous material diffuses downward through the second gas filling the receptacle and is then absorbed by the absorption liquid. The rich liquid then flows back to the generator where by the application of heat ammonia gas is again expelled.

The machine of Geppert is based on the theoretically correct idea that a pressure drop requiring throttle valves and pump becomes unnecessary in a refrigerating machine, if in the evaporator the liquid ammonia meets with a gas in whose presence the ammonia evaporates. The machine as designed refused to work and Geppert has himself seen the drawbacks of a design in which the ammonia has to diffuse through a thick layer of inert gas. This is apparent from other drawings later on submitted by him. In the next design he reduced the thickness of this layer and employed a fan to aid the evaporation, by having the lower parts of the fan blades dip into the liquid. By doing this he was able to further separate the cold evaporator from the warm absorber thereby reducing the refrigerating losses. The fan had to be operated by a motor and this was one of the pieces of equipment that Geppert had set out to eliminate. Another reason why the machine proved impractical was that when the ammonia vapors are absorbed

by water heat is liberated. The absorber therefore acts as a heater. Cooling water had to be provided in pipes located within the absorber. Notwithstanding this, heat liberated during the absorption rose into the evaporator space above, thus either entirely or partially counteracting the heat withdrawn from the surroundings by the evaporation of the ammonia. Effective refrigeration therefore cannot take place, or only in a very limited degree.

In the year 1901, Geppert attempted another design which was somewhat of an improvement over the two previous models. He still maintained the combined vaporizer and absorber. The receptacle was provided with a double wall, cooling water circulating in its hollow space. Into the receptacle is inserted a cylinder at a very slight distance from the inner face of the double wall of the receptacle. The cylinder contains salt water. The cylinder does not extend to the bottom of the receptacle. Into the free space flows from the boiler "poor solution." The operation was as follows:

The ammonia which had become expelled from the rich solution and liquified in the condenser flows through a small pipe to the outer surface of the wall of the cylinder, which wall is covered with porous material. There the ammonia becomes distributed and evaporates. Heat is therefore withdrawn from the salt water contained in the receptacle and cold is produced. The produced ammonia vapors diffuse through the small intermediate space to the opposite inner surface of the double wall of the receptacle. This surface is sprayed by poor solution which by means of a small pump is continually pumped through the pipes from the lower portion of the receptacle upwards into the space between the double wall of the receptacle and the cylinder. The surface on which the poor solution flows down is cooled by the cooling water in the hollow space of the double wall. As the poor solution flows down, it absorbs the ammonia gases which are diffused in its direction from the opposite surface and thereby is enriched with ammonia. Thus the outer surface of the cylinder acts as a vaporizer, and the inner surface of the wall of the receptacle as an absorber. The absorber therefore, is, not like in his previous patent, below the vaporizer, but the absorber

and vaporizer located in one and the same vessel, at the same level side by side. It will be noted that Geppert had to take recourse to the pump, which is one of the pieces of equipment he started out to eliminate. While he succeeded in producing cold, with his last design, the efficiency was small—also he failed to attain one of his objects, namely to eliminate the pump.

After Geppert failed, no trace can be formed of any practical and useful small refrigerating machine of any importance, operating according to the absorption principle in a continuous manner, until the year 1922 when two students, Baltzar Carl Von Platen and Carl George Munters of the Royal Swedish Institute of Technology developed and designed a working model which dispensed with all moving and mechanical parts.

This unit was later developed by the Electrolux Aktiebolaget in Europe and the Electrolux Servel Corporation in the United States, so that today we have a workable and saleable refrigerating unit that is indeed marvelous. In order to develop the present day product a large laboratory for research work was established in Stockholm, Sweden, and in Brooklyn, New York. In these laboratories developments and experiments are taking place so as to develop new types for further commercial applications. How well this unit with refrigerator has been developed was evidenced at the American Gas Association Convention at Atlantic City, where three complete refrigerators and an exposed unit were presented for the inspection of the gas industry.

Platen-Munters, independent of Geppert had like him the idea to have in the entire system, by the introduction of a second gas, everywhere the same uniform total pressures and to effect the pressure difference required for the vaporization of the refrigerating medium. Contrary to Geppert, however, they carried out this idea in a manner which at once resulted in a practical solution. They recognized what has remained concealed to Geppert that in such a system into which is introduced a pressure compensating gas there occurs within the system inner forces, i. e., physical actions which can be utilized in order to effect the circulation required for such a system. Furthermore, they recognized that this peculiar action can be

still considerably improved upon if the pressure compensating gas possesses special characteristics, for instance, as regards its specific weight differing considerably from that of the vapors of the refrigerating medium. There were ways of avoiding the pitfalls of Geppert.

First.—As regards the pump. By applying heat from a source the solution rich in ammonia, is made to boil in a tube and by the thermo-syphon action thus established, the liquid is raised from the lower level of the absorber to the high level of the generator.

Second.—Stagnation and poor circulation. Instead of using air as Geppert had done hydrogen gas was used. Absorber and evaporator are placed at about the same level or the latter somewhat higher than the former. When the ammonia vapor has been absorbed in the absorber, pure hydrogen flows through the upper pipe into the evaporator, where it mixes with the vapors from the evaporating liquid ammonia. The mixture of ammonia vapor and hydrogen being specifically lighter the greater its percentage of hydrogen, it follows that the column of gas in the evaporator will be heavier than that in the absorber. An automatic circulation of gas consequently takes place, giving an upward flow in the absorber and a downward flow in the evaporator. If instead of hydrogen, the inert gas had been nitrogen the flow would have been reversed.

The apparatus comprises the generator, condenser, evaporator, absorber, heat exchanger, thermo-syphon, which are interconnected by pipes. In all portions of the completely and tightly closed apparatus exists the same total pressure. The boiler is to a large extent filled with aqua ammonia (so called rich solution) only the upper vapor space of the boiler is free from liquid.

Into the bottom of the generator is inserted an electric heating element, connected to a source of electrical energy. From the upper free space of the generator leads a pipe to the condenser and said pipe continues on into the top of the evaporator. The latter is filled with hydrogen gas. At the bottom as well as at the top there is a connecting pipe to the absorber. The absorber is surrounded by a jacket through which circulates cooling water, which then passes to the condenser. From

the bottom of the absorber a pipe runs to and coils around the heating element. In addition there is a pipe connecting the bottom of the generator with the top of the absorber. This pipe where it is horizontal surrounds the pipe which passes from the absorber to the upper space of the generator.

The apparatus is operated as follows: Current supplied to the heating element heats the rich solution in the generator. The ammonia gas expelled from the rich solution fills the upper free space of the generator and flows through the pipe into the water cooled condenser. Because of the cooling the hot ammonia gases are condensed to pure ammonia liquid. This liquid flows to the evaporator. There in the presence of hydrogen the liquid ammonia evaporates. Through the evaporation heat is withdrawn from the brine tank surrounding the evaporator and consequently cold is produced. The ammonia gases in the evaporator diffuse into the hydrogen, and the mixture, sinks downward, because as compared to the gas mixture in the absorber it is heavy. In its downward movement it passes on to the absorber. In this vessel the gas mixture meets with the water (poor solution) coming from the generator. The liquid level in the generator is higher than the "poor solution" pipe to the absorber; there is therefore, a continual flow of poor liquid into the absorber. In the absorber the poor solution absorbs from the gas mixture the ammonia gas and collects at the bottom of the absorber as "strong or rich liquid," while the lighter hydrogen free from ammonia ascends and through the pipe connecting the absorber with the evaporator, again enters the top of the evaporator.

The rich solution is conveyed through the coils of the pipe around the lower end of the heating element and is thereby preheated so that the ammonia gas bubbles around the pipe. These bubbles carry along globules of liquid, which thereby reach the upper portion of the generator, from which we began the cycle of operation.

Outside the cycle of the ammonia which takes place in all four vessels (generator, condenser, evaporator and absorber) there occurs in the apparatus still two other cycles. On the one hand the circulation of the water, or poor solution from the

bottom of the generator, to the top of the absorber down to the bottom of that vessel as strong solution, then to the top of generator, through the thermosyphon pipe. On the other hand, the circulation of the hydrogen gas from the bottom of the evaporator to bottom of absorber, and from top of absorber to top of evaporator.

The above description covers the machine as originally designed. Rarely, has an invention required less time to perfect. On August 18, 1922, the first patent was deposited in Sweden and in 1925 a great number of refrigerating machines were in commercial service.

The Electrolux Servel Corporation has by exhaustive tests and experiments developed a machine somewhat different than the original Swedish design. These changes have practically doubled the "ice melting capacity of the machine" and have greatly increased its efficiency. They have in addition perfected the machine for gas heat instead of electric heat and have reduced the quantity of cooling water needed to properly operate the unit. In order to do this several changes had to be made to the apparatus.

1. Inner flue placed in generator to permit the use of a gas flame for heat.
2. Rectifier—to catch water that may be carried over with ammonia gas.
3. New type condenser—simplified construction.
4. Gas heat exchanger—placed between rectifier and the absorber and the evaporator, where the cold ammonia hydrogen mixture coming from the evaporator is warmed by the hot ammonia coming from the rectifier and the hot hydrogen from the absorber.
5. The liquid heat exchanger. The two pipes located between the absorber and the generator the one being placed inside the other, act as a heat exchanger on the counter flow principal, by means of this the hot, weak liquid, which flows from the bottom of the generator into the absorber, is pre-cooled by the comparatively cool strong liquid that flows from the absorber to the thermo-syphon. This solution is at the same time pre-heated before entering the generator.

The unit before being charged with ammonia, distilled water and hydrogen is given a careful air and hydraulic test under the most rigid factory supervision and after being charged is hermetically sealed by welding. The original charge does not have to be renewed, as there is no leakage.

The unit is equipped with a thermostatic safety burner which automatically shuts off the gas supplied if for any reason the supply is interrupted. One of the features of the unit is that the operation involves absolutely no danger even if the condenser water supply should be interrupted for any length of time.

Inasmuch as there are no moving parts and being rigidly constructed, no servicing is necessary, and that is saying a lot.

The refrigerator is a steel box of approximately $6\frac{1}{2}$ cubic feet of food space—finished with several coats of duco over baked white lacquer. The cooling section inside the box is of cast aluminum having five trays with a capacity of about fifty cubes. The box is insulated with three inches of high grade corkboard, thus bringing the thermal losses and operating costs down to a minimum. (From address delivered by F. E. Sellmann before the New York Section of the American Society of Refrigerating Engineers in October, 1926.)

The original ice melting capacity of the Swedish machine was about forty-five pounds per twenty-four hours while its thermal efficiency was about 18 per cent. The Swedish public were apparently content to utilize a manually controlled machine, the control simultaneously regulating both gas and water. It was found that in order to make the machine salable in this country it would have to be designed so as to operate and give sufficient refrigeration where room temperatures of 100° F. and cooling water of 90° F. were encountered. It further had to be developed so that the machine would have to give desired refrigerating effect automatically, and with controls making the unit serviceable for use with either manufactured gas, natural gas, electricity or oil. A laboratory was established in Brooklyn where exhaustive developments were made by united effort of engineers of the American and Swedish companies. During the next year these men were able to redesign the machine so as to bring about an ice melting capacity of seventy-five pounds per twenty-four hours and to raise the efficiency to $32\frac{1}{2}$ per cent when operated by gas. When operated electrically the efficiency rose to 38 per cent. The machine was also capable of producing sufficient

refrigerating effect to take care of the designed refrigerator under conditions of 100° F. room temperature and 90° F. cooling water.

The maximum efficiency of the original Swedish unit was reached when an input of 730 B.t.u.'s per hour was furnished, while the maximum efficiency of the machine developed in America was reached when 1350 B.t.u.'s were used. The capacity reached its maximum at about 1300 B.t.u.'s with the Swedish machine, but with about 1650 for the American machine. These improvements both as to capacity and efficiency were brought about by many developments including a new type of rectifier, improved Thermo-syphon, and the use of a gas heater exchanger. The figures quoted above were furnished from tests conducted by the Consolidated Gas Company of New York.

As the efficiency and capacity increased with the increase in B.t.u.'s furnished the unit, it was therefore necessary to control the heat input so as to get a predetermined refrigerating effect. Using gas of 540 B.t.u. per cubic foot heating value the minimum gas required to assure satisfactory pumping through the Thermo-syphon was $1\frac{1}{2}$ cubic feet per hour and this flame had to be increased to a maximum of three cubic feet per hour when maximum refrigeration was desired. This meant therefore a development of a burner that would burn satisfactorily between the ranges of $1\frac{1}{2}$ cubic feet and three cubic feet per hour and that the burner in addition must be of the safety type so that, if for any reason the gas flame were extinguished that the gas supply to the burner would be automatically shut off. The first burner developed possessed these characteristics but was designed for a gas pressure of about $2\frac{1}{2}$ inches of water and 540 B.t.u. gas. With the sending of refrigerating units into districts where gas pressures and B.t.u. values vary considerably it was necessary to develop burners suitable for both water coke-oven and natural gases and to test and approve gas pressure regulators.

As the minimum gas required at any time was $1\frac{1}{2}$ cubic feet per hour the gas thermostat was therefore designed so as to always allow that quantity of gas to pass through it, but when the thermostat acted on the gas supply it augmented

gradually the flow until three cubic feet capacity was reached. The thermostat is of simple construction easily set and adjusted. It consists of a six inch bulb located within the food chamber. The operating mechanism of the thermostat is located in the machine compartment and is inter-connected by capillary tubing. The bulb is partly filled with a liquid which when expanded into a gas, actuates by pressure through the tube a diaphragm located in the body of the thermostat.

With operating the machine electrically, similar conditions must of course be taken care of so that the machine will continually pump. With this in mind a double heating element was developed which furnished a minimum wattage to keep up pumping but increased the wattage to take care of maximum load. From the consumption curve of the cooling water needed it will be noticed that after a certain amount of water had been used further increase in water consumption becomes unnecessary and wasteful. This therefore clearly indicated that no desirable control could be developed for controlling water simultaneously with the gas and that any water control developed would have to be designed using as a controlling factor a predetermined cooling water outlet temperature. Such a device was developed and with the outlet water temperature maintained at 90° F. the water consumption was practically halved as compared to that which was used prior to the development of this water control. The machine is now operating satisfactorily with about three gallons of water per hour with water inlet temperature of 70° F. The machine will operate and produce ample refrigerating effect with cooling water up to 90° F. With temperatures above this, the water would flow through unrestricted parts in the valve and the valve become unnecessary, but where cooling water is encountered below 90° F. the saving in water is very material. Those familiar with early tests must realize the material saving made in the water consumption and that the objections raised to water cooling, both as to waste of water and costs has been overcome.

The machine unit comprising the generator, evaporator, absorber, rectifier and gas heat exchanger is made of heavy steel tubing inter-connected by steel pipes, all joints being

oxy-acetyline welded. This produces a completely sealed unit from which there is no danger of leakage. The units are designed to withstand a pressure of 3100 pounds per square inch although only about 200 pounds charging pressure is used, and a certain proportion of the run of units are tested to this pressure at the factory. Each unit, however, is subjected to a high pressure test in order to detect any possible imperfections in welding.

From time to time one hears many stories reflecting on the safety of gas-fired absorption machines. This all emanated from experiences of ten to fifteen years ago when a few gas-fired intermittent absorption machines were being marketed, most of them of large capacity for commercial use. A few serious accidents practically eliminated further progress in this type of machine, and produced adverse legislation. The cause of this trouble was largely due to a lack of understanding as to the necessary safety devices that are required on a large intermittent machine. In other words, a machine of this kind requires automatic mechanism to shut off the fuel at the end of the boiling period, to apply cooling water at the right time both for condensing and absorbing purposes, and a pressure limiting device in the event that the gas fuel or condensing water did not function properly. The fact is these variously needed devices had not been properly perfected before the machines were marketed. Since that time there has been considerable progress made in small intermittent machines, so that in some cases for certain types of work the objections of the past have as a rule been overcome.

The Electrolux-Servel unit incorporates features which make safety devices not only unnecessary but undesirable. The fuel burns continuously, and continued operation of the maximum burner adjustment would merely produce an extremely cold box. In practice this is prevented by making the gas consumption depend upon box temperature. If, for any reason, the cooling water were to fail nothing would happen other than that the refrigeration would cease. The reason that no safety device is required to meet this condition is due to the design of the machine, which provides so much radiating surface, in proportion to the heating surface,

that all parts, with the exception of the generator will throw off the heat as fast as it is applied, through all the surfaces as represented by the evaporator, heat exchanger, absorber, condenser and rectifier, and a state of equilibrium will be reached when these surfaces will throw off the heat at the same rate as heat is applied to the generator. These two features absolutely eliminate the need of any safety devices whatsoever for the purpose of safe operation.

For an entirely different reason, however, a fusible plug is installed on the absorber end of the gas heat exchanger. This was made at the suggestion of the New York Fire Department, as well as the National Board of Fire Underwriters, and is to provide for that emergency which would be brought about by intense exterior heat being applied to all parts of the machine as would be the case if a fire occurred in the room in which the refrigerator were installed. To meet this emergency the fusible plug set to melt at 200° F. would simply relieve the refrigerator charge. This is a precaution which would be just as important if the machine were simply filled with either water or air, as the unlimited heat supply would simply produce an internal pressure which would eventually rupture the machine. These facts are borne out by the approval of the machine by the National Board of Fire Underwriters' Laboratory in Chicago, and by recent changes in the proposed code for the city of New York.

This machine has long since passed its experimental stage. When first brought out into production 250 sample boxes were sold to the various gas and public utility companies for the purpose of having them conduct tests and determine if the machine and box were what they desired and what was claimed it would do. Apparently the machine and boxes designed met with instant approval as is evidenced by the large order placed for this machine. The machine lends itself to and is particularly suitable for apartment house service especially in large and congested cities where the fact that it is absolutely noiseless, safe and serviceless has been deciding factors in its reception.

The unit may also be used in specially built boxes of varying sizes, built to fit into particular niches as seems to be the growing demand in new apartment house construction. There

is also a combination of a gas stove and refrigerator where a gas stove is mounted on a refrigerator box the same gas service line serving both. There are operating right now in the Eastern districts embracing environment of Metropolitan district of New York approximately one thousand machines. The servicing of these machines, in case it were necessary, would, of course, be done by the gas company, and from the information received they advise that so far they have not experienced any servicing whatsoever.

One question has undoubtedly occurred to a good many of you. "What effect has the gas flame with its products of combustion on the interior of the gas flue which passes through the generator?" In view of the fact that the gas flame is not extinguished but ranges in degrees from $1\frac{1}{2}$ cubic feet per hour to 3 cubic feet per hour results in the gas flue always being kept at a temperature higher than the dew point.

Numerous people have asked the question, "What corrosion will take place within the unit?" Before the unit is charged with ammonia, distilled water and hydrogen, a high vacuum is pumped. Practically all oxygen is therefore removed. The machine, of course, has not been in service more than a few years so we can go back no further—but machines that have operated for this length of time in Sweden have been cut open and no trace of corrosion has been found.

The dissociation of ammonia into nitrogen and hydrogen is an old story in absorption systems where numerous joints and connections are used. In the Platen-Munters Refrigerating unit—there are no joints, no possibilities of air leakages. Then, too, if there should be a tendency to break down the ammonia into nitrogen and hydrogen—it must be remembered that the unit has already a heavy charge of hydrogen and this would tend to repel the dissociation.

Another question that has apparently been causing some comment by refrigerating engineers has been the possibility of leakage of hydrogen through the steel. As long ago as about 1860 it became known that hydrogen is absorbed by certain metals and can be diffused through them. This matter has since this time been subject to a large number of investigations which have mostly centered on the diffusion of hydro-

gen through iron and steel, as this for several reasons is of considerable technical interest.

It was known from these investigations that gaseous hydrogen easily penetrates and diffuses into steel at red heat. This diffusion, however, is sharply reduced with the lowering of the temperature and has seldom been observed at a temperature below 300°C or 572°F ., wherefore some investigators have assumed a discontinuity of the diffusion at this temperature, or a "hydrogen point" of the steel. On the other hand it was shown that hydrogen which had been introduced into the steel electrolytically would diffuse through the metal at even room temperature.

As the Platen-Munters refrigerating unit contains hydrogen at ordinary room temperature under relatively high pressure, it was desired to determine if any appreciable loss of hydrogen would occur under these conditions. Earlier investigations had indicated that the losses would be quite small, but as no figures were available regarding their actual magnitude, tests were arranged and conducted by Professors Borelius and Lindblom at the Royal Technical School at Stockholm.

Applying the data obtained to the Platen-Munters refrigerating unit, we find that no danger exists of loss of hydrogen through the wall of the apparatus. For instance, if we take a 60 cal. refrigerator which contains 1.5 gr. hydrogen and which will still operate if 0.3 gr. of this hydrogen were lost, we would find that it would take one hundred eighty years before sufficient hydrogen escaped making the apparatus inoperative. This certainly gives a wide margin of life.

Thousands of people have examined this machine, among them a large number of engineers; in fact, generally speaking, the more technical a person is, the greater appeal has been made by the machine. The fact that the machine is noiseless, free from moving parts, compact, economical in operation and has apparently unlimited life, cannot but make us reflect on its effect on domestic refrigeration.

When we consider that this machine is the first of its kind, and if we compare it with other developments in the past, we can readily visualize that the continuous absorption machine will also follow in the path of progress.

Does this not make us wonder if the absorption principle will not soon be a vital factor in domestic refrigeration? (From an address delivered by F. E. Sellmann at the American Society of Refrigerating Engineers meeting in May, 1927.)

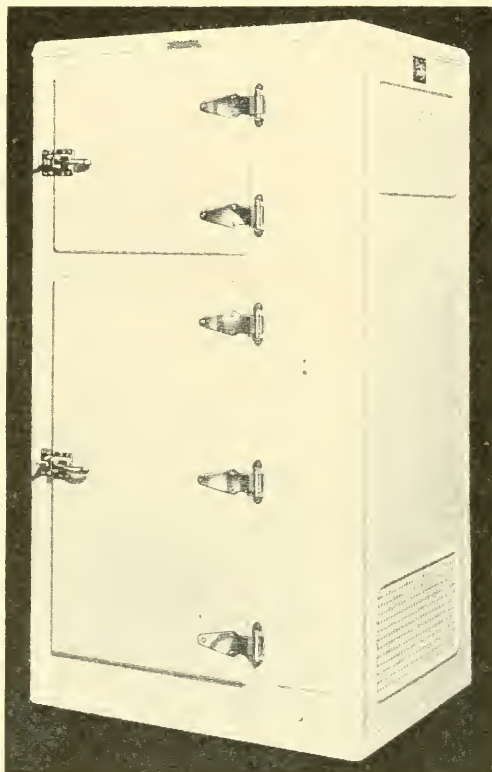


FIG. 166. ELECTROLUX SERVEL REFRIGERATOR CABINET.

Fig. 166 shows the refrigerator cabinet. The exterior is made of lead coated steel finished with white duco. Fig. 167 shows the cooling unit and food compartment space. The food capacity is $6\frac{1}{2}$ cubic feet. The box is insulated with three inches of corkboard. The lining is of porcelain and the cooling section is of cast aluminum having five trays with a capacity of fifty cubes of ice.

Fig. 168 shows the machine mounted on the side of the cabinet. The water control valve is mounted on an outlet water line. The purpose of the water control is to throttle

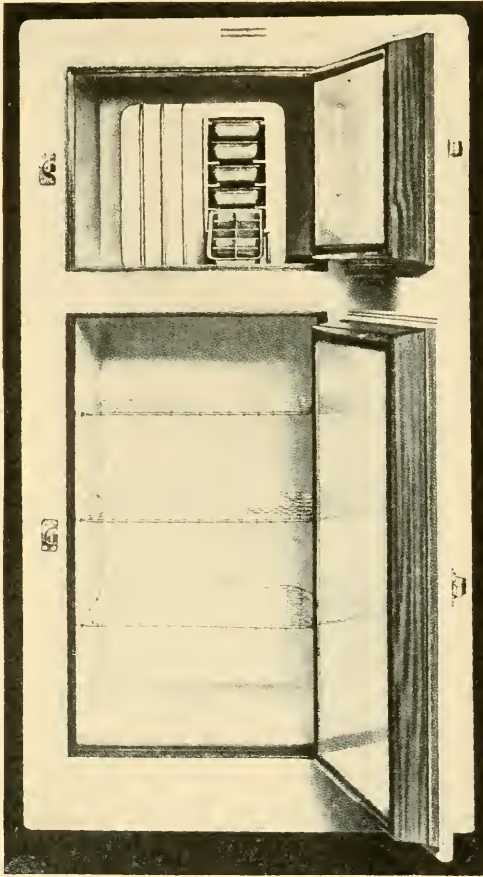


FIG. 167.—SHOWING COOLING UNIT AND FOOD COMPARTMENT SPACE.

the water used in the condenser so as to maintain a constant outlet temperature under all conditions of inlet temperature and pressure. The gas thermostat automatically regulates the supply of gas responsive to the temperature of the food compartment.

A safety gas burner is used so that the gas supply is automatically shut off if for any reason the gas flame is extinguished.

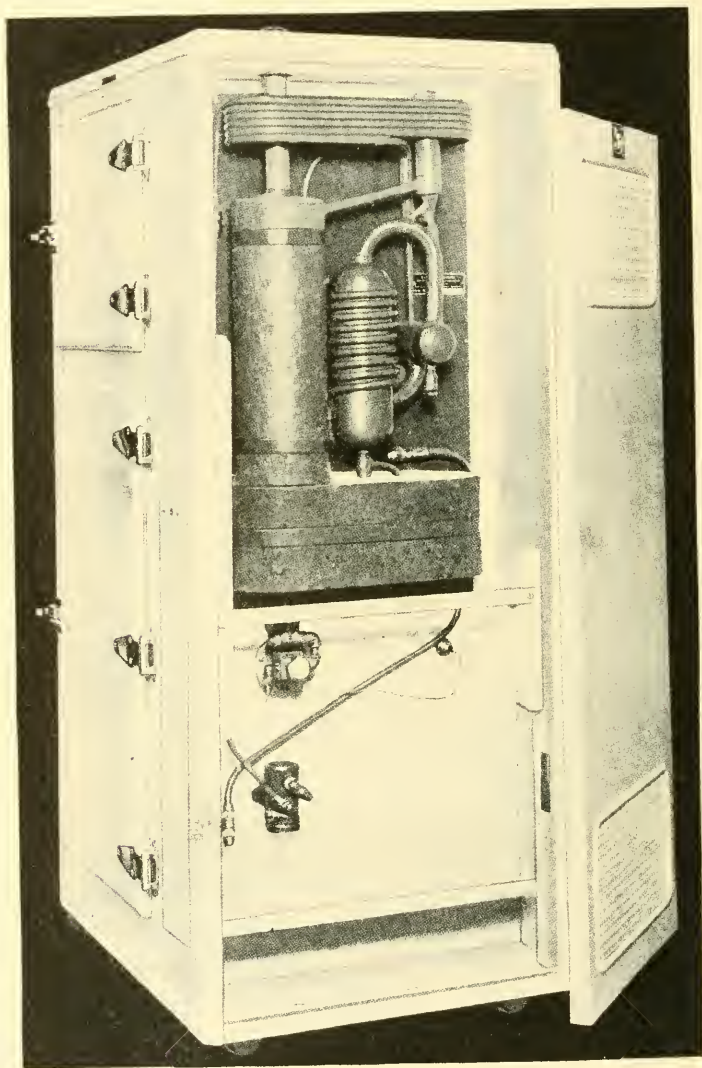


FIG. 168.—SHOWING ELECTROLUX SERVEL MACHINE MOUNTED ON SIDE OF CABINET.

Sorco Gas Absorption Refrigerator.—The new Sorco Gas Absorption Refrigerator (Figs. 169 and 170) which is manufactured by the Gas Refrigeration Corporation, with sales office at 18 East 41st Street, New York City, has a great num-

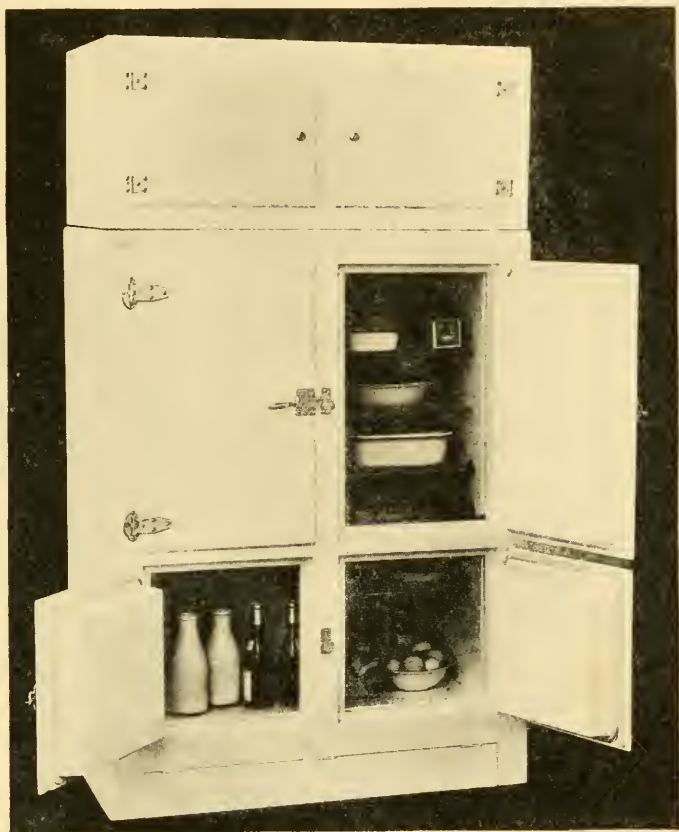


FIG. 169.—SORCO GAS ABSORPTION REFRIGERATOR.

ber of new features not shown in their old construction described heretofore.

The boiler absorber contains a solution of ammonia and water. As cold water attracts and absorbs or dissolves ammonia, the rate at which it does so and the amount it absorbs depend on the temperature of the absorbent. On the other

hand, hot water repels ammonia in the form of a gas. Hence during the heating period, ammonia is liberated from the boiler, liquefied in the condenser and fills the evaporator. During the refrigerating or absorbing period of the cycle which

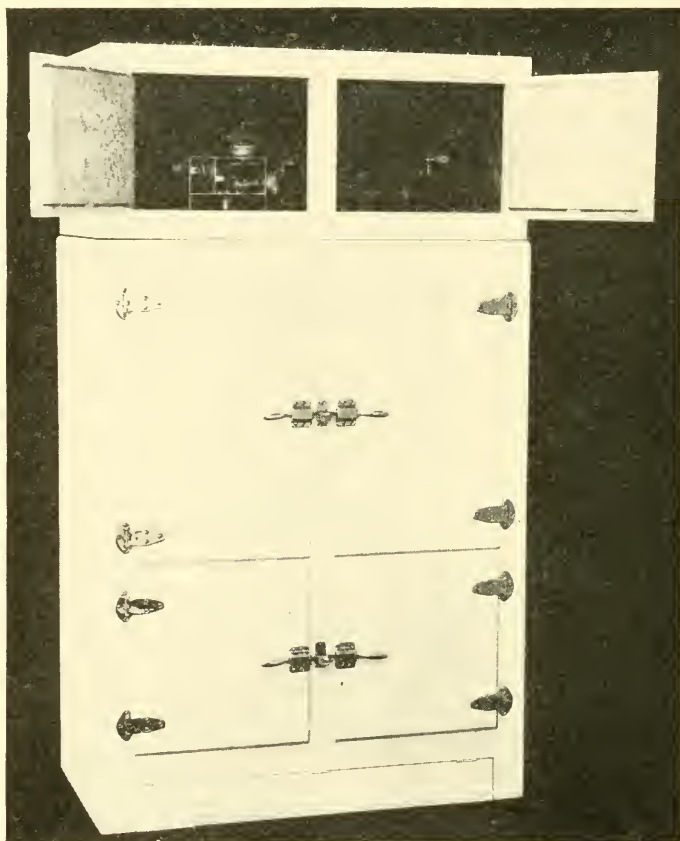


FIG. 170.—SORCO GAS ABSORPTION UNIT INSTALLED IN REFRIGERATOR.

may last from eight (8) to seventeen (17) hours, according to the required amount of cold, the liquid anhydrous ammonia gasifies from the evaporator and returns to the boiler absorber where it is reabsorbed by the weak liquor. The heat absorbed by the evaporating ammonia as well as the heat of association generated by the absorption of the ammonia gas in the weak

liquor in the boiler absorber are carried off by the cooling water.

The patented construction and design of the Sorco Boiler Absorber are extremely simple as it contains no moving parts such as valves of any kind, floats, by-passes, packing or stuffing boxes or anything that can possibly get out of order. In all intermittent absorption machines ammonia gas must be expelled from the top of the liquid level and re-absorbed underneath the surface of the liquid. We accomplish this by an application of gas heat to the boiler as well as the absorber, at which time an over pressure is created in the absorber during the boiling period which keeps the aqua ammonia floating in the boiler compartment until a predetermined maximum is reached in the boiler when the required amount of ammonia gas is expelled to the condenser.

Shortly after the beginning of the absorption period the remaining weak liquor in the boiler flows back to the absorber to a lower pressure created by the cooling water flow which is diverted through the absorber at the same time the heat is turned off.

A number of novel patented features are embodied in the Evaporator construction. As shown in the diagram attached, there is no moveable part in the ammonia system which is hermetically sealed in steel vessels and seamless steel tubing welded to the tanks. As the same pressure exists during the boiling period in all parts of the evaporator a great part of the ammonia would condense in the cold evaporator which would warm it up so that the food compartments and the ice in the evaporator would melt. Condensation in the evaporator is reduced to a minimum in the construction shown. The first entering fluid ammonia fills above the coils. Condensation cannot take place in the coils as they never become empty. Condensation must then first take place in the evaporator in the reduced surface area inside the main upper vessel which quickly increases the temperature of this vessel at the beginning of the heating period. But as soon as the temperature of this main vessel reaches a certain temperature slightly above the cooling water temperature, condensation stops there automatically. This is due to the fact that only a small part of

the latent heat can escape through the air insulation between the main vessel and the housing of the evaporator. Condensation thereafter takes place only in the condenser. The evaporator housing remains unaffected by this heat which cannot circulate. The ice evaporator is able to make six (6) pounds of ice in form of 72 ice cubes, within the short time of two to three hours.

There is always a small amount of moisture in the distilled ammonia when it enters the evaporator during the heating period. This moisture not only has the tendency to increase the boiling point of the ammonia in the evaporator, thereby preventing the evaporator from reaching its minimum possible temperature, but it also would gradually accumulate in the evaporator because it does not evaporate back in the boiler absorber with the evaporating ammonia. The amount of moisture generally increases with increasing cooling water temperature and has to be removed automatically. The Sorco evaporator is equipped with a marvelously operating patented return suction tube cup which has no moveable part and is based on two functions. First, a continuously separating operation, and, second, a removing operation. The first one is performed by the ice tray supporting coils in combination with the vertical tube during the whole absorption period. The lower ends of these coils are over orifices in communication with the vertical tube, so that liquid circulation between the vertical tube and the two coils is avoided. At the start of the boiling period the remaining aqueous solution in the vertical tube and in the lower part of the coils is forced through an orifice into the sump at the bottom of the evaporator. Due to the drop in pressure shortly after the end of the boiling period a small predetermined amount of liquid in the tube cup is drawn back into the absorber. This takes place shortly after the end of each boiling period with an astonishing regularity and without returning an appreciable amount of ammonia.

The Sorco is now as formerly 100 per cent automatically operated. The attractive feature, however, is that electricity is no longer required to operate the control of the gas heated unit. The movement of the few parts in the patented control

is so simple and slight, that noise and wear are reduced to practically nil. The two thermostatic power elements, one in the boiler and one in the evaporator, control the water flow by a snap action in a simple and unique manner. The starting and stopping of the boiling period as well as three different water flows are accomplished: First, the water flow during the boiling period; second, a strong flow during the first part of the absorption period through the absorber to cool the machine down quickly, and third, a minimum amount of water flows during the most of the absorption period to extract the heats of evaporation and association.

The advantages of this non-electric control are manifold. First, it regulates the length of the cycle automatically according to the required amount of cold. Second, it is completely foolproof—if for example the power element in the evaporator should not operate due to an overload in the evaporator, the control of the machine would automatically be operated by the thermostat in the boiler. The length of the absorption period would be determined by the rate of radiation from the boiler. This condition would last as long as there is an overload in the evaporator and thereafter the evaporator thermostat would automatically start its normal operation again. Third, it is selfstarting, that is, it does not matter during which operating condition the machine was shut off as it shifts automatically to the proper starting position. Fourth, the elimination of the necessity for any electric connections in the machine, or the elimination of the possible failure of the electric current. Fifth, the elimination of the possible failure of the many intricate electrical parts such as wiring, contacts, switches, pilot wires, etc., all of which also require an electrical knowledge in the servicing.

There is a safety pilot light which automatically lights the gas whenever it is turned on. Unburned gas cannot escape, due to the automatic gas shut-off of the safety pilot; if for instance, the pilot light should go out. The gas burner cannot be lighted unless cooling water flows through the system. As long as the cooling water flows through the system it is impossible to attain abnormal or dangerous pressures in the system, and in order to comply with the Safety Code there

is a rupture device which would exhaust the refrigerant with the cooling water in closed pipes at a safe pressure below the bursting pressure of the weakest part of the system, which bursting pressure is more than twelve times the maximum normal working pressure. The normal working pressure during the refrigeration period range from 10 to 35 pounds gauge. The maximum normal working pressures during the heating periods are from 125 to 175 pounds per square inch, all of which vary according to room and cooling water temperatures.

The machine can be manufactured in all sizes. One size is on the market which has an ice making capacity of about 23 pounds per cycle. The maximum capacity is therefore about 92 pounds in 4 cycles per 24 hours.

The Sorco machine automatically defrosts the evaporator each cycle. The box temperature increases 5 to 6 degrees Fahrenheit during the boiling period.

The Sorco needs little servicing as it contains no movable parts beside the control and every machine, even when it is continuously operating, must have a control unless it is not fully automatic.

The average operating cost of the Sorco refrigerator is 11 cents per day, on one dollar gas and water at one dollar per thousand cubic feet. The third of this cost is for water and two-thirds for gas.

The Sorco Model E consumes from 40 to 80 cubic feet of gas per day according to conditions and the required refrigerating effect. The average water consumption is under 200 gallons per day.

CHAPTER IX

TYPES AND CONSTRUCTION OF HOUSEHOLD REFRIGERATORS

Household Refrigerators.—The following pertains to the description of the general type and a detailed description of some of the leading household refrigerators on the market at present. The different makes of household refrigerators which are described have been selected promiscuously, and do not include all of the makes which are produced at present. However, the description of the following makes will convey an idea of the general types, as well as the various details of construction used in some of the leading makes at present. Special attention is given to wall construction, linings, outer case construction, construction of doors, etc.

Bohn.—In Fig. 171 is shown a typical refrigerator made by the Bohn Refrigerator Company of St. Paul, Minnesota, for electrical refrigeration.

The exterior is of white porcelain on steel. The lining also is made of porcelain. The walls and doors contain eleven insulating members, including two thicknesses of flaxlinum. The insulation is framed in with heavy members, insuring permanency of position and long life. It is so constructed as to present a complete refrigerator before the outer steel, porcelain case is installed. The porcelain steel case is added to beautify its appearance and as an added protection to the inner walls. The walls are $3\frac{1}{2}$ inches thick and the doors $3\frac{1}{4}$ inches.

Doors are built on the safe door principle, with several rabbets to hold back the air leakage and in addition are furnished with cushion gaskets.

All hardware is solid brass, nickeled in the company's plant. Corners are trimmed with solid brass tubing, heavily

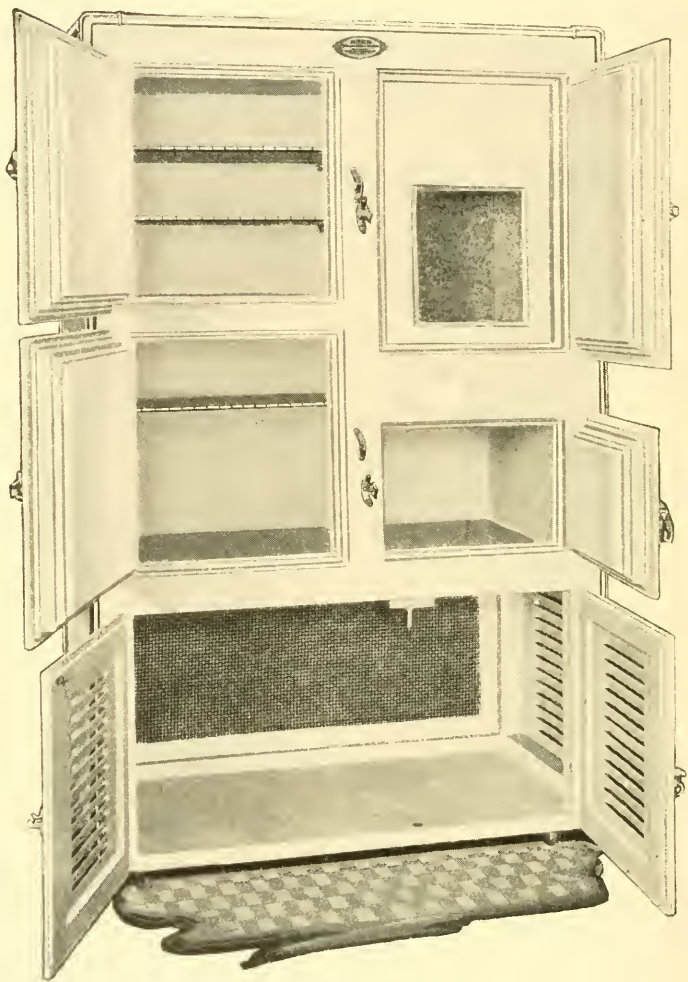


FIG. 171.—TYPICAL BOHN REFRIGERATOR.

nickeled. Underneath this trim are white wood mouldings, which seal the porcelain plates together—an additional moisture proofing.

The food chamber lining is one-piece heavy steel, porcelainized, with full rounded corners and rolled door edges. All porcelain steel, inside and outside, has one ground coat on both sides of the sheet and then two additional coats of white, each coat fused on separately, in its own plant, in ovens carrying two thousand degrees of heat.

The cooling chamber is lined with the highest quality galvanized steel with a copper alloy base.

The drain pipe is solid brass, with a spun copper funnel top and solid brass base, all heavily nicked. The drain trap is double—a large opening if ice should be used, and an auxiliary, removable, smaller trap within the larger trap, for defrosting drainage. Defrosting drainage should be carried away from the inside of the refrigerator and never be left in a pan inside the refrigerator because of the high content of bacteria and food decay in the melted frost. The provision shelves are meshed wire, heavily tinned.

There are proper circulation principles, inbuilt, leading the air in a complete circulating course throughout every part of the provision and cooling chambers.

Equipment includes a porcelain shield for cooling chamber door opening. Stud bolts in ceiling of cooling compartment with basket hanger, where necessary, and a sleeved hole in back; complete equipment for installation of cooling unit.

A full line of household refrigerators, with or without sub-bases, is manufactured.

The porcelain base may be used to house the refrigerating machine. When the machine is not placed in the base, the base can be used for the storage of water bottles, kitchen ware or canned goods.

Cavalier.—Fig. 172 shows the construction of a refrigerator made by the Tennessee Furniture Corporation, Richmond, Indiana. This view has the walls cut away to show steel frame construction. A structural frame of angle iron is used. The joints are electrically and acetylene welded.

There is an exterior case of porcelain enameled steel sheets, backed up by wall board and bolted to the steel frame. Next is a $\frac{3}{4}$ -inch air space, and $1\frac{1}{2}$ inches of corkboard. The interior porcelain lining is encased in an airtight envelope of

insulation. The corkboard walls are entirely covered with a special preparation. Seal Tight, which is waterproof, closes all air-cells, and prevents deterioration.

A removable plate at the back of the ice chamber is for the convenience of those who wish to install an electric refrigerating unit.

Doors are made with a heavy wood case, to which the cork insulated door pans and wood moulding are firmly fastened.

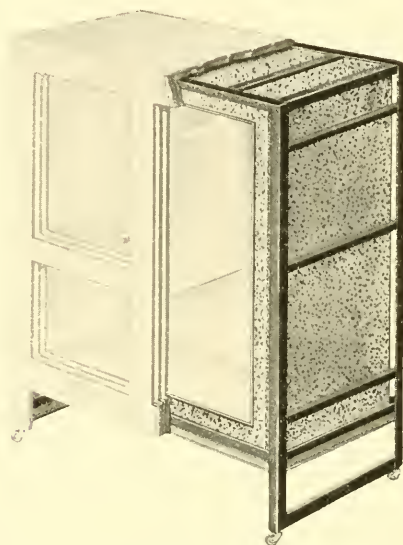


FIG. 172.—CAVALIER REFRIGERATOR, SHOWING CONSTRUCTION.

The door surface is covered with a metal case held firmly in place by flanges folded over the edge of the wood core. All doors are of the heavy, overlap type and are fitted with "Wirfs" insulating gaskets to prevent air leakage and to give cushion action at the door jamb.

Fig. 173 shows one of the white porcelain lining and exterior models. These refrigerators are so constructed that an electrical refrigerating unit may easily be installed.

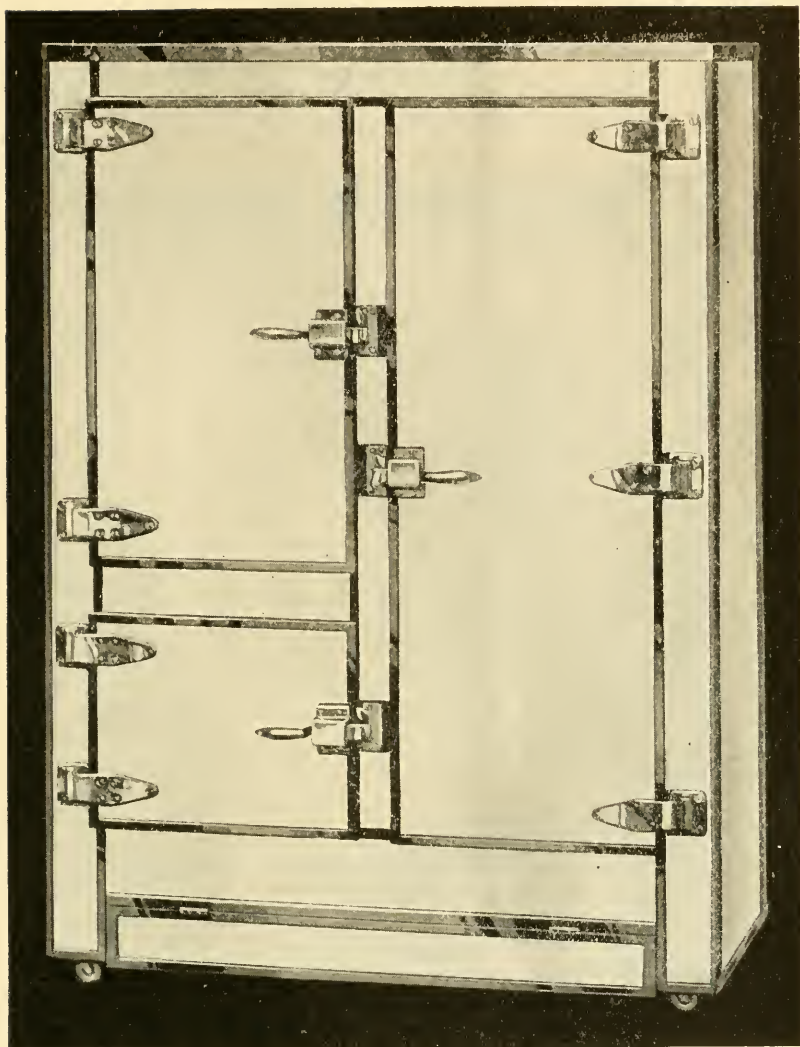


FIG. 173.—CAVALIER REFRIGERATOR, WHITE PORCELAIN EXTERIOR.

Crystal Refrigerator.—Fig. 174 shows an all-metal refrigerator made by the Crystal Refrigerator Company, Fremont, Neb.

Some new and interesting features of construction are incorporated in the design of this cabinet.

The walls both outside and inside are made of one-piece, galvanized sheet metal with a hard, baked white enamel finish. Porcelain linings can also be supplied.

The walls are insulated with from 2 to 5 inches of pure

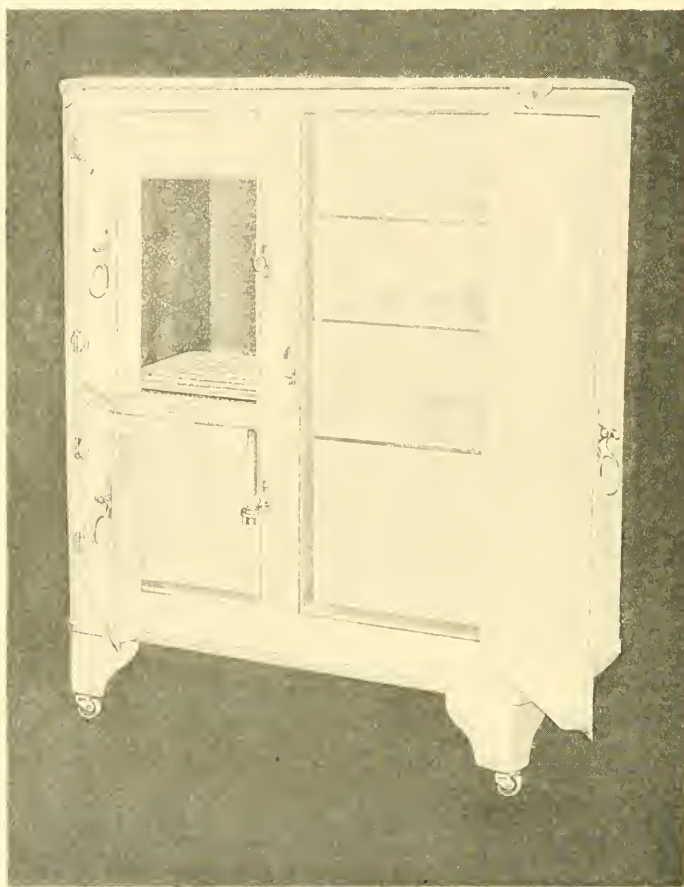


FIG. 174.—CRYSTAL REFRIGERATOR

granulated cork. A wooden frame is used to strengthen the walls and to support the door latches and hinges.

Aluminum moldings and corner pieces at the top and an aluminum band at the bottom add to the appearance and protect the enamel.

Solid glass shelves are used. The ends of the shelves are square while the ends of the cabinet are oval, thus forming a passageway for the air circulation. Part of the air goes across the shelves and the balance to the bottom of the food compartment.

The doors are constructed of metal. The ice chest, shelves, and all inside parts can be easily removed for cleaning.

The trap is aluminum and located inside the refrigerator.



FIG. 175.—CRYSTAL STEEL REFRIGERATOR

Both apartment and side icer cabinets are built in ice capacities from 50 to 250 lbs. Cubical contents range from 3.6 cu. ft. to 20.2 cu. ft.

"White-Steel" Refrigerator, Fig. 175, shows an all-steel refrigerator of the square type by the Crystal Refrigerator Company, Fremont, Neb.

The walls are constructed the same as the Crystal but are not so heavy. They are insulated with $1\frac{1}{2}$ in. to $3\frac{1}{2}$ in. of pure granulated cork.

Wire shelves are used.

The doors are constructed of metal. The ice chest, shelves and all inside parts can be easily removed for cleaning.

The trap is aluminum and located inside the refrigerator.

Made in apartment and side icing styles in ice capacities from 50 to 150 lbs. Cubical contents range from 4.2 cu. ft. to 9.6 cu. ft.

Jewett Refrigerator.—The Jewett Refrigerator Company of Buffalo, N. Y., has been building refrigerators since 1849. Fig. 176 shows a typical Jewett side icer cabinet.

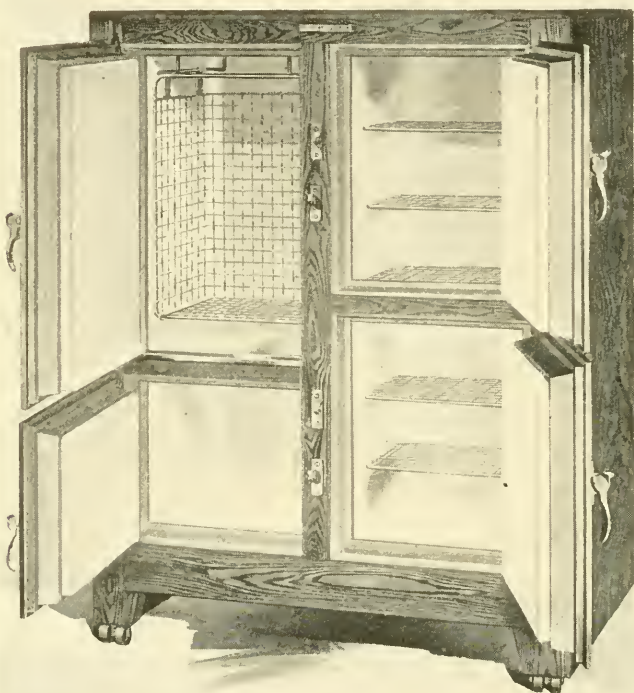


FIG. 176.—JEWETT REFRIGERATOR.

The lining is of solid porcelain $1\frac{1}{4}$ in. thick. This lining is of earthenware which is fused at 2500° F. The ice compartment is lined with the same material. A modern pottery is used to make these linings and they form an ideal interior surface for a refrigerator. This lining has some heat insulating value and has a certain heat capacity which acts as a

stabilizer of temperatures in the food compartment. The amount of ice in the refrigerator may vary considerably without appreciable effect on the temperature of the food compartment. The doors are lined with white opal glass. The flues are formed in the porcelain linings and are of generous size insuring good circulation.

The drain, shelf supports, flues, and ice compartment floor are all cleverly molded into the lining, affording a simplicity

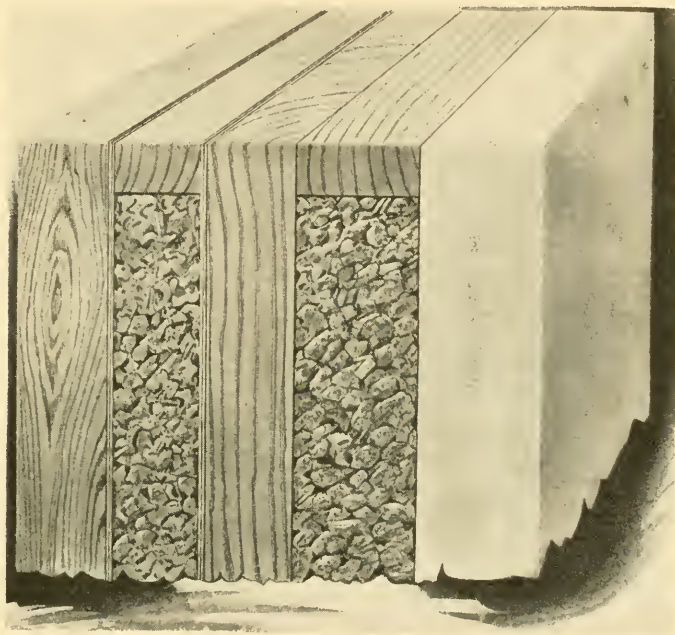


FIG. 177.—JEWETT REFRIGERATOR WALL SECTION.

of design which greatly adds to the appearance of the interior of the cabinet.

The insulation is shown in Fig. 177. The total thickness of this wall is $5\frac{3}{8}$ in. The interior case is of solid ash, doweled and glued; next comes two layers of waterproof insulating paper, then 1 inch of pure sheet cork, two more courses of heavy waterproof insulating paper, a course of $\frac{7}{8}$ in. tongued and grooved lumber, $1\frac{1}{4}$ in. of pure cork, one course of insulating paper and then $1\frac{1}{4}$ in. of solid porcelain lining. This

construction insures a wall of low heat conductivity, and a wall which will not be damaged by very low food compartment temperatures.

The ice is supported in a heavy mesh container, which is held by rods bolted firmly to the ceiling. This container is easily removed for cleaning.



FIG. 178.—JEWETT REFRIGERATOR.

The door construction is very rigid. The design includes a door of good appearance which will close tightly and not warp out of shape under severe humidity conditions. Cabinets are constructed with holes through the lining so as to accommodate mechanical refrigerating units.

Another line of refrigerators, Fig. 178, is made having a lining of one piece seamless steel coated with white vitreous enamel baked on at high temperature. The corners are rounded.

The insulation is 3 in. of pure sheet cork bonded to the lining with moisture-proof hydrolene. This prevents any dead air spaces between the lining and corkboard.

The exterior may be obtained in natural ash or white

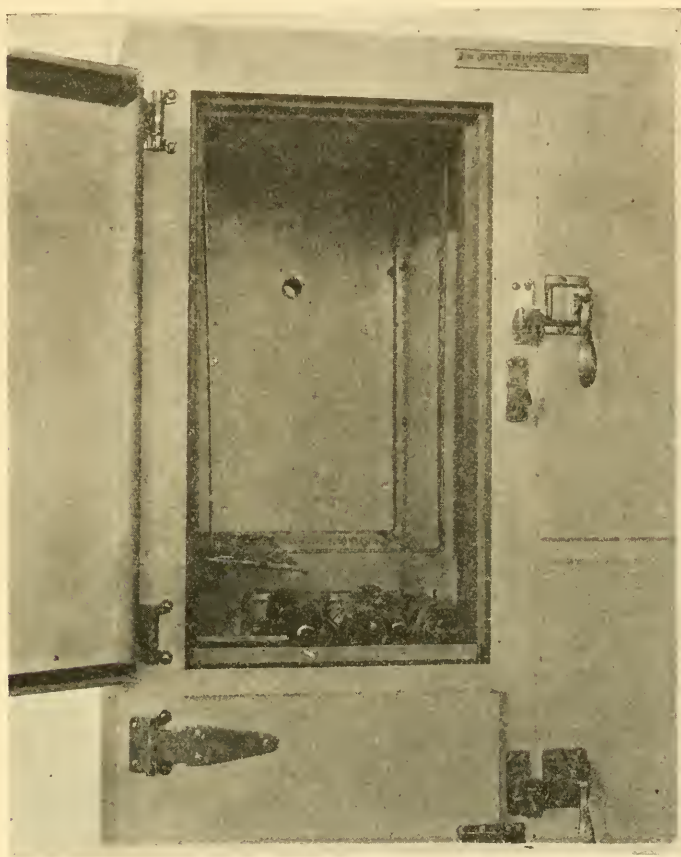


FIG. 179.—SHOWING SPECIAL COMPARTMENT JEWETT REFRIGERATOR.

enamel finish. The partition around the ice compartment is easily removable. The shelves are made of heavy woven wire coated with pure block tin.

A special utility space, Fig. 179, is located directly under the ice compartment to be used for cooling bottles, storing extra ice cubes, or chilling fruit or vegetables.

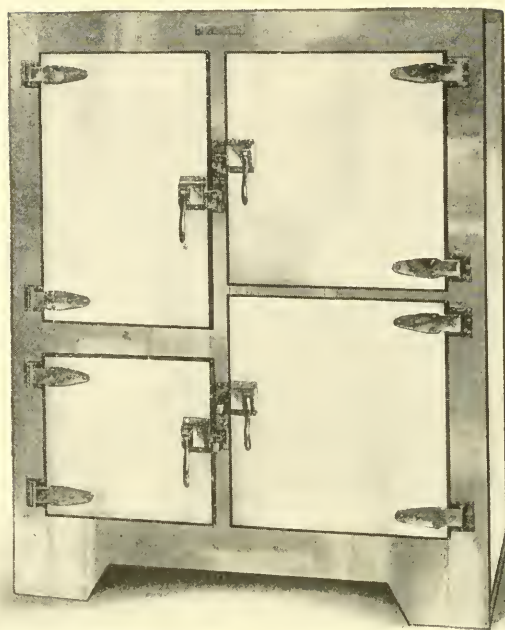


FIG. 180.—JEWETT REFRIGERATOR WITH MONEL METAL EXTERIOR.

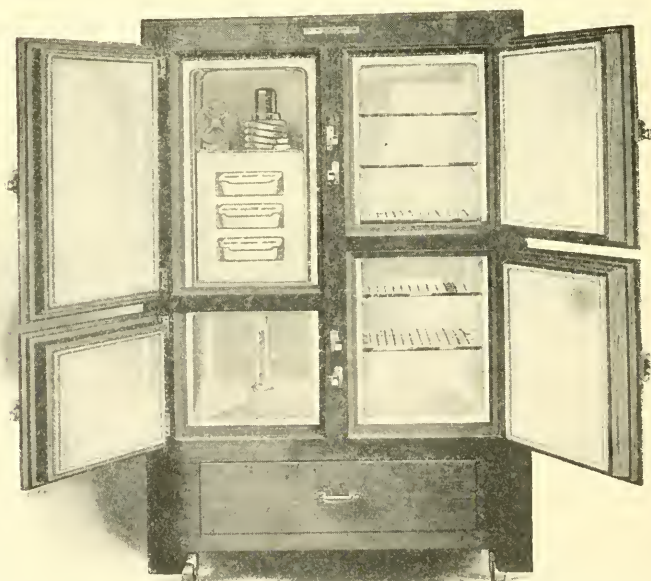


FIG. 181.—JEWETT REFRIGERATOR, NATURAL COLOR EXTERIOR FINISH.

Another line of refrigerators, Fig. 180, is made. This model has a porcelain enamel and monel metal exterior. The lining is of solid porcelain.

Two other standard exterior finishes are furnished. Natural color, brown ash, Fig. 181, with three coats of varnish, satin finish. The hardware is of solid cast brass. The other standard exterior finish is five coats of white enamel, with nickel hardware.

Cabinets are made in side and top icer types with ice capacities from 75 to 240 lbs. The Jewett Company also makes a specialty of building cabinets to order.

Leonard Refrigerator.—Fig. 182 shows a typical refrigerator as built by the Grand Rapids Refrigerator Company, Grand Rapids, Michigan.

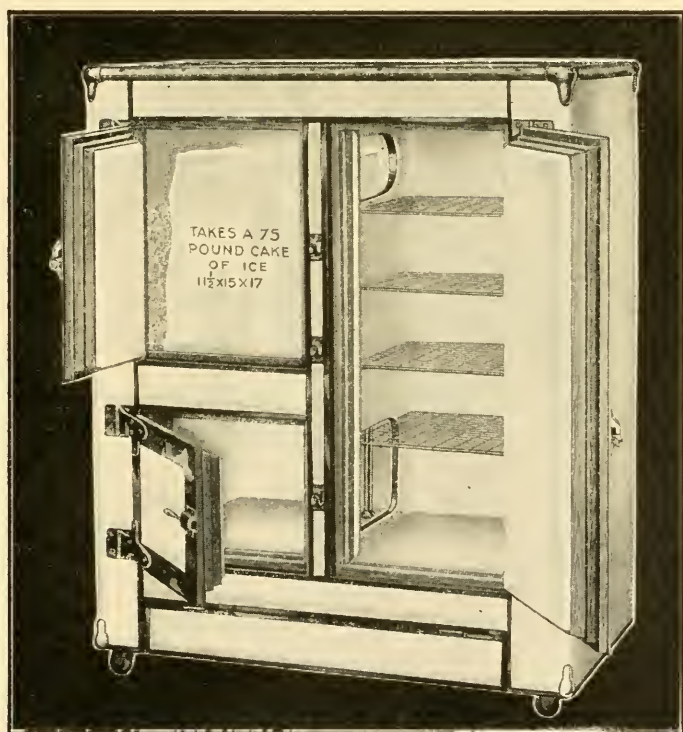


FIG. 182.—LEONARD REFRIGERATOR.

The Leonard refrigerator has been built for over 43 years and represents the latest cabinet construction for large quantity production.

The exterior case on the different models is made of porcelain on steel, white enamel on steel, 5-ply laminated wood or quarter-sawed oak.

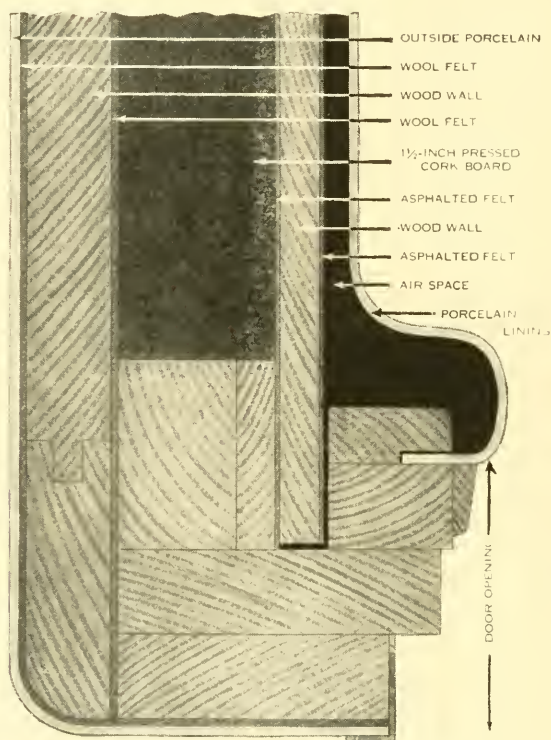


FIG. 183.—SECTION OF LEONARD REFRIGERATOR WALL.

The better grade of cabinets have corkboard insulation. A typical wall construction is shown in detail in Fig. 183.

One-piece porcelain linings are used. These linings are made of Armco ingot iron. The sheets of iron are first cut, punched, and welded, forming one piece of steel, thus producing a lining with a smooth, hard surface which eliminates cracks and sharp corners. They are next immersed in acid

to remove all grease or dirt, through other cleaning processes and then thoroughly dried. The steel linings are then dipped in a dark-blue porcelain composition which is fused on to the steel at a temperature of about 1800° F. Two coats of white

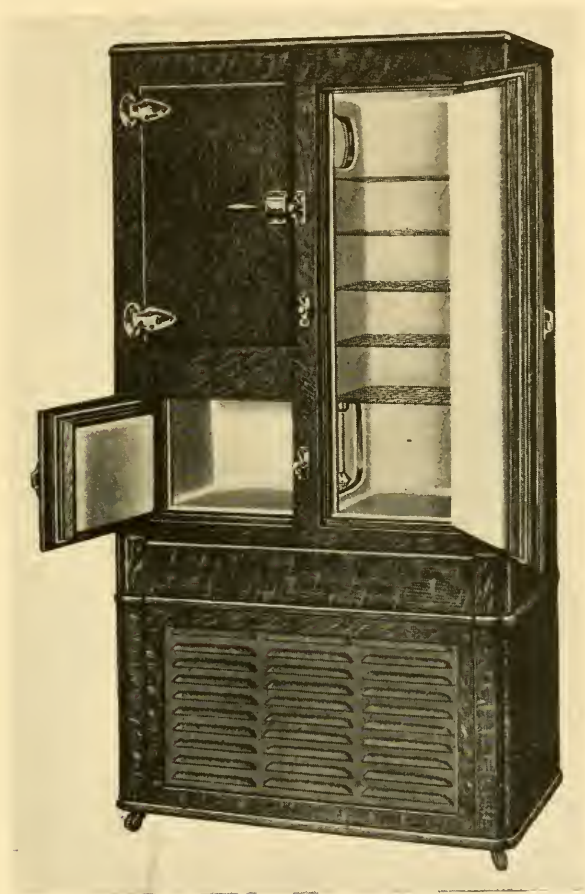


FIG. 184.—LEONARD OAK REFRIGERATOR WITH DETACHABLE BASE FOR ELECTRICAL REFRIGERATING UNIT.

porcelain are then applied and baked on in a similar way. This forms a white surface which is impervious to rust and disintegration.

The cold-air flue construction between the bottom of the ice chamber and the top of the small porcelain provision

chamber is such as to allow for a free circulation of air into and through the provision chambers, there being a circular opening in the porcelain lining.

Many different types and sizes of refrigerators are made with ice capacities from 20 to 495 pounds.

Fig. 184 shows an oak cabinet with a special detachable base for electrical refrigerating machines. In this refrigerator the necessary bolts and perforations have been inserted to make it convenient to install the cooling unit in the ice chamber.

This cabinet is made in all-porcelain, oak-porcelain, ash-porcelain and steel-klad lines. Openings are provided for ventilation.

Many other different types and sizes of refrigerators are made with ice capacities for 20 to 495 pounds.

McCray Refrigerator.—The McCray refrigerator has been built at Kendallville, Indiana, for over thirty-five years. Fig. 185 shows one of the side-icer type McCray cabinets.

The standard exterior construction is quarter-sawed oak made of 5-ply laminated wood. The top and bottom of the refrigerators are so constructed that the plywood is not exposed to the outside.

The linings are made of one-piece porcelain enamel on steel. The inside of the doors is also covered with porcelain. Some of the larger refrigerators are made with both lining and exterior case constructed of $\frac{7}{16}$ -inch white opal glass. The floor is of hexagon vitreous tile laid in special cement.

The insulation consists of 2 inches of pure corkboard sealed with hydrolene cement. The wall section comprises:

1. Porcelain enamel lining.
2. Dead air space.
3. Inside wood lining.
4. Waterproof paper.
5. Two in. of corkboard sealed with hydrolene cement.
6. Waterproof paper.
7. Exterior case of 5-ply laminated wood.

Every model has studs in the ceiling of the ice compartment on which cooling units may be hung for electrical refrigeration.

A sub-base for any stock model may be supplied so that the electrical refrigerating unit may be installed under the refrigerator cabinet. This base is slatted to permit using an air-cooled refrigerating machine.

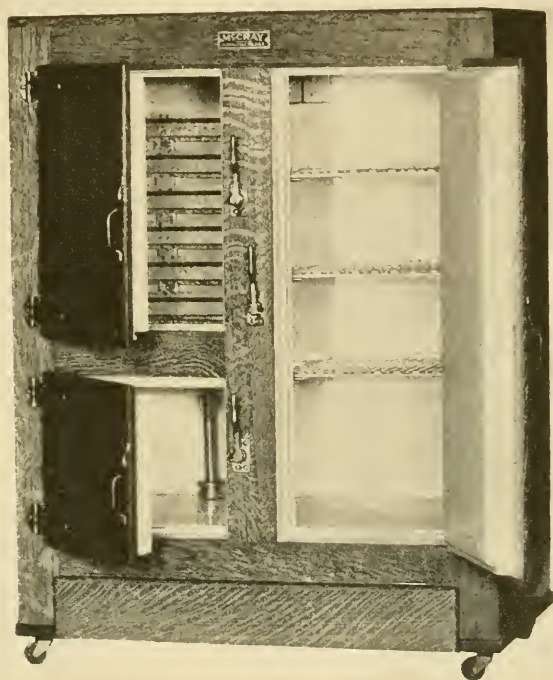


FIG. 185.—McCRA Y REFRIGERATOR.

Cabinets of various types with ice capacities from 60 to 840 pounds are made.

Fig. 186 shows one of the all-metal exterior refrigerators for electrical refrigeration.

The exterior of these all-metal refrigerators is covered with automobile steel. The joints of this steel are braced together making this exterior practically one piece. A pyroxyline lacquer white finish is applied making a beautiful white exterior. This is the same finish as used by high-grade automobile body manufacturers.

The doors are flush paneled. They have a $\frac{3}{4}$ -inch raise, and are provided with gaskets which make this refrigerator practically air tight. The hardware and hinges are of heavy

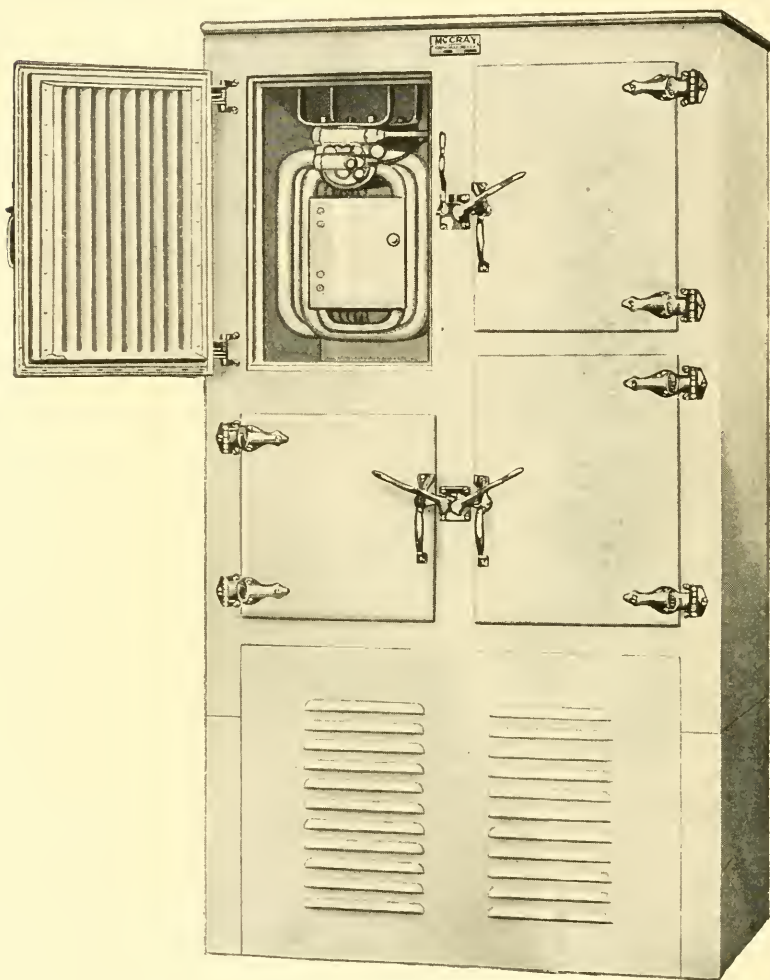


FIG. 186.—McCray ALL-METAL REFRIGERATOR FOR ELECTRICAL UNIT.

brass, nickel plated. Fasteners are of the self-closing type. All refrigerators are mounted on piano casters.

The interior of these all-metal exterior refrigerators is of the highest quality one-piece porcelain.

The insulation consists of 2 inches of pure corkboard, all joints being carefully sealed with hydrolene cement.

Reol Refrigerator.—The accompanying illustration shows the Reol, manufactured by the Reol Refrigerator Company of Baltimore, Md., in process of construction. The section in

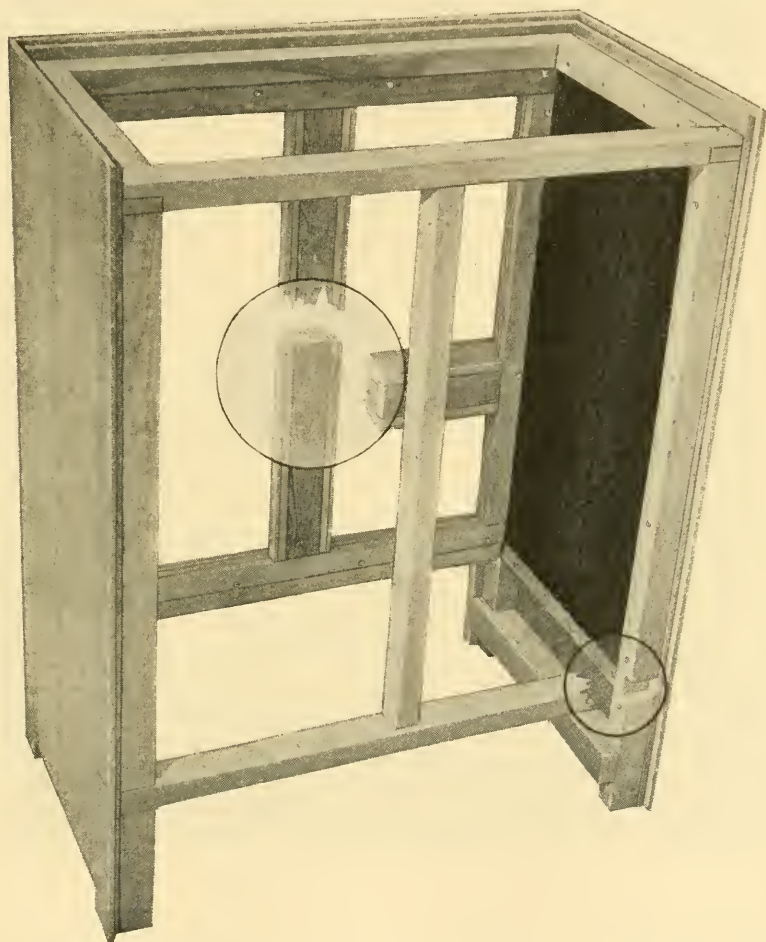


FIG. 187.—THE REOL REFRIGERATOR IN PROCESS OF CONSTRUCTION.

the small ring shows the mortised and tenoned method of joining the framework. A view of the finished refrigerator is also shown.

The framework of the Reol Refrigerator is very strong, very rigid, and very durable. It is made with ash, corner posts in one continuous piece from top to bottom. The lower ends of the corner posts extend about 8 inches below the floor



FIG. 188.—REOL REFRIGERATOR.

of the refrigerator, to form a sanitary base. The framework of the Reol is mortised and tenoned, glued, and fastened solidly together to form a rigid foundation on which to build up the completed refrigerator.

The exterior finish is of solid oak, free from knots and

imperfections, with the long boards of the side panels held together with deep tongues and grooves. The oak is filled, stained, and rubbed down coat after coat, to a hard satin smoothness, beautiful and enduring.

The insulation in the Reol Refrigerator consists of pure corkboard 2 in. thick, securely fastened to the framing. The insulation is continuous over all of the refrigerator surfaces, and is broken only by the casings of the doors on the sixth surface. The corkboard is covered with a coat of protective water-proofing on both sides, to prevent any possibility of dampness getting into it either from the outside or the inside, thus eliminating decay or odors.

The food compartment is lined with vitreous porcelain which is extremely durable and sanitary. It does not chip unless exposed to hammer blows and it will last a lifetime if given just ordinary good care. Snow white, glassy, and free from all imperfections and discolorations.

The hardware used on the Reol is of solid brass, heavy and durable. It is handsome in appearance, and will give a real lifetime of service.

The doors of the Reol contain the same insulation as the sides of the box, and in the same amount. They are made specially air tight with a series of rabbets on the door, which fit into corresponding ledges in the door casings. As a further precaution, around the uttermost ledge is a gasket of rubber and compressible cotton wick. When the door is closed, the gasket compresses and keeps the warm air out.

Rhineland Refrigerator.—The refrigerator shown in Fig. 189 is manufactured by the Rhineland Refrigerator Company, Rhineland, Wisconsin.

The exterior is of white porcelain with trim strips of polished metal. Fig. 190 shows the interior of the same cabinet. Other models are made with hardwood exteriors in various finishes.

The lining is of the one-piece porcelain type. Cabinets are also made with white enamel linings. Corkboard is used to insulate the walls and doors.

HOUSEHOLD REFRIGERATION

Fig. 191 is one of the refrigerators designed for mechanical refrigeration units. This cabinet has a white porcelain interior lining with exterior case of steel, white lacquer finished. It is cork insulated. The equipment includes hanger bolts and pipe opening in the rear.

The different models include side and top icers, grocery and meat refrigerators of ice capacities from 50 to 575 pounds.

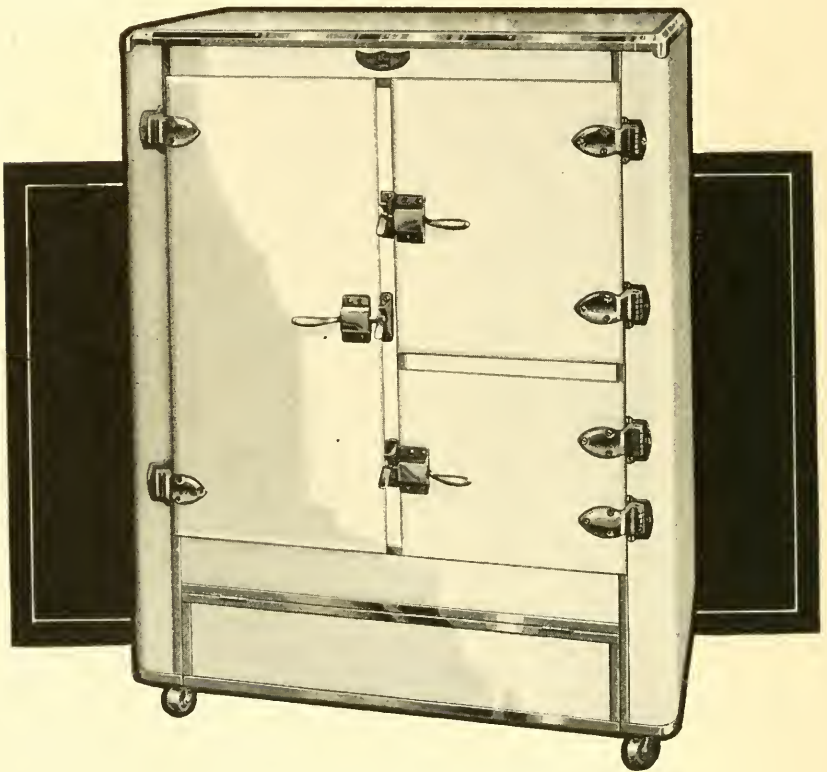


FIG. 189.—RHINELANDER REFRIGERATOR.

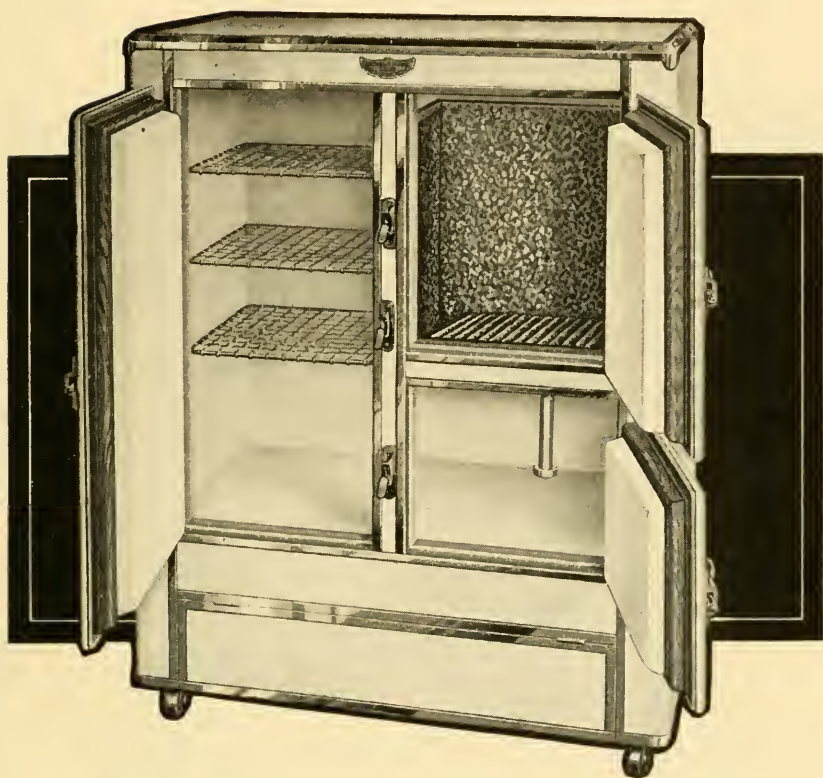


FIG. 190.- INTERIOR OF REFRIGERATOR SHOWN ON OPPOSITE PAGE.

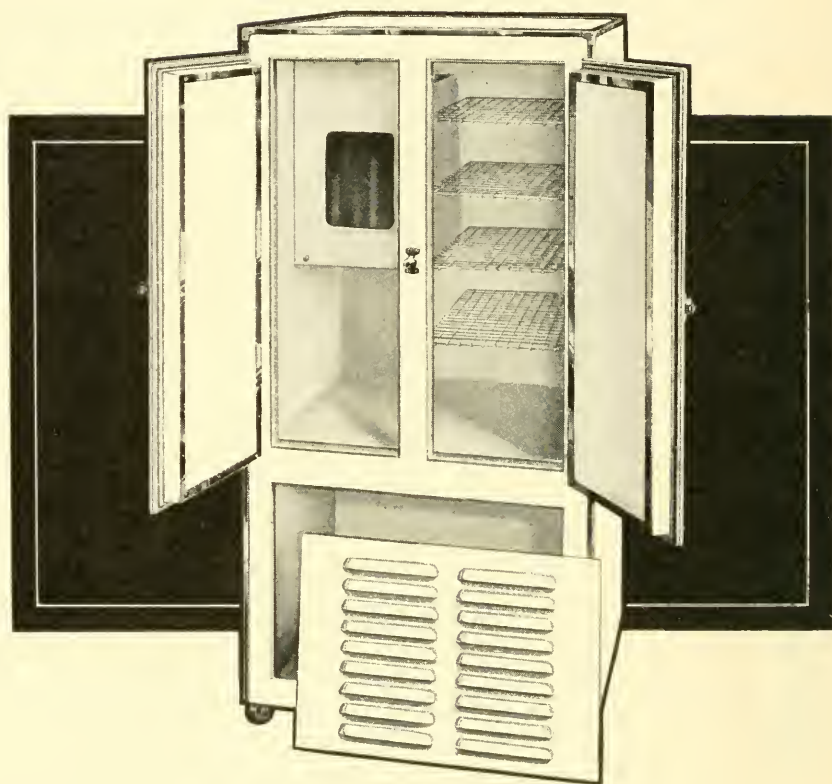


FIG. 191.--RHINELANDER REFRIGERATOR DESIGNED FOR MECHANICAL UNIT.

Seeger Refrigerator.—Fig. 192 shows a typical refrigerator made by the Seeger Refrigerator Company of Saint Paul, Minnesota, for electrical refrigeration.

The exterior and interior are of white porcelain on steel. They are equipped with porcelain defrosting pan and insu-

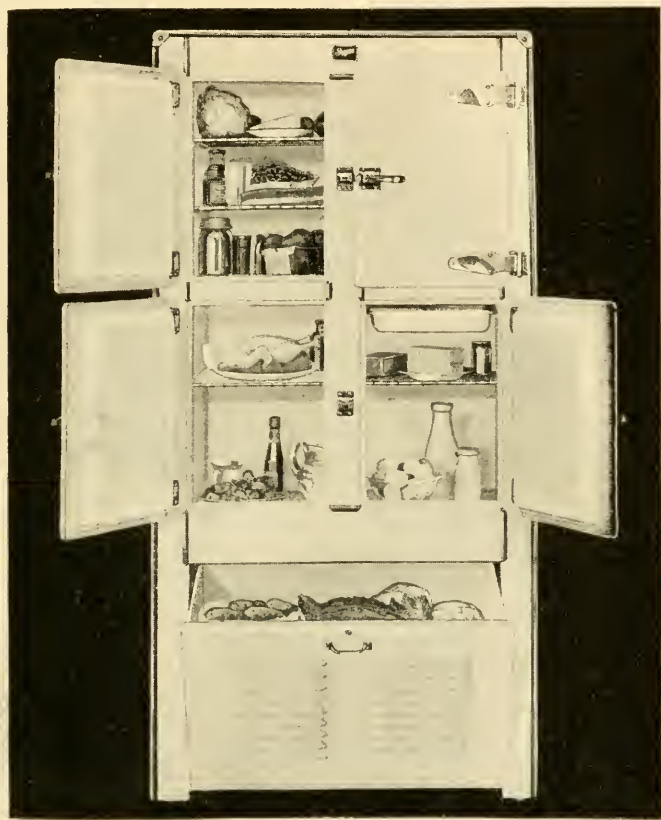


FIG. 192.—SEEGER REFRIGERATOR FOR MECHANICAL UNIT.

lated removable porcelain baffle wall. The insulating material used is corkboard.

Vegetable storage compartments can be supplied for all models. These are shipped as separate units complete with fittings. The vegetable storage compartment opens forward like a flour bin.

The insulation consists of waterproof insulating paper, heavy insulating board and pure sheet corkboard, hydrolene sealed, 2 inches or more in thickness.

White Frost.—Fig. 193 shows one of the White Frost refrigerators manufactured by the Home Products Corporation, Jackson, Michigan, who have been building them for twenty-five years.



FIG. 193.—WHITE FROST REFRIGERATOR.

It is built of special rust-resisting steel and insulated with pure granulated cork in sealed air space. Cork is introduced by a special method to prevent settling. The construction is all steel. The seams and joints are sealed to be permanently air and moistureproof.

This cabinet is round with revolving food shelves, making entire shelf area accessible for storage. Shelves and ice chamber lift out for cleaning.

Construction makes it easy to maintain correct refrigeration temperatures and secure efficient circulation of pure, cold, dry air to each part of the food chamber.

The illustration shows a water-cooler type. Two sizes are available of 100 and 50-pound ice capacity. Each size is furnished with or without water-cooling system. The cabinets are finished in lacquer or white or grey enamel.

Wall Construction.—Fig. 194 shows a refrigerator wall using mineral wool insulation and a metal lining. The air

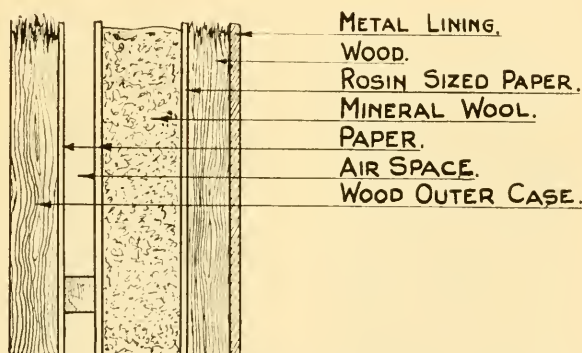


FIG. 194.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

space is placed well out from the inside lining. With usual service conditions, the air space in this position would be effective as a heat insulator.

Fig. 195 shows another wall using mineral wool and air spaces. The air spaces are placed near the inside lining. Water vapor in the dead air spaces would condense, collecting on the surface of the lining. This design is very poor from an insulation standpoint.

Fig. 196 shows a solid wall insulated with corkboard. The inside wooden frame strengthens the cabinet and prevents breaking the opal glass lining in shipment. The wooden frame

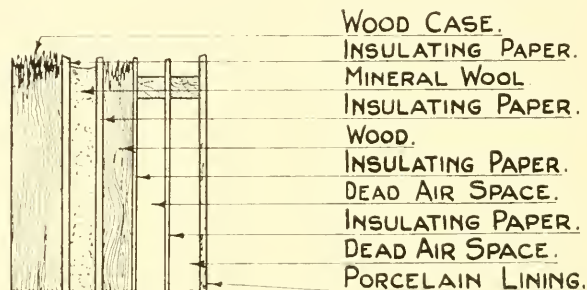


FIG. 195.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

also provides a place for the screws necessary to hold the lining in place. This construction is used on some of the best quality cabinets.

Fig. 197 shows a wall construction used for a cabinet with a composition lining. The lining must be well supported to

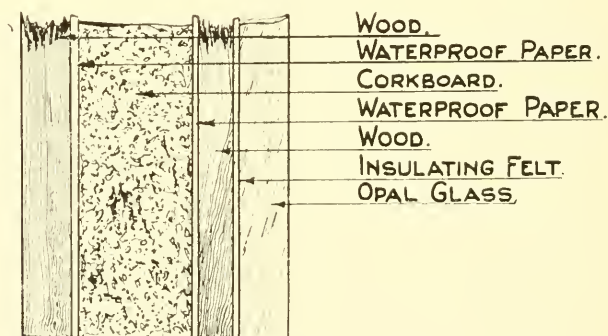


FIG. 196.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

prevent breakage in shipment. This type lining because of its large heat holding capacity, tends to keep the food compartment temperature uniform.

Fig. 198 shows a wall using fiber board insulation. This type cabinet is easily assembled at the expense of being poorly insulated. The dead air space near the lining would condense

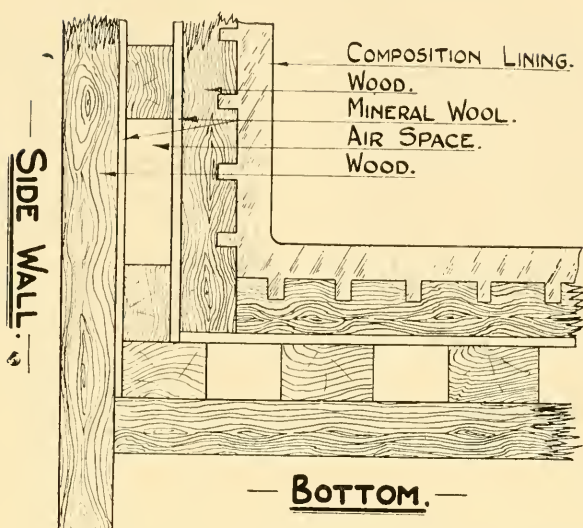


FIG. 197.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

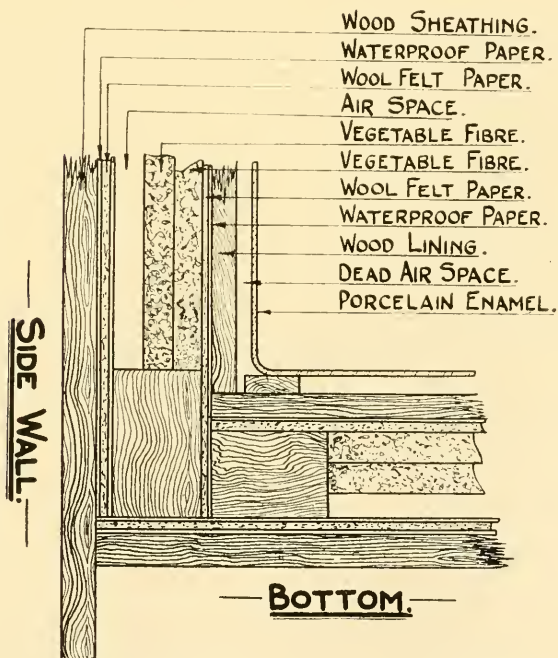


FIG. 198.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

water vapor which would, in time, wet the insulation, thus lowering its efficiency. The solid wooden corners produce large heat losses by conduction from the outside case to the lining.

Linings.—The lining is a very important part of the household refrigerator. It represents from 10 to 25 per cent of the total cost of the refrigerator.

The lining material should have a smooth, hard, and preferably white surface. The surface should be stain and acid-proof and must not chip, crack, discolor, peel or craze. The surface should be such that dirt or grease will not adhere to it. The material itself should be free from joints and cracks, non-porous and should not absorb moisture or odors. It is also desirable to have a material suitable for making rounded corners.

Following is a list of the different linings in common use in refrigerator construction:

- Baked white porcelain on sheet iron.
- Solid porcelain.
- Solid stone.
- White opal glass.
- Galvanized iron.
- Enamel on steel.
- Wood spruce, oak, pine.
- Ceramic tile (floor).
- Rust resisting metal.
- Cement.

Porcelain on Iron Lining.—The standard lining for refrigerators is porcelain on iron. The sheet iron for the base is carefully selected, otherwise blisters may result. The sheet is cut, punched, and formed. The necessary welding is performed. It is then treated with acid to remove all grease and dirt. Sometimes other "pickling" baths are used. The lining is then dipped into a bath of blue porcelain. This porcelain composition usually consists of feldspar, borax, china clay, and other chemicals, in accordance with carefully prepared and tested formulas.

These materials are fused or melted in a smelting furnace. The melted mass is drawn off into a tank partly filled with

water. When it comes in contact with the water, it is instantly cooled and broken into small pieces of porcelain grit. This is placed in a revolving mill and ground as fine as flour. When taken from the mill it is thinned to cream-like consistency, and then taken to the dipping room where it is poured into metal vats.

The steel linings are first dipped into dark blue liquid, both inside and outside being covered with this first coat. This blue coat renders the surface impervious to rust and disintegration.

After the linings are dipped they are placed in drying chambers of high temperature where they remain for several hours to remove the moisture. If the moisture is not removed, the coating would run off when the lining is placed in the furnace.

After drying, these linings are placed on compressed air machinery in front of the furnace. The operator, who is forced by the intense heat to stand some distance from the furnace, by means of compressed air levers, raises the furnace doors and sends the linings forward in the furnace, where the porcelain is melted and fused onto the steel at a temperature of about 2000° F.

Two more coats of white porcelain are usually applied to the interior of the lining, the second being dried and melted on as above described before the third is applied.

This type lining gives a very good surface which fulfills most of all the various requirements. The surfaces, however, are not flat, as the baking process causes the metal to expand and warp. Considerable difficulty is experienced by the porcelain cracking at corners and welded joints.

Solid Porcelain Linings.—Solid porcelain linings are used in some of the better grade refrigerators. They are very heavy and require a solidly constructed cabinet to prevent breaking the lining in shipment. Most of the refrigerators using solid porcelain linings have an extra frame work of wood to make a rigid construction necessary with this type of lining. The walls are more than one inch thick.

The manufacture of solid porcelain linings is an art to which modern machinery has given very little assistance. The

clay is very carefully selected and is molded by hand in a form. These are placed in drying rooms for weeks where the temperature is gradually increased. The enamel is then applied with a brush; many coats are required with a period for drying between each coat, then several coats of glaze are applied. The linings are placed in the kiln and each one must be completely enclosed with fire brick. The baking lasts for about one week and a temperature of 2500° F. is reached. This entire process requires several months, so that this type lining is expensive to make, and is not well suited to quantity production.

The solid porcelain lining has a rather large heat storage capacity and the temperature in the food compartment will not change quickly with an increase or decrease in the amount of ice. These linings have an irregular surface on the insulation side so that it is necessary to apply a loose insulating material to fill up these irregularities.

White Opal Glass.—White opal glass lining has extensive use in refrigerators. The usual construction is to use the white opal glass lining on the sides, ceiling and doors. It is not suitable for the floor. Vitreous tile is usually used for lining the floors as it stands the rather severe service much better. Opal glass in common use is $\frac{7}{16}$ inch or $\frac{5}{16}$ inch thick. This type of lining presents a flat surface on both sides and this lessens insulation troubles. The corners and joints are usually covered with strips of metal. Other manufacturers use cement and in some cases wooden strips are used to cover the joints. White opal glass is used to line the doors in cabinets having solid porcelain linings.

Galvanized Iron.—Galvanized iron is not used to any great extent for linings except on a few of the cheaper boxes. It has been found that this material does not resist corrosion and rust as well as the other linings. Some manufacturers use galvanized iron for lining the ice compartments; however, it is losing favor even for this service.

Wood Linings.—Wood linings are being used more extensively even on some high-grade cabinets. An odorless

wood is used. The surface keeps dry. The wood lining must be carefully made to avoid crevices between the boards. Some manufacturers use a white enamel paint over the wood, while others use varnish.

General Considerations.—The one-piece porcelain or steel lining is gradually losing favor with the refrigerator manufacturers. This is probably due to the difficulty of making and handling these linings. When the porcelain coating cracks or chips at corners it cannot be repaired satisfactorily.

An additional disadvantage is experienced in assembling cabinets with the single-piece lining. The insulation and outer walls of the cabinet must be built around the lining.

Sheet porcelain is now being used extensively for lining cabinets. Metal strips are used to hold the sheets in place and to seal around the corners. With this method of construction, it is possible to make the various cabinet walls on benches in quantities. The final assembly of the cabinet is then a simple process, requiring very little labor. This method of construction is preferable for quantity production.

Outer Case Construction.—The outer wall of most refrigerators is of wood. The best wood for this purpose is ash. Oak, fir, spruce, and pine are also used to some extent.

Most manufacturers use a panel wood construction for the outer case. These panels have a clearance at the edges great enough to allow for expansion and contraction, due to temperature and humidity changes. A careful study of these panels in service will show that they actually expand or contract, frequently breaking the paint or finish around the edge of the panel.

Some advantages of panel construction are :

1. Constructed of short pieces of light boards reducing waste lumber.
2. Less weight.
3. Heavy wall at corners where it is needed for structural strength.
4. Panels properly proportioned give an attractive appearance.
5. Reduces warping troubles.

Some of the more expensive cabinets use a veneer panel which it is claimed eliminates warping. Metal outer cases are used, such as porcelain enamel on steel, baked white enamel on steel, sheet steel zinc plated with a white baked enamel surface, white opal glass and monel metal.

Some troubles are experienced with the metal boxes in joining the lining with the outer case at the doors. There is usually a large heat loss here, and trouble with the moisture collecting on the outer metal case around the doors. Sheet steel is being used extensively for the outer case, the usual finish is white duco enamel.

Doors.—The door construction is a very important part of refrigerator design. The frame for the door and the door opening is usually of wood several inches thick. This double wooden frame has a poor heat insulating property, which is less than half that of corkboard. Figs. 199, 200, 201, and 202 show methods of refrigerator door construction in common use.

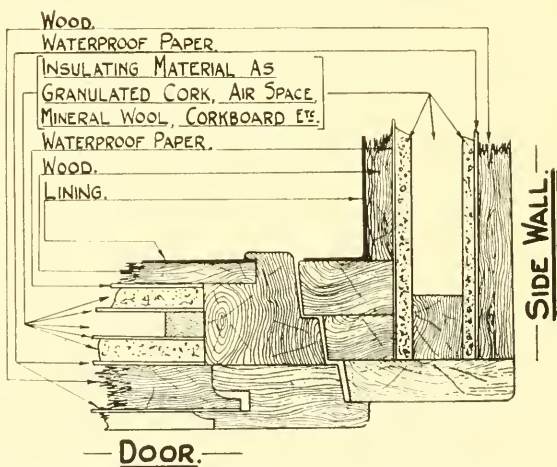


FIG. 199.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION

The insulation is usually less on the front of a refrigerator than on any other side. This has been determined by tests using thermo-couples on the outside surface of the cabinet to obtain the surface temperature. Another indication of insuf-

ficient insulation around the doors is the fact that moisture condenses on these parts first when there is a high room humidity.

The door heat loss is especially large when metal is used to line the door frame or the edges of the door itself. There is need for a new material to make the door opening frame and the door frame. Wood does not have sufficient heat

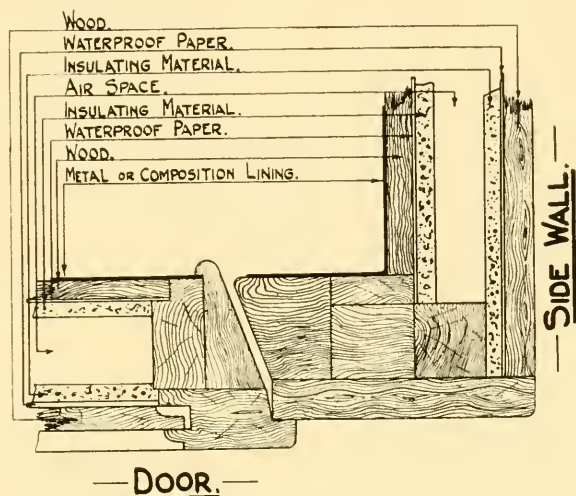


FIG. 200.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION.

insulating property. Following are some of the more important points to be considered in door design:

1. Increased heat loss by conduction through solid or metal framework.
2. Heat loss due to doors not closing tightly causing too rapid ventilation with outside air. This loss is especially large if the door does not fit properly at the top and bottom and varies according to the room or environment humidity, being greater with higher humidity.
3. Damage to the finish and the exterior surface around the doors caused by the condensation of moisture.
4. Warped doors due to constant changes in moisture, temperature and humidity, and the difference in these conditions on the outside and inside surfaces of the door.
5. Heat loss due to improper design of angle and clearance allowing large air wedge between edge of door and frame.

The refrigerator door has to stand a severe surface condition of humidity and temperature. The humidity frequently attains such conditions as 90 per cent on one side and 40 per cent on the other. The temperature usually has a differential of from 20 to 40 degrees on the outside and inside of the box. Ash is one of the best woods to use for this severe service.

Various kinds of gaskets are available for making a tight seal around the door. Some of the materials for this purpose are rubber, felt, rubberized cotton, and thin copper metal strips. The high grade boxes do not depend upon gaskets for a close fit. Most gaskets are affected by moisture or lose their resiliency after a few months of service. Gaskets are used very effectively on large cold storage doors where it is not practical or necessary to make a good wood-to-wood fit. When a well-made door is fitted properly it will close tightly on all four sides against a strip of ordinary writing paper.

Some manufacturers use a series of steps in the door and

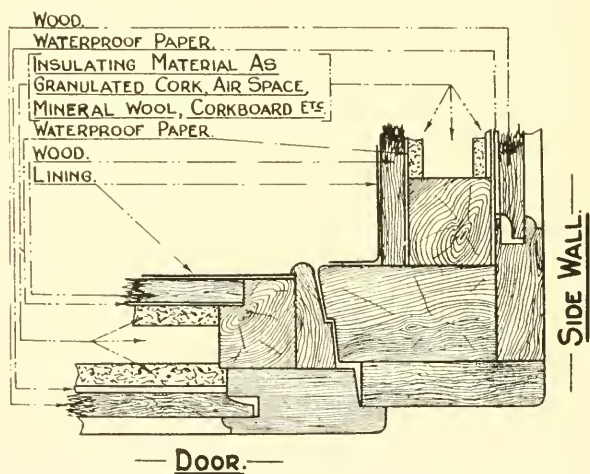


FIG. 201.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION.

the door frame. The better boxes have only one or two steps and fit well against the outside surface of the box. No attempt is made to fit closely between any of the other surfaces.

The door-facing strip should have a slope on the side of the door opposite the hinges. This slope is usually applied to

the other three sides of the door and door opening, although this is entirely unnecessary except for symmetry. The angle of this slope is easily determined by the radius from the center of the hinge to the inside of the door stop on the opposite side.

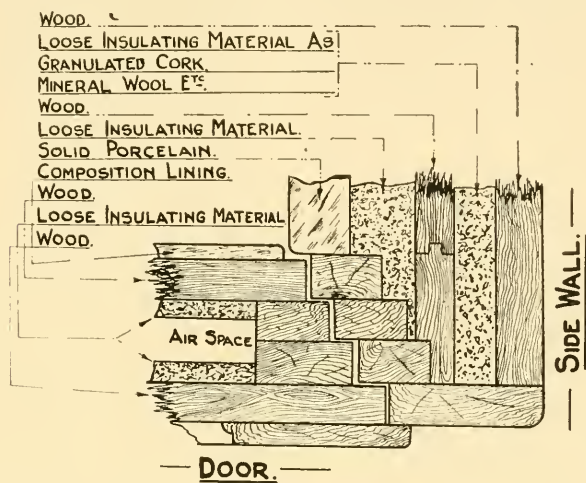


FIG. 202.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION.

The door construction is one of the most difficult problems encountered in making an all-metal box. Even at a room humidity of 50 or 60 per cent, condensation will probably form around the doors of an all-metal box. This may damage the exterior finish of the metal.

The door to the ice compartment should always have an opening at least 12 inches wide. This will allow the thickest end of a manufactured cake of ice, $11\frac{1}{2}$ inches on a 300-pound size and $11\frac{3}{8}$ inches on a 400-pound cake, to enter without chipping.

Shelves.—The shelf arrangement is an important design feature frequently neglected in refrigerator construction.

The ratio of shelf area to food storage volume is a good method of checking this part of the design.

Tables LXII and LXIII show that the top icer and ell type refrigerators have practically the same shelf surface for the same rated ice capacity.

Shelves are usually made of small mesh wire heavily tinned. Glass shelves are used to a limited extent. Some

TABLE LXII.—SHELF AREA OF TOP ICER REFRIGERATORS.

| Rated Ice Capacity (Pounds) | 50 | 75 | 100 |
|-----------------------------|------------------------|-----|-----|
| | Shelf Area Square Feet | | |
| Box 1 | 4.8 | 6.2 | 7.0 |
| " 2 | 4.2 | 5.1 | 5.9 |
| " 3 | 4.9 | 5.4 | 7.2 |
| " 4 | 4.0 | 5.6 | 8.1 |
| " 5 | 3.4 | 4.3 | 6.1 |
| " 6 | 3.6 | 6.5 | 7.8 |
| " 7 | 5.2 | 5.3 | 5.4 |
| Average | 4.3 | 5.6 | 6.8 |

All of these boxes have three shelves.

shelves are constructed of small steel bars welded together into a unit and heavily tinned. Some of the advantages of wire shelves are:

1. Cheapness of construction.
2. Light weight.
3. Easily removed and cleaned.
4. Allow free air circulation.
5. Permit seeing through them to locate articles underneath.
6. Surface not damaged by heavy food containers.
7. Do not rust or corrode readily.

TABLE LXIII.—SHELF AREA OF ELL TYPE OF REFRIGERATORS.

| Rated Ice Capacity (Pounds) | 75 | 100 | 200 |
|-----------------------------|------------------------|-----|------|
| | Shelf Area Square Feet | | |
| Box 1 | 5.8 | 8.7 | 16.0 |
| " 2 | 6.6 | 8.3 | 10.5 |
| " 3 | 5.3 | 6.0 | 12.0 |
| " 4 | 6.2 | 6.5 | 16.0 |
| " 5 | 5.6 | 7.8 | 10.0 |
| " 6 | 5.0 | 8.5 | 16.2 |
| " 7 | 4.0 | 7.4 | 18.0 |
| Average | 5.5 | 7.6 | 14.1 |

Some refrigerators are made with shelf supports adjustable for height. It has been found in actual service that this

feature is not used, as the owner evidently does not appreciate the advantage of spacing the shelves to conform with certain requirements.

TABLE LXIV.—INSULATORS USED IN REFRIGERATORS.

| | |
|------------------------|----|
| Wood | 42 |
| Air Space | 28 |
| Paper | 28 |
| Granulated Cork | 13 |
| Mineral Wood | 12 |
| Corkboard | 8 |
| Flax Composition | 6 |
| Felt Paper | 2 |
| Cocoa Fiber | 1 |
| Vegetable Fiber | 1 |
| Eel Grass | 1 |
| Hairfelt | 1 |
| Wood Fiber | 1 |
| Sea Grass | 1 |

The shelf spacing in cabinets using mechanical refrigeration is usually closer than on refrigerators using ice. This close spacing is permissible because of the colder temperature and more active circulation.

Materials for Refrigerators.—The insulating materials used in 50 standard refrigerators are listed in Table LXIV.

The foregoing indicates the number of times each insulating material was used in the construction used by 50 different manufacturers.

Table LXV shows the woods used in 50 standard refrigerators for outside case and linings:

TABLE LXV.—WOODS USED IN REFRIGERATORS.

| | |
|---------------------|----|
| Oak | 21 |
| Ash | 13 |
| Fir or Spruce | 7 |
| Yellow Pine | 1 |
| White Pine | 1 |
| Black Ash | 1 |
| Poplar | 1 |
| Cypress | 1 |
| Birch | 1 |

Table LXVI gives a list of some of the woods which are suitable for refrigerator construction. The botanical name and locality where such wood grows are included also.

HOUSEHOLD REFRIGERATION

TABLE LXVI.—WOODS MOST SUITABLE FOR REFRIGERATORS.

| Common Name | H = Hard S = Soft or Coniferous | Botanical Name | Locality Where Grown |
|---------------------------|---------------------------------------|---|-------------------------|
| Ash, black | H | <i>Fraxinus nigra</i> | Mich. Wis. |
| Ash, Oregon | H | <i>Fraxinus oregona</i> | Oregon |
| Ash, white, forest grown | H | <i>Fraxinus americana</i> | Ark. W. Va. |
| Ash, white, second growth | H | <i>Fraxinus americana</i> | New York |
| Basswood | H | <i>Tilia americana</i> | Penn. Wis. |
| Beech | H | <i>Fagus atropunicea</i> | Ind. Penn. |
| Birch, sweet | H | <i>Betula lenta</i> | Pennsylvania |
| Birch, yellow | H | <i>Betula lutea</i> | Penn. Wis. |
| Birch, black | H | | |
| Birch, white | H | | |
| Butternut | H | <i>Juglans cinerea</i> | Tenn. Wis. |
| Butternut, white walnut | H | | |
| Buttonwood, sycamore | | | |
| Chestnut | H | <i>Castanea dentata</i> | Md. Tenn. |
| Cottonwood | H | <i>Populus deltoides</i> | Missouri |
| Cottonwood, black | H | <i>Populus trichocarpa</i> | Washington |
| Cypress, bald | S | <i>Taxodium distichum</i> | La. Mo. |
| Cypress, yellow | S | <i>Chamaescypris</i> <i>nootkatensis</i> | Oregon |
| Douglas fir—also called | | <i>Pseudotsuga taxifolia</i> | Wyoming. Mo. |
| Oregon pine | S | | Wash. Ore. |
| Dogwood, flowering | H | <i>Cornus florida</i> | Tennessee |
| Dogwood, western | H | <i>Cornus muttallii</i> | Oregon |
| Elm, gray | H | | |
| Fir, white | S | <i>Abies concolor</i> | |
| Fir, red | S | | |
| Fir, yellow | S | | |
| Gum, black | H | <i>Nyssa sylvatica</i> | Tennessee |
| Gum, red | H | <i>Liquidambar</i> <i>styraciflua</i> | Missouri |
| Gum, sap | H | | |
| Hackberry | H | <i>Celtis occidentalis</i> | Wis. Ind. |
| Hemlock, black | S | <i>Tsuga mertensiana</i> | Montana |
| Hemlock, eastern | S | <i>Tsuga canadensis</i> | Tenn. Wis. |
| Hemlock, western | S | <i>Tsuga heterophylla</i> | Washington |
| Locust, black | H | <i>Robinia pseudacacia</i> | Tennessee |
| Locust, honey | H | <i>Gleditsia triacanthos</i> | Mo. Ind. |
| Maple, Oregon | H | <i>Acer macrophyllum</i> | Washington |
| Maple, red | H | <i>Acer rubrum</i> | Penn. Wis. |
| Maple, silver | H | <i>Acer saccharinum</i> | Wisconsin |
| Maple, sugar | H | <i>Acer saccharum</i> | Ind. Pa. Wis. |
| Maple, rock | H | | |
| Maple, hard | H | | |
| Maple, soft | H | | |
| Oak, California black | H | <i>Quercus californica</i> | Cal. Oregon |
| Oak, canyon live | H | <i>Quercus chrysollipsis</i> | California |
| Oak, chestnut | H | <i>Quercus Prinus</i> | Tennessee |
| Oak, cow | H | <i>Quercus nichaurii</i> | Louisiana |
| Oak, laurel | H | <i>Quercus laurifolia</i> | Louisiana |
| Oak, Pacific post | H | <i>Quercus garryana</i> | Oregon |
| Oak, post | H | <i>Quercus minor</i> | Ark. La. |

TABLE LXVI.—WOODS MOST SUITABLE FOR REFRIGERATORS—(Cont'd)

| Common Name | H = Hard S = Soft or Coniferous | Botanical Name | Locality Where Grown |
|---------------------------------|---------------------------------------|------------------------------------|----------------------------|
| Oak, red | H | <i>Quercus rubra</i> | Ark. La. Ind. Tennessee |
| Oak, Spanish highland | H | <i>Quercus digitata</i> | Louisiana |
| Oak, Spanish lowland | H | <i>Quercus pagodaefolia</i> | Louisiana |
| Oak, white | H | <i>Quercus alba</i> | Ark. La. Md. |
| Oak, willow | H | <i>Quercus phellos</i> | Louisiana |
| Oak, yellow | H | <i>Quercus velutina</i> | Ark. Wis. |
| Oak, English | H | | |
| Pine, jack | S | <i>Pinus heterophylla</i> | Florida |
| Pine, longleaf | S | <i>Pinus palustris</i> | Fla. La. Miss. |
| Pine, Norway | S | <i>Pinus resinosa</i> | Wisconsin |
| Pine, pitch | S | <i>Pinus rigida</i> | Tennessee |
| Pine, shortleaf | S | <i>Pinus echinata</i> | Ark. La. |
| Pine, sugar | S | <i>Pinus lambertiana</i> | California |
| Pine, table mountain | S | <i>Pinus pungens</i> | Tennessee |
| Pine, western white | S | <i>Pinus monticola</i> | Montana |
| Pine, western yellow | S | <i>Pinus ponderosa</i> | Colo. Mont. Ariz. |
| Pine, white | S | <i>Pinus strobus</i> | Wash. Calif. Wisconsin |
| Pine, northern yellow | S | | |
| Pine, southern yellow | S | | |
| Pine, Georgia | S | | |
| Pine, spruce | S | | |
| Poplar, yellow | H | <i>Liriodendron tulipifera</i> | Tennessee |
| Poplar, white | H | | |
| Poplar—also called whitewood | H | | |
| Redwood, California | | | |
| Sassafras | H | <i>Sassafras sassafras</i> | Tennessee |
| Spruce, Engelmann | S | <i>Picea engelmanni</i> | Colorado |
| Spruce, red | S | <i>Picea rubens</i> | N. H. Tenn. |
| Spruce, litka | S | <i>Picea sitchensis</i> | Washington |
| Spruce, white | S | <i>Picea canadensis</i> | N. H. Wis. |
| Sumac, staghorn | H | <i>Rhus hirta</i> | Wisconsin |
| Sycamore | H | <i>Platanus occidentalis</i> | Ind. Tenn. |
| Tamarack | S | <i>Larix laricina</i> | Wisconsin |
| Willow, western | H | <i>Salix lasiandra</i> | Oregon |

Ice Capacity of a Refrigerator.—The ice capacity of a refrigerator is an arbitrary figure at the best, inasmuch as the pieces of ice that are put into it vary considerably in size and so make more or less waste space. Ice capacities in refrigerators are usually figured in the following way:

The cubic inches of ice chamber divided by 1,728 gives total cubic feet and this multiplied by 57.5, which is the weight

of a cubic foot of ice, gives the total ice capacity in terms of pounds of ice. From this deduct 25 per cent, considered as a fair allowance for waste space or irregular shaped ice, and the remainder is the figure of ice capacity of a refrigerator.

TABLE LXVII.—RATED ICE CAPACITIES OF REFRIGERATORS.
Summary of Data on 473 Different Standard Models. (Side Icers.)

| Total Inside Volume Cubic Feet. | Average Rated Ice Capacity Pounds. | Maximum Rated Ice Capacity Pounds. | Minimum Rated Ice Capacity Pounds. |
|---------------------------------------|--|--|--|
| 4—5 | 58 | 75 | 40 |
| 5—6 | 81 | 110 | 50 |
| 6—7 | 93 | 110 | 50 |
| 7—8 | 103 | 125 | 50 |
| 8—10 | 126 | 200 | 65 |
| 10—12 | 142 | 200 | 75 |
| 12—16 | 177 | 250 | 85 |
| 16—20 | 204 | 300 | 150 |
| 20—24 | 244 | 375 | 170 |
| 24—30 | 284 | 350 | 235 |
| 30—40 | 310 | 425 | 190 |
| 40—60 | 420 | 550 | 300 |

Table LXVII gives the rated ice capacities of refrigerators obtained from the data on 473 different standard models of side icer refrigerators. Data are given for refrigerators having volumes varying from 4 cubic feet to 60 cubic feet. It is interesting to note the difference in the minimum rated ice capacity, average rated ice capacity, and the maximum rated ice capacity. Table LXVIII gives similar rated ice capacities from data on 88 different models of the top icer lift lid icing door construction.

TABLE LXVIII.—RATED ICE CAPACITIES OF REFRIGERATORS.
Summary of Data on 88 Different Models (Top Icers, Lift Lid Icing Door).

| Total Inside Volume Cubic Feet. | Average Rated Ice Capacity Pounds. | Maximum Rated Ice Capacity Pounds. | Minimum Rated Ice Capacity Pounds. |
|---------------------------------------|--|--|--|
| 3—4 | 56 | 120 | 40 |
| 4—5 | 69 | 151 | 65 |
| 5—6 | 92 | 117 | 75 |
| 6—7 | 106 | 133 | 69 |
| 7—8 | 133 | 188 | 100 |
| 8—9 | 105 | 110 | 100 |
| 9—10 | 124 | 150 | 100 |
| 10—11 | 150 | 150 | 150 |

Table LXIX gives additional rated ice capacities of refrigerators. The data in this table was obtained from an average

of information on 282 different models of the top icer construction, including both lift lid and front door icers.

TABLE LXIX. RATED ICE CAPACITIES OF REFRIGERATORS.
Summary of Data on 282 Different Models (Top Icers Including Lift Lid and Front Door Icers.)

| Total Inside Volume Cubic Feet. | Average Rated Ice Capacity Pounds. | Maximum Rated Ice Capacity Pounds. | Minimum Rated Ice Capacity Pounds. |
|------------------------------------|--|--|--|
| 3—4 | 62 | 120 | 40 |
| 4—5 | 74 | 151 | 55 |
| 5—6 | 85 | 135 | 60 |
| 6—7 | 101 | 190 | 65 |
| 7—8 | 122 | 188 | 60 |
| 8—9 | 121 | 165 | 75 |
| 9—10 | 144 | 175 | 100 |
| 10—11 | 165 | 224 | 125 |
| 11—12 | 142 | 220 | 110 |
| 12—15 | 194 | 235 | 160 |
| 15—22 | 224 | 420 | 150 |

Table LXX gives the rated ice capacities of refrigerators obtained from 194 different standard models of the top icer construction, with the icing door on the front.

TABLE LXX.—RATED ICE CAPACITIES OF REFRIGERATORS
Summary of Data on 194 Different Standard Models. (Top Icers, Icing Door on Front).

| Total Inside Volume Cubic Feet. | Average Rated Ice Capacity Pounds. | Maximum Rated Ice Capacity Pounds. | Minimum Rated Ice Capacity Pounds. |
|------------------------------------|--|--|--|
| 3—4 | 59 | 100 | 50 |
| 4—5 | 81 | 104 | 55 |
| 5—6 | 95 | 135 | 60 |
| 6—7 | 113 | 190 | 65 |
| 7—8 | 120 | 176 | 60 |
| 8—9 | 125 | 165 | 75 |
| 9—10 | 154 | 175 | 140 |
| 10—11 | 172 | 224 | 125 |
| 11—12 | 142 | 220 | 110 |
| 12—15 | 194 | 235 | 160 |
| 15—22 | 224 | 350 | 150 |

Table LXXI gives some interesting information on ice refrigerators of the ell type construction. Three sizes, 75, 100, and 200 pounds rated ice capacity, are included. It is interesting to note the variation of shelf area, per cent of ice storage space used at rated ice capacity, per cent of inside volume used for ice storage, and the ratio of the shelf area to the food storage volume. Similar ice refrigerator cabinet data

HOUSEHOLD REFRIGERATION

TABLE LXXI.—ICE REFRIGERATOR CABINET DATA: ELL TYPE.

| Rated Ice Capacity | | Pounds | 75 | 100 | 200 |
|---|--------------|--------|------|------|------|
| Outside Dimensions | Width Inches | | 32.0 | 34.6 | 43.4 |
| | Depth | | 18.6 | 20.6 | 24.6 |
| | Height | | 43.0 | 46.4 | 56.0 |
| Ice Compartment | Width Inches | | 12.4 | 13.1 | 17.3 |
| | Depth | | 13.6 | 15.0 | 18.9 |
| | Height | | 17.3 | 19.7 | 26.1 |
| Total Volume Overall | Cu. Ft. | | 14.9 | 19.2 | 35.5 |
| Food Storage Space | Cu. Ft. | | 3.6 | 5.0 | 10.5 |
| Ice Storage Space | Cu. Ft. | | 1.7 | 2.2 | 5.9 |
| Shelf Area. | Sq. Ft. | | 5.5 | 7.2 | 14.1 |
| Percent Ice Storage Space used at Rated Ice Capacity | | | 77.1 | 79.6 | 59.1 |
| Percentage of Inside Volume for Ice Storage | | | 32. | 31. | 36. |
| Shipping Weight (Pounds) | | | 214 | 293 | 477 |
| Ratio of Shelf Area to Food Storage Volume | | | 1.53 | 1.45 | 1.34 |

This table is computed from ten standard refrigerators with baked porcelain one piece linings.

are given in Table LXXII for refrigerators of the top icer construction, having rated ice capacities of 50, 75, and 100 pounds. These data are shown graphically by Figs. 203 and 204.

TABLE LXXII.—ICE REFRIGERATOR CABINET DATA: TOP ICER.

| Rated Ice Capacity | | Pounds | 50 | 75 | 100 |
|---|--------------|--------|------|------|------|
| Outside Dimensions | Width Inches | | 23.4 | 26.3 | 29.1 |
| | Depth | | 16.3 | 17.7 | 18.9 |
| | Height | | 41.4 | 43.7 | 48.1 |
| Ice Compartment | Width Inches | | 15.8 | 18.9 | 21.7 |
| | Depth | | 10.8 | 12.4 | 13.3 |
| | Height | | 10.3 | 11.7 | 12.9 |
| Total Volume Overall | Cu. Ft. | | 9.1 | 12.3 | 15.3 |
| Food Storage Space | Cu. Ft. | | 1.94 | 2.9 | 3.8 |
| Ice Storage Space | Cu. Ft. | | 1.02 | 1.59 | 2.15 |
| Shelf Area | Sq. Ft. | | 4.3 | 5.6 | 6.8 |
| Percent Ice Storage Space used at Rated Ice Capacity | | | 85.8 | 82.4 | 81.3 |
| Percent of Inside Volume used for Ice Storage | | | 34.5 | 35.5 | 36.2 |
| Shipping Weight, pounds | | | 143 | 173 | 215 |
| Ratio of Shelf Area to Food Storage Volume. | | | 2.22 | 1.93 | 1.79 |

This table is computed from ten standard refrigerators with baked porcelain one piece linings.

ICE REFRIGERATOR CABINET DATA

FROM 10 STANDARD MAKE REFRIGERATORS OF EACH TYPE

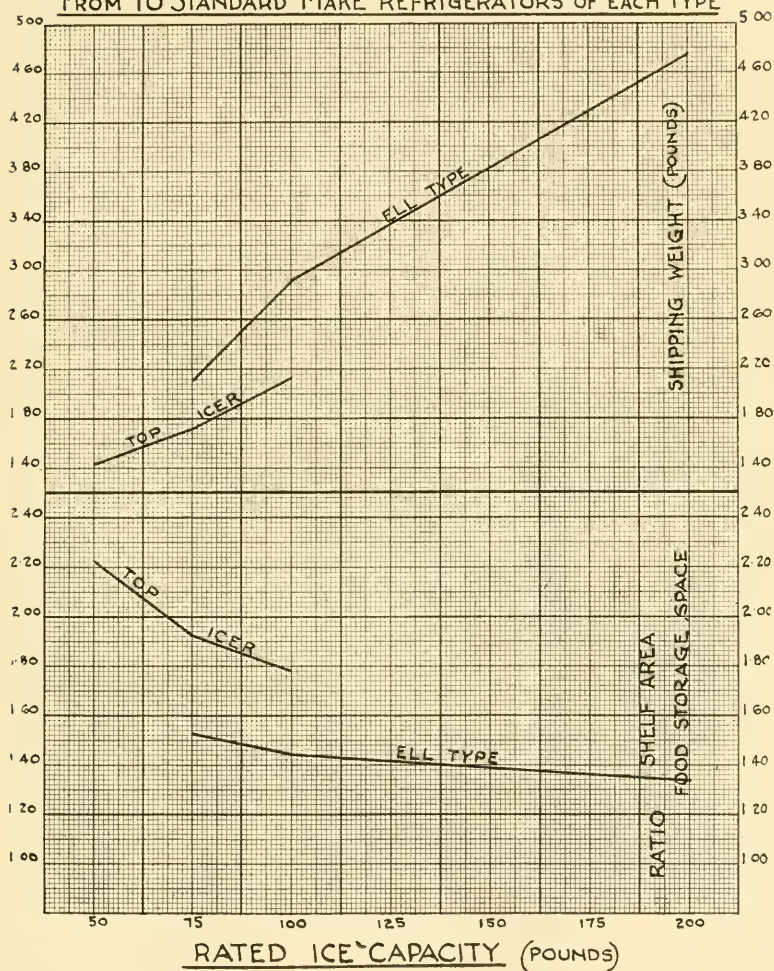


FIG. 203.—ICE REFRIGERATOR CABINET DATA.

ICE REFRIGERATOR CABINET DATA

FROM 10 STANDARD MAKE REFRIGERATORS OF EACH TYPE

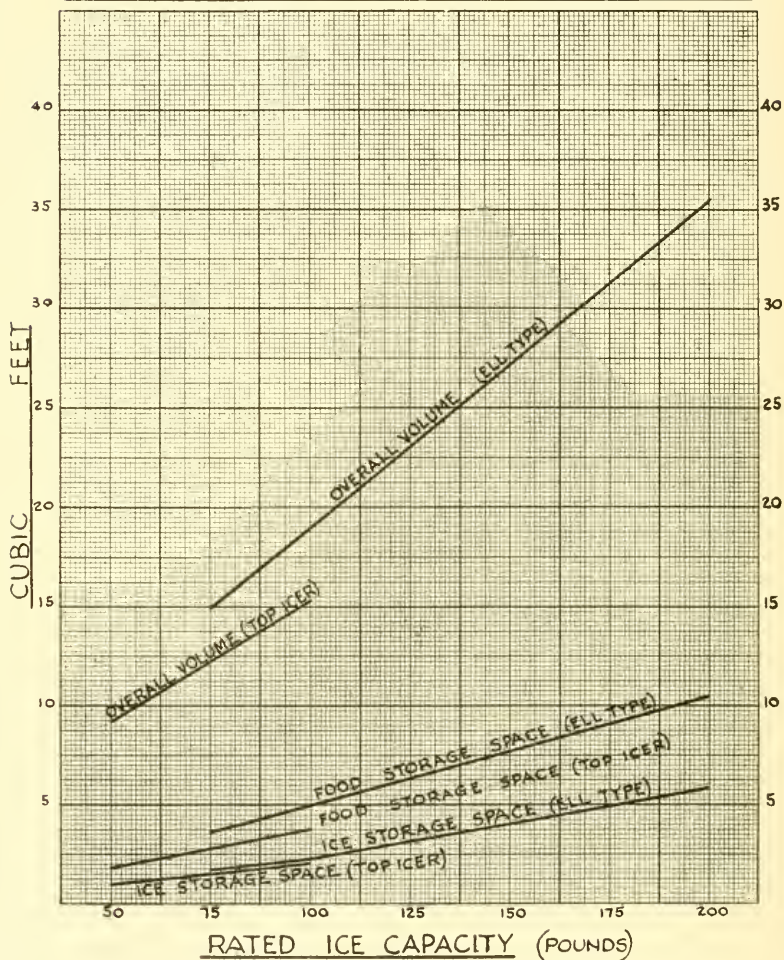


FIG. 204.—ICE REFRIGERATOR CABINET DATA.

CHAPTER X

OPERATION OF ICE REFRIGERATORS.

Temperature.—The usual method of solving the household refrigeration problem is by the use of ice in any of the standard type refrigerators.

The refrigerator using ice will have a temperature in the food storage compartments 20 to 30 degrees lower than room temperature.

The better type refrigerators with very good insulation will approach the 30 degree temperature difference when there is a good supply of ice.

A temperature difference of about 10 degrees between the coldest and warmest part of the food storage compartments is necessary to insure good circulation of the enclosed air. In this way heat is transferred from the food to the ice compartment. This heat transfer is mostly by convection, the circulating air acting as the carrier.

The coldest part of the food storage space is the lower part directly under the ice compartment. The circulating air becomes warmer as it rises in the food compartment, absorbing heat from the walls, food and food containers.

The temperature in the warmest part of a refrigerator should never be higher than 50° F. for the proper preservation of food.

The temperature of the coldest air dropping into the food compartment is usually between 40° and 50° F., depending

upon the amount of ice, the type and construction of the box and the temperature of the air entering the top of the ice compartment. The melting ice, of course, is always at a temperature of 32° F.

It is necessary to have a well-insulated refrigerator to obtain by the use of ice a temperature suitable for the storage of perishable food products.

The desirable temperatures which are recommended for refrigerators by different authorities are given in Table LXXIII. The authorities quoted are as follows: New York Tribune Institute, United States Department of Agriculture, Dr. L. K. Hirschberg, and Dr. John R. L. Williams.

It will be further noted that the recommendations for the most desirable temperatures for refrigerators varies from 40° to 50°, with 45° as an average.

Operating Conditions.—The effect of room temperature on the amount of refrigeration required for a refrigerator can be easily approximated.

For example, if the average operating condition is at 45° F., food compartment temperature in a 70° F. room, the temperature difference is 25° F. The increase in refrigeration required in higher temperature rooms would be as follows:

| Food Compartment Temperature | Room Temp. | Tempera- ture Diff. | Increase in Refrigeration required per cent |
|---------------------------------|---------------|------------------------|---|
| 45 | 70 | 25 | .. |
| 45 | 80 | 35 | 40 |
| 45 | 90 | 45 | 80 |

Usually at a higher room temperature the food compartment temperature will be higher and the increase in refrigeration will be somewhat less than the amount indicated by this table.

Circulation of Air.—There is a constant circulation of air in refrigerators as long as the ice lasts. For the preservation of food, it is equally as necessary to have good air circulation as it is to maintain a low temperature in the food compartment. No matter how cold the air is, it will not preserve the food properly unless the air is in active circulation.

TABLE LXXIII.—DESIRABLE TEMPERATURE FOR REFRIGERATORS.

| Temperature Recommended Deg. F. | Authority | Published in | Extracts. |
|------------------------------------|--|--|--|
| 40°—50° | New York Tribune Institute | New York Tribune | 40° to 50° averaging 45°; these are the aims of a super refrigerator. A temperature of 40° to 45° is considered ideal for home refrigerator purposes. It should not go above 50°. |
| 50° or less | U. S. Depart- ment of Agriculture | Farmers' Bulletin No. 1207 | The best temperature for keeping milk is 50° or less. If a thermometer placed inside a refrigerator registers more than 50°, the fault cannot be laid entirely to the quality of the milk. Even a temporary rise in the temperature of milk will help the development of bacteria. |
| 45° or less | Dr. L. K. Hirshberg | Chicago Evening Post | Refrigerators, ice boxes, cold storage, etc., which keep food well below 45°, help to keep it free of any great increase and growth of bacteria. |
| 40°—50° | U. S. Depart- ment of Agriculture M. H. Abel | Farmers' Bulletin No. 375 | If on a warm summer day you put your hand into an ice box well filled with ice you may think that the temperature is very low, and yet it is in all probability nearer 50° than 40° F. The ice box no matter how well cooled, is and must be damp, and dampness is one of the requirements for bacterial growth. |
| 50° or less | U. S. Depart- ment of Agriculture J. T. Brown | Bulletin No. 98 | Proper refrigeration is of the utmost importance in the preservation of milk. Without thorough cooling it is impracticable to keep milk for any considerable length of time in a condition that would justify its use for household purposes. It should be cooled to 50° F. or below. |
| 50° or less | John R. Williams, M. D. | Report at 3rd. Int. Ref. Con- gress | A box or room for the storage of perishable foods to be at all efficient, must have a temperature not in excess of 50° F., preferably below 45° F. |

It is a well-known fact that cold air falls while warm air rises. The cold air cooled by contact with the surface of the ice is carried down by its own weight, forcing ahead of it warmer air in other parts of the food compartment. This warmer air taking heat from the food, food containers and walls, rises to the top of the refrigerator where it passes into the ice compartment. It is cooled again and repeats this cycle, thus establishing continuous circulation.

Circulation is very important as it distributes the cool air to all parts of the refrigerator. The circulating air in passing the ice loses some of the moisture and the odor which it has taken up from the food.

The opening for the air to enter and leave the ice compartment should be as large as possible as the maximum velocity of the circulating air is relatively quite low.

Government tests on nine standard refrigerators of average quality or better, give the rate of air circulation as 10.1 to 21.4 cubic feet per minute at 60° F.

Melting ice has a temperature of 32° and the best circulation which can be obtained will not keep the warmest part of the food compartment at a temperature less than 50° in a room of 90°. Therefore, it is desirable to have as rapid a circulation as possible.

A good indication of the rate of air circulation in the refrigerator is the difference in temperature between the lower or coldest, and the upper or warmest part of the food compartment. This value is usually 10° or 15° in the average household refrigerator of from 50 to 150 pounds ice capacity.

Some typical refrigerator boxes are shown in Figs. 205 and 206 with arrows indicating the path of the circulating air. A gain in efficiency can be made by having the warm air flues against the exterior wall getting the path of the cold air in the center of the box. This will make an appreciable saving in the amount of ice used.

It is advantageous to have the ice compartment so constructed that the ice will never project above the lower level of the warm-air opening into this compartment. Careful tests have shown that there is a real gain in efficiency by doing this.

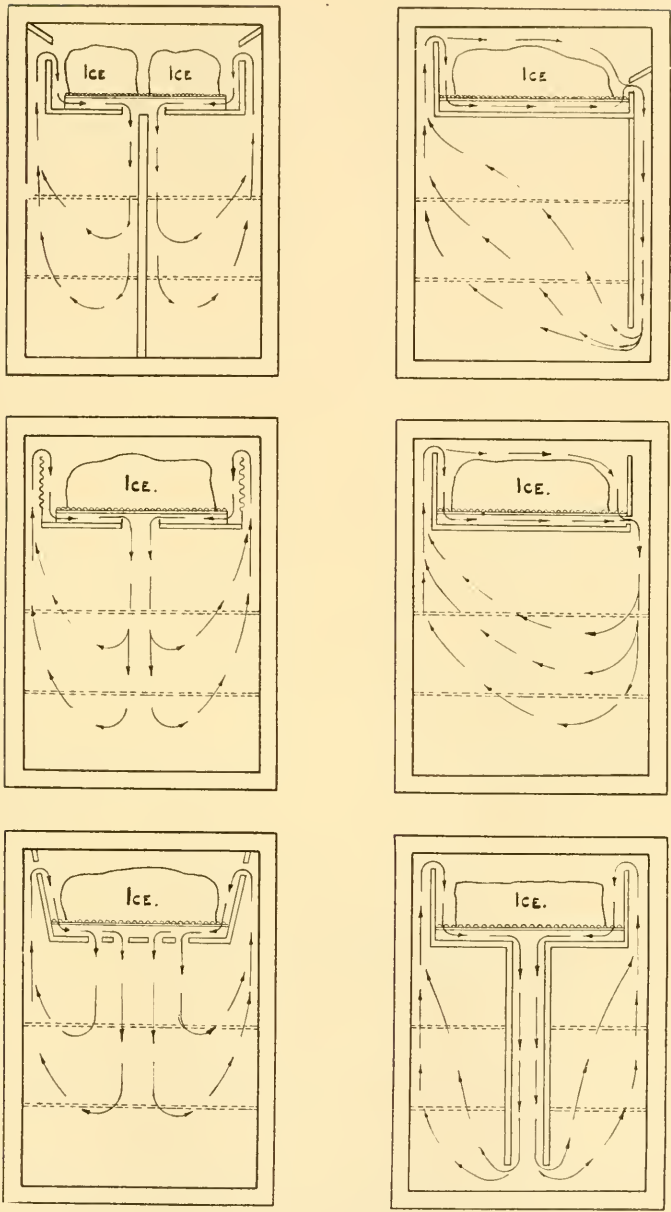


FIG. 205.—AIR CIRCULATION IN REFRIGERATORS.

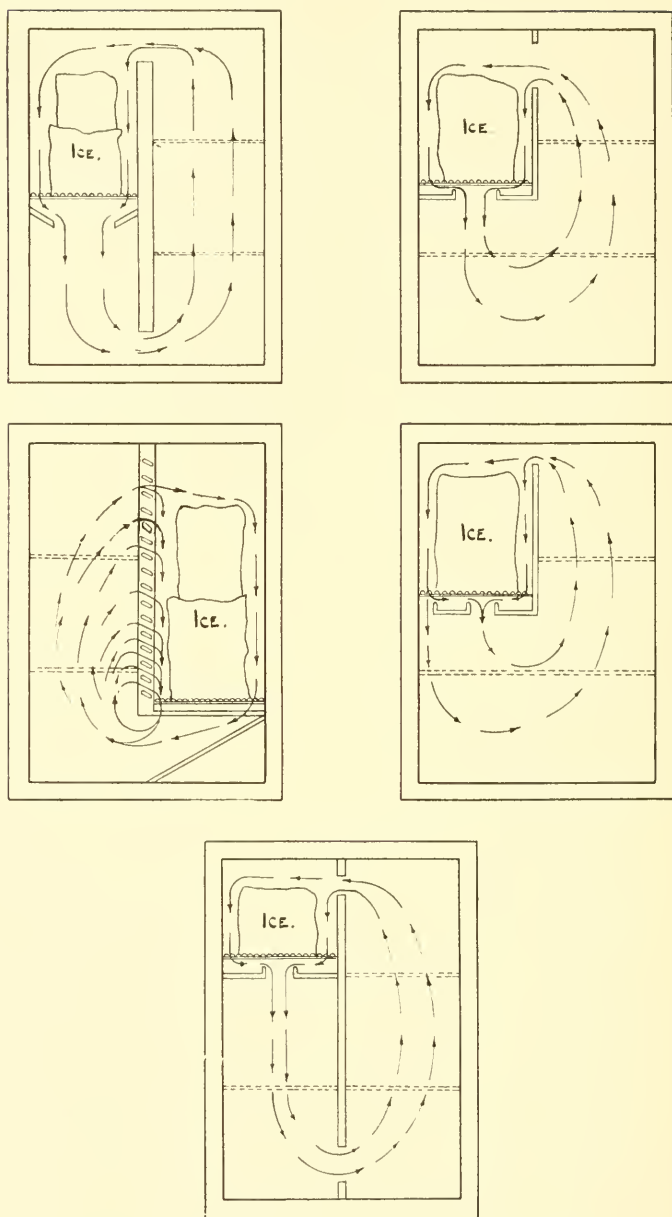


FIG. 206.—AIR CIRCULATION IN REFRIGERATORS.

Good air circulation in a refrigerator prevents the mixing of food tastes to a large extent. Foods such as onions, lemons, and brussels sprouts, which have the property of mixing their tastes with other foods, should be placed in the upper part of the refrigerator as most of the gases will then be absorbed by the water on the surface of the ice.

Circulation in Ice Chambers.—Fig. 207 shows various methods of producing circulation in a refrigerator.

In the upper figure there is no baffle plate. Local circulation is produced near the surface of the cake of ice. This condition is not satisfactory for storing food as the humidity would be unusually high in the food storage compartment. This construction causes food odors and favors high temperatures.

The center figure shows a metal baffle plate. This improves the condition in the food compartment. The baffle plate would probably be covered with condensation on the food compartment side. This construction would insure lower and more uniform temperature in the food compartment than obtained with the previous method.

The lower figure shows an insulated baffle plate. This is the ideal construction, affording a still better condition of lower and more uniform temperature, lower humidity and good air circulation. The baffle plate usually requires insulation equivalent to one-half or one-third of that used in the walls of the cabinet.

Air Circulation Tests.—A simple method of measuring the rate of air circulation is to place an anemometer in a flue opening in various positions to find the average velocity. Knowing the velocity of the air through this opening and its area, the amount of air circulating can be calculated.

A heat balance method is sometimes used to determine the approximate rate of circulation. The heat loss through the walls is determined by an ice-melting test. It is then assumed that this loss is due to the circulating air carrying the heat by convection from the walls of the cabinet to the ice. The heat transfer by radiation and conduction from the walls to the ice is relatively small and therefore not consid-

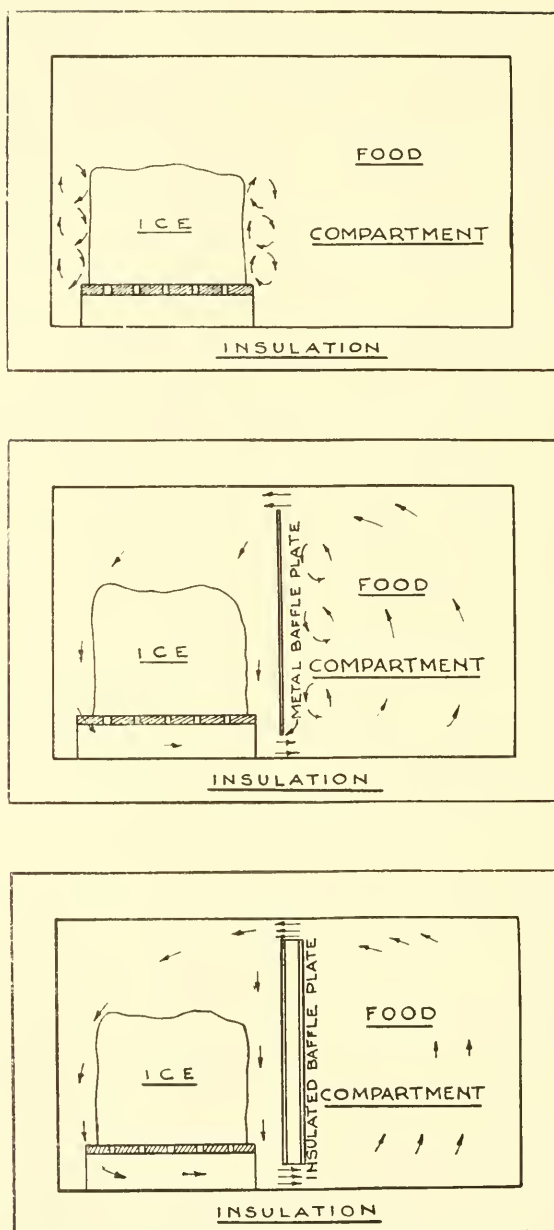


FIG. 207.—AIR CIRCULATION IN ICE CHAMBERS.

ered. The temperature difference of the circulating air entering and leaving the ice compartment can easily be determined by thermometers in the flue openings.

The following equation will approximate the amount of air circulating per hour:

$$\begin{array}{l} \text{Pounds of Ice Melted} \\ \text{per hour} \times 144 \end{array} = \frac{\begin{array}{l} \text{Pounds of} \\ \text{Air circu-} \\ \text{lating per} \\ \text{hour} \end{array} \times \begin{array}{l} \text{Specific} \\ \text{Heat} \end{array} \times \begin{array}{l} \text{Temp.} \\ \text{Difference} \end{array}}{\begin{array}{l} \text{Pounds of Ice Melted per hour} \times 144 \\ 0.24 \times \text{temp. difference of air entering and} \\ \text{leaving ice compartment} \end{array}}$$

The humidity of the circulating air will have an effect on its heat-carrying capacity. However, this is a relatively unimportant factor and is not usually considered, as this difference in the final result is less than other variables which are not taken into account.

Air circulation tests on a well-insulated cabinet cooled with a mechanical system show that the circulation through the food compartment varies from 1.0 to 5.0 feet per minute. As the flue opening has an area equivalent to 1/10 of the food compartment, the rate of air circulation through the flue opening varies from 10 to 50 feet per minute.

Humidity.—Humidity is the water vapor in the air. Atmospheric air always contains a certain amount of water vapor mixed with it. Air at a certain temperature and pressure can contain a definite amount of water vapor. When this amount is exceeded, the excess water vapor will condense.

Perfect refrigeration depends as much upon dryness as it does upon cold. It is very essential to have a circulation of so-called "dry" air in order to properly preserve food in a refrigerator. It is just as important that the humidity be low as it is that the temperature be low. A practical example is the poor results obtained by keeping foods in the ordinary ice chest where there is considerable moisture and poor air circulation. Foods will spoil more rapidly in an ice chest than in the ordinary refrigerator, even though the temperature in the ice chest be as low or even lower than that in the refrigerator.

Most cellars are unsuitable for storing perishable foods because of the dampness or high humidity in the air.

One hundred cubic feet of air at atmospheric pressure can contain the definite amounts of water vapor at the temperatures given in Table LXXIV.

TABLE LXXIV.—WATER VAPOR IN AIR.

| Temperature Deg. F. | Weight of Water Vapor per 100 cu. ft. of air. |
|------------------------|--|
| 32 | 0.0304 |
| 40 | 0.0410 |
| 50 | 0.0587 |
| 60 | 0.0827 |
| 70 | 0.1145 |
| 80 | 0.1564 |
| 100 | 0.2850 |

The amount of water vapor which the air can contain increases with the temperature and decreases with pressure.

Relative humidity is the per cent of water vapor actually present in the air in relation to the maximum amount of water vapor which the air can contain at a definite pressure and temperature.

Example: Suppose atmospheric air at 80° F. had a relative humidity of 60 per cent. The amount of water vapor in each 100 cubic feet of air would be

$$\frac{60}{100} \times 0.1564 \text{ or } 0.09384 \text{ pounds}$$

The relative humidity inside a refrigerator is highest where the cold air drops out of the ice compartment. The relative humidity is lowest at the top of the food compartment where the warm air enters the ice compartment. There is a gradual increase between these two points as the circulating air becomes warmer.

The average relative humidity within the food storage compartment in refrigerators using ice is from 50 to 80 per cent. The humidity is increased by placing in the refrigerator foods or liquids which have a high moisture content.

In summer the humidity in the kitchen is usually higher than in the refrigerator. Opening the refrigerator doors will then temporarily increase the humidity inside.

Example: Assume a refrigerator of 10 cubic feet inside capacity containing 50° air at 60 per cent relative humidity. The kitchen temperature is 80° with 80 per cent humidity. The refrigerator doors are left open long enough to replace half the cold dry air with warm vapor laden room air. What is the loss in refrigeration by this change?

Cool 5 cu. ft. dry air 80° to 50°:
 5 cu. ft. or $5 \times 0.071 = 0.355$ pounds.
 $0.355 \times 0.238 \times 30 = 2.5347$ B.t.u.

Amount of water vapor cooled:
 At 80 degrees 0.001564 pounds per cu. ft.
 $5 \times 0.001564 \times 0.80 = 0.006256$ lbs.

Cooling water vapor (80° to 50°):
 $30 \times 0.006256 = 0.18768$ B.t.u.

Amount of water vapor condensed:
 At 50° and 60 per cent humidity
 $5 \times 0.000587 \times 0.60 = 0.001761$ pounds
 $0.006256 - 0.001761 = 0.004495$ pounds

Heat required to condense 0.004495 lbs. of water vapor:
 $0.004495 \times 1000 = 4.495$ B.t.u.

| | |
|------------------------------|---------------|
| Total heat loss: | |
| Cooling air | 2.5347 B.t.u. |
| Cooling water vapor | .1877 B.t.u. |
| Condensing water vapor | 4.495 B.t.u. |

| | |
|-------------|----------------------|
| Total | <u>7.2174</u> B.t.u. |
|-------------|----------------------|

This problem shows the important part humidity plays in ordinary household refrigeration problems.

The results of the humidity tests in a mechanical household refrigerator are shown in Table LXXV. From the second and third columns of Table LXXV, it will be observed that the food compartment relative humidity increased gradually as the relative humidity of the room increased, although not in the same proportion. The temperatures of the room, top of food compartment, and bottom of food compartment were maintained approximately constant during the test.

Humidity Test.—This test was made on a well-insulated cabinet, cooled with a brine tank. The temperature of the brine during the test varied from 18° F. to 22° F. Several tests similar to this one indicate that the relative humidity of the food compartment can be approximately determined by computation. It is only necessary to know the tempera-

ture of the cooling element and the temperature of the food compartment. The air in contact with the cooling element is nearly saturated with moisture.

TABLE LXXV.—HUMIDITY TEST ON A MECHANICAL HOUSEHOLD REFRIGERATOR.

To determine the effect on the food compartment humidity when the humidity in the room is gradually increased.

| Time | Percent Relative Humidity | | Temperature | | |
|---------------|---------------------------|-------------------------|-------------|----------------------|-------------------------|
| | Room | Food Compartment—Bottom | Room | Top Food Compartment | Bottom Food Compartment |
| 9:30 A. M. | 28 | 28 | 80 | 54.5 | 44 |
| 9:45 | 35 | 29 | 80 | 54 | 44 |
| 10:15 | 40 | 34 | 81 | 53.7 | 44 |
| 10:45 | 45 | 40 | 80 | 53.5 | 43.6 |
| 11:15 | 50 | 42 | 80 | 53.3 | 43 |
| 11:45 | 55 | 45 | 80 | 53.1 | 42.5 |
| 1:30 P. M. | 60 | 48 | 80 | 52.8 | 42.5 |
| 2:00 | 65 | 49 | 80 | 52.8 | 42.5 |
| 2:30 | 70 | 50.5 | 80 | 53 | 42.5 |
| 3:00 | 75 | 51.5 | 80 | 53 | 42.5 |
| 4:00 | 80 | 52.5 | 80 | 53 | 42.5 |
| 5:00 | 85 | 52.5 | 80 | 53.5 | 42.7 |
| 6:00 | 90 | 54 | 80 | 53.8 | 43 |
| 6:15 | 93 | 54.2 | 80 | 54 | 43.1 |
| Following Day | | | | | |
| 4:00 P. M. | 90 | 56.5 | 80 | 53.3 | 43 |

With a 20° F. brine tank temperature, the circulating air passing through the cold-air flue is at least 10° F. warmer than the brine-tank temperature, as only part of this air actually comes in contact with the 20° F. brine-tank surface.

If we then assume that the air is saturated with moisture at a temperature of 10° F. warmer than the surface of the cooling unit, this value will closely approximate the actual condition in service. Then knowing the higher temperature at any part of the food compartment, the relative humidity can easily be obtained from the humidity tables.

The warmer air having a greater water vapor capacity therefore, the per cent relative humidity gradually decreases as the circulating air passes up through the food compartment.

Desirable Humidity Indoors.—Humidity control in homes is becoming more and more important, especially in localities where the outdoor temperature in winter drops to below freez-

ing. The average relative humidity in heated rooms ranges from 10 to 20 per cent in winter. This is a dryness greater than that of the deserts. The relative humidity should not be below 40 per cent for good conditions in regard to health and comfort. The usual practice in buildings where the humidity is controlled is to regulate the relative humidity to between 40 and 50 per cent.

TABLE LXXVI.—WEIGHT PER CUBIC FOOT OF AIR, WATER AND SATURATED MIXTURES OF AIR AND WATER VAPOR AT DIFFERENT TEMPERATURES AND UNDER ORDINARY ATMOSPHERIC PRESSURE OF 29.921 INCHES OF MERCURY.

| Temp. Deg. F. | Weight of the Air in Pounds | Weight of the Vapor in Pounds | Weight of Mixture in Pounds |
|------------------|-----------------------------------|-------------------------------------|-----------------------------------|
| 0 | 0.0863 | 0.00079 | 0.08709 |
| 12 | 0.0840 | 0.000130 | 0.084130 |
| 22 | 0.0821 | 0.000202 | 0.082302 |
| 32 | 0.0802 | 0.000304 | 0.080504 |
| 42 | 0.0784 | 0.000440 | 0.078840 |
| 52 | 0.0766 | 0.000627 | 0.077227 |
| 60 | 0.0751 | 0.000830 | 0.075930 |
| 62 | 0.0747 | 0.000881 | 0.075581 |
| 70 | 0.0731 | 0.001153 | 0.074253 |
| 72 | 0.0727 | 0.001221 | 0.073921 |
| 82 | 0.0706 | 0.001667 | 0.072267 |
| 92 | 0.0684 | 0.002250 | 0.070650 |
| 100 | 0.0664 | 0.002848 | 0.069248 |
| 102 | 0.0659 | 0.002997 | 0.068897 |
| 112 | 0.0631 | 0.003946 | 0.067046 |
| 122 | 0.0599 | 0.005142 | 0.065042 |
| 132 | 0.0564 | 0.006639 | 0.063039 |
| 142 | 0.0524 | 0.008473 | 0.060873 |
| 152 | 0.0477 | 0.010716 | 0.058416 |
| 162 | 0.0423 | 0.013415 | 0.055715 |
| 172 | 0.0360 | 0.016682 | 0.052682 |
| 182 | 0.0288 | 0.020536 | 0.049336 |
| 192 | 0.0205 | 0.025142 | 0.045642 |
| 202 | 0.0109 | 0.030545 | 0.041445 |
| 212 | 0.0000 | 0.036820 | 0.036820 |

Table LXXVI gives the weight per cubic foot of air, water and saturated mixture of air and water vapor at different temperatures, and under the normal atmospheric pressure of 29.921 inches of mercury for temperatures ranging from 0° F. to 212° F. The second column shows how the weight of the dry air in the mixture decreases when the temperature increases. The last column shows how the total weight of the mixture in pounds decreases with the increase in temperature.

The relation of the air temperature and the difference between the wet and dry bulb thermometer readings, as affecting the relative humidity of air, is shown by Fig. 208. The various curves in this figure, labeled 20, 30, 40, 50, 60, 70, 80, and 90, are relative humidity curves of air in per cent of the saturated condition at 30 inches of mercury as the atmospheric pressure. The data shown on this figure were taken from reports of the United States Weather Bureau. The air temperature which is plotted on the left-hand side of the diagram corresponds directly to the temperature of the dry-bulb thermometer. The figure shows graphically how the relative humidity increases with the relative increase of the dry-bulb temperature and the relative increase of the difference between the wet and dry-bulb thermometer readings.

Placing of Food and Ice in Refrigerators.—The National Association of Ice Industries has recently published bulletins in reference to the operation of household refrigerators, in which attention is given to "Where to Place Food in Household Refrigerators" and "How to Use Ice." These bulletins have been extracted as follows:

WHERE TO PLACE FOOD IN THE HOUSEHOLD REFRIGERATOR

The home refrigerator is really the food warehouse of the family, just as the great, clean cold warehouses in the big cities are the refrigerators of the people of the cities, to keep food clean, sound, and wholesome, between the time the refrigerator car brings it from the country and the time that the people are ready to eat it. Just as the house manager must keep some food supplies for the near future, so must the food distributing industry in the cities keep a food supply ahead of food consumption. One is just a magnification of the other.

The big warehouses have great rooms where low temperatures which do not vary the year around, are adapted to the kinds of food to be kept. For instance, eggs are kept at 29° to 31° F., while butter is frozen hard and kept about 5° below zero. All the rooms are very clean.

Just so should we plan for the home refrigerator. The refrigerator should be spic and span. Everything that goes into it should be as clean as possible. This will help in two ways: First by keeping out bacteria, and second, by making the cleaning of the refrigerator a much more simple matter.

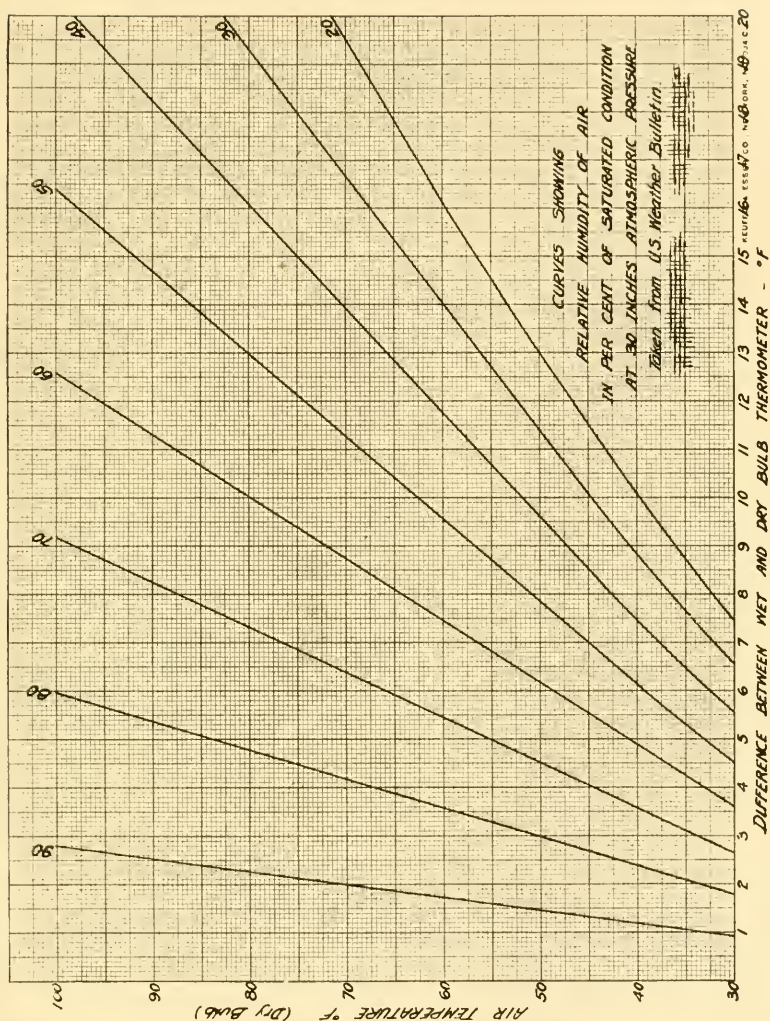


FIG. 208.—RELATIVE HUMIDITY CURVES.

Foods requiring the lowest temperatures obtainable should be placed in the coldest part of the food chamber, while those commodities which do not demand such care may be placed in less cold locations.

Let us consider the placing of food in the refrigerator on this basis. First, look critically at the construction of your refrigerator. Is it an "over-head" or a "top-icer" type? In an "over-head" icer type, the coldest place is in the middle of the top shelf where the cold air drops down from the ice chamber, and the warmest place is on the sides of the lower shelves where the warmed air travels back to the ice chamber. In a refrigerator of the "side-icer" type, the coldest part is in the compartment directly under the ice chamber.

Keep Air Ducts Open.—When food is placed in the household refrigerator, be careful not to shut off the exit of cold air from the ice and the entrance of warm air into the ice chamber. There must be circulation in order to insure a steady supply of clean, dry, cold air. For this reason, leave enough room between containers on the shelves to enable the air to flow freely.

How to Use the "Side-Icer."—Foods that are delicate and absorb odors should be placed directly under the ice chamber where they will be coldest and get fresh, clean cold air. Milk, butter, meat broths, and moist cooked foods such as cereals, custards, and cream sauces come under this head.

Of all the perishable foods going into the refrigerator, milk needs the most intelligent care. It is an ideal medium for bacterial growth at favorable temperatures. Because milk is a food depended upon by young children and invalids, the decomposition of products produced by bacteria should be especially guarded against. Fortunately low temperatures are excellent deterrents to bacterial multiplication and unless the milk freezes—which does not happen until below 28° F., they do not alter it either chemically or physically. Therefore, place the milk in the coldest part of the refrigerator which, as stated before, is just below the cold air down drop. Milk bottles may take some dirt into this most important compartment of the refrigerator. They should be washed, but care must be taken that the cap is not soaked nor water permitted to remain on the cap because if it gets wet, bacteria can easily enter the bottle.

Next to milk, meat broths are probably the most delicate foods to be cared for. They should be placed, while hot, in sterilized containers, covered tightly, and allowed to cool to room temperature, then placed in as cold a location as your refrigerator affords. In fact, all these delicate foods should be placed in sterilized covered containers.

Butter should be placed here for two reasons. First, the temperature tends to hold back rancidity; second, butter absorbs odors

and flavors very readily. Therefore, give it a tight container or hold it in the original package.

Drinking Water.—During warm weather some people want drinking water cold but not iced. Choose clean containers such as quart fruit jars, fill them with water and place them just below the ice chamber. Sometimes spring water is purchased or the water supply must be boiled to make it fit for human consumption. If water must be boiled do so, then put it into sterilized containers, let it cool to room temperature and place the covered jars in the refrigerator just under the ice chamber. This gives a supply of well cooled water.

Desserts.—Jellies, charlottes, and heavy cream desserts go in the coldest compartment until they are set, then if space is scarce they may be transferred to the meat compartment.

Meats.—Uncooked meats should have the next coldest place. Always remove the paper wrapper from the meat when it comes from the market. Paper left on meat sticks, and becomes very difficult to remove, and a slime may develop. Place the meat on a clean dish and put it on the bottom of the food compartment. Cooked meats dry out very quickly, so if you wish to keep them in the best condition, put them in tightly covered containers. Space is valuable in this compartment, so use containers that are relatively high and narrow. Use as few plates as possible. While large pieces of meat, such as roasts and poultry, must be put on plates, many meats such as steaks, chops and meat for stews, may be placed in tall containers that require less room. This applies in general to all parts of the refrigerator. If containers that are as tall as will fit well on the shelves are used, the space in the refrigerator will be utilized to much better advantage.

Fish.—Fish may be kept in the refrigerator safely if it is placed in a tightly covered vessel. The purchase of a white enameled container for this purpose will be a wise one because fish should be a frequent food in the home.

Left-overs.—The question of left-overs is a very important one. They should be placed in the coldest location space permits if they contain cream sauces or custards, or are some delicate vegetable such as asparagus. All others should go in the meat compartment or directly over it. In any case, do not place the left-overs in the refrigerator in the dishes in which they were served at the table. It is hard on the china and also takes up more room than is necessary. Try putting left-overs in the various jars that accumulate in the household from the purchase of mayonnaise and other products, adapting the size of the jar to the quantity to be salvaged. Save these small portions, mix them with originality and imagination, two of the finest

ingredients in the food catalog, and utilize them as attractive dishes for lunch or supper or even another dinner.

Berries and Cherries.—On the shelf above the meat compartment place berries and cherries. They are especially subject to a white mold which causes quick decay. Dry cold air checks the growth of this mold. Do not wash the berries until ready to use them. Put them in a well-ventilated container, such as a wire sieve with the handle removed, or in the original wooden box if clean and dry, but remember not to crowd the berries, for they will resist mold longer if the dry air can circulate freely around them.

Eggs.—On the same shelf place eggs and such fruits and vegetables as do not have a decided odor or flavor. Contrary to the general opinion, eggs do not need the coldest place in the refrigerator. If they are placed on the middle shelf of the food compartment they will keep well.

Vegetables and Fruit.—Try washing lettuce and celery when it comes from the market. Shake it free of water, and then put it in a tightly covered jar. It will keep fresh and crisp for days and does not get broken so readily as when stored in a towel or paper. It also makes a neater appearance in the refrigerator. Try, also, keeping new carrots, fresh peas, string beans, and other succulent vegetables cold until needed for use. Set the bunch of asparagus in a shallow pan of water and give it refrigerator room.

Place all foods with strong odors high up in the food compartment where the air current strikes them just before it returns to the ice chamber. Then the odors will be absorbed by the film of water on the melting ice and pass off with the meltage. Foods such as melons, oranges, peppers, cabbages and apples are on this list. They all dry out readily so do not remove the oiled or tissue paper wrapper that comes on the fruit.

How to Use the "Over-head" Icer.—When the ice in the refrigerator is above the food compartment, the cold air outlet may be a long narrow opening at the back of the ice chamber, or there may be an opening in the middle of this floor through which the cold air is discharged. Generally the warmed air rises along the side walls and passes through ducts or flues into the ice chamber. The path which the air takes shows us where to place the various foods depending upon their susceptibility to the effect of temperature.

Of course the coldest place is just under the cold air drop and the warmest is usually at the extreme edge of the bottom shelf. The top shelf in this type of construction just reverses the "side-icer" rule and is our low temperature location. Each succeeding shelf shows a slight increase in temperature, but, ordinarily, the extremes of high

and low are not so far apart as when ice is placed in the upper side quarter.

With these fundamentals clearly in mind, we readily see that milk, butter and broths and other very delicate products should have the middle portion of the top shelf; meats, fish and the delicate desserts should occupy the middle of the shelf just below, while fresh vegetables and rather resistant foods should be placed on the floor of the refrigerator. Foods with pronounced odors such as cabbage, oranges and apples should be placed near the side walls where the air currents are traveling quickly to the ice chamber. There they discharge their load of heat and odors and the moisture which the expanding air gathers from the food.

Don't forget that the well constructed refrigerator, well filled with ice, maintains an active circulation and so causes some evaporation of moisture. Therefore, heed the advice about keeping the tissue paper wrapping on such fruits as oranges and apples.

Remember too, that the wrapped orange has never been touched by human hands. Good fruit handling demands gloves on all pickers and graders. Just think! Forty-seven per cent of our people are engaged, in one way and another, in the feeding of us all. It is one of the wonders of the modern world—this production and distribution of foods. The home refrigerator is the last link in the long chain necessary for the proper distribution of food.

HOW TO USE ICE.

We are all interested in knowing about the proper use of ice—how to get the most benefits from its use—how to make sure of food and health protection, but how much thought, frankly, have you ever given to the importance of using ice the year round? If yours is the average family, you have given it little thought indeed, because the average family lets the weather decide its use of ice.

The people in the business know that the high-climbing thermometer will always be the greatest ice salesman, but we also know that more and more thoughtful people are using ice every month and day in the year.

Ice is the only certain, sure, positive protector of food's purity—no matter whether the day be New Year's or the Fourth of July. Doctors will tell you this. Domestic science authorities confirm the fact. No cellar, window box or back porch can keep and protect the foods which cost so much more than the few cents of ice needed to keep them properly.

You are taking chances when you try to keep food outside of a well-iced refrigerator. You are exposing it to all manner of dangerous, sickness-breeding bacteria. You are exposing it to dust, grime

and the unevenness of temperatures that never gives real food preservation.

How to Keep Food Properly.—A refrigerator furnishes an even, bacteria-destroying low temperature. The housewife who tries to keep food in any other way is continually risking the family health. Bacteria multiply in all foods when the temperature is above a safe point. Most authorities agree that the dividing line between danger and safety in food temperatures is 50 degrees. Only in a refrigerator will you find the low temperature that precludes danger of contamination, spoilage and germs.

How to Gain Real Economy.—While many housewives grant the fact that food can be kept properly in refrigerators—and in that way alone—they fail to keep their food properly by taking less ice than they need. They let the ice chamber get so low that it is frequently less than half full. Then the refrigerator cannot do its part; it takes ice and plenty of it to obtain proper refrigeration. Also, from the pocketbook standpoint, ice melts rapidly when the supply gets low—more rapidly than when you keep the ice chamber comfortably filled. If you let your refrigerator get warm, it takes much more ice to chill it again than it would to keep it cold. Ice is an article you cannot economize on by skimping.

Simple Rules for Preventing Waste.—Keep the ice chamber of your refrigerator well filled. The ice melts more slowly.

Have the refrigerator large enough. Do not crowd it full of food. It is not the size of the box so much as the quality of food which consumes the ice.

Keep the refrigerator in a cool spot, away from draft.

Close the doors tightly to prevent warm air from seeping in. Open the doors as little as possible.

Don't put any food on the ice or in the ice chamber; leave the ice uncovered.

You may have been told that wrapping your ice in newspapers, cloths or blankets, tends to keep it from melting. This practice is bad, because it prevents the free circulation of air around the ice, and that in turn prevents the purification of the air. The whole surface of the ice is needed to purify the air properly.

Never put hot food in the refrigerator. Let it cool a bit first.

It is a great mistake to have too small a refrigerator for the amount of food in it. There is not room for enough ice. The food is a heating element, and melts the ice faster than the ice can chill the food. Too much crowding of food also obstructs the air circulation so essential to keeping the flavor fresh and appetizing.

Placing the Refrigerator.—Your refrigerator may look stout and tough, but in reality, great care must be taken to see that it is properly placed. Few people realize the importance of this.

Place the refrigerator where it won't overheat or be exposed to moisture, draft or sudden changes of weather.

A porch, even though protected, and a cellar are bad places for it. The best place is in the kitchen near the rear entrance. This may not be as convenient as a little nearer the working section; but it saves the iceman crossing your kitchen. The ideal arrangement, of course, is an outside icer opening on the porch.

Opening and Closing Refrigerator Doors.—One of the quickest ways of spoiling the efficiency of your refrigerator as a preserver of food is to open the doors too often and keep them open too long. Tests have shown that in opening the door the temperature inside rises at least two degrees.

Some housewives open the box every time they want a single article of food, instead of taking out several articles at once which may be needed about the same time.

Refrigerator doors should be kept tightly closed. When not quite shut they leave a crack between the door and its frame and warm air sneeps in or the cold air pours out. Under such conditions, it is impossible to keep the inside cold. It is also bad for the doors. The meeting of warm air on one side and cold on the other develops moisture and that makes the door warp and swell. This "sweating" is especially noticeable on warm, damp days.

Keeping the Refrigerator Clean.—It is very important to keep your refrigerator spotlessly clean. That is literally true. A single drop of spilled milk or of other food can contaminate a refrigerator in a few days. One drop of milk can develop millions of bacteria if the temperature is right for it.

In cleaning a refrigerator use a sponge or soft cloth and clean water. Don't use any sponge or cloth and any water. You do not have to give your refrigerator a weekly hot scald. You can clean it thoroughly with lukewarm or cold water and washing soda, followed by a rinse with clear cold water and then a thorough drying. Hot water heats the wall unnecessarily. Be sure to leave them perfectly dry. Moisture is bad.

A friction powder or steel wool may be used on the ice compartment and drain only. The drain is the most difficult part to clean; use a long handled brush with steel wool packed into it.

To be thoroughly clean a refrigerator should have no cracks or crevices in which dirt or germs can lodge. It is almost impossible to clean them out. In purchasing a new refrigerator, be sure to get one that may be easily and thoroughly cleaned.

CHAPTER XI.

TESTING OF ICE REFRIGERATORS.

Constant Temperature Room.—A constant temperature room is necessary to accurately test the heat leakage of a refrigerator. Electrical thermostats and heaters are of considerable value for tests of this kind. It is easily possible to maintain a room temperature which will vary not more than 1° F.

Fig. 209 shows an arrangement which has proven very satisfactory for a constant temperature room. The electrical heaters are screened so that radiant heat will not pass directly from the heaters to the outside surface of the refrigerator being tested. It is always difficult to measure radiant heat. With high room temperature, the heaters must be on a greater percentage of the time, therefore the heat exchange by radiation would increase greatly unless the heaters are screened. An asbestos curtain is used for this purpose. There is a circulation of air as indicated by the arrows, insuring a uniform temperature in different parts of the constant temperature room.

Fig. 210 shows another arrangement for a constant temperature room using a double wall. The heaters are placed between the walls and the warm air circulates under the floor, over the ceiling and along the walls. This method reduces variation in radiation and convection, due to using the heaters in order to operate at a high room temperature.

In order to obtain accurate results, it is best to use as little electrical heat as possible and yet keep the temperature of the test room constant. In this way the heat losses due

to radiation and abnormal convections are reduced to a minimum.

It is also desirable to control the humidity of the constant temperature room. This factor is not as important on a heat insulation test as with an ice melting test.

Ice Melting Method.—A simple method of measuring the heat leakage is by the ice melting method. The refrigerator

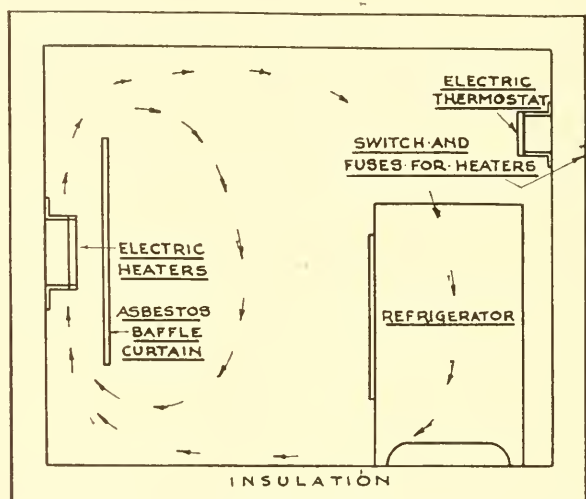


FIG. 209.- CONSTANT TEMPERATURE TESTING ROOMS.

must be in use at least 24 hours in order to have the lining and insulation cooled to about the same temperature as they will be during the test. The author has found that a cabinet insulated with three inches of corkboard required three days to establish a temperature equilibrium in the walls.

A weighed block of ice is then placed in the ice compartment, noting the shape of the block so that on a subsequent test a similar shape can be used. Then after a certain period, say 24 to 48 hours, the ice block is weighed again to detect the amount of ice melted. Suppose the pounds of ice melted per 24 hours to be W . Then the heat leakage for the cabinet H

would be $144 \times W$ in B.t.u. per 24 hours. The heat leakage h , per sq. ft. per degree F. per day would be:

$$\frac{144 \times W}{\text{Sq. ft. mean area} \times (\text{room temp.} - \text{average cabinet temp.})}$$

Temperatures should be taken of the coldest and warmest part of the food compartment. It is very important to have

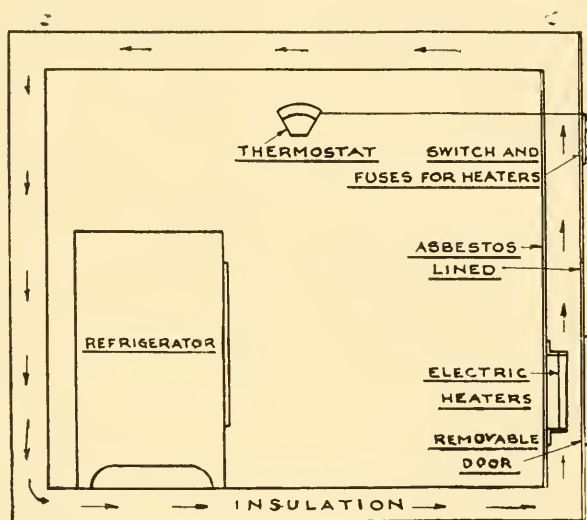


FIG. 210.—CONSTANT TEMPERATURE TESTING ROOMS.

a certain amount of dishes and food on the shelves in making a test if the actual service conditions are desired. Service conditions can be closely duplicated by having plates of potatoes in 10 or 20-pound units. Two or three times a day a certain number of cold units are removed from the cabinet and the same number of warm units (at room temp.) are used to replace them.

Some of the more important variable factors entering into a heat leakage test by ice melting are as follows:

1. Constantly changing weight, surface and form of ice cake.
2. Circulation is affected by size and position of ice cake.
3. The water from the melting ice may assist in cooling cabinet.

The instruments required for a test are thermometers, preferably of the recording type. If regular glass stem mercury thermometers are used, it is advisable to place them in a small flask filled with oil. The flask should have a cork with the thermometer held in place in a small hole through the cork. This eliminates the error of reading a rapidly rising temperature when the door of the cabinet is opened.

Electrical Heater Method.—The electrical heater has advantages over the ice-melting method of testing the heat leakage of a refrigerator cabinet. The circulation is not changed by a different shape of the ice cake, and the rate of heat supply may be kept quite uniform and may be measured accurately even without opening the doors of the cabinet under test.

Suppose an ice test indicates that a cabinet would be used with an average food compartment temperature of 45° F. in a 75° F. room. The temperature differential through the wall is therefore 30° F. To conduct a heat test, say in an 80° F. constant temperature room, a heating element is placed in the cabinet so that it will have the same wall differential temperature of 30° F. Therefore, the food compartment temperature is maintained at 80° F. plus 30° F. or 110° F.

If the electrical heating element requires 20 watts in order to maintain this 30° F. temperature difference through the walls of the cabinet, then the total heat leakage in B.t.u. per 24 hours = $20 \times 24 \times 3.416 = 1640$. (1 watt hour of electrical energy is equivalent to 3.416 B.t.u.)

The heat leakage is usually rated by the number of B.t.u. lost per square foot per degree temperature difference per day. Suppose the average surface of the inside and outside walls to be 20 sq. ft., then

$$\frac{1640}{30 \times 20} = 2.73 \text{ B.t.u. heat leakage per sq. ft. per degree F. per 24 hours.}$$

Sources of Heat Losses in Refrigerators.—The following pertains to a test on an ice refrigerator to determine rate of ice melting due to heat loss of insulation, opening doors, and changing food.

The object of this test was to determine the relative amount of ice melted by the three principal heat losses which occur in an average household refrigerator. These are:

1. Heat transfer through the insulated walls.
2. Opening doors allowing warm air to enter, and cold air to drop out of the refrigerator.
3. Changing food or placing in the refrigerator, food and dishes to be cooled.

The refrigerator was a top icer with panel construction throughout and had the following specifications:

| | Inches Height | Inches Depth | Inches Width |
|------------------------------------|------------------|------------------|------------------|
| Outside Compartment | 60 | 21 | 29 |
| Food Compartment | 28 | 15 $\frac{3}{4}$ | 22 $\frac{1}{2}$ |
| Ice Compartment | 16 $\frac{1}{2}$ | 16 $\frac{1}{2}$ | 20 $\frac{1}{2}$ |
| Food Compartment Door Opening..... | 26 | .. | 20 $\frac{1}{2}$ |
| Ice Compartment Door Opening..... | 14 | .. | 20 $\frac{1}{2}$ |
| Volume Food Compartment | 5.7 cubic feet | | |
| Volume Ice Compartment | 3.2 cubic feet | | |
| Total Inside Surface | 28.9 square feet | | |
| Total Outside Surface | 40.0 square feet | | |

The insulation consisted of the following:

1. Oak case.
2. $\frac{1}{2}$ -inch mineral wool.
3. 2 air spaces.
4. Layers insulating paper.
5. $\frac{3}{8}$ -inch spruce wall.
6. Porcelain on steel lining.

The rated ice capacity of the refrigerator was 120 pounds and the net weight of the refrigerator was 280 pounds. The flue opening was 1 $\frac{1}{8}$ inches wide on both sides of the ice compartment and extended the total depth of the compartment. There was a 2-inch air space under the ice shelf.

The test was conducted in a constant temperature room. The room had double walls on all six sides. The effect of heat transfer by radiation from the electric heaters used to maintain a constant temperature was eliminated by placing the heaters between the double walls of the room. The operation of these heaters was controlled by a thermostat. The humidity of the room was controlled by an electric humidostat.

It was found necessary to maintain constant condition of temperature and humidity for several days before an accurate

reading could be obtained of the amount of ice melted for each particular test condition.

Throughout the entire test, the room temperature was maintained at 75° F., while the relative humidity was maintained at 40 per cent. The quantity of ice, as well as the ice surface exposed, was kept as nearly uniform as possible throughout the test.

The refrigerator was first operated without any food changes or door opening process. The food compartment was empty so that the heat losses were due entirely to the heat transfer through the insulation of the cabinet. Of course, a very small percentage of this heat loss was caused by cooling and dehumidifying warm air which leaked into the cabinet, replacing cold drier air which leaked out, and a small loss due to heat transfer by radiation which could not easily be measured.

The food change test was then conducted, the food which, in this case, was potatoes, being changed three times each day. The potatoes were removed at the temperature of the food compartment, while the potatoes placed in the box at each change were at room temperature. The food change consisted of removing a china plate weighing 2.4 pounds holding 8.6 pounds of potatoes, and then placing a similar quantity of plate and potatoes in the food compartment.

Finally, a door opening test was conducted in conjunction with the food changing test. This approximated the average household service condition, indicating the difference between a laboratory test and actual household service conditions.

During this test, the relative humidity of the room was maintained at 40 per cent, while the relative humidity in the lower part of the food compartment of the refrigerator varied from 62 to 68 per cent.

The results of the ice-making tests indicated that 93 per cent of the ice was melted, due to heat transmitted through the insulation, 4 per cent was required for cooling the food at the rate of 33 pounds per day, and that 3 per cent was lost in the opening of the doors which occupied one minute per hour, or a total of ten minutes during the test. These losses are shown graphically by Fig. 211. The foregoing data, to-

gether with Fig. 211, illustrate the great importance of having a refrigerator efficiently insulated.

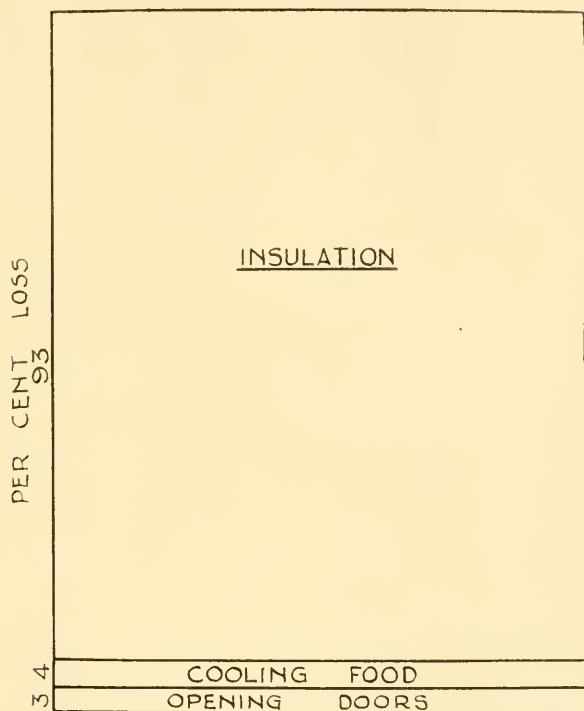


FIG. 211.—COMPARISON OF REFRIGERATOR HEAT LOSSES.

Effect of Room Humidity.—The following test was on an ice refrigerator to determine the effect of room humidity on the rate of ice melting. The refrigerator used in this experiment was the top icer described in the previous report. The test was conducted in a constant temperature room in which the humidity could be regulated and controlled very closely. The room temperature was maintained at 75° F. during the entire test which lasted 22 days.

During this test the food storage space in the refrigerator contained only a recording thermometer and a recording humidostat. The quantity of ice as well as the amount of ice surface was maintained as nearly constant as possible. The

following results were obtained with two different conditions of room humidity:

| Room Temperature Degrees F. | Per cent Relative Humidity | | Ice melted per day, pounds |
|--------------------------------|----------------------------|------|----------------------------------|
| | Food Compartment | Room | |
| 75 | 65 | 40 | 17.75 |
| 75 | 65 | 75 | 22.56 |

This test shows that the rate of ice melting was increased about 27 per cent, simply by changing the relative humidity of a 75 degree room from 40 to 75 per cent. This difference would be greater in actual service conditions as the doors are opened more frequently and sometimes not closed tightly, thus greatly increasing the amount of air leakage.

It is therefore very important in refrigerator tests to know the relative humidity both of the air inside the refrigerator and of the room in which the refrigerator is located.

Room or refrigerator environment air is constantly leaking into the upper part of a refrigerator, replacing the cold air leaking out of the lower part. This warm air circulates and is cooled to the food compartment temperature by coming in close contact with the ice or cooling element. Heat must be absorbed, either by melting ice or evaporating the liquid refrigerant, to counteract the following heat losses:

Heat losses due to air leakage or refrigerator ventilation.

1. To cool incoming dry air.
2. To cool moisture of incoming air.
3. To condense part of moisture of incoming air.
4. To freeze the condensed moisture. In a mechanical refrigerator the surface temperature of the cooling element is usually below 32° F.
5. To cool the frozen moisture.

It is then readily understood that with a nearly constant supply of warm room air entering the refrigerator, it will require more heat to cool and dehumidify to the same dryness the 75 per cent humidity air than it would to cool and dehumidify the 40 per cent humidity air.

Humidity Diagram for Room and Refrigerator.—Fig. 212 shows the relation between room and food compartment humidities. This test was made in a constant temperature room held at 86° F.

The mechanical refrigerator maintained a temperature of 42° F. in the lower and 50° F. at the top of the food compart-

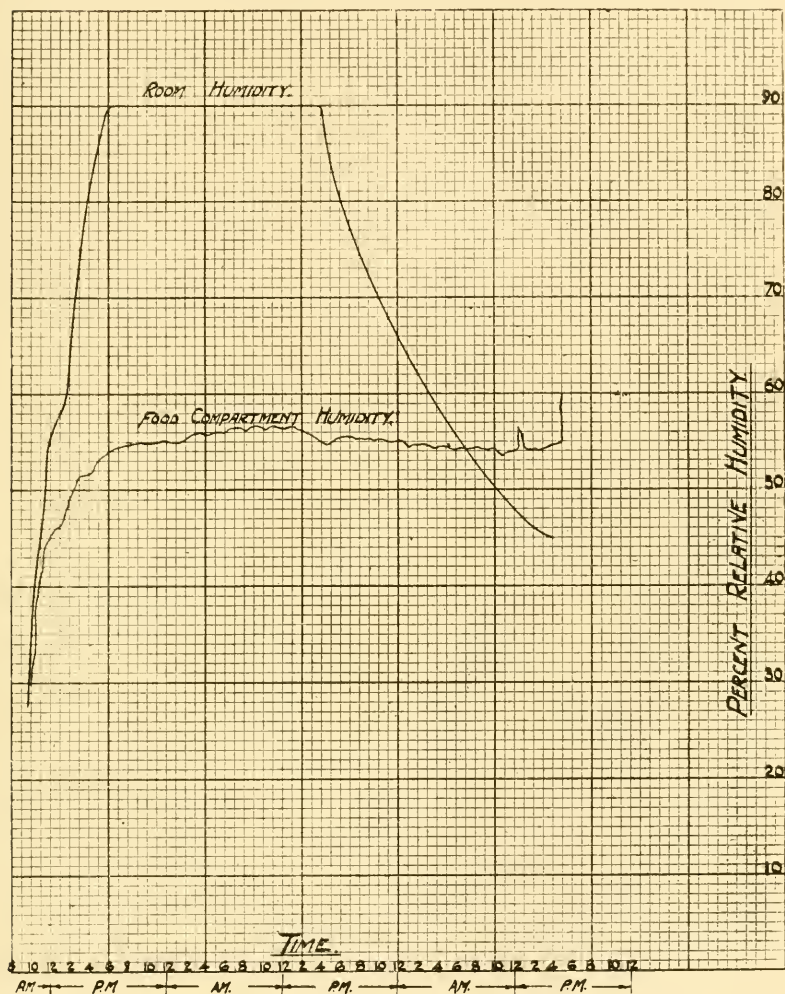


FIG. 212.—RELATIVE HUMIDITY IN REFRIGERATOR.

ment. The refrigerator contained only the recording instruments. The average brine tank temperature was 20° F.

The test was started with a warm refrigerator so that the temperature and humidity of both room and food compartment were equalized.

Calorimeter Testing.—There is a great difference of opinion as to the proper method of determining the exact or comparative rating of household and small commercial compressor units.

From tests compiled by various manufacturers of household machines, the simplest and by far the most practical for every day usage, was found to be actual measurement by volume of the refrigerant circulated, usually in a calibrated drum with sight glass, located directly under the condenser. By using the pressure on this drum at the beginning and end of the test, the mean pressure is obtained for determining the exact density of the liquid from authoritative tables on refrigerants.

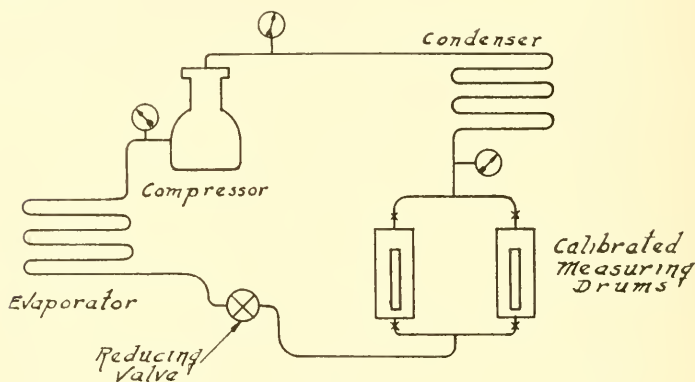


FIG. 213.

After the actual pounds of refrigerant circulated has been found, the net available B.t.u. per pound of refrigerant can be determined from the table. This value multiplied by the pounds circulated gives the total B.t.u. of refrigerating work done in the evaporator.

As numerous tests have demonstrated, superheating of the suction gas to the compressor has very little effect on compressor capacity under normal operating conditions, so that the volume of gas per pound of liquid can be obtained from the refrigerant table for the suction pressure noted near the compressor. This volume per pound multiplied by the pounds circulated will give the volume of gas handled by the compressor.

If the volume of gas handled by the compressor is divided by the piston displacement of the compressor for the same interval of time, the actual efficiency of the compressor is obtained. It has been found that the error between this determination method and the use of a calorimeter or B.t.u. measurement box around the evaporator is practically negligible, and is much simpler.

As a general rule, the determination which is most desired by all users of refrigeration is how much power must be paid for at the end of each month for holding the refrigerator at a temperature which best conserves food. The problem then becomes, how many kilowatts or their equivalent B.t.u.s must be paid for in power consumption for a definite number of B.t.u.s actually abstracted from the refrigerator?

If a unit B.t.u. per hour abstraction is used as a basis, the machine requiring the minimum B.t.u. input for this work would be the most efficient overall, which, in the end, is the determining factor, provided the machines rate equal mechanically in construction. This value has been given the name "Performance Factor" and from the consumer's viewpoint is the most important, if other considerations such as appearance, size, arrangement, ice cubes, etc., are basically equal. A unit of comparison sometimes used is B.t.u. per Watt hour.

From the manufacturer's standpoint, however, the problem is somewhat different, as it is the individual parts and their efficiencies which affect him, so that each piece of equipment, compressor, evaporator, condenser or motor must be brought up to its maximum efficiency, which in turn will automatically take care of the overall efficiency or "Performance Factor."

Looking at it from this angle the testing must include such factors as discharge pressure, compressor r.p.m. and size, size and type evaporator, size condenser and quantity of air to be blown over it, type drive, type motor and size, arrangement of parts, noise, vibration, lubrication, control, type suction and discharge valves, kind of refrigerant, etc.

Tests are subject to a great many variations which cause duplication of determined data to often be a difficult problem. In tests on a refrigerator load some of the variables that occur

would be: door leakage, air circulation, insulation efficiency, cooling chamber shape and size, location of cooling unit with its shape, size and arrangement, and the important factor of frost accumulation.

As one or more of these variables are always present, test results are subject to numerous interpretations, consequently the least possible number of variation factors that can be included in a test, the more correct will be the analyzed results.

If comparative tests are to be run, the factors entering into the results need only be considered and held the same for all tests and the resultant values will give a true comparison.

When running a comparative test on various makes of equipment and boxes, it is assumed that each manufacturer has made each part of his apparatus as efficient as he knows how, commensurate with cost, consequently the "Performance Factor" test appears to be the most logical and at the same time, the most acceptable method of true accomplishment.

A comparative method for determining compressor efficiency and at the same time, a very simple one, is the so called "Pump up" test. By using the same receiver on the discharge side of the compressor, and finding the interval of time necessary to pump a pressure of, say, 75 pounds on the receiver, a quick and comparatively accurate comparison is obtained on compressors of the same bore, stroke and r.p.m.

This method can be carried somewhat further and by reducing the volume of 75 pounds compressed air to 0 pounds or atmospheric intake pressure, assuming the temperature to remain the same, the volumetric efficiency of the compressor can be found by dividing this volume by the actual piston displacement for the "Pump up" time interval.

Another method for obtaining approximate compressor efficiencies, is by means of metering the discharge of air through an air meter for atmospheric intake and varying discharge pressures, using compression ratios for conversion into an equivalent amount of refrigerant gas.

A suggestion for standard conditions of testing for all makes of household refrigerating equipment would be the

power consumption of the motor, where an average temperature of 45° is maintained in the food compartment with 80° average outside air temperature. Another test should be made with an average outside temperature of 100° .

Earlier Research on Refrigeration in the Home.—Research on refrigeration in the home was carried out by John R. Williams, M. D., to obtain data in order to present a paper before the Third International Congress of Refrigeration, on the subject of "A Study of Refrigeration in the Home and the Efficiency of Household Refrigerators."

Dr. Williams has obtained some interesting information in reference to the construction of household refrigerators in actual use, the temperatures prevailing in the rooms and in the refrigerators, the relative amounts of ice used, etc. Dr. Williams' paper was as follows:

A STUDY OF REFRIGERATION IN THE HOME, AND THE EFFICIENCY OF HOUSEHOLD REFRIGERATORS.

The problem of preserving fresh food from decomposition is one which every household is called upon to solve. The cheapest, most efficient, and most available agency for this purpose is refrigeration or storage at low temperature. In the home the pantry, cellar or an ice-box is depended upon to furnish the low temperature required for proper food preservation.

There is scientific as well as practical basis for this use of cold. It has been demonstrated by laboratory experts that bacteria, which are the cause of food decomposition, are markedly retarded in their growth by temperature below 45° F., and that temperatures between 45° and 50° inhibit to a slightly less extent the propagation of these organisms. Above 50° F. bacteria multiply prolifically. This means that foods favorable for the growth of bacteria, as milk, meat, etc., undergo very slight decomposition when kept at temperatures ranging below 50° F., but above that temperature they spoil very rapidly. It follows, therefore that a box or room for the storage of perishable foods, to be at all efficient, must have a temperature not in excess of 50° F., preferably below 45° F.

Even the most favored cities in the United States, in the matter of climate, have periods of from 5 to 7 months when the temperature averages above 50° F. Thus the northern city of Rochester for more than six months of the year has a mean monthly temperature above 50° , as will be seen by the following tabulation, showing the mean monthly temperature of Rochester, N. Y., from 1872 to 1911, inclusive, for the warm months of the year:

HOUSEHOLD REFRIGERATION

| | Degrees F. | | Degrees F. |
|------------|------------|-----------------|------------|
| May | 56.7 | August | 68.9 |
| June | 66.2 | September | 62.8 |
| July | 70.9 | October | 50.0 |

During these warm months, artificial means must or should be employed to protect fresh foods from decomposition. House temperatures, even in the cellar, are rarely much lower than those of the outside air. The mean temperature for the month of August, 1912, was 68.9°, while the average temperature of 266 cellar bottoms was 63° F. The importance of these facts will be better appreciated when it is understood that nearly half of the homes in Rochester rely upon the cellar for the protection of their perishable foods. In an investigation of more than 5,450 homes, it was discovered that 2,450 families do without ice the year round and depend upon the cellar or pantry to afford the proper temperature conditions for food preservation. Yet in the study of cellar temperatures in several hundred homes not one was found having a temperature below 55° F. Pantries and kitchens were observed to be even warmer, for not one of either was found having a temperature below 60° F. The obvious conclusion from this investigation is that every home should have artificial means of refrigeration.

As has just been indicated, about 55 per cent of the homes in Rochester use ice during a part of the year, and most of these homes are provided with some kind of an ice box. The endeavor was made to determine how efficient are these refrigerators, and also to learn with some accuracy to what extent ice is used, its cost, etc. Investigation of the problem was undertaken in various sections of the city, each differing from the others in social or economic conditions. These distinctions are indicated in the accompanying tables. Upwards of 100 homes in each district were studied in the following manner:

A trained investigator, equipped with a set of accurate and delicate thermometers and other measuring devices, visited the homes and made the observations. Cellar temperatures were taken approximately twelve inches from the cellar bottom; refrigerator temperatures were taken in the food chamber. Each temperature observation lasted at least fifteen minutes. In making the test the refrigerator door was opened, the instrument placed inside, and the door closed as quickly as possible. When a box was low in ice, or when conditions were discovered which affected the validity of the test, another observation was made on the following day or the questionable data was rejected.

In this study of ice boxes, a large number were examined and the data from 300 accepted as trustworthy. Of these, only 123 had temperatures below 50° F., the other 177 registered above that temperature and were therefore worthless for preserving food.

The main reason for the inefficiency of these refrigerators is to be found in their defective construction and insulation. Most of them are wooden boxes built of half inch lumber, and are lined with tin, galvanized iron, or zinc. The walls vary in thickness from less than two inches to more than four inches. The space between the metal lining and the wooden sides is supposed to contain some insulating material, as felt, mineral wool, vegetable fibre, or some preparation of cork. In many of them nothing more is to be found than a sheet or two of paper. Since the efficiency of a refrigerator depends in large part on the character and thickness of the insulating material, consideration must be given to these factors.

It has been proven both experimentally and practically that confined air is the best insulator. The property of retarding or resisting the transmission of heat by an insulating agent rests largely in the fact that air is incarcerated within its fibers or cells. The more completely the air is confined, the more efficient is the insulation. An insulating agent, to be of value, must not permit of the circulation of air, nor must it absorb moisture. Moisture and air currents are fatal enemies to good insulation. A refrigerator wall which contains a space large enough to permit of air circulation, will be found defective because the air then carries the heat by convection. Wood, felt, mineral wool, charcoal, sawdust, etc., are fairly efficient when they are dry, but as soon as they absorb moisture, as most of them do, their efficiency markedly declines. When there is inferior or inadequate insulation in the wall of the refrigerator, the heat percolates through, warms the air next to the metal lining and thus favors the condensation of moisture on the metal within the wall. The poorer the insulation, the greater is the precipitation of moisture. This dampness not only serves to corrode the metal lining, but also becomes the medium for the growth of germs and filth. If the insulation has the property of absorbing moisture, as have most of the cheap insulating agents, this water of condensation is soaked up and the efficiency of the insulation is correspondingly lowered. Furthermore, this absorbed moisture serves to warp and rot the wood casing, with the result that doors become ill fitting, permitting warm air to leak into the box, still further lowering the efficiency of the refrigerator, besides uselessly melting the ice. Some manufacturers avoid the corrosion of the metal lining by the use of glass, tile, or vitreous enameled metal. The manufacturers of shoddy boxes are imitating these by coating the cheap metal linings with white paint. Such refrigerators usually have little or no insulation, and are worthless for food protection.

The conditions just described were commonly noted in the examination of refrigerators, particularly in the cheap boxes found in the homes of working people. Many were discovered where the door could not be closed tightly. The effect of these evils is evidenced in

Tables LXXVII and LXXVIII. The average temperature inside of the food chamber in practically all of the cheap boxes was above 50° F., and the lowest temperatures noted, taken usually soon after icing and under the most favorable conditions, were not low enough to be of dependable value. A properly constructed and operated ice box, with reasonable ice consumption, should constantly maintain a difference of at least 25 degrees between the temperature of the food chamber and that of the outside air when the latter is 70° F. or thereabout. As the outside temperature goes down, this difference will diminish. A box which will not maintain an average difference of more than 20 degrees is not much good, and those with even smaller differences.

TABLE LXXVII.—SHOWING TEMPERATURE OF REFRIGERATORS, LIVING ROOMS AND CELLARS DURING MONTH OF AUGUST, 1912.
ROCHESTER, N. Y.

| Section | Refrigerators | | | Living Rooms | | | Cellars | | | |
|--------------------------|---------------|------------|------------|--------------|-----------|------------|-----------|-----------|-----------|-----------|
| | Below 45° | 45° to 50° | 51° to 60° | Above 60° | Below 60° | 60° to 70° | Above 70° | Below 55° | Below 60° | Above 60° |
| Well-to-do American | 29 | 43 | 62 | 4 | 0 | 64 | 61 | 0 | 6 | 78 |
| American laboring | 3 | 17 | 19 | 10 | 0 | 24 | 21 | 0 | 22 | 31 |
| Jewish laboring | 9 | 20 | 47 | 8 | 0 | 28 | 63 | 0 | 0 | 75 |
| German-American laboring | 1 | 0 | 49 | 2 | 0 | 4 | 18 | 0 | 4 | 29 |
| Italian laboring | 0 | 1 | 6 | 0 | 0 | 0 | 7 | 0 | 0 | 10 |
| Totals | 42 | 81 | 153 | 24 | 0 | 120 | 170 | 0 | 32 | 253 |

Since the writer undertook to study the problem of home refrigeration, he has been deluged with inquiries as to the best makes of ice boxes and how it can be determined whether or not a given box is a good one. The answer is neither easy nor simple because the problem deals with the combined complexities of economies and the physics of refrigeration. It seems worth while, however, to discuss simply and briefly the technical questions involved.

The amount of money a family can afford to pay for a refrigerator or for proper insulation depends largely upon the cost of ice. If ice can be procured for nothing, then there is little need to pay much to prevent it from wasting. If, however, it is costly, then it will be found economical to pay for good refrigerator construction. The average retail price of ice in Rochester is \$8.50 per ton, and this will be used as a basis of calculation in the following discussion. Next in order of importance to the cost of ice, is the cost and efficiency of the insulating agent used in the wall of the box. The purpose of the insulation is to prevent the passage of heat from the outside to

the inside of the box. As said before, the chief value of an insulator depends upon the amount of air entrapped within its cellular structure, and upon its freedom from moisture. If an insulator disintegrates so as to lose its cellular character or air spaces, its efficiency correspondingly declines. If it becomes wet, its value is almost cut in two. In the study of an ideal refrigerator for the home, two factors must be seriously considered, the cost of ice and the cost and efficiency of insulation.

TABLE LXXVIII.—SHOWING THE COMPARATIVE TEMPERATURE OF DIFFERENT MAKES OF REFRIGERATORS IN USE IN ROCHESTER, N. Y., AUGUST, 1912.

| Total Boxes Examined | Average Temperature Inside Box, Deg. F. | Average Temperature Outside Box. | Average Difference, Deg. F. | Grade of Box | Insulation. |
|----------------------|---|----------------------------------|-----------------------------|--------------|--|
| 39 | 48.4 | 70.9 | 22.5 | Best | 1½-in. mineral wool, 1½-in. flax and paper, 3-in. board. |
| 9 | 46.3 | 69.0 | 22.7 | Best | 1-in. mineral wool, 3-⅞-in. boards, ½-in. felt. |
| 7 | 45.5 | 69.1 | 23.6 | Best | 1-in. vegetable fiber, 2-⅞-in. boards, felt sheathing. |
| 6 | 47.6 | 69.7 | 22.1 | Best | 1½-in. board, ¼-in. vegetable fiber. |
| 7 | 52.2 | 69.7 | 17.5 | Medium | |
| 13 | 51.7 | 70.4 | 18.7 | Medium | |
| 13 | 52.7 | 72.3 | 19.6 | Medium | |
| 11 | 54.5 | 73.6 | 19.1 | Medium | Paper, 2-⅞-in. boards. |
| 21 | 53.7 | 73.1 | 19.4 | Cheap | Paper, air space, ⅞-in. boards. |
| 6 | 54.9 | 70.0 | 15.1 | Cheap | Paper, and board. |
| 8 | 52.6 | 73.8 | 21.2 | Cheap | Paper, and board. Air space. |
| 9 | 52.2 | 68.9 | 16.7 | Cheap | Paper, air space. |
| 6 | 57.0 | 74.4 | 17.4 | Cheap | Paper, air space. |
| 7 | 56.6 | 71.5 | 14.9 | Cheap | Paper, air space. |
| 7 | 50.9 | 66.5 | 15.6 | Cheap | Home-made boxes, built-in boxes and those unnamed. |
| 22 | 51.0 | 71.3 | 20.3 | Mixed | |
| 104 | 53.3 | 71.3 | 18. | Mixed | Miscellaneous boxes, more than 70 different makes. |

The average working man who uses a refrigerator spends between \$5.00 and \$10.00 for the ice he uses during the four or five warm months of the year. See Table LXXIX showing the amount spent for ice by various classes of people. Well-to-do families spend between \$15.00 and \$40.00 a year for ice. The cost to families in moderate circumstances varies between these extremes.

Refrigerators in the homes of working people cost, at retail, between \$10.00 and \$20.00. In the homes of those in better circumstances, ice boxes costing from \$25.00 to \$150.00 are to be found. Most of the low-priced boxes are built more with regard to appear-

ance than efficiency. The majority of them contain practically no insulation. It is not within the province of this paper, nor has the writer the qualifications which would enable him to intelligently discuss the cost of making refrigerators, but it is within the scope of this discussion to consider the economic value to the consumer of improving the quality of the boxes now in use.

TABLE LXXIX.—SHOWING PRICE PAID FOR ICE PER YEAR.
DATA FROM 321 FAMILIES.

| Section | Under \$5.00 | \$5.00 to \$10.00 | \$10 to \$15.00 | \$15 to \$20.00 | \$20.00 and over |
|--------------------------------|-----------------|----------------------|--------------------|--------------------|---------------------|
| Well-to-do | 6 | 36 | 33 | 13 | 34 |
| American laboring | 34 | 16 | 5 | 1 | 4 |
| Jewish laboring | 22 | 72 | 10 | 6 | 1 |
| German-American laboring | 8 | 14 | 1 | 1 | 0 |
| Italian laboring | 4 | 0 | 0 | 0 | 0 |
| Total | 74 | 138 | 49 | 21 | 39 |

NOTE: By this table it will be seen that working people spend from less than \$5.00 to \$10.00 or more for ice in the four or five months of the year in which they use it. Those in better circumstances spend correspondingly more. At least 60 per cent of this money is wasted and lost in the inefficient and uneconomical refrigerators in use. Were this loss applied to the purchase of a good ice box, these families in a short time would have adequate and economical refrigeration, in place of the present wasteful and unsanitary methods.

This point can best be illustrated by considering a specific example. In Table LXXX is shown the relation between the amount of insulation, ice consumption, and cost of operation. The refrigerator is of medium size (42x30x18), of good make, and, as ice boxes go, is well insulated. It retails for about \$20.00, more or less, depending upon the trimmings. To be efficient, this box should maintain a fairly constant temperature of 45° F. within the food chamber. To do this, it must maintain an average difference of 20 degrees temperature between the inside and outside of the box. To overcome the heat radiation from a box of this size, and with the kind of insulation within its walls, it would require an ice meltage of approximately 158 pounds per week, or 3,400 for the five warm months. This ice would cost the consumer, at current prices, \$14.45.

If one inch of high grade insulation were added to the walls (corkboard is used as an illustration and is the basis of calculation), it would reduce the quantity of ice necessary to maintain this temperature difference to 90 pounds weekly, or 1,950 pounds for the summer. This would mean a saving of 1,450 pounds in ice and \$6.15 in cost of operation. This added insulation would increase the initial cost of the ice box about \$3.50, but it would pay for itself in about three months.

If two inches of corkboard were added to the insulation in box No. 1, the weekly ice meltage to overcome the radiation would amount

to but 65 pounds, or 1,370 pounds for the summer. This would mean a saving of about one ton of ice during the summer and would reduce the ice bill \$8.65. To get this increased efficiency would add approximately \$5.80 to the initial cost of refrigerator. Obviously, a good refrigerator will pay for itself in the ice it saves in three or four years.

TABLE LXXX.—SHOWING HOW THE EFFICIENCY OF A REFRIGERATOR MAY BE INCREASED, THE COST OF OPERATION REDUCED AND THE SAVING TO THE CONSUMER BY ADDING MORE INSULATION.

| Box No. | Insulation | Heat Transmission Factor Per Sq. Ft. Wall Surface, B.t.u. | Ice Meltage for 150 Days to Maintain Temperature Difference of 20° F. | Ice Meltage Per Week. | Cost of Ice for 150 Days at \$8.50 Per Ton. | Cost of Added Insulation. | Ice Saved by Added Insulation. | Money Saved by Less Ice Consumption. |
|---------|--|---|---|-----------------------|---|---------------------------|--------------------------------|--------------------------------------|
| 1 | 2-7/8-in. boards, 2 sheets water-proof paper, 1-in. mineral wool | 4.60 | 3,400 lbs. | 158 lbs. | \$14.45 | | | |
| 2 | Insulation of box No. 1, plus 1-inch corkboard..... | 2.64 | 1,950 | 90 | 8.30 | \$3.50 | 1,450 | \$6.15 |
| 3 | Insulation of box No. 1, plus 2-inch corkboard..... | 1.85 | 1,370 | 65 | 5.80 | 5.80 | 2,030 | 8.65 |

NOTE: Were the refrigerators in Rochester brought up to a state of efficiency they would save in lower ice bills to the consumer at least \$350,000 yearly.

Conclusions: Neither the cellar nor pantry in the home are sufficiently cold to keep perishable foods from spoiling during the warm months of the year; therefore, every home should have a good refrigerator.

Only about half the homes in the city have refrigerators; the other half are compelled to depend upon the inadequate protection afforded by the cellar.

The majority of domestic refrigerators are inefficient because they consume too much ice and do not maintain a temperature low enough to prevent food from spoiling.

The chief explanation of their inefficiency is to be found in the lack of sufficient and proper insulation.

There are a large number of shoddy refrigerators on the market which contain no other insulation than a sheet or two of paper. They are sold chiefly to working people who can ill afford to use them, because they are both unsanitary and grossly uneconomical in the consumption of ice.

The waste from ice meltage because of improper insulation of refrigerators in Rochester homes (population of city, 230,000) amounts to 60,000 tons yearly, or about \$350,000.

At least \$100,000 more is wasted yearly in the present competitive system of delivery.

Unnecessary waste is now making refrigeration cost consumers from three to five times as much as it should.

There are certain simple directions which will be of assistance in selecting a refrigerator. If they are observed, the purchaser can at least avoid being defrauded.

One should insist upon seeing a section of the wall of the refrigerator which he contemplates buying. Honest manufacturers are always willing to let customers know the character of their wares.

Do not buy a box which does not bear the name and address of the maker, nor one sold only under the name of a retail dealer. If the manufacturer is ashamed to acknowledge his handiwork, you are justified in suspecting fraud.

TABLE LXXXI.—SHOWING THICKNESS OF WALLS OF REFRIGERATORS.

| Section | Less than 2 in. | 2 in. to 2½ in. , | 2½ in. to 2¾ in. inclusive | 3 in. or more. |
|------------------------------|-----------------|-------------------|-------------------------------|----------------|
| Well-to-do | 5 | 36 | 34 | 19 |
| American laboring | 9 | 23 | 4 | 3 |
| Jewish laboring | 17 | 42 | 8 | 1 |
| German-American laboring.... | 4 | 13 | 3 | 1 |
| Italian laboring | 0 | 0 | 0 | 0 |
| Totals | 35 | 114 | 49 | 24 |

Do not buy a box which contains less than three inches of good insulation, not including the wooden cases or the metal or tile lining.

Beware of impossible "vacuum," doubtful "dead air space," and no-good paper insulation.

Money invested in insulation will be returned many times in the saving of ice bills. Added insulation means not only economy in ice consumption, but also lower temperature in the refrigerator and the less spoiling of food.

A refrigerator is of little value which will not operate with reasonable care and ice consumption at 45° F. during the summer months.

There is a big field for the manufacturer who will put on the market an efficient ice box which can be sold at a price within the means of people in moderate circumstances.

Not one cellar was found cold enough to prevent the rapid decomposition of milk and meat. Living rooms were found to be even worse, therefore refrigerators are really a necessity. Only forty-two refrigerators of 300 examined were found as cold as they should be, while 177 of them were above 50° F., at which temperature they are of little value.

TABLE LXXXII.—SHOWING A NUMBER OF HOMES USING VARIOUS AMOUNTS OF ICE WEEKLY.

| Section | 50 lbs. or less | 75 lbs. | 100 lbs. | 200 lbs. | 201 to 300 lbs. | 301 lbs. | plus Total |
|--------------------------------|--------------------|---------|----------|----------|--------------------|----------|---------------|
| Well-to-do | 0 | 3 | 24 | 79 | 28 | 15 | 149 |
| American laboring | 11 | 16 | 18 | 32 | 3 | 4 | 84 |
| Jewish laboring | 5 | 18 | 8 | 26 | 3 | 0 | 60 |
| German-American laboring | 3 | 5 | 10 | 19 | 0 | 0 | 37 |
| Italian laboring | 4 | 0 | 0 | 5 | 0 | 0 | 9 |
| Totals | 23 | 42 | 60 | 161 | 34 | 19 | 339 |

A good refrigerator should maintain an average inside temperature of not higher than 45° F., because food spoils rapidly at 50° F. This means a temperature difference of from 20° to 30° during the summer. A box which will not average 20° difference for the five warm months, with a reasonable consumption of ice, is no good. All of the better class of refrigerators use some efficient insulation. None of them use enough. The poorer makes use little or none, excepting a sheet or two of paper. Some manufacturers attempt to obtain cheap insulation by creating small air chambers of paper and wood, which they call "dead air space," a physical and practical impossibility in refrigerator construction. Such boxes are usually worthless.

A properly constructed ice box, to be economically operated, should have a wall of efficient insulating material at least six inches thick. Such a box at the current prices of ice, will have a theoretical efficiency of about 80 per cent. The 149 refrigerators whose wall thickness is less than 2¼ inches, even were they made of the best possible construction, could not have an efficiency above 40 per cent. The remaining seventy-eight refrigerators with walls averaging less than three inches, could not have an efficiency of above 50 per cent. As a matter of fact, with the shoddy and imperfect insulating materials used, most of the ice boxes in common use rate far below their theoretical efficiency.

It is interesting to note that Italian working people use very little ice. It was observed that they avoid very largely the use of perishable foods requiring refrigeration in the home. Thus, condensed milk is used largely in place of fresh milk and preserved meat in place of fresh meat. Jewish people use much milk and therefore much ice.

HOUSEHOLD REFRIGERATION

Unfortunately these people get the benefit of not much more than 20 to 30 per cent of the ice they buy because of the defective ice boxes. There are about 55,000 families in Rochester. They use approximately 100,000 tons of ice yearly in their homes. Beyond all question more than 60,000 tons of this ice is wasted, entailing a loss to these consumers of at least \$350,000.

TABLE LXXXIII.—SHOWING NUMBER OF MONTHS ICE IS USED DURING YEAR BY HOMES IN VARIOUS SECTIONS OF ROCHESTER.

| Section | 1 mo. | 2 mo. | 3 mo. | 4 mo. | 5 mo. | 6 mo. | 7 mo. | 8 mo. | 9 to 12 mos. |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|--------------|
| Well-to-do | 0 | 2 | 5 | 15 | 22 | 24 | 15 | 8 | 33 |
| American laboring | 1 | 6 | 10 | 14 | 21 | 3 | 4 | 4 | 3 |
| Jewish laboring | 0 | 4 | 16 | 26 | 47 | 15 | 5 | 1 | 1 |
| German-American laboring | 1 | 1 | 4 | 8 | 15 | 0 | 0 | 0 | 1 |
| Italian laboring | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 2 | 13 | 37 | 63 | 105 | 42 | 24 | 13 | 38 |

NOTE:—This table shows, among other things, the seasonal character of the use of ice. This adds greatly to the cost of distribution, because it necessitates a large investment in equipment, most of which is idle during one-half of the year.

There is a different dealer for each five to fifteen consumers on every street in Rochester, a tremendously wasteful and uneconomical method of distribution. If an economical system of distribution were to replace the present method, a saving could be made to the consumer of at least \$1.00 per ton or \$100,000 yearly for the whole city.

TABLE LXXXIV.—SHOWING THE OVERLAPPING OF ROUTES OF DEALERS IN THE DISTRIBUTION OF ICE.

| Street | Number of consumers | Number of dealers supplying consumers |
|-----------------|---------------------|---------------------------------------|
| Dartmouth | 39 | 5 |
| Baden | 48 | 8 |
| Frank | 17 | 7 |
| Kenwood | 47 | 6 |
| Adams | 21 | 7 |
| Oxford | 25 | 3 |

Table LXXXV gives a summary of the data on weekly amounts of ice, cost of ice per year and relative temperatures. From the "Study of Refrigeration in the Home and the Efficiency of Household Refrigerators," by John R. Williams.

TABLE LXXXV.—DATA FROM STUDY OF HOUSEHOLD REFRIGERATORS
IN ROCHESTER, N. Y.

| Weekly Amounts Ice | | Cost of Ice per Year | |
|----------------------|------|----------------------|------|
| 50 lbs or less | 7% | Under \$5 | 23% |
| 51 to 75 | 12% | \$ 5 to \$10 | 43% |
| 76 to 100 | 18% | \$10 to \$15 | 15% |
| 101 to 200 | 47% | \$15 to \$20 | 7% |
| 201 to 300 | 10% | \$20 and over..... | 12% |
| 301 and over | 6% | | |
| | 100% | | 100% |

TEMPERATURES

| In Refrigerators | | Living Rooms | | Cellars | |
|------------------|-----|-----------------|-----|-----------------|-----|
| Below 45° | 14% | Below 60° | 0% | Below 55° | 0% |
| 45 to 50° | 27% | 60 to 70° | 42% | Below 60° | 8% |
| 50 to 60° | 51% | Above 70° | 58% | Above 60° | 92% |
| Over 60° | 8% | | | | |

Bureau of Standards' Tests on Refrigerators.—The United States Bureau of Standards has conducted certain tests on refrigerators. This was reported in the Bureau of Standards Circular No. 55. The following extract and Table LXXXVI gives the principal data in this bulletin:

TABLE LXXXVI.—RESULTS OF TESTS OF REFRIGERATORS.

| Refrigerator Number | Room Temperature | Coldest Inside Temperature | Warmest Inside Temperature | Weight of Ice Melted per Hour | Heat Transmission per Hour B.t.u. per Sq. Ft. per Deg. F. | Air Circulation, Cu. Ft. per Min. | Inside Volume | Average Weight of Ice in Box During Test. |
|---------------------|------------------|----------------------------|----------------------------|-------------------------------|---|-----------------------------------|---------------|---|
| | Deg. F. | Deg. F. | Deg. F. | Lbs. | | at 60° F. | Cu. Ft. | Lbs. |
| 1 | 92.1 | 52.7 | 64.4 | 1.50 | 0.14 | 21.4 | 16.5 | 42.2 |
| 2 | 91.8 | 57.2 | 72.1 | 1.78 | 0.21 | 19.6 | 18.1 | 37.1 |
| 3 | 91.3 | 49.3 | 70.7 | 1.63 | 0.19 | 12.7 | 18.0 | 41.1 |
| 4 | 90.0 | 46.6 | 70.3 | 1.43 | 0.14 | 10.1 | 18.0 | 43.2 |
| 5 | 89.6 | 49.5 | 68.7 | 1.41 | 0.15 | 12.1 | 16.5 | 41.2 |
| 6 | 91.1 | 55.9 | 69.8 | 1.54 | 0.18 | 18.5 | 18.2 | 42.7 |
| 7 | 91.5 | 46.9 | 66.2 | 1.63 | 0.15 | 13.8 | 17.1 | 41.8 |
| 8 | 92.0 | 44.1 | 64.0 | 1.59 | 0.14 | 13.0 | 17.3 | 41.7 |
| 9 | 93.1 | 51.8 | 66.6 | 1.65 | 0.19 | 18.5 | 19.0 | 40.7 |

Table LXXXVI gives some results of tests on nine refrigerators of average quality or better, where the air in the refrigerator averages nearly as much warmer than the ice as it is cooler than the air out-

side; thus, with a room at about 90°, the lowest temperatures inside the refrigerators range from 44° to 57° and the highest 64° to 72°. It has been found (Bulletin No. 98 of United States Department of Agriculture) that in milk kept at 60°, about fifteen times as many bacteria will develop in one day as in milk kept at 50° F., and much the same is true of many other foods. It is important, therefore, to find the coldest places in a refrigerator (usually near where the air leaves the ice chamber) and use these places for foods such as milk and meats which need to be kept as cool as possible to prevent spoiling.

The outside dimension of the refrigerators listed in Table LXXXVI averaged 24 inches deep, 40 inches wide, and 50 inches high.

The figures in the column headed "Heat transmission" gives the amount of heat in British thermal units (B.t.u.) that passes through every square foot of the outside surface of the refrigerator in an hour when the room temperature is one degree F., higher than the average inside temperature of the refrigerator. If the room temperature were ten degrees higher than the inside of the refrigerator, ten times this amount of heat would pass through every square foot of the walls.

The sixth column of Table LXXXVI, headed "Heat Transmission," illustrates the relative merits of the different refrigerators, since it tells directly how much cooling is wasted, that is, how much heat enters the refrigerator through the walls per hour for each square foot of wall, and for each degree difference in temperature between the inside and outside. For instance, to hold the average temperature inside refrigerator No. 1, 30 degrees below the temperature outside would require two-thirds as much ice for No. 2. To be sure, No. 2, though a much poorer refrigerator, used only about one-fifth more ice than did No. 1, but its inside temperature was not nearly so low, and therefore it would not have kept food fresh so long as No. 1.

Slow melting of the ice does not necessarily indicate a good refrigerator. Unless the ice melts, it can absorb no heat, and is therefore of no use in a refrigerator. Protecting the ice in a refrigerator by covering it up is a good way to save ice but a poor way to save food. The only proper way to use less ice is by using a refrigerator with better insulated walls, and by opening the doors as seldom and for as short a time as possible.

N. Y. Tribune Institute Tests.—The N. Y. Tribune Institute reports the ice consumption, as determined by twenty-seven tests on well known standard refrigerators, to be between 0.00407 and 0.0100 pounds of ice melted per hour per cubic foot of food storage space, per degree of difference in temperature between room and refrigerator. These values in B.t.u. would be 0.58608 and 1.44 respectively. The results of these tests are shown by tables LXXXVII and LXXXVIII.

Tests of Balsa Refrigerators.—Household refrigerators of an improved design constructed entirely of balsa wood, with an interior and exterior coating of a magnesite composition applied in plastic form, were built by the American Balsa Co. The tests described in the following were made on the 100-lb. ice capacity side icer type, by Dr. M. E. Pennington in February, 1923. The results are shown graphically in Figs. 131, 132, and 133. The summary of the performance test of the balsa refrigerator of the household type is shown in Table LXXXIX. From the last column of this table, it will be noted that an average of 3.16 B.t.u. were transmitted per 24 hours per degree of temperature difference per square foot of radiating surface.

TABLE LXXXVII.—TESTS BY NEW YORK TRIBUNE INSTITUTE.

| Insulation | Average Room Temperature Deg. F. | Average Food Compartment Temperature Deg. F. | Average Ice Consumption Pounds per Hour. | Radiation Area Sq. Ft. | Heat Loss B.t.u. per Hour | Heat Loss B.t.u. per Sq. Ft. per Day per Degree Temperature Difference |
|--------------------------------|----------------------------------|--|--|--------------------------|---------------------------|--|
| Fibre Board and Air | 74.6 | 55.3 | 0.746 | 33 | 123 | 4.7 |
| Granulated Cork and Wood | 69.6 71.0 | 43.1 45.4 | 0.826 1.085 | 44.5 44.5 | 127 168 | 2.6 3.5 |
| Flaxinum, Wood, Felt and Paper | 68.1 71.6 7.9 79.7 | 46.6 47.5 49.7 49.8 | 0.691 0.792 1.279 1.539 | 33 33 40.6 40.6 | 108 125 198 253 | 3.85 4.05 4.0 4.9 |
| Fibre Board and Air | 69.3 70.8 | 47.0 47.6 | 0.763 0.750 | 28.2 28.2 | 120 118 | 4.6 4.4 |
| Mineral Wool, Paper and Wood | 67.5 68.4 | 47.6 48.0 | 0.739 0.741 | 36.9 36.9 | 117 117 | 3.2 3.7 |
| Wool Felt, Paper, Air and Wood | 67.6 66.7 | 48.2 46.5 | 0.582 0.511 | 21.2 21.2 | 92 80 | 5.4 4.5 |
| Flax Fibre, Wood and Air | 69.3 70.5 | 47.8 48.0 | 0.891 1.085 | 39.9 39.9 | 141 171 | 4.0 4.6 |
| Iron, Cork, Air and Wood | 72.3 | 47.2 | 0.828 | 32 | 124 | 3.7 |

NOTE:—Radiation area is the average between the outside and inside surfaces of the cabinet. The heat loss includes both the effect of melting ice and heating the resulting ice water.

TABLE LXXXVIII.—ICE REFRIGERATOR TESTS BY NEW YORK TRIBUNE INSTITUTE.

| Test Method | Average Room Temperature Deg. F. | Average Food Compartment Temperature Deg. F. | Radiation Area Sq. Ft. | Heat Loss B.t.u. per Hour | Heat Loss B.t.u. per Sq. Ft. per Day per Degree Temperature Difference |
|---------------------------------------|----------------------------------|--|------------------------|---------------------------|--|
| Test A, Fibre Board and Air | | | | | |
| Ice | 55.3 | 74.6 | 33. | 123. | 4.6 |
| Non-Circulating Heat | 102. | 77. | 33. | 169 | 4.9 |
| Test B, Granulated Cork and Wood | | | | | |
| Non-Circulating Heat | 99. | 71.4 | 35.2 | 185.5 | 4.6 |
| Circulating Heat | 95. | 68.0 | 35.2 | 215. | 5.4 |
| Test C, Granulated Cork, Air and Wood | | | | | |
| Ice | 47.2 | 72.3 | 32. | 124. | 3.75 |
| Circulating Heat | 104. | 62.6 | 32. | 221. | 4.0 |

NOTE:—Each set of readings is the average value of two tests. Radiation area is the average between the outside and inside surfaces of the cabinet. Heating element is shielded to reduce heat loss to walls by radiation. In heat tests a "dummy" ice cake was used to offer similar resistance to air circulation as in ice melting test. A small fan was used in the circulating heat test. These tests indicate that the non-circulating heat method of testing gives results corresponding very closely to the results by the ice melting test. The electric heating element is placed in the food compartment and, of course, produces some air circulation inside the cabinet. The electrical has many advantages over the ice melting method.

The purpose of the test was to determine ice meltage, box temperatures, and efficiencies under several conditions of icing as indicated in the three following tests:

Test "A" was an average of four consecutive 24-hour test periods. Ice was replaced at beginning of each test period by new cake of same approximate, original weight. Results graphically shown on Fig. 211.

Test "B" was an average of two consecutive 48-hour periods. Ice replaced at beginning of each test period by new cake of same approximate original weight. Results graphically shown on Fig. 212.

Test "C" was a continuous 96-hour test period without re-icing. The results are graphically shown on Fig. 213.

Box Specifications.—Box was designed and built by the American Balsa Co., for the National Association of Ice Industries, Dr. M. E. Pennington, consulting and advisory technical expert for the association:

DIMENSIONS OF REFRIGERATOR

| | Width | Depth | Height |
|--|---------|---------|---------|
| Outside dimensions over all..... | 35½-in. | 21 -in. | 50 -in. |
| Inside dimensions | 30⅞-in. | 15⅝-in. | 38⅝-in. |
| Ice compartment (Including Baffle).... | 14⅞-in. | 15⅝-in. | 27 -in. |

| | | | |
|------------------------|---------|-----------------------|-----------------------|
| Milk compartment | 13 -in. | 15 $\frac{5}{8}$ -in. | 11 $\frac{5}{8}$ -in. |
| Food compartment | 16 -in. | 15 $\frac{5}{8}$ -in. | 38 $\frac{5}{8}$ -in. |

DOOR OPENINGS IN REFRIGERATOR

| | Width | Depth | Height |
|------------------------|-----------------------|-------|-----------------------|
| Ice compartment | 12 -in. | ..... | 25 -in. |
| Milk compartment | 12 -in. | ..... | 10 $\frac{1}{8}$ -in. |
| Food Compartment | 13 $\frac{5}{8}$ -in. | ..... | 38 $\frac{5}{8}$ -in. |

The box is lined and covered by American Balsa Company's synthetic stone, applied directly to 2-inch Balsa insulation, making a seamless lining and covering finished in white enamel inside and out. Baffle, shelves ice tray and pan, bunker and drain pipe are entirely removable.

The tests were made at the Bronx Plant of the American Balsa Co., in experimental refrigerator test room where room temperatures could be reasonably controlled.

Temperature Observations.—Room temperatures and averages were determined from S. & B. recording thermometer. Reading averaged hourly from recording chart. Leads & Northrup resistance thermometers and reading box were used to determine all box temperatures. These thermometers read to 0.1 degree and were calibrated before and after tests. Box temperatures were observed at the following locations:

1. Warm air inlet.
2. Middle food compartment.
3. Bottom food compartment.
4. Cold air drop.
5. Middle milk compartment.
6. Middle top shelf.

Average temperature, middle food compartment, was determined by averaging middle milk compartment and middle top shelf compartment temperatures. This average temperature was used in all calculations.

Ice Meltage.—Rates of ice meltage were determined from actual meltages, by removing ice from box at end of 24-hour periods and weighing. After weighing, cake was replaced or new cake substituted as conditions of test demanded. Check meltages were taken by weighing drip water, but these figures were not used in calculations. Readings were taken at 9 a. m. and 10 a. m., at noon and at 3 p. m. and 5 p. m. Twenty-four hour test and ice weighing intervals were from 10 a. m. to 10 a. m.

Results.—Results of tests are shown graphically in Figs. 214, 215 and 216 and Table LXXXIX, and comprise the complete results of this test, which is the American Balsa Company's Laboratory Experiment No. 258.

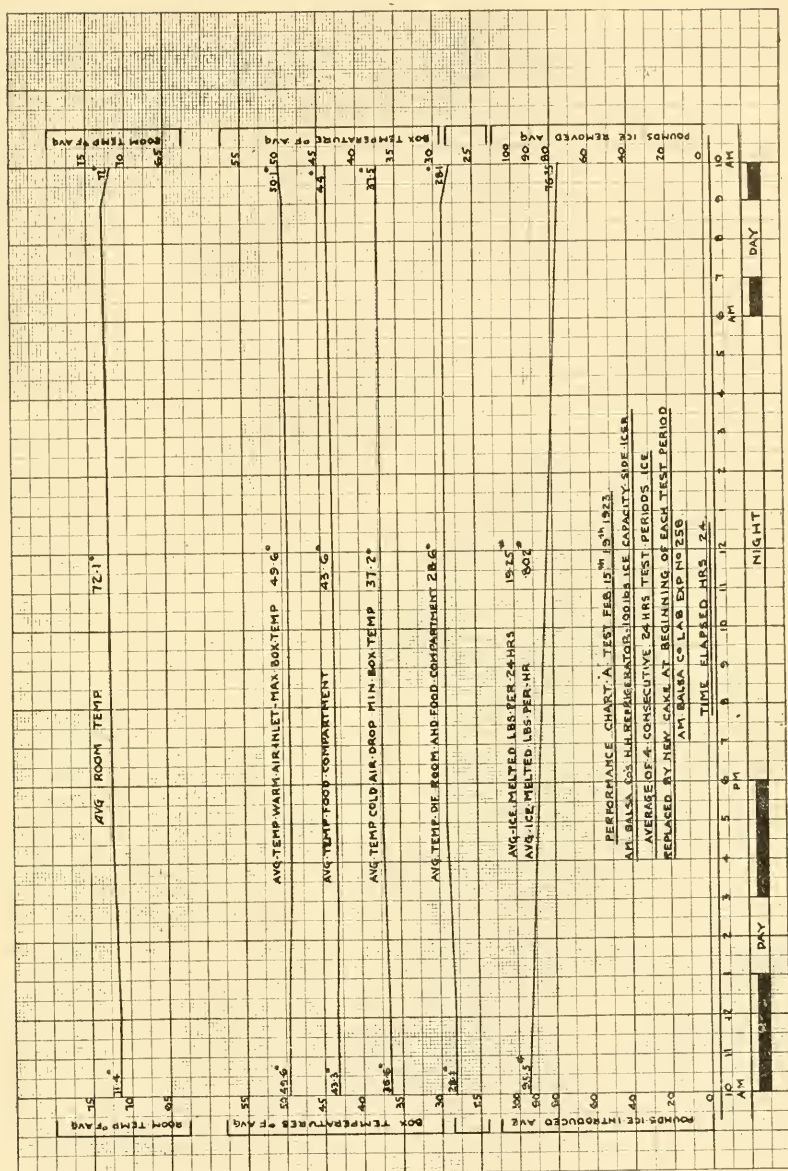


FIG. 214.—BALSA REFRIGERATOR TEST CHART.

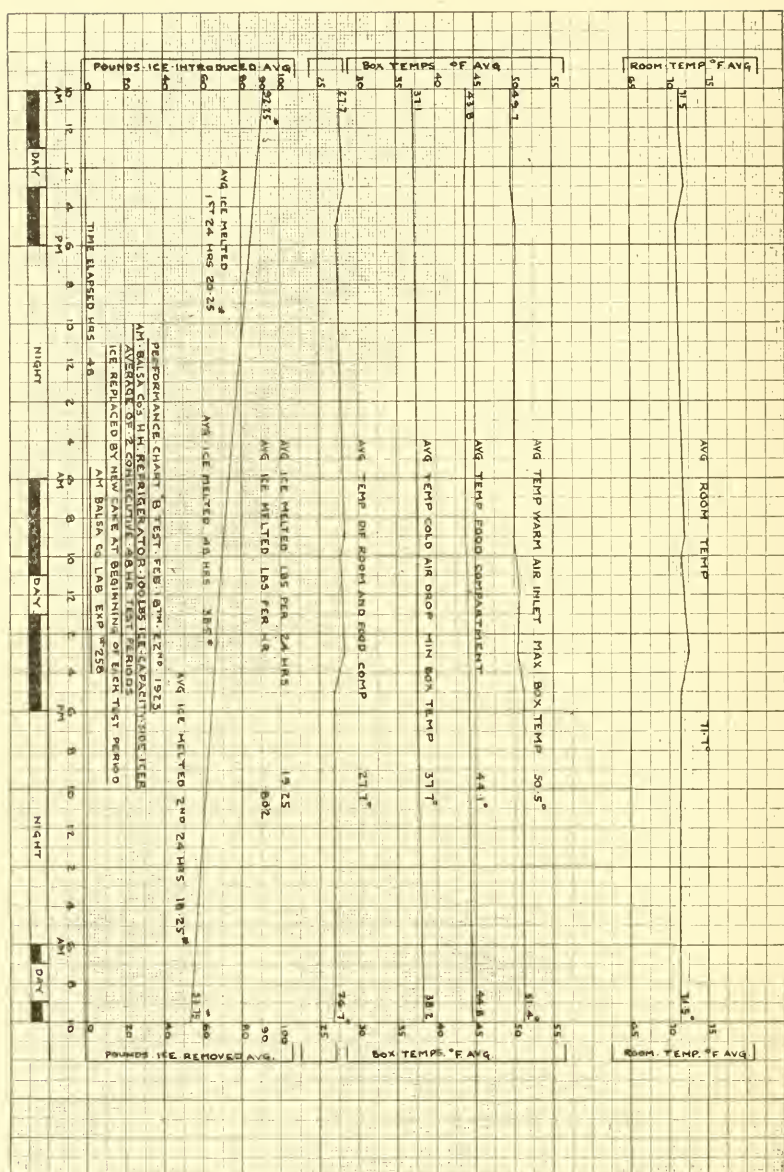


FIG. 215.—BALSA REFRIGERATOR TEST CHART.

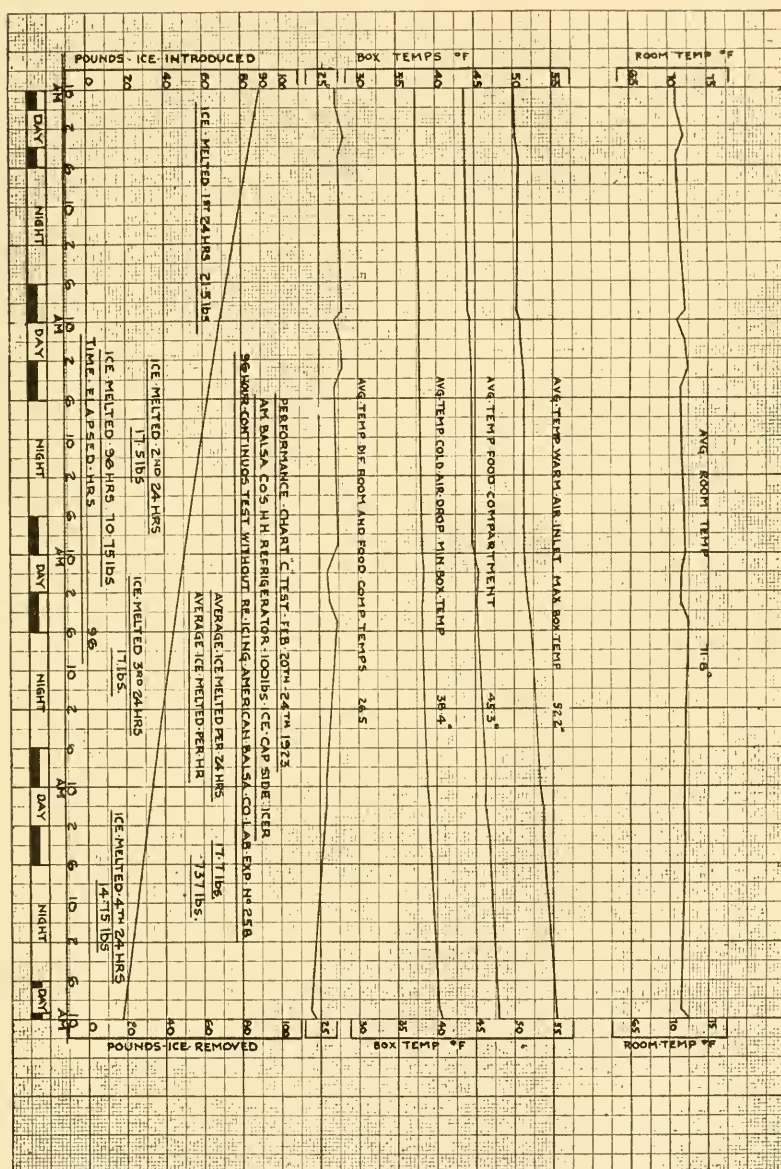


FIG. 216.—BALSA REFRIGERATOR TEST CHART.

Tests at University of Illinois.—An exhaustive test in the University of Illinois laboratories compared three refrigerators purchased from the stock of local dealers. One was with granulated cork insulation, while the other two used mineral wool and other insulations. The lower melting rate per hour, proved that the refrigerator with its granulated cork insulation was the most economical refrigerator for general use. The figures are as follows:

| | Hours Tested | Ice Melt | Melt Rate Per Hour |
|-------------------------------|--------------|-----------|--------------------|
| No. 1. (Graulated Cork) | 219.0 hours | 109¼ lbs. | 0.498 lbs. |
| No. 2. (Mineral Wool) | 119.9 hours | 71 lbs. | 0.592 lbs. |
| No. 3. (Mineral Wool) | 168.95 hours | 141¾ lbs. | 0.839 lbs. |

Assuming that a refrigerator is used for six months of each year, and that the ice will cost fifty cents per cwt., the cost of the ice for the year will be as follows:

| | |
|-------------------------------------|---------|
| No. 1—2,151 lbs. of Ice at 50c..... | \$10.75 |
| No. 2—2,557 lbs. of Ice at 50c..... | 12.79 |
| No. 3—3,624 lbs. of Ice at 50c..... | 18.12 |

Tests by Good Housekeeping Institute.—The Good Housekeeping Institute, conducted by the Good Housekeeping Magazine of New York City, reports the following result of a test on Bohn Syphon refrigerator:

The refrigerator is well-constructed throughout, and provided with a one-piece seamless lining with rounded corners, that is, a smooth, hard surface, easily kept clean and in a sanitary condition. In tests of one hundred consecutive hours duration, the following results were obtained.

| Average Food Compartment Temperature | Average Room Temperature | Average Ice Consumption lbs. Per Hour |
|--|--------------------------------|---|
| 45.5 F. | 75.1 F. | 0.750 |
| 41.2 F. | 68.1 F. | 0.613 |

The method of rating was as follows:

| | |
|------------------------------|-----------|
| Construction | Good |
| Efficiency of Design..... | Very Good |
| Efficiency of Operation..... | Very Good |
| Initial Cost | Medium |
| Upkeep Cost | Low |

The refrigerator scores 94 points.

The detailed specifications of this cabinet are as follows:

| | Width Inches | Depth Inches | Height Inches |
|------------------------------|-----------------|-----------------|------------------|
| Outside | 36 | 21 | 47 |
| Large Provision Chamber..... | 13¼ | 14¼ | 32 |

| | | | |
|---|------------------|------------------|------------------|
| Small Provision Chamber..... | 15 | 14 $\frac{1}{4}$ | 9 $\frac{3}{4}$ |
| Ice Chamber | 13 $\frac{3}{4}$ | 15 $\frac{3}{8}$ | 18 |
| Ice Chamber Door Opening..... | 11 $\frac{1}{4}$ | .... | 14 $\frac{7}{8}$ |
| Ice Chamber Capacity, 100 pounds | | | |
| Shipping Weight, 335 pounds | | | |
| Total Volume Overall..... | | 20.5 | Cu. Ft. |
| Food Storage Space | | 4.7 | Cu. Ft. |
| Ice Storage Space..... | | 2.2 | Cu. Ft. |
| Shelf Area | | 6.7 | Sq. Ft. |
| Insulation: Wood, flax fibre, dead air space, wool felt, paper, and waterproof paper. | | | |

The pounds of ice melted per hour per cu. ft. food storage space per degree temperature difference were as follows:

| | |
|------------------|---------|
| First Test..... | 0.0054 |
| Second Test..... | 0.00484 |

Tests on Ice Refrigerators.—The following data, on testing of ice refrigerators, has been published by the Davison All-Steel Refrigerator Co., in Montreal, Canada. The room temperature during the test was 68° F.; one piece of ice weighing initially sixteen pounds was used, and the refrigerator tested was the Frost River type No. 24. The piece of ice lasted for sixty-eight hours and the lowest temperature obtained in the food chamber was 48° F., the insulation consisting of linofelt and air space. The outside volume of the refrigerator was seventeen cubic feet. The food compartment was 5.65 cu. ft. The shelf area was 8.2 sq. ft. and the total shipping weight was 162 pounds.

TABLE XC.—REFRIGERATOR TEST.

| Date | Time | Temperature of Food Chamber | Amount of Ice |
|--------|----------|-----------------------------|---------------|
| May 9 | 2 P. M. | 66 | 16 Pounds |
| | 10 P. M. | 54 | |
| | 2 P. M. | 52 | |
| | 4 P. M. | 52 (Temp. Ice Chamber 42) | |
| May 10 | 12 Noon | 50 | |
| | Midnight | 50 | |
| | 7 P. M. | 48 | |
| May 11 | 7 A. M. | 48 | |
| | 12 Noon | 49 | |
| May 12 | 7 A. M. | 58 | |
| | 12 Noon | 60 Out of Ice | |

Tests on Average Household Refrigerators.—Table XCI gives the result of the tests on fifteen average household refrigerators used in homes. From this, it is interesting to note that the average temperature inside of the refrigerator

at the middle shelf was 55°, that the average number of pounds of ice consumed per day was 29.6 and that the average cost of ice per day per refrigerator was 14.8 cents.

TABLE XCI.—TEST ON FIFTEEN AVERAGE HOUSEHOLD REFRIGERATORS IN USE IN HOMES.

| | |
|---|-----------------------|
| Average Room Temperature..... | 79 degrees |
| Average Temperature Inside Refrigerator at Middle Shelf.. | 55 degrees |
| Average Pounds of Ice Consumed per Day..... | 29.6 lbs. |
| Cost of Ice..... | 56 cents per 100 lbs. |
| Average Cost of Ice per Day for Each Refrigerator..... | 14.8 cents |

Refrigerator Score Card.—A refrigerator score card for the purpose of comparing different kinds of refrigerators has been prepared by F. O. Riek, of the Rhinelander Refrigerator Co., who has used some data and suggestions contained in a score card for refrigerators originally published in the Chicago Tribune by Dr. W. A. Evans, and is as follows:

REFRIGERATOR SCORE CARDS

Name of manufacturer.....
Name or other method of designating refrigerator.....

| Points of Score | Perfect Score |
|-------------------------------------|---------------|
| 1. Temperature of Food Chamber..... | 45 |
| 2. Ice Economy or Efficiency..... | 20 |
| 3. Humidity | 8 |
| 4. Circulation | 7 |
| 5. Interior Finish..... | 12 |
| 6. Drainage | 3 |
| 7. Exterior Finish | 5 |
| Total | 100 |

Explanation of Score Card:

1. *Temperature Test:* Standard conditions for test demand refrigerator to be in a room free from drafts and at an even temperature. Box should not contain food. Door should not be opened except when taking readings. Refrigerator should be cold throughout. Have the ice chamber full. Place thermometer in the center of the food chamber. Make four readings at intervals of not less than one hour. Take room temperature four times.

Rate as follows:

When temperature is:

The score will be under:

| | |
|---------|----|
| 40° F. | 45 |
| 45 | 43 |
| 50 | 36 |
| 55 | 23 |
| 60 | 9 |
| over 60 | 0 |

2. *Ice Economy*: Refrigerator should be cold when test is begun. Weigh ice at the beginning of test. Weigh ice left at termination of test. Obtain data:

- Temperature of food chamber.
- Temperature of room.
- Square feet of surface exposure calculated on exterior dimensions.

To determine substitute in the following formula:

$$R = \frac{I \ 144}{S (T - t)}$$

where R equals "efficiency" of rate of heat transmission which may be defined as the number of B.t.u. which pass through one square foot of surface daily when the difference between the surface is 1° F. I equals the number of pounds of ice melted daily. 144 equals B.t.u. required to melt one pound ice. S equals surface exposure. T equals average atmospheric temperature. t equals average temperature of food chamber.

Rate as follows:

Where R equals

| | |
|------|---------|
| 1.13 | rate 20 |
| 1.63 | rate 18 |
| 2.00 | rate 16 |
| 2.33 | rate 14 |
| 2.66 | rate 12 |
| 3.00 | rate 10 |
| 3.33 | rate 8 |
| 3.66 | rate 6 |
| 4.00 | rate 4 |
| 4.33 | rate 2 |
| 4.66 | rate 1 |
| 5.00 | rate 0 |

3. *Humidity*: In making humidity tests a wet and dry bulb thermometer should be used. At least four readings are to be taken at intervals of one hour.

See Bureau of Standard tables for readings calculated upon differences in temperatures of wet and dry thermometers. Score as follows:

| Percentage humidity ranges | |
|----------------------------|---------------|
| 55 to 65 | rate..... 8.0 |
| 65 to 75 | rate..... 7.5 |
| 45 to 55 | rate..... 7.5 |

HOUSEHOLD REFRIGERATION

| | |
|------------------------|-----|
| 40 to 45 rate..... | 7.2 |
| 75 to 80 rate..... | 6.4 |
| 30 to 40 rate..... | 6.0 |
| 80 to 85 rate..... | 4.8 |
| 20 to 30 rate..... | 4.8 |
| 85 to 95 rate..... | 2.4 |
| 90 and over rate..... | 0.0 |
| 20 and under rate..... | 0.0 |

4. *Circulation of Air*: Note Whether the box can be ventilated. Credit for possibility for ventilating. Credit for probability that cold air will pass from ice to food and air returns from the food to the ice. If any wall is moist subtract at least two. If air cannot reach ice, subtract two.

5. *Interior Finish*: Ease of cleaning refers to cleaning of food chamber, all shelves therein, and the drain pipes. If ease of cleaning is ideal, value six. If finish is hard and non-absorbent, value three. If color is white, value five.

6. *Drainage*: A. See that the trap in the drain pipe works. If there is proper trapping, value two. If there is proper tubing, value one.

B. Construction of Refrigerator:

1. Arrangement of chamber—show diagram.
2. Temperature maintained.
 - a.—Ice chamber.
 - b.—Food chamber side.
 - c.—Food chamber below.
3. Insulation—show diagram.
4. Economy of space in food chambers.

C. Cost:

1. First Cost.
2. Maintenance Cost.

D. Manufacturer's Claims:

Does the manufacturer over-emphasize minor details in advertising his refrigerator?

References:

- Lynde, "Household Physics."
 Bureau of Standards Circular No. 55, Measurements for the Household.
 Manufacturers' Catalogs.
 Good Housekeeping Institute.
Good Housekeeping Magazine, May, 1914.
 A study of Refrigeration in the Home and the Efficiency of Household Refrigerators.—J. R. Williams.

Determining the Efficiency of a Refrigerator Wall.*—To determine the heat transmission value of a wall in B.t.u.'s per square foot per degree Fahrenheit temperature difference, it

*From Rhineland "Handbook of Refrigeration."

is necessary to know three things. That is, when structure of wall is not known.

These three factors are:

1. Square feet of surface exposure calculated the mean transmission surface on exterior dimensions and also interior surface.
2. The weight of ice melted in 24 hours.
3. The difference between the average temperature of inside refrigerator food chamber and room temperature.

To find the average or "mean transmission surface" get, first of all, the square feet of surface calculated on exterior dimensions. Then get total square feet inside by measuring inside surface. Average of two square surfaces—exterior and interior is mean transmission surface.

The weight of ice melted is determined by weighing the empty water pan at start of test, then at conclusion of 24 hour test weighing the water and pan, deducting the initial weight of empty water pan.

To get temperature tests outside and inside standard conditions for test require refrigerator to be in a room free from drafts and at fairly even temperature. Box should not contain food. Doors should not be opened; except when taking readings. Refrigerator should be thoroughly chilled, at least 48 hours before making test. Have ice chamber full. Place thermometer in the center of food chamber and make at least four readings at about three hour interval. Take room temperature at same time. Average all food temperatures and outside room temperature and then find difference between the two averages.

Use following formula:

$$X \text{ equals } \frac{I \ 144}{S \ (T-t)}$$

I equals ice melted.

144 equals B.t.u. required to melt one pound of ice or Latent Heat.

S equals mean transmission surface.

T equals average room temperature.

t equals average temperature of food chamber.

X equals number of B.t.u.'s passing through one square foot of surface per degree Fahrenheit temperature difference.

CHAPTER XII.

PRESERVATION OF FOODS IN THE HOME

Influence of Temperature on Bacteria in Foods.—Temperature has an important influence on the growth of bacteria. Most bacteria, yeasts, molds, and related organisms grow best at a temperature between 68° and 122° F., and do not grow at a temperature below 45° to 55° F. Cold retards their growth and tends to preserve these microorganisms as well as the food unchanged. It is well known that foods removed from cold storage are inferior in keeping qualities to the corresponding fresh foods. Freezing decreases the number of bacteria but does not immediately kill them. Most molds are easily destroyed by freezing.

Bacteria will multiply in milk as long as it is not frozen entirely solid. Milk of good quality will stay sweet and in perfect condition for more than a week if it is held at a temperature slightly above the freezing point. The temperature at which it is held determines the rate and kind of decomposition which takes place. Milk should stay sweet when stored properly for at least ten days.

Heating milk to 212° F. for about fifteen minutes will kill all except a few spores of bacteria. Several heatings are necessary to kill all vegetative cells.

Most of the living bacteria in butter diminish when it is refrigerated—a few kinds may multiply. There is a slow increase in acidity. The bacteria and chemical composition remain practically the same in frozen butter. The keeping qualities of butter depend largely upon the cleanliness and the quality of the materials used in making it.

Fruits and vegetables are usually adapted to preservation for short periods at ordinary temperatures. The best storage conditions for them is at temperatures slightly above the freezing point and a humidity of 60 per cent saturation. A higher humidity favors the development of molds.

Bacteria do not multiply in ice as they have nothing upon which to feed. When liquids are frozen solid the number of bacteria decreases very slowly.

Effect of Refrigeration Upon Foods.—Cold does not destroy the microbes in food but retards their activity and growth. The decomposition of foods is caused by the action of their own enzymes and more frequently by the activity of bacteria, yeast, and molds.

Fruits and vegetables should be stored at a temperature slightly above 32° F. and in a humidity at about 60 per cent of saturation, in order to diminish evaporation without developing molds. The best storage condition to prevent the development of bacteria and molds, is to keep the fruits and vegetables in a very constant humidity and a very constant temperature, slightly above 32° F.

Laboratory tests prove that the bacteria which cause food decomposition have their growth greatly retarded below a temperature of 45° F. Between 45° and 50°, they grow at a slightly greater rate, and above 50° F. the bacteria multiply prolifically. Perishable foods should be stored in a temperature not over 50° F. and preferably below 45° F.

It is important that foods be used shortly after they are removed from cold storage. Cold foods often condense moisture from the atmosphere on their surface, and it is well known that their keeping qualities are then inferior to corresponding fresh foods.

Ice and Its Relation to Food.—Dr. Leonard Keene Hirschberg, writing in the *Chicago Evening Post*, gives the following on the use of ice as a means of preservation of food:

Ice checks the growth of living things to the extent that it almost causes the smallest forms of vegetable and animal creation to cease

to exist as life. Usually, it does not kill, but it produces a condition of latent life, like the winter sleep of bears, beavers, snakes, and other creatures.

Ice thus becomes a help to man. It checks the birth, growth, multiplication, vitality, virulency, and noxious activity of bacteria, molds and other such living things which spoil foods, and especially those such as the typhoid bacilli.

The reason milk and so much food spoils in summer is because these unseen colonies of bacteria and other vegetation multiply and incubate in the warmed food. Its texture, appearance, color, taste, flavor, odor, and value thus depreciate.

Bacteria are everywhere on even the cleanest hands, but many more are on soiled hands and dirty nails. Flies, ants, roaches, dust, wind, and water carry them.

Ice keeps down the growth of bacteria, but you can only prevent them from spoiling food or causing disease by being sure of pure milk, pure water, sterile vessels, and dishes. You should scald everything, including linens.

Even where foods are apparently not spoiled, such germs as those of dysentery, scarlatina, colds, tuberculosis, typhoid, diphtheria, influenza, botulism, and others may be germinating, just as a seed does in summer in fertile soil.

Scrupulous cleanliness or surgical cleanliness means more than soap and water cleanliness. It means freedom of everything from germs by asepsis and sterilization.

Sunlight, harmless disinfectants, sterilization or boiling keep down to a minimum the growth of germs.

Ice boxes, refrigerators, cold storage, porous earthenware, coolers, vacuum jacketed bottles, and other measures to keep food in summer well below 45°, all help to keep it free of any great increase and growth of bacteria.

Perhaps more difficult to keep and most important in the summer kitchen is milk. If there are infants about, their very lives depend upon milk free of bacteria.

Sour milk is not the only milk teeming with bacteria. Indeed, the sweetest and richest milk is often alive with deadly germs, which becomes planted in the little one's intestines.

Unless milk goes directly into sterilized bottles from a cow whose hide is made germ-free by disinfectants, by the time it passes through hands, cans, bottles, and nipples it has millions of dangerous bacteria in it.

The only safe way to keep milk in summer is to boil it twenty minutes and put it on ice at once, and keep it there until given to the child.

In summer especially, but also in the winter, ice should not be spared around the house. It is one of the cheapest and most useful of modern conveniences. As a health preserver, it is seldom given its due need of praise.

Care of Milk in the Home.—Farmers' Bulletin No. 1207 of the United States Department of Agriculture gives the following dissertation on the care of milk in the home:

No matter how well milk has been handled up to the time it is delivered to the consumer, it can not be expected to keep well if it is then carelessly treated. Milk should be kept clean, covered, and cool, these three points, consumer as well as producer should never disregard.

In towns and cities, the best way of buying milk is in bottles. In this form it can be kept clean and cool more easily during delivery and is much more convenient to handle. Dipping milk from large cans and pouring it into customers' receptacles on the street with the incident exposure to dusty air, is bad practice. Drawing milk from the faucet of a retailer's can is not quite so bad as dipping, but the milk is not kept thoroughly mixed and some consumers will receive less than their share of cream. By whichever of these methods the milk is measured, it should be delivered personally to some member of the household, if possible, or a covered vessel may be set out, such as a bowl covered with a plate, or better still a glass jar, used for no other purpose, with a glass lid but without a rubber. Under no circumstances should an uncovered vessel be set out to collect thousands of bacteria from street dust before the milk is poured into it. Money and paper tickets are often more or less soiled; hence neither should be put into the can, bowl or jar.

Sometimes milk is delivered as early as 4 o'clock in the morning, remains out of doors in a place exposed to sunshine and perhaps accessible to cats and dogs until 9 or 10 o'clock. This is wrong. If the milk cannot conveniently be brought into the house at once, the delivery man should be asked to leave it in a sheltered place or in a covered box provided for the purpose. Even a temporary rise in the temperature of milk will help the development of bacteria that have been held in check by keeping the milk cool, and domestic animals rubbing against a milk container may contaminate it with bacteria dangerous to health.

As soon as possible after delivery, milk should be put in a cool, clean place and kept there until used. It deteriorates by exposure to the air of pantry, kitchen, or nursery. Unless it is in the bottle into

which it was put in the dairy, it should be poured into a freshly scalded vessel and covered.

The best temperature for keeping milk is 50° F. or less, and good milk kept that cool should remain sweet for 12 hours at least, and ordinarily 24 hours or more, after it reaches the consumer. If ice cannot be obtained, an iceless refrigerator or some such device is a help even though a temperature as low as 50° F. can rarely be maintained in it.

In the ordinary refrigerator, unless the milk container is in actual contact with the ice, the milk will be colder at the bottom of the refrigerator than in the ice compartment, for cold air settles rapidly. The refrigerator should be kept clean and sweet at all times. Inspecting it thoroughly at least once a week is a good plan, to see that outlet for water from the melting ice is open and that the space under the ice rack is clean. Also the food compartments should be scalded every week. A single drop of spilled milk or a particle of neglected food will contaminate a refrigerator in a few days.

Sometimes in very hot weather housekeepers complain that, in spite of all precautions, milk sours quickly, even in the refrigerator, which, although cool in contrast with the heat outside, is really not cold enough to check the growth of the bacteria in milk. If a thermometer placed inside registers more than 50° F., the fault cannot be laid entirely to the quality of milk.

Milk should be kept covered to exclude not only dirt and bacteria but also flavors and odors, which it readily absorbs. It should be kept away from foods of strong odor, such as onions, cabbage, or fish.

Bottled milk should be kept in the bottles in which it is delivered until needed for use. In fact, from a sanitary standpoint, serving milk on the table in the original bottles is excellent practice. In any case a milk bottle, especially the mouth, should be cleaned carefully before the milk is poured from it, and only what is needed for immediate use should be poured out at a time. This bottle should be kept covered with a paper cap or an inverted tumbler as long as there is milk in it.

New milk should never be mixed with old unless it is to be used at once; the old milk is likely to contain a larger proportion of bacteria. Some persons even go so far as to say that milk or cream that has been exposed to the air by being poured into other vessels for table or cooking use should not be poured into the general supply.

As soon as a milk bottle is empty, it should be rinsed first in cold water, and then in warm water until it appears clear; then set bottom up to drain. It should not be used for any other purpose than for milk.

All utensils with which milk comes in contact should be rinsed in cold water, washed, and scalded with water at or near the boiling

point every time they are used. It is a good plan to set them away unwiped. In no case should they be cleaned in water that has been used for other dishes since it was scalded.

The Application of Refrigeration to Milk.—The following data on the application of refrigeration for cooling and storing milk is taken from United States Department of Agriculture Bulletin No. 98:

Effect of Freezing on Milk.—While the action of cold on milk at a temperature above the freezing point has no other effect than that of varying the density and viscosity at a temperature below the freezing point, it changes the chemical and physical composition.

According to Kasdorf, when raw milk which was partly frozen at a temperature of 10.5° F., in the ordinary container, during transportation, it was found that ice first formed around the sides and at the bottom of the can; the central core contained most of the casein, sugar, and other mineral ingredients, while most of the fat was found in the top layer of the liquid portion.

When milk has been frozen gradually, without agitation, and thawed out, clots will be found floating in the liquid, composed mostly of albumen and fat, which may be dissolved by cooking; on the other hand, if the milk is preserved in a frozen condition for three or four weeks, these clots will be very hard to dissolve, and the difficulty experienced in dissolving them increased as the length of time the milk is preserved in a frozen state. For this reason, the freezing of milk, for the purpose of transportation, has hitherto been little used.

If the milk is held at 32° F., for a few days, some types of bacteria may grow and multiply slowly. With a good quality of milk, i. e., that containing few bacteria, it may take weeks or even months for them to gain great headway. What few bacteria develop at low temperatures are of different species from those ordinarily found at the higher temperatures, and they may produce marked changes in the chemical composition of the milk, without especially changing its appearance. Consequently, it is unsafe to assume that milk which has been held for several days at a low temperature is in good condition. According to Pennington, milk exposed continually to a temperature of 29° to 32° F., causes, after a lapse of from 7 to 21 days, the formation of small ice crystals which gradually increase until the milk is filled with them, and there may be an adherent layer on the walls of the vessel. The milk does not freeze solid. In spite of the fact that the milk was a semi-solid mass of ice crystals, an enormous increase in bacterial content took place. Though the bacterial content was numerically in the hundreds of millions per cubic centimeter there was neither taste nor odor to indicate that such was the case.

Neither did the milk curdle when heated, and the unfitness of the milk for household purposes would not ordinarily be detected until the lactic acid bacteria decreased in numbers and the putrefactive bacteria began to develop.

Influence of Temperature on the Bacteriological Flora of Milk.—

Each species of bacterium found in milk and each particular variety has an upper and lower temperature limit beyond which it does not grow, and a certain temperature, called the optimum, at which it grows best.

The optimum temperature of most forms occurring in milk is between 70° and 100° F. As the temperature of milk is lowered, the rate of growth is diminished until at 40° F., the multiplication is very slow, and at a temperature just above the freezing point the development practically ceases; in fact, there is an apparent decrease in the number, at least for a short time. The action of cold at this temperature, however, does not totally destroy life in the bacteria, but causes them to lie dormant. When the temperature of the milk is raised, they again begin to multiply. As an illustration of the relative variation in the growth of bacteria in milk held at different temperatures, one writer gives the data found in Table XCII, in which "I" is assumed to represent the number of bacteria in the fresh milk, and the relative numbers which will be found at the end of 6, 12, 24, and 48 hours, at the two temperatures, are shown in the succeeding columns. The figures are based on a number of actual counts and illustrate the effect of a difference of 18 degrees on the multiplication of bacteria. If the milk had contained at the beginning 1,000 bacteria, the part held at the lower temperature would have contained at the end of 24 hours only 4,100 bacteria, while the other would have contained at the same stage 6,128,000. Table XCIII from Bulletin 133 (Extension Bulletin 8) of the Agricultural Experiment Station of Nebraska, illustrates the importance of holding cream at low temperatures.

TABLE XCII.—MULTIPLICATION OF BACTERIA IN MILK HELD AT DIFFERENT TEMPERATURES.

| Milk Held at | Relative Number of Bacteria Held at | | | |
|--------------|-------------------------------------|--------|---------|-----------------|
| | 0 hrs. | 6 hrs. | 12 hrs. | 24 hrs. 48 hrs. |
| 50° F. | 1 | 1.2 | 1.5 | 4.1 6.2 |
| 68° F. | 1 | 1.7 | 24.2 | 6,128. 357,499. |

Rogers, Lore A., *Bacteria in Milk*. U. S. Department of Agriculture, Farmers' Bulletin 490. Washington, D. C.

Influence of Time on the Bacteriological Flora of Milk.—The influence of temperature and time bear certain definite relations to each other; hence, a study of one necessarily includes a study of the other. Table XCIV serves to illustrate the effect of time as well as tem-

perature on the keeping qualities of milk. If the table is read downward, we note the effect of temperature and if read across, the effect of time. When milk is first drawn from the cow it usually contains bacteria, even though it is produced under sanitary conditions, and if held at the ordinary temperature of the surrounding air, in a short while the bacteria will grow and increase in numbers so rapidly, that when such milk reaches the consumer it will contain many thousand bacteria per cubic centimeter.

TABLE XCIII.—THE EFFECT OF TEMPERATURE ON THE GROWTH OF BACTERIA IN CREAM.

| Temperature of Cream | Time Held | Number of Bacteria per C. C. | Temperature of Cream | Time Held | Number of Bacteria per C. C. |
|----------------------|-----------|------------------------------|----------------------|-----------|------------------------------|
| Degrees Fahr. | Hours | | Degrees Fahr. | Hours | |
| 32 | 10 | 3,300 | 70 | 11 | 188,000 |
| 50 | 10 | 11,580 | 80 | 11 | 2,631,000 |
| 60 | 10½ | 15,120 | 90 | 11½ | 4,426,000 |

Conn furnishes an example of milk, giving the following results:

| | Bacteria per c. c. |
|---------------------------|--------------------|
| Milk drawn at 59° F. | 153,000 |
| After 1 hour | 616,000 |
| “ 2 hours | 539,000 |
| “ 4 hours | 680,000 |
| “ 7 hours | 1,020,000 |
| “ 9 hours | 2,040,000 |
| “ 24 hours | 85,000,000 |

According to Park, two samples of milk maintained at different temperatures for 24, 48, 96 and 168 hours, respectively, showed the development of bacteria as indicated in Table XCIV. The first sample was obtained under the best possible conditions, while the second sample was obtained in the usual way. When received, the first sample contained 3,000 bacteria, and the second 30,000 per cubic centimeter.

In Table XCIV, it will be noted that at 32° F., there is an actual decrease in the number of bacteria in both samples of milk during the 168 hours, while at all other temperatures there is an increase in the numbers of bacteria. Ordinarily, the consumer receives milk when it is from 24 to 48 hours old; hence, it becomes an easy matter to deliver the milk in good condition, providing the milk is produced under sanitary conditions and is properly cooled and held at a temperature of 50° F., or below. An examination of the tables and figures will show how intimately the two influences of time and temperature act and interact in relation to the multiplication of bacteria in milk.

From the foregoing, it is obvious that proper refrigeration is of the utmost importance in the preservation of milk. In fact, without thorough cooling, it is impracticable to keep milk for any considerable length of time, in a condition that would justify its use for household purposes. It should be cooled at 50° F. or below as quickly as possible after it is drawn from the cow, as such cooling will at once check the increase of bacteria.

TABLE XCIV.—EFFECT OF TIME AND TEMPERATURE ON THE GROWTH OF BACTERIA IN MILK.

| Temperature | 24 Hours | 48 Hours | 96 Hours | 168 Hours |
|----------------|----------------------------------|----------------------------------|-------------------------|-------------------------|
| 32° F. (0 C.) | 2,400 30,000 | 2,100 27,000 | 1,850 24,000 | 1,400 19,000 |
| 39° F. (4 C.) | 2,500 38,000 | 3,600 56,000 | 218,000 4,300,000 | 4,200,000 38,000,000 |
| 42° F. (5 C.) | 2,600 43,000 | 3,600 210,000 | 400,000 5,760,000 | |
| 46° F. (6 C.) | 3,100 42,000 | 12,000 360,000 | 1,480,000 12,200,000 | |
| 50° F. (10 C.) | 11,600 89,000 | 540,000 1,940,000 | | |
| 55° F. (13 C.) | 18,800 187,000 | 3,400,000 38,000,000 | | |
| 60° F. (16 C.) | 180,000 900,000 | 28,000,000 168,000,000 | | |
| 68° F. (20 C.) | 450,000 4,000,000 | 25,000,000,000 25,000,000,000 | | |
| 86° F. (30 C.) | 1,400,000,000 14,000,000,000 | | | |
| 94° F. (35 C.) | 25,000,000,000 25,000,000,000 | | | |

Bacteria in Milk.—Farmers' Bulletin No. 1207 of the United States Department of Agriculture gives the following discussion on the development and growth of bacteria:

Besides the chemical compounds, milk also contains large numbers of minute organisms called bacteria. Few, if any, are normally present in the milk within the udders of clean, healthy cows, but they are so abundant everywhere in the air, especially about the stable and barnyard, and cling in such numbers to the bodies of the cows, that they are almost always found in milk as soon as it leaves the udders or even just inside the teats. Utensils that have not been sterilized are another very common source of bacteria in milk. Bacteria reproduce very rapidly in a favorable medium, such as warm milk, and the number present becomes very large unless measures are taken to hinder their increase. The amount in milk of a given age varies of course with the conditions.

A great many kinds of bacteria have been found in milk, each of which occasions a special set of changes as it develops. Perhaps the most prevalent kinds are those that cause the ordinary souring of milk and are the first to produce any noticeable change in the taste and odor. In their growth they feed upon the milk sugar and convert it into lactic and volatile acids, which give slightly soured milk its peculiar taste and odor. When enough of this lactic acid has formed it acts upon the casein, causing it to separate into loose, light flakes and to form, upon standing, the ordinary "clabbered" milk. Other bacteria developing in sour milk may give it a strong, unpleasant odor or flavor, and still others, which occur occasionally color it very brightly or give it a slimy or ropy consistency. Some of the products of bacterial action on milk are desirable, however,—for instance, those that give to butter and cheese the characteristic flavors and odors.

Since there is frequently more or less dirt in freshly drawn milk (most of it fine particles of litter and manure that fall into the pail from the body of the cow), milk should always be strained directly after the milking is over. Of course, the amount of dirt varies with the condition in which the cow and her surroundings are kept. Under ideal dairy conditions only very small quantities are found, while milk from untidy establishments may contain enough in a quart to form a noticeable sediment. Milk with enough dirt to be visible indicates a badly kept dairy and should not be tolerated. Moreover, visible dirt does not tell the whole story; some of the manure that falls into milk is dissolved and it sometimes carries disease-producing bacteria. Consumers should always insist upon having clean milk, and they should also remember that cleanliness should not stop at the dairy but should be scrupulously maintained at every step of the way to the final consumption of the milk.

Ice Chests.—Mrs. Mary Hinman Abel, under the heading "Care of Food in the Home," gives the following considerations in reference to ice chests and refrigerators:

There are many varieties of ice chest or refrigerator, all built on one of two general plans. In one kind, both ice and food are kept in one large compartment. In the other, the ice is placed in a top compartment, below which are cupboards for the food; the principle here utilized is that cold air seeks a lower level and that the air cooled by the melting ice will sink to the shelves below. It probably better utilizes a given amount of ice, for the further reason that the ice compartment may remain tightly closed except when being filled. In both cases, the air space between the outside wall and the zinc lining is filled with some non-conducting material as cork or asbestos.

It is of great convenience to have the ice chest built against the outer wall of kitchen or pantry, so that it may be filled from the outside by means of a small door cut for that purpose. In such a case, it is of course advisable to choose a wall on which there is little or no sunshine. The ice box may also be drained by a pipe leading to the outside and then properly cared for, thus saving much labor in the emptying of pans. It is not considered safe to connect it with the house sewer, because of the danger of sewer gases backing into it, even if a good trap is provided.

Care of Ice Chests.—Farmers' Bulletin No. 375 of the United States Department of Agriculture gives the following instructions in reference to care of ice chests:

If on a warm summer day you put your hand into an ice box well filled with ice you may think that the temperature is very low, and yet it is in all probability nearer 50° than 40° F. As low a temperature as 40° or 45° is only to be obtained in a very well-constructed box with a large receptacle for ice, and then only for a short time after it is filled. A box that maintains but 60° is, however, very useful in keeping food from day to day.

The ice box, no matter how well cooled, is and must be damp, and dampness is one of the requirements for bacterial growth. It must be remembered, also, that some varieties of bacteria grow at low temperatures. Therefore, the interior of an ice chest should be wiped every day with a dry cloth and once a week everything should be removed, so that sides, shelves, and drain may be thoroughly scalded. The water must be actually boiling when it is poured in, and the process repeated several times.

It must be remembered that refrigerator ice is often dirty, and that it may bring in putrefactive or even typhoid bacilli, for most bacteria are resistant to low temperature and are not destroyed by freezing. On this account, no food should be brought in direct contact with it, nor should it be put into drinking water, unless its purity is above suspicion.

All cooked food should be cooled as soon as possible before being placed in the ice box. Butter may be kept from taking up the flavors of other food by keeping it in a tightly covered receptacle. Milk requires more access of air, but in a clean ice box in which no strong-smelling food is kept, milk should remain uninjured in flavor for twelve to twenty-four hours. If vegetables or other foods of pronounced odor are kept in glass jars with covers, or in covered earthenware receptacles, there will be a fewer odors to be communicated. Portions of canned food should never be put into the ice box in the tin cans. Such food does not of necessity develop a poisonous product, as has sometimes been claimed, but experiments show that

ptomaines are particularly liable to develop in such cases. Casting out this somewhat remote possibility, the "tinny" taste acquired by such keeping is enough to condemn the practice.

Foods that are to be eaten raw, such as lettuce and celery, should be carefully cleaned before being placed in the ice box, and may with advantage be wrapped in a clean, damp cloth. If they are to be kept for some days they should, however, be put in without removing the roots, the further precaution being taken to wrap them carefully in clean paper or to put them into grocers' bags.

Keeping of Vegetables, Fruits, and Meats.—The Farmers' Bulletin No. 375 of the United States Department of Agriculture gives some additional considerations in reference to the keeping of vegetables, fruits, and meats in the home. These are as follows:

The following hints regarding the keeping of different kinds of food may be found useful:

Potatoes are kept without difficulty in a cool, dry, and dark place. Sprouts should not be allowed to grow in the spring.

Such roots as carrots, parsnips, and turnips remain plump and fresh if placed in earth or sand filled boxes on the cellar floor.

Sweet potatoes may be kept until January if cleaned, dried, and packed in chaff so that they will not touch each other.

Pumpkins and squash must be thoroughly ripe and mature to keep well. They should be dried from time to time with a cloth and kept not on the cellar floor, but on a shelf, and well separated from each other.

Cabbages are to be placed in barrels, with the roots uppermost.

Celery should be neither trimmed nor washed, but packed, heads up, in long, deep boxes, which should then be filled with dry earth.

Tomatoes may be kept until January, if gathered just before frost, wiped dry, and placed on straw-covered racks in the cellar. They should be firm and well-grown specimens, not yet beginning to turn. As they ripen they may be taken out for table use, and any soft or decaying ones must be removed.

Apples, for use during the autumn, may be stored in barrels without further precaution than to look them over now and then to remove decaying ones; but if they are to be kept till late winter or spring they must be of a variety known to keep well and they must be hand-picked and without blemish or bruise. They should be wiped dry and placed with little crowding on shelves in the cellar. As a further precaution they may be wrapped separately in soft paper.

Pears may be kept for a limited time in the same way, or packed in sawdust or chaff; which absorbs the moisture which might otherwise favor molding.

Oranges and lemons are kept in the same way. Wrapping in soft paper is here essential, as the uncovered skins if bruised offer good feeding ground for mold. Oranges may be kept for a long time in good condition if stored where it is very cold, but where freezing is not possible. Lemons and limes are often kept in brine, an old-fashioned household method.

Cranberries, after careful looking over to remove soft ones, are placed in a crock or firkin and covered with water. A plate or round board placed on top and weighted serves to keep the berries under water. The water should be changed once a month.

In winter, large pieces of fresh meat may be purchased and hung in the cellar. Thin pieces, as mutton chops, are sometimes dipped in mutton suet, which keeps the surface from drying and is easily scraped off before cooking.

Turkeys, chickens, and other birds should be carefully drawn as soon as killed and without washing hung in the coolest available place.

Smoked ham, tongue, beef, and fish are best put in linen bags and hung in the cellar.

Salt pork and corned beef should be kept in brine in suitable jars, kegs, or casks, and should be weighted so as to remain well covered. A plate or board weighted with a clean stone is an old-fashioned and satisfactory device.

Eggs may be packed for winter use in limewater or in water-glass solution, methods which are described in an earlier bulletin of this series. Many housekeepers have good success in packing them in bran, in oats, or in dry salt, but according to experiments summarized in the aforementioned bulletin, the preference is to be given to the 10 per cent solution of water-glass. Exclusion of the air with its accompanying microorganisms and the prevention of drying out are what is sought in all cases. Packed eggs are not equal to fresh eggs in flavor, but when they are well packed are of fairly good quality and perfectly wholesome.

Apples.—The United States Department of Agriculture, in Farmers' Bulletin No. 1160, gives the following information in reference to the keeping of apples:

Apples will stand a temperature several degrees below freezing (32° F.). The danger point is at about 28° F. The effect of freezing is to cause brown spots which extend to the surface and are easily seen. These spots may appear on any part of the apple, but usually occur at places where the water content is highest. Freezing has about the same effect on either green or ripe fruit. Slightly frozen apples may be thawed out slowly without injury except to the quality. Apples should be packed in barrels, allowing good ventilation when stored for long periods. Some of the common diseases of apples are: Scab, blotch, fruit spot, Jonathan spot, bitter pit, drought spot, stig-

nonose, water core, bitter, anthracnose, black rot, altervaria rot, blue mold, pink rot, spongy dry rot, brown rot, gray mold, soft scald, and scald.

Drinking Water.—The desirable temperature for drinking water is 45° to 50° F. Tests have proven that at this temperature it is a mild heart stimulant and slightly reduces the internal temperature of the body. When drinking water colder than 45° F. is used there is danger of cramps.

The amount of drinking water required in industrial plants is usually considered to be approximately $\frac{1}{4}$ gallon per man per working hour. This amount is based on using fountains and includes the waste.

The amount of refrigeration required to cool drinking water varies from 0.0003 to 0.0005 tons refrigeration per hour per man.

Fig. 217 shows the refrigerating effect due to placing one, two, and three cubes of ice in a glass of drinking water. The weight of the water in the glass was 0.4 lbs.; the weight of the ice cube was 0.1 lb.; the size of the glass was three inches in diameter at the top, 2.3 inches in diameter at the bottom and five inches high; the room temperature was 75°, and the glass was placed on a wooden table. Inasmuch as 50° is the desirable temperature for the water, it will be observed that this temperature is practically obtained by the use of two cubes of ice per glass of water. It is further noted from Fig. 134, that the use of three cubes of ice, maintained the temperature of the water at a fairly low temperature at a considerable length of time, and that one cube does not produce the desirable refrigerating effect.

Specific and Latent Heat of Foods.—Table XCV gives the specific heats and latent heats of some of the common foods. The second column gives the specific heat of the foods before freezing, expressed in B.t.u. per lb., while the third column gives the corresponding specific heat after freezing. The latent heat of fusion which is liberated during the freezing process is given in the last column of this table.

Ice Cream Making in the Home.—The National Association of Ice Industries has recently published a small bulletin

entitled "Ice Cream Making and Appliances in the Home," which was prepared by M. A. Pennington, director of Household Bureau. The following extract on the subject of "Ice Cream Making in the Home" is taken from that bulletin:

The most satisfactory temperatures for the freezing of ice cream range from about 16° F. to about 6° F. These temperatures are ob-

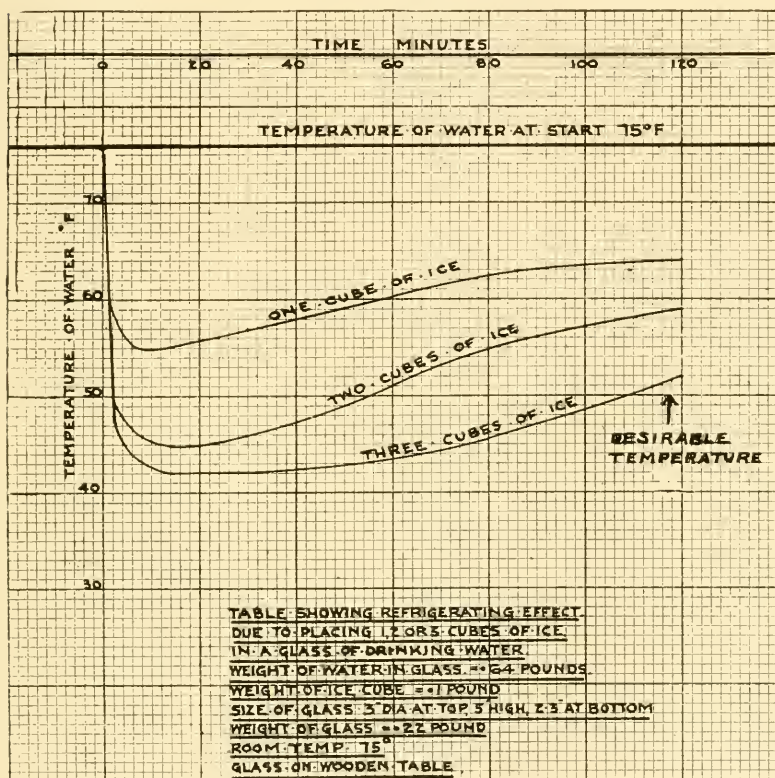


FIG. 217.—REFRIGERATING EFFECT OF ICE IN DRINKING WATER.

tained by the use of from 12 to 17 per cent of salt by weight, which is from 12 to 1 to 8 to 1 parts by volume. For uniformly good results, the ice and salt must be really measured, not just dumped in.

A great variety of flavors and ingredients can go into the making of ice creams and ices. Very palatable and nourishing "creams" can be made from very inexpensive materials. Again, however, proportions must be exact and directions must be followed.

The ice cream freezers on the market would seem to be sufficiently varied in capacity, operation, and price, to fill the need of

most individuals. The woman with the longer pocket-book can make the electric current do the churning for her. By substituting for the extra money outlay, exact attention to small details of manipulation

TABLE XCV.—SPECIFIC AND LATENT HEATS OF FOODS.

| Article | Specific Heat | | Latent Heat |
|------------------|-----------------|----------------|-------------|
| | Before Freezing | After Freezing | |
| Apples | .92 | ----- | ----- |
| Beans (green) | .91 | ----- | ----- |
| Beef (fresh) | .75 | .40 | 100 |
| Beef (salt) | .60 | ----- | ----- |
| Beer | .90 | ----- | ----- |
| Berries | .91 | ----- | ----- |
| Butter | .60 | .84 | 84 |
| Cabbage | .93 | .48 | 129 |
| Cantaloupes | .92 | ----- | ----- |
| Carrots | .87 | .45 | 118 |
| Cherries (fresh) | .92 | ----- | ----- |
| Cherries (dried) | .84 | ----- | ----- |
| Cheese | .64 | ----- | ----- |
| Chicken | .80 | .42 | 105 |
| Celery | .91 | ----- | ----- |
| Cider | .90 | ----- | ----- |
| Cream | .68 | .38 | 84 |
| Dates | .84 | ----- | ----- |
| Eggs | .76 | .40 | 100 |
| Eels | .69 | .38 | 88 |
| Fish (fresh) | .80 | .42 | 100 |
| Fish (dried) | .58 | ----- | ----- |
| Fruits (dried) | .89 | ----- | ----- |
| Game | .80 | .40 | 105 |
| Grapes | .92 | ----- | ----- |
| Grape Fruit | .92 | ----- | ----- |
| Ice Cream | .78 | .42 | 80 |
| Lemons | .92 | ----- | ----- |
| Lobster | .81 | .42 | 108 |
| Milk | .90 | .47 | 124 |
| Mutton | .67 | .81 | ----- |
| Onions | .91 | ----- | ----- |
| Oranges | .92 | ----- | ----- |
| Oysters | .84 | .44 | 114 |
| Peaches | .92 | ----- | ----- |
| Pears | .92 | ----- | ----- |

TABLE XCV.—SPECIFIC AND LATENT HEATS OF FOODS.—(Continued).

| Article | Specific Heat | | Latent Heat |
|------------------|-----------------|----------------|-------------|
| | Before Freezing | After Freezing | |
| Pigeon | .78 | .41 | 102 |
| Pork (fresh) | .50 | .30 | 70 |
| Potatoes | .80 | .42 | 105 |
| Poultry | .80 | .40 | 102 |
| Sausage | .70 | ----- | ----- |
| Sausage (smoked) | .60 | ----- | ----- |
| Strawberries | .92 | ----- | ----- |
| Veal | .70 | .39 | 90 |
| Watermelons | .92 | ----- | ----- |
| Wines | .90 | ----- | ----- |

and using mixtures, comparatively rich in cream, the crankless type of freezer can be made to produce excellent results. The athletic woman, who doesn't mind turning a crank nor shifting a staunchly made tub around, can get a freezer that will withstand hard knocks and long wear and tear; while the kitchenette apartment woman can buy a little, light appliance, that takes almost no room and is so inexpensive that she can leave it behind when she moves without qualm of conscience. First of all, the woman must understand her own problem well enough to make an intelligent selection. Such understanding can only come from a knowledge of the facts of the case.

Food Arrangement in Refrigerators.—Fig. 218 shows one of the suggested arrangements of food in household refrigerators. From this, it will be noted that the foods are stored with reference to two considerations. In the first place, special consideration is given to the temperature in different parts of the refrigerator. Those foods requiring the lowest temperatures are placed immediately under the ice compartment, and in the bottom part of the refrigerator, while those which require a higher temperature are placed in the top food compartment. A second consideration is the storing of foods which give off characteristic odors. Foods such as onions, lemons, cabbage, cheese, etc., are placed in the uppermost food compartment, so that the air in passing directly into the ice chamber from this food compartment, carries with it the odor from such foods. Thus the air allows part of the odors to be condensed and eliminated.

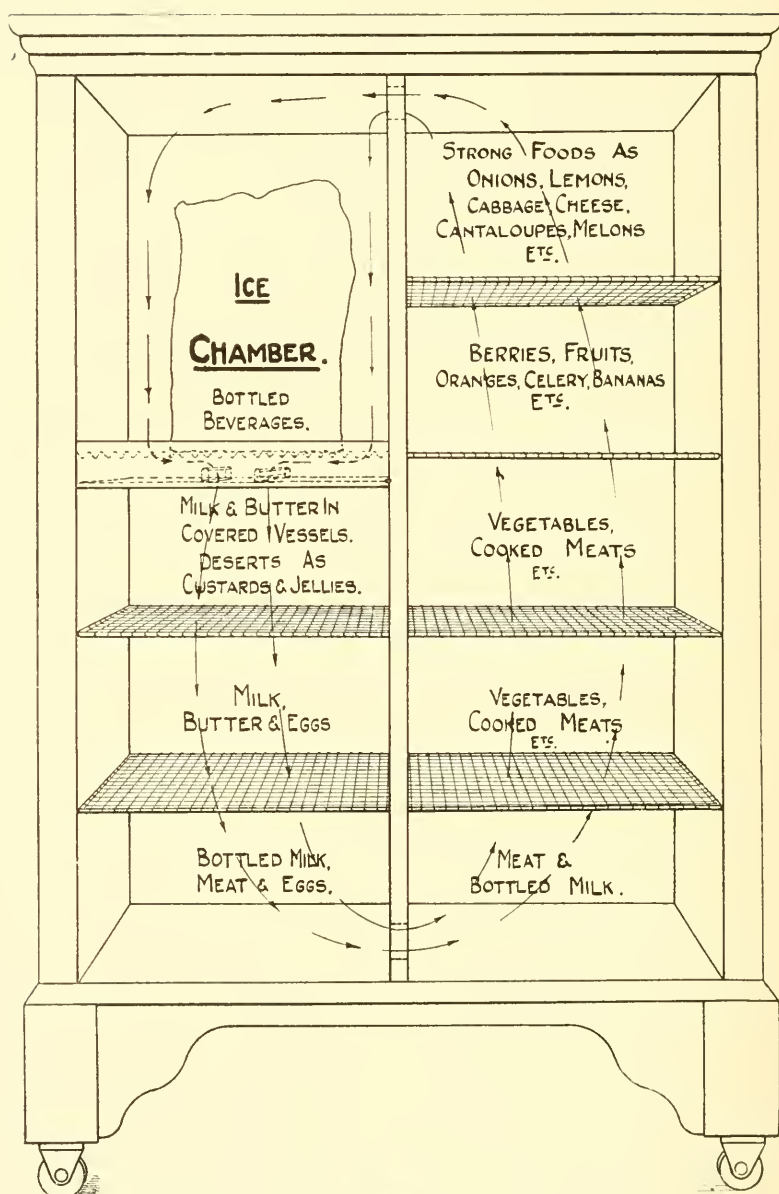


FIG. 218.—FOOD ARRANGEMENT IN REFRIGERATORS.

CHAPTER XIII.

MISCELLANEOUS TABLES.

Miscellaneous Tables.—The following miscellaneous tables may be classified into two divisions. In the first division are those tables which are especially related to the design, construction, and operation of both ice and mechanically cooled household refrigerators. In the second division are those which are only indirectly related to the subject of "Household Refrigeration." They pertain mostly to physics and mechanics.

Table XCVI gives some summer temperatures for the different states in the United States. The second column gives the average summer temperature in degrees F., while the third column gives the maximum temperature in degrees F. Some temperatures by months in various cities of France are given in Table XCVII. The temperatures in this table are degrees Centigrade. The average annual humidities for various cities in the United States are shown by Table XCVIII. Table XCVIX shows average summer and yearly tap water temperatures for a number of cities.

Table C gives the domestic water rates for a number of cities in the United States. This table includes the population of the various cities, the highest domestic rate per gallon of water, and the minimum annual water charge.

Table CI gives some average figures for the household consumption of water per year for a number of cities. It will be noted that the average consumption of water for the cities stated per household is 6369 cubic feet. This is equivalent to 17.5 cubic feet per day or 131 gallons per day.

TABLE XCVI.—SUMMER TEMPERATURES IN THE UNITED STATES.
(U. S. Weather Reports.)

| State | Average Summer Temp. Deg. F. | Maximum Summer Temp. Deg. F. |
|----------------|------------------------------------|------------------------------------|
| Arizona | 92 | 120 |
| Oklahoma | 83 | 114 |
| Texas | 83 | 112 |
| Louisiana | 83 | 110 |
| Arkansas | 83 | 106 |
| Georgia | 82 | 108 |
| Connecticut | 82 | 106 |
| Delaware | 82 | 102 |
| North Carolina | 81 | 109 |
| South Carolina | 81 | 109 |
| Florida | 81 | 109 |
| Alabama | 81 | 105 |
| Mississippi | 81 | 105 |
| Missouri | 80 | 113 |
| Tennessee | 80 | 107 |
| Kansas | 79 | 116 |
| Nevada | 79 | 110 |
| Maryland | 79 | 106 |
| Utah | 79 | 106 |
| New Mexico | 79 | 105 |
| Iowa | 78 | 111 |
| Kentucky | 78 | 97 |
| California | 77 | 117 |
| Virginia | 76 | 104 |
| Nebraska | 75 | 112 |
| West Virginia | 75 | 102 |
| Pennsylvania | 74 | 105 |
| Colorado | 73 | 106 |
| Ohio | 73 | 105 |
| Indiana | 73 | 104 |
| Illinois | 73 | 102 |
| New Jersey | 73 | 102 |
| Washington | 71 | 114 |
| New York | 71 | 104 |
| Michigan | 71 | 104 |
| Massachusetts | 70 | 105 |
| New Hampshire | 70 | 105 |
| Wisconsin | 70 | 103 |
| Wyoming | 69 | 108 |
| Rhode Island | 69 | 99 |
| Maine | 68 | 105 |
| Montana | 67 | 106 |
| North Dakota | 67 | 102 |
| South Dakota | 67 | 102 |
| Vermont | 65 | 102 |
| Minnesota | 63 | 102 |
| Idaho | 63 | 94 |
| Oregon | 62 | 99 |

Table CII gives the quantities of water which are discharged by house service pipes in gallons per minute. This table is for various diameters of pipes, with certain initial water pressures, no back pressure, and through 100 feet of service pipe.

Table CIII gives the list of cities which use electric current different from the standard alternating current, 60 cycles and 110 or 220 volts.

TABLE CXVII.—TEMPERATURES BY MONTHS IN FRANCE.
(1912-1917 Inclusive.)

| | Angers Degrees C. | Auxerre Degrees C. | Bordeaux Degrees C. | Chaumont Degrees C. |
|-----------|----------------------|-----------------------|------------------------|------------------------|
| January | 4. | 2. | 5. | 0.5 |
| February | 5. | 4. | 6. | 2. |
| March | 7. | 6. | 8.5 | 5. |
| April | 10.5 | 10.5 | 11.5 | 9.5 |
| May | 14. | 13. | 14.5 | 13. |
| June | 17. | 18. | 17.5 | 16.5 |
| July | 19. | 19.5 | 20. | 18.5 |
| August | 19. | 19. | 20. | 18. |
| September | 15.5 | 15.5 | 17.5 | 14.5 |
| October | 11. | 10.5 | 13. | 9.5 |
| November | 7. | 6. | 8.5 | 5. |
| December | 4. | 2. | 5. | 1.1 |
| Average | 11.0 | 10.5 | 12.0 | 9.5 |

From French Government Weather Reports.

Summer and Winter Tap Water Temperatures.—Table C shows the relative importance of tap water temperature and density of population in the important cities of United States and Canada.

It is readily seen that the summer water temperatures are mostly under 75° F., while 80° includes nearly all of the important cities.

In winter 65° is the maximum temperature reached in nearly all of the larger cities.

In some parts of Texas summer tap water temperatures as high as 120° are reported.

HOUSEHOLD REFRIGERATION

TABLE XCVIII.—RELATIVE HUMIDITIES IN VARIOUS CITIES.
(U. S. Weather Reports.)

| Average Annual Humidities for Various Cities of United States. | | |
|--|---------|---------|
| City | 8 a. m. | 8 p. m. |
| Albany, N. Y. | 78 | 72 |
| Asheville, N. C. | 85 | 71 |
| Atlanta, Ga. | 79 | 65 |
| Atlantic City, N. J. | 80 | 79 |
| Augusta, Ga. | 82 | 66 |
| Baltimore, Md. | 72 | 66 |
| Boston, Mass. | 73 | 70 |
| Hartford, Conn. | 74 | 68 |
| Jacksonville, Fla. | 83 | 77 |
| Key West, Fla. | 78 | 77 |
| Macon, Ga. | 83 | .... |
| New Haven, Conn. | 75 | 72 |
| New York, N. Y. | 75 | 62 |
| Norfolk, Va. | 80 | 75 |
| Philadelphia, Pa. | 74 | 66 |
| Portland, Me. | 75 | 73 |
| Providence, R. I. | 74 | 71 |
| Savannah, Ga. | 81 | 75 |
| Washington, D. C. | 76 | 68 |
| Wilmington, N. C. | 81 | 77 |
| Birmingham, Ala. | 79 | 65 |
| Galveston, Texas | 84 | 78 |
| Mobile, Ala. | 84 | 74 |
| Montgomery, Ala. | 82 | 64 |
| New Orleans, La. | 83 | 72 |
| Pensacola, Fla. | 80 | 75 |
| San Antonio, Texas | 81 | 53 |
| Tampa, Fla. | 84 | 76 |
| Buffalo, N. Y. | 77 | 73 |
| Chattanooga, Tenn. | 80 | 63 |
| Chicago, Ill. | 78 | 71 |
| Cincinnati, Ohio | 76 | 62 |
| Cleveland, Ohio | 77 | 70 |
| Columbus, Ohio | 79 | 66 |
| Detroit, Mich. | 80 | 71 |
| Duluth, Minn. | 81 | 71 |
| Grand Rapids, Mich. | 82 | 70 |
| Indianapolis, Ind. | 77 | 64 |
| Louisville, Ky. | 76 | 61 |
| Dayton, Ohio | 80 | 67 |
| Milwaukee, Wis. | 78 | 72 |
| Nashville, Tenn. | 80 | 62 |
| Pittsburgh, Pa. | 77 | 66 |
| Rochester, N. Y. | 75 | 71 |
| Syracuse, N. Y. | 77 | .... |
| Toledo, Ohio | 79 | 69 |
| Davenport, Iowa | 80 | 65 |
| Des Moines, Iowa | 80 | 63 |
| Kansas City, Mo. | 77 | 62 |
| Memphis, Tenn. | 79 | 65 |
| St. Louis, Mo. | 77 | 63 |
| St. Paul, Minn. | 80 | 63 |
| Springfield, Ill. | 79 | 65 |

TABLE XCVIII.—RELATIVE HUMIDITIES IN VARIOUS CITIES.

(U. S. Weather Reports.)—(Continued).

| Average Annual Humidities for Various Cities of United States. | | |
|--|---------|---------|
| City | 8 a. m. | 8 p. m. |
| Fort Worth, Texas | 78 | .... |
| Lincoln, Neb. | 79 | 59 |
| Oklahoma City, Okla. | 80 | 59 |
| Omaha, Neb. | 78 | 60 |
| Sioux City, Iowa | 81 | 61 |
| Wichita, Kan. | 78 | 57 |
| Denver, Colo. | 63 | 41 |
| El Paso, Texas | 54 | 26 |
| Helena, Mont. | 68 | 50 |
| Phoenix, Ariz. | 54 | 28 |
| Pueblo, Colo. | 64 | 37 |
| Reno, Nev. | 72 | 39 |
| Salt Lake City, Utah | 60 | 45 |
| Santa Fe, N. Mex. | 58 | 40 |
| Spokane, Wash. | 77 | 50 |
| Los Angeles, Cal. | 78 | 62 |
| Portland, Ore. | 86 | 63 |
| Sacramento, Cal. | 82 | 52 |
| San Diego, Cal. | 79 | 70 |
| San Francisco, Cal. | 87 | 72 |
| Seattle, Wash. | 87 | 67 |

TABLE XCIX.—TAP WATER TEMPERATURES.

| City | Average Summer Temp. Deg. F. | Average Yearly Temp. Deg. F. |
|--------------------|---------------------------------|---------------------------------|
| Augusta, Ga. | 81 | 66 |
| Atlanta, Ga. | 81 | 62 |
| Albany, N. Y. | 76 | 56 |
| Allentown, Pa. | 60 | 57 |
| Akron, Ohio | 74 | 55 |
| Birmingham, Ala. | 80 | 65 |
| Buffalo, N. Y. | 71 | 52 |
| Boston, Mass. | 69 | 54 |
| Columbus, Ohio | 74 | 56 |
| Charleston, W. Va. | 70 | 40 |
| Cleveland, Ohio | 72 | 56 |
| Cincinnati, Ohio | 80 | 62 |
| Cambridge, Mass. | 70 | 50 |
| Cedar Rapids, Iowa | 68 | 55 |
| Dayton, Ohio | 70 | 60 |
| Detroit, Mich. | 67 | 50 |
| Davenport, Iowa | .... | 56 |
| Duluth, Minn. | 55 | 45 |
| Des Moines, Iowa | 65 | 58 |
| Decatur, Ill. | 73 | 53 |
| Erie, Pa. | 70 | 53 |
| East Orange, N. J. | 58 | 58 |
| Elizabeth, N. J. | 60 | 50 |
| Fort Wayne, Ind. | .... | 50 |
| Gary, Ind. | 62 | 52 |

TABLE XCIX.—TAP WATER TEMPERATURES.—(Continued).

| City | Average Summer Temp. Deg. F. | Average Yearly Temp. Deg. F. |
|----------------------|---------------------------------|---------------------------------|
| Grand Rapids, Mich. | 74 | 55 |
| Galveston, Texas | 85 | 80 |
| Hamilton, Canada | 55 | 43 |
| Haverhill, Mass. | 58 | 40.7 |
| Johnstown, Pa. | 65 | 50 |
| Jackson, Miss. | 65 | 45 |
| Jacksonville, Fla. | 82 | 76 |
| Kansas City, Kan. | 77 | 62 |
| Lincoln, Neb. | 60 | 55 |
| Louisville, Ky. | 70 | 60 |
| Little Rock, Ark. | 70 | 50 |
| Los Angeles, Cal. | 62 | 60 |
| Lowell, Mass. | 56 | 54 |
| Lexington, Ky. | 67.8 | 57.4 |
| Lawrence, Mass. | 60 | 55 |
| Milwaukee, Wis. | 52 | 50 |
| Montreal, Ont., Can. | 67 | 51 |
| Minneapolis, Minn. | 72 | 54 |
| Mt. Vernon, N. Y. | 73 | 55 |
| Malden, Mass. | 69 | 54 |
| Mobile, Ala. | 70 | 60 |
| New Brunswick, N. J. | 60 | 57 |
| New York, N. Y. | 65 | 55 |
| New Haven, Conn. | 65 | 58 |
| Nashville, Tenn. | 75 | 60 |
| New Orleans, La. | 80 | 65 |
| New Bedford, Mass. | 69 | 55 |
| Oklahoma City, Okla. | 75 | 60 |
| Ottawa, Ont., Can. | 77 | 54 |
| Omaha, Neb. | 86 | 60 |
| Oakland, Cal. | 70 | 55 |
| Providence, R. I. | 74 | 53 |
| Portland, Maine | 70 | 50 |
| Patterson, N. J. | 60 | 50 |
| Pawtucket, R. I. | 72 | 55 |
| Pittsburgh, Pa. | 72.5 | 52.8 |
| Portland, Ore. | 50 | 42 |
| Pasadena, Cal. | 63 | 57 |
| Roanoke, Va. | 60 | 60 |
| Rochester, N. Y. | 69 | 51 |
| Richmond, Va. | 74 | 70 |
| Rockford, Ill. | 58 | 58 |
| Springfield, Mass. | 64 | 49 |
| Superior, Wis. | 60 | 47 |
| Springfield, Mo. | 65 | 60 |
| Spokane, Wash. | 52 | 50 |
| Salt Lake City, Utah | 50 | 45 |
| Sommerville, Mass. | 69 | 53.5 |
| Springfield, Ohio | 58 | 57 |
| St. Joseph, Mo. | 77 | 54 |
| St. Paul, Minn. | 65 | 54 |
| Sioux City, Iowa | 51 | 49 |
| St. John, N. B. | 65 | 51 |
| San Francisco, Cal. | 65 | 57 |

TABLE XCIX.—TAP WATER TEMPERATURES.—(Continued).

| City | Average Summer Temp. Deg. F. | Average Yearly Temp. Deg. F. |
|----------------------|---------------------------------|---------------------------------|
| Seattle, Wash. | 55 | 49 |
| Toledo, Ohio | 76.4 | 56 |
| Terre Haute, Ind. | 76 | 57 |
| Tacoma, Wash. | 60 | 40.5 |
| Troy, N. Y. | 70 | 60 |
| Utica, N. Y. | 68 | 55 |
| Waterbury, Conn. | 71 | 54 |
| Winnipeg, Man., Can. | 70 | 56 |
| Woonsocket, R. I. | 70 | 50 |
| Worcester, Mass. | 72 | 68 |
| Washington, D. C. | 75.4 | 60.5 |
| Youngstown, Ohio | 90.8 | 68.7 |

TABLE C.—DOMESTIC WATER RATES.
(*American City Magazine.*)

| City | Population | Highest Domestic Rate per 1,000 Gal. | Minimum Annual Charge |
|-------------------------|------------|---|-----------------------------|
| Mobile, Ala. | 69,151 | 15c | 6.00 |
| Montgomery | 43,464 | 15c | 12.00 |
| Los Angeles, Cal. | 578,000 | 13.3c | 9.00 |
| San Diego | 74,683 | 14.7c | |
| Stockton | 40,296 | 25c | 12.00 |
| Colorado Springs, Colo. | 30,105 | 15c | 12.00 |
| Bridgeport, Conn. | 143,538 | 18c | 10.00 |
| Hartford | 138,036 | 16c | 5.00 |
| Meriden | 29,842 | 15c | 7.50 |
| New Britain | 59,316 | 10c | 5.00 |
| Norwich | 29,685 | 26.7c | 5.00 |
| Stamford | 35,086 | 20c | 6.00 |
| Wilmington, Del. | 110,168 | 10c | 10.00 |
| Washington, D. C. | 437,571 | 10c | 5.65 |
| Miami, Fla. | 29,549 | 20c | 12.00 |
| Atlanta, Ga. | 200,616 | 13.3c | 9.60 |
| Augusta | 52,548 | 25c | 9.00 |
| Savannah | 83,252 | 12c | ..... |
| Honolulu, Hawaii | 83,327 | 10c | 6.00 |
| Boise, Idaho | 28,000 | 27c | 12.00 |
| Bloomington, Ill. | 28,725 | 35c | 3.25 |
| Cicero | 44,995 | 13.3c | 6.00 |
| Decatur | 43,818 | 8c | 4.00 |
| Evanston | 37,215 | 6.8c | 6.00 |

HOUSEHOLD REFRIGERATION

TABLE C.—DOMESTIC WATER RATES.—(Continued).
(*American City Magazine.*)

| City | Population | Highest Domestic Rate per 1,000 Gal. | Minimum Annual Charge |
|--------------------|------------|---|-----------------------------|
| Peoria | 76,121 | 30c | 3.20 |
| Quincy | 35,978 | 50c | 10.00 |
| Rock Island | 35,177 | 18.7c | 8.10 |
| Evansville, Ind. | 85,549 | 20c | 2.00 |
| Fort Wayne | 86,549 | 16c | 6.00 |
| Richmond | 26,765 | 20c | 6.00 |
| South Bend | 70,983 | 12c | 7.20 |
| Terre Haute | 66,083 | 25c | 9.00 |
| Cedar Rapids, Iowa | 45,566 | 25.3c | 9.00 |
| Council Bluffs | 36,162 | 35c | 6.00 |
| Des Moines | 126,468 | 30c | 4.00 |
| Sioux City | 71,227 | 25c | None |
| Topeka, Kan. | 50,022 | 45c | 4.80 |
| Covington, Ky. | 57,121 | 24c | 8.00 |
| Lexington | 41,534 | 25c | 6.00 |
| Louisville | 234,891 | 40c | 12.00 |
| New Orleans, La. | 387,408 | 10c | 3.00 |
| Shreveport | 43,874 | 25c | 7.80 |
| Bangor, Maine | 25,978 | 33.3c | 12.00 |
| Biddeford | 28,000 | 26.7c | 16.00 |
| Baltimore, Md. | 738,826 | 8.7c | |
| Cumberland | 29,837 | 7c | 8.00 |
| Hagerstown | 28,066 | 30c | 6.00 |
| Hyattsville | 50,000 | 12c | 4.00 |
| Brookline, Mass. | 37,748 | 16c | None |
| Brockton | 66,138 | 25.3c | |
| Cambridge | 109,694 | 10c | 5.00 |
| Chelsea | 43,184 | 14.7c | 6.00 |
| Chicopee | 36,214 | 20c | 10.00 |
| Everett | 40,120 | 16.7c | 6.00 |
| Fall River | 120,485 | 28c | None |
| Fitchburg | 41,013 | 24c | 5.00 |
| Haverhill | 53,884 | 21.3c | 10.00 |
| Lawrence | 94,270 | 24c | 8.00 |
| Lowell | 112,759 | 28c | 10.50 |
| Lynn | 99,148 | 20c | 10.00 |
| New Bedford | 121,217 | 15c | 5.00 |
| Quincy | 47,876 | 33c | 8.00 |
| Revere | 28,823 | 20c | 10.00 |
| Salem | 42,529 | 20c | 3.00 |
| Somerville | 93,091 | 16c | 6.00 |
| Springfield | 129,563 | 30c | None |
| Taunton | 37,137 | 25c | 6.00 |
| Waltham | 30,915 | 27c | 5.00 |
| Worcester | 179,754 | 20c | 4.00 |

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TABLE C.—DOMESTIC WATER RATES.—(Continued).
(*American City Magazine.*)

| City | Population | Highest Domestic Rate per 1,000 Gal. | Minimum Annual Charge |
|---------------------|------------|---|-----------------------------|
| Battle Creek, Mich. | 36,164 | 13c | 3.00 |
| Bay City | 47,554 | 10c | 6.00 |
| Highland Park | 46,499 | 70c | 5.00 |
| Jackson | 48,374 | 13.3c | 3.20 |
| Lansing | 57,327 | 16c | 7.80 |
| Saginaw | 61,903 | 11c | 10.00 |
| Duluth, Minn. | 98,917 | 20c | 6.00 |
| Minneapolis | 380,498 | 8c | |
| St. Paul | 234,595 | 8c | 3.60 |
| Joplin, Mo. | 29,855 | 35c | 12.00 |
| Lincoln, Neb. | 54,934 | 15c | 6.00 |
| Manchester, N. H. | 78,384 | 13.3c | 8.00 |
| Nashua | 28,379 | 24c | 16.00 |
| Belmar, N. J. | 25,000 | 23.3c | 10.50 |
| Camden | 116,309 | 25c | 8.00 |
| Jersey City | 279,864 | 12c | None |
| Kearney | 26,724 | 20c | 6.76 |
| Montclair | 28,810 | 30c | 10.00 |
| Newark | 414,216 | 13.3c | 6.00 |
| New Brunswick | 32,779 | 20c | 15.00 |
| Paterson | 135,866 | 30c | 12.00 |
| Albany, N. Y. | 113,344 | 13.3c | |
| Binghamton | 66,800 | 10c | 4.00 |
| Buffalo | 506,775 | 8c | 10.00 |
| Elmira | 45,305 | 40c | 6.00 |
| Jamestown | 38,917 | 20c | 6.00 |
| Kingston | 26,688 | 22.2c | 14.00 |
| Mt. Vernon | 42,726 | 40c | 12.00 |
| New York City | 5,621,151 | 13.4c | None |
| N. Y. C. Brooklyn | 2,022,262 | 13.3c | |
| N. Y. C. Queens | 172,775 | . | |
| N. Y. C. Richmond | 115,959 | 13.3c | None |
| Niagara Falls | 50,760 | 8c | 6.00 |
| Poughkeepsie | 35,000 | 26.7c | 1.00 |
| Rochester | 295,750 | 14c | 4.00 |
| Rome | 26,341 | 20c | 5.00 |
| Schenectady | 88,723 | 7c | 3.00 |
| Syracuse | 171,717 | 14.8c | 4.00 |
| Troy | 72,013 | | |
| Utica | 94,156 | 40c | |
| Yonkers | 100,226 | 21.3c | 8.00 |
| Charlotte, N. C. | 46,338 | 26c | 6.00 |
| Wilmington | 33,372 | 21.6c | 13.00 |
| Akron, Ohio | 208,435 | | |
| Cincinnati | 410,247 | 16c | 4.80 |

HOUSEHOLD REFRIGERATION

TABLE C.—DOMESTIC WATER RATES.—(Continued).
(*American City Magazine.*)

| City | Population | Highest Domestic Rate per 1,000 Gal. | Minimum Annual Charge |
|----------------------|------------|---|-----------------------------|
| Cleveland | 796,836 | 5.3c | 2.50 |
| Columbus | 237,031 | 16c | 4.00 |
| Dayton | 152,559 | 12c | 6.60 |
| Lakewood | 41,732 | 12c | 5.40 |
| Lorain | 37,295 | 2.00 | 8.00 |
| Mansfield | 27,824 | 26.7c | 6.00 |
| Newark | 26,718 | 24c | 6.00 |
| Springfield | 60,840 | 10c | 4.00 |
| Steubenville | 28,508 | 40c | 5.00 |
| Toledo | 243,109 | 13.3c | 8.50 |
| Youngstown | 132,358 | 26.7c | None |
| Zanesville | 29,569 | 15c | 6.00 |
| Oklahoma City, Okla. | 91,258 | 32c | 7.00 |
| Tulsa | 72,075 | 25c | 9.00 |
| Portland, Ore. | 258,288 | 10.7c | 6.00 |
| Allentown, Pa. | 73,502 | 106.70 | .72 |
| Chester | 58,030 | 34.5c | 6.96 |
| Harrisburg | 75,917 | 5.7c | 4.00 |
| Johnston | 67,327 | 27c | 12.00 |
| Philadelphia | 1,823,158 | 13.3c | |
| Pittsburgh | 588,193 | 18c | 8.00 |
| Newport, R. I. | 30,255 | 40c | |
| Providence | 237,595 | 20c | 8.00 |
| Charleston, S. C. | 67,957 | 24.7c | 12.00 |
| Sioux Falls, S. D. | 25,176 | 40c | 9.00 |
| Knoxville, Tenn. | 77,818 | 18c | 10.08 |
| Memphis | 162,351 | 33.3c | 12.00 |
| Nashville | 118,342 | 17.7c | 6.00 |
| Austin, Texas | 34,876 | 20c | 6.00 |
| Dallas | 158,977 | 25c | |
| El Paso | 77,543 | 27.5c | 15.00 |
| Fort Worth | 106,482 | 60c | 13.80 |
| Galveston | 44,255 | 26.7c | 3.00 |
| Waco | 38,500 | 37.5c | 9.00 |
| Salt Lake City, Utah | 118,110 | 7.3c | 6.00 |
| Danville, Va. | 25,000 | 10c | 6.00 |
| Lynchburg | 29,956 | 28.8c | |
| Richmond | 171,667 | 13.5c | 7.20 |
| Bellingham, Wash. | 25,570 | 23.3c | 12.00 |
| Seattle | 315,652 | 13.3c | 6.00 |
| Spokane | 104,437 | 10c | 9.60 |
| Tacoma | 96,965 | 13.3c | 6.00 |

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TABLE C.—DOMESTIC WATER RATES.—(Continued).

| City | Population | Highest Domestic Rate per 1,000 Gal. | Minimum Annual Charge |
|-------------------------|------------|--------------------------------------|-----------------------|
| Charleston, W. Va. | 39,608 | 30c | 12.00 |
| Clarksburg | 27,869 | 35c | 9.00 |
| Huntington | 50,177 | 20c | 9.00 |
| Wheeling | 54,322 | 15c | |
| Kenosha, Wis. | 40,472 | 16c | 6.00 |
| La Crosse | 30,363 | 20c | |
| Madison | 38,378 | 10c | 4.00 |
| Milwaukee | 457,147 | 8c | None |
| St. John, New Brunswick | 60,000 | None | 12.00 |
| Sydney, Nova Scotia | 27,000 | 25c | 8.00 |
| Brantford, Ontario | 32,700 | 35c | 4.00 |
| London | 60,000 | 16.8c | 8.00 |
| Ottawa | 112,000 | | |
| Toronto | 499,278 | 13.8c | |
| Montreal, Quebec | 694,000 | 12.8c | |
| Quebec | 120,000 | 60c | |

TABLE CI.—AVERAGE HOUSEHOLD CONSUMPTION OF WATER.

| City | Cubic Feet Per Year |
|---------------------|---------------------|
| Boston, Mass. | 6,000 |
| Cincinnati, Ohio | 6,000 |
| Cleveland, Ohio | 9,000 |
| Dayton, Ohio | 3,600 |
| Flint, Mich. | 7,200 |
| Grand Rapids, Mich. | 8,000 |
| Milwaukee, Wis. | 5,300 |
| Peoria, Ill. | 6,400 |
| Pontiac, Mich. | 8,000 |
| Richmond, Ky. | 2,400 |
| Rockford, Ill. | 8,400 |

Average: 6,391 cubic feet yearly, 17.5 cubic feet per day, 131 gallons per day.

TABLE CII.—QUANTITY OF WATER DISCHARGED FROM HOUSE SERVICE PIPES IN GALLONS PER MINUTE.

Through 100 Ft. of Service Pipe, No Back Pressure.

| Pressure in Main Lbs. per sq. in. | 1/2 | 3/4 | 1 | 1 1/2 | 2 |
|--------------------------------------|------|------|------|-------|------|
| 30 | 4.94 | 8.65 | 13.8 | 28.2 | 15.9 |
| 40 | 5.76 | 10.0 | 15.8 | 32.6 | 184. |
| 50 | 6.44 | 11.2 | 17.7 | 36.4 | 206. |
| 60 | 7.04 | 12.3 | 19.4 | 39.9 | 225. |
| 75 | 7.85 | 13.8 | 21.7 | 44.6 | 252. |
| 100 | 9.12 | 15.9 | 25.1 | 51.6 | 291. |
| 130 | 10.4 | 18.1 | 28.6 | 58.8 | 352. |

HOUSEHOLD REFRIGERATION

TABLE CIII.—CITIES USING ELECTRIC CURRENT DIFFERENT FROM THE STANDARD A. C. 60 CYCLES, 110-220 VOLTS.

(Cities of 50,000 population or over.)

| Location. | D. C. | A. C. | Cycles | Volts |
|-------------------------|-------|-------|-----------|-----------------------|
| Mobile, Ala. | x | x | 60 | 118 |
| Little Rock, Ark. | x | x | 60 | 110 |
| Los Angeles, Cal. | x | x | 50 | 110-220-440 |
| Pasadena, Cal. | | x | 50 | 115 |
| Glendale, Cal. | | x | 50 | 110-220 |
| Canon City, Colo. | | x | 30 | 120 |
| Denver, Colo. | x | x | 60 | 110 |
| Bridgeport, Conn. | x | x | 60 | 110 |
| Hartford, Conn. | x | x | 60 | 110-220 |
| Wilmington, Del. | x | x | 60 | 110-115 |
| Atlanta, Ga. | | x | 25 & 60 | 110-220 |
| Savannah, Ga. | x | x | 60 | 110 |
| Chicago, Ill. | x | x | 60 | 115 |
| Alton, Ill. | | x | 25 | 110 |
| Indianapolis, Ind. | x | x | 60 | 118 |
| Richmond, Ind. | x | x | 60 | 116 A. C. & 500 D. C. |
| Des Moines, Iowa | x | x | 60 | 115-230 |
| Sioux City, Iowa | x | | | 104 |
| Topeka, Kan. | x | x | 60 | 115 |
| New Orleans, La. | x | x | 60 | 110-220 |
| Portland, Maine | x | x | 60 | 116 |
| Baltimore, Md. | x | x | 60 | 120 |
| Boston, Mass. | x | x | 60 | 113 |
| Detroit, Mich. | x | x | 60 | 120 & 240 |
| Crookston, Minn. | x | x | 60 | 110 |
| Kansas City, Mo. | x | x | 60 & 25 | 110 & 220 |
| Kearney, Neb. | | x | 60 | 125 |
| Portsmouth, N. H. | | x | 60 & 25 | 117 |
| New Egypt, N. J. | x | | | 220 |
| Albany, N. Y. | | x | 40 | 115 |
| Borough of Brooklyn | x | x | 25 & 62.5 | 120 |
| Borough of Manhattan | x | x | 60 | 110 A. C. & 120 D. C. |
| Niagara Falls, N. Y. | | x | 25 | 110 |
| Rochester, N. Y. | x | x | 60 & 25 | 117 |
| Syracuse, N. Y. | | x | 25 & 60 | 110 |
| Spray, N. C. | x | | | 220 |
| Cincinnati, Ohio | x | x | 60 | 118 |
| Toledo, Ohio | x | x | 60 & 25 | 110 |
| Portland, Ore. | x | x | | 120-240 |
| Altoona, Pa. | x | x | 60 | 110 |
| Philadelphia, Pa. | x | x | 60 | 110 |
| Scranton, Pa. | x | x | 60 | 115 |
| Columbia, S. C. | | x | 40 | 115 |
| Dallas, Texas | x | x | 60 | 110-220 |
| Galveston, Texas | x | x | 60 | 110 |
| Rutland, Vermont | | x | 25 & 60 | 115 |
| Norfolk, Va. | x | x | 60 | 112 |
| Milwaukee, Wis. | x | x | 25 & 60 | 120-240 |
| Laramie, Wyo. | x | x | 60 | 110 |
| Brandon, Canada | x | x | 60 | 120 |
| Hamilton, Ontario, Can. | | x | 66⅔ | 110-220 |
| Stratford, Ont. | | x | 25 | 110-220 |
| Toronto, Ont. | | x | 25 | 115 |

TABLE CIII.—CITIES USING ELECTRIC CURRENT DIFFERENT FROM THE STANDARD A. C. 60 CYCLES, 110-220 VOLTS.—(Continued.)

(Cities of 50,000 population or over.)

| Location. | D. C. | A. C. | Cycles | Volts |
|----------------------------|-------|-------|--------|----------|
| Quebec | | x | 64 | 104 |
| Guadalajara, Mexico | | x | 100 | 104-1040 |
| Victoria, Mexico | | x | 125 | 104 |
| Mexico, Mexico | | | 50 | 210-3000 |
| Barbados, West Indies | | x | 50 | 210 |
| Havana | x | | 62½ | 110 |
| Santo Domingo | | x | 133 | 104 |
| Georgetown, British Guiana | | x | 125 | 104 |

TABLE CIV.—TEMPERATURE CONVERSION CENTIGRADE TO FAHRENHEIT.

| C. | F. | R. | C. | F. | R. | C. | F. | R. |
|-------|---------|--------|------|---------|--------|------|--------|-------|
| +100° | +212.0° | +80.0° | +53° | +127.4° | +42.4° | + 6° | +42.8° | +4.8° |
| 99 | 210.2 | 79.2 | 52 | 125.6 | 41.6 | 5 | 41.0 | 4.0 |
| 98 | 208.4 | 78.4 | 51 | 123.8 | 40.8 | 4 | 39.2 | 3.2 |
| 97 | 206.6 | 77.6 | 50 | 122.0 | 40.0 | 3 | 37.4 | 2.4 |
| 96 | 204.8 | 76.8 | 49 | 120.2 | 39.2 | 2 | 35.6 | 1.6 |
| 95 | 203.0 | 76.0 | 48 | 118.4 | 38.4 | 1 | 33.8 | 0.8 |
| 94 | 201.2 | 75.2 | 47 | 116.6 | 37.6 | Zero | 32.0 | Zero |
| 93 | 199.4 | 74.4 | 46 | 114.8 | 36.8 | - 1 | 30.2 | - 0.8 |
| 92 | 197.6 | 73.6 | 45 | 113.0 | 36.0 | 2 | 28.4 | 1.6 |
| 91 | 195.8 | 72.8 | 44 | 111.2 | 35.2 | 3 | 26.6 | 2.4 |
| 90 | 194.0 | 72.0 | 43 | 109.4 | 34.4 | 4 | 24.8 | 3.2 |
| 89 | 192.2 | 71.2 | 42 | 107.6 | 33.6 | 5 | 23.0 | 4.0 |
| 88 | 190.4 | 70.4 | 41 | 105.8 | 32.8 | 6 | 21.2 | 4.8 |
| 87 | 188.6 | 69.6 | 40 | 104.0 | 32.0 | 7 | 19.4 | 5.6 |
| 86 | 186.8 | 68.8 | 39 | 102.2 | 31.2 | 8 | 17.6 | 6.4 |
| 85 | 185.0 | 68.0 | 38 | 100.4 | 30.4 | 9 | 15.8 | 7.2 |
| 84 | 183.2 | 67.2 | 37 | 98.6 | 29.6 | 10 | 14.0 | 8.0 |
| 83 | 181.4 | 66.4 | 36 | 96.8 | 28.8 | 11 | 12.2 | 8.8 |
| 82 | 179.6 | 65.6 | 35 | 95.0 | 28.0 | 12 | 10.4 | 9.6 |
| 81 | 177.8 | 64.8 | 34 | 93.2 | 27.2 | 13 | 8.6 | 10.4 |
| 80 | 176.0 | 64.0 | 33 | 91.4 | 26.4 | 14 | 6.8 | 11.2 |
| 79 | 174.2 | 63.2 | 32 | 89.6 | 25.6 | 15 | 5.0 | 12.0 |
| 78 | 172.4 | 62.4 | 31 | 87.8 | 24.8 | 16 | 3.2 | 12.8 |
| 77 | 170.6 | 61.6 | 30 | 86.0 | 24.0 | 17 | 1.4 | 13.6 |
| 76 | 168.8 | 60.8 | 29 | 84.2 | 23.2 | 18 | - 0.4 | 14.4 |
| 75 | 167.0 | 60.0 | 28 | 82.4 | 22.4 | 19 | - 2.2 | 15.2 |
| 74 | 165.2 | 59.2 | 27 | 80.6 | 21.6 | 20 | 4.0 | 16.0 |
| 73 | 163.4 | 58.4 | 26 | 78.8 | 20.8 | 21 | 5.8 | 16.8 |
| 72 | 161.6 | 57.6 | 25 | 77.0 | 20.0 | 22 | 7.6 | 17.6 |
| 71 | 159.8 | 56.8 | 24 | 75.2 | 19.2 | 23 | 9.4 | 18.4 |
| 70 | 158.0 | 56.0 | 23 | 73.4 | 18.4 | 24 | 11.2 | 19.2 |
| 69 | 156.2 | 55.2 | 22 | 71.6 | 17.6 | 25 | 13.0 | 20.0 |
| 68 | 154.4 | 54.4 | 21 | 69.8 | 16.8 | 26 | 14.8 | 20.8 |
| 67 | 152.6 | 53.6 | 20 | 68.0 | 16.0 | 27 | 16.6 | 21.6 |
| 66 | 150.8 | 52.8 | 19 | 66.2 | 15.2 | 28 | 18.4 | 22.4 |
| 65 | 149.0 | 52.0 | 18 | 64.4 | 14.4 | 29 | 20.2 | 23.2 |
| 64 | 147.2 | 51.2 | 17 | 62.6 | 13.6 | 30 | 22.0 | 24.0 |
| 63 | 145.4 | 50.4 | 16 | 60.8 | 12.8 | 31 | 23.8 | 24.8 |
| 62 | 143.6 | 49.6 | 15 | 59.0 | 12.0 | 32 | 25.6 | 25.6 |
| 61 | 141.8 | 48.8 | 14 | 57.2 | 11.2 | 33 | 27.4 | 26.4 |
| 60 | 140.0 | 48.0 | 13 | 55.4 | 10.4 | 34 | 29.2 | 27.2 |

TABLE CIV.—TEMPERATURE CONVERSION CENTIGRADE
TO FAHRENHEIT.—(Continued).

| C. | F. | R. | C. | F. | R. | C. | F. | R. |
|----|-------|------|----|------|-----|----|------|------|
| 59 | 138.2 | 47.2 | 12 | 53.6 | 9.6 | 35 | 31.0 | 28.0 |
| 58 | 136.4 | 46.4 | 11 | 51.8 | 8.8 | 36 | 32.8 | 28.8 |
| 57 | 134.3 | 45.6 | 10 | 50.0 | 8.0 | 37 | 34.6 | 29.6 |
| 56 | 132.8 | 44.8 | 9 | 48.2 | 7.2 | 38 | 36.4 | 30.4 |
| 55 | 131.0 | 44.0 | 8 | 46.4 | 6.4 | 39 | 38.2 | 31.2 |
| 54 | 129.2 | 43.2 | 7 | 44.6 | 5.8 | 40 | 40.0 | 32.0 |

Fahrenheit degrees = $1.8 \times \text{Centigrade degrees} + 32^\circ$.Centigrade degrees = $(\text{Fahrenheit degrees}) - 32^\circ \div 1.8$.

TABLE CV.—DECIMAL EQUIVALENTS OF FRACTIONS OF ONE INCH.

| | | | |
|-------|-----------------|-------|-----------------|
| | 1/64 — .015625 | | 33/64 — .515625 |
| | 1/32 — .03125 | | 17/32 — .53125 |
| | 3/64 — .046875 | | 35/64 — .546875 |
| 1/16 | — .0625 | 9/16 | — .5625 |
| | 5/64 — .078125 | | 37/64 — .578125 |
| 3/32 | — .09375 | 19/32 | — .59375 |
| | 7/64 — .109375 | | 39/64 — .609375 |
| 1/8 | — .125 | 5/8 | — .625 |
| | 9/64 — .140625 | | 41/64 — .640625 |
| 5/32 | — .15625 | 21/32 | — .65625 |
| | 11/64 — .171875 | | 43/64 — .671875 |
| 3/16 | — .1875 | 11/16 | — .6875 |
| | 13/64 — .203125 | | 45/64 — .703125 |
| 7/32 | — .21875 | 23/32 | — .71875 |
| | 15/64 — .234375 | | 47/64 — .734375 |
| 1/4 | — .25 | 3/4 | — .75 |
| | 17/64 — .265625 | | 49/64 — .765625 |
| 9/32 | — .28125 | 25/32 | — .78125 |
| | 19/64 — .296875 | | 51/64 — .796875 |
| 5/16 | — .3125 | 13/16 | — .8125 |
| | 21/64 — .328125 | | 53/64 — .828125 |
| 11/32 | — .34375 | 27/32 | — .84375 |
| | 23/64 — .359375 | | 55/64 — .859375 |
| 3/8 | — .375 | 7/8 | — .875 |
| | 25/64 — .390625 | | 57/64 — .890625 |
| 13/32 | — .40625 | 29/32 | — .90625 |
| | 27/64 — .421875 | | 59/64 — .921875 |
| 7/16 | — .4375 | 15/16 | — .9375 |
| | 29/64 — .453125 | | 61/64 — .953125 |
| 15/32 | — .46875 | 31/32 | — .96875 |
| | 31/64 — .484375 | | 63/64 — .984375 |
| 1/2 | — .5 | 1 | — 1. |

TABLE CVI.—TEMPERATURES, CENTIGRADE AND FAHRENHEIT FRACTIONAL EQUIVALENTS.

| Degrees Centigrade | Degrees Fahrenheit |
|--------------------|--------------------|
| 0.55 | 0.10 |
| 0.1 | 0.18 |
| 0.11 | 0.20 |
| 0.17 | 0.30 |
| 0.2 | 0.36 |
| 0.22 | 0.40 |
| 0.28 | 0.50 |
| 0.3 | 0.54 |
| 0.33 | 0.6 |
| 0.39 | 0.7 |
| 0.4 | 0.72 |
| 0.44 | 0.8 |
| 0.5 | 0.9 |
| 0.55 | 1.0 |
| 0.6 | 1.08 |
| 0.7 | 1.26 |
| 0.8 | 1.44 |
| 0.9 | 1.62 |
| 1.0 | 1.80 |

TABLE CVII.—PRESSURE EQUIVALENTS.

| Unit | Equivalent Value in Other Units |
|--|--|
| 1 lb. per sq. inch = | $\left\{ \begin{array}{l} 144 \text{ lbs. per square foot.} \\ 2.0355 \text{ in. of mercury at } 32^{\circ} \text{ F.} \\ 2.0416 \text{ in. of mercury at } 62^{\circ} \text{ F.} \\ 2.309 \text{ ft. of water at } 62^{\circ} \text{ F.} \\ 27.71 \text{ in. of water at } 62^{\circ} \text{ F.} \end{array} \right.$ |
| 1 atmosphere (14.7 lbs.) = | $\left\{ \begin{array}{l} 2116.3 \text{ lbs. per square foot.} \\ 33.947 \text{ ft. of water at } 62^{\circ} \text{ F.} \\ 30 \text{ in. of mercury at } 62^{\circ} \text{ F.} \\ 29.922 \text{ in. of mercury at } 32^{\circ} \text{ F.} \end{array} \right.$ |
| 1 inch of water at $62^{\circ} \text{ F.} =$ | $\left\{ \begin{array}{l} 0.0361 \text{ lb. per square inch.} \\ 5.196 \text{ lbs. per square foot.} \\ 0.0736 \text{ in. of mercury at } 62^{\circ} \text{ F.} \end{array} \right.$ |
| 1 inch of water at $32^{\circ} \text{ F.} =$ | $\left\{ \begin{array}{l} 5.2021 \text{ lbs. per square foot.} \\ 0.036125 \text{ lb. per square inch.} \end{array} \right.$ |
| 1 foot of water at $62^{\circ} \text{ F.} =$ | $\left\{ \begin{array}{l} 0.433 \text{ lb. per square inch.} \\ 62.355 \text{ lbs. per square foot.} \\ 0.883 \text{ in. of mercury at } 62^{\circ} \text{ F.} \end{array} \right.$ |
| 1 inch of mercury at $62^{\circ} \text{ F.} =$ | $\left\{ \begin{array}{l} 0.49 \text{ lb. per square inch.} \\ 70.56 \text{ lbs. per square foot.} \\ 1.132 \text{ ft. of water at } 62^{\circ} \text{ F.} \\ 13.58 \text{ ins. of water at } 62^{\circ} \text{ F.} \end{array} \right.$ |

TABLE CVIII.—POWER EQUIVALENTS.

| Unit | Equivalent Value in Other Units | |
|--|---------------------------------|------------------------|
| 1 Kilowatt Hour Equals = | 1,000 | Watt Hours |
| | 1.34 | Horse-Power Hours |
| | 2,654,200 | Foot-Pounds per Hour |
| | 3,412 | Heat Units per Hour |
| | 367,000 | Kilogram Meters |
| 1 Horse-Power Equals = | 746 | Watts |
| | 0.746 | Kilowatt |
| | 33,000 | Foot-Pounds per Minute |
| | 550 | Foot-Pounds per Second |
| | 2,545 | Heat Units Per Hour |
| | 42.4 | Heat Units Per Minute |
| | 0.707 | Heat Units per Second |
| 1 British Thermal Unit Equals = | 1,055 | Watt Seconds |
| | 778 | Foot-Pounds |
| | 107.6 | Kilogram Meters |
| | 0.000293 | Kilowatt Hour |
| | 0.000393 | Horse-Power Hour |
| 1 Pound of Water Evap- orated from and at 212 degrees Fahren- heit Equals = | 0.283 | Kilowatt Hour |
| | 0.379 | Horse-Power Hour |
| | 970.4 | Heat Units |
| | 103,900 | Kilogram Meters |
| | 751,300 | Foot-Pounds |

TABLE CIX.—METRIC CONSTANTS.

| EQUIVALENT OF LIQUIDS | | |
|-------------------------------------|---------|-------------------------|
| One cubic meter of water..... | 220.1 | Imperial gallons. |
| One cubic meter of water..... | 61028 | Cubic inches. |
| One cubic meter of water..... | 1000 | Kilograms. |
| One cubic meter of water..... | 1 | Ton (approximate.) |
| One cubic meter of water..... | 1000 | Litres. |
| One cubic meter of water..... | 2204. | pounds. |
| Column of water 1 foot high..... | 0.434 | pounds per square inch. |
| Column of water 1 meter high..... | 1.43 | pounds per square inch. |
| Column of water 2.31 feet high..... | 1 | pound per square inch. |
| One imperial gallon of water..... | 277.274 | Cubic inches. |
| One imperial gallon of water..... | 10 | pounds. |
| One cubic inch of water..... | 0.3607 | pounds. |
| One cubic foot of water..... | 62.35 | pounds. |
| One cubic foot of water..... | 0.577 | Hundredweight. |
| One cubic foot of water..... | 0.028 | Ton. |
| One pound of water..... | 27.72 | Cubic inches. |
| One pound of water..... | 0.1 | Imperial gallon. |
| One pound of water..... | 0.4537 | Kilograms. |
| One litre of water..... | 0.22 | Imperial gallon. |
| One litre of water..... | 61 | Cubic inches. |
| One litre of water..... | 0.0353 | Cubic feet. |

TABLE CIX.—METRIC CONSTANTS.—(Continued).

| METRICAL EQUIVALENTS (WEIGHTS AND MEASURES) | | |
|---|------------|-------------|
| | Meters | Reciprocals |
| Inch | 0.02539954 | 39.37079 |
| Foot | 0.3047945 | 3.280899 |
| Yard | 0.91438348 | 1.093633 |
| Pole | 5.029109 | 0.1988424 |
| Chain | 20.11644 | 0.0497106 |
| Furlong | 201.1644 | 0.004971 |
| Mile | 1609.3149 | 0.00062138 |

METRICAL EQUIVALENTS (WEIGHTS AND MEASURES)

| | | |
|----------------------|-------|------------------------------------|
| 1 Inch | 2.54 | centimeters. |
| 1 Meter | 3.281 | feet. |
| 1 Square inch | 6.452 | square centimeters. |
| 1 Square meter | 10.76 | square feet.....1.196 square yard. |
| 1 Cubic inch | 16.39 | centimeters. |
| 1 Cubic meter | 35.31 | cubic feet. |
| 1 Kilogram | 2.205 | pounds |

TABLE CX.—AVERAGE TAP WATER TEMPERATURES OF (SUMMER)
FOR CITIES OF UNITED STATES AND CANADA.

| City | State | Deg. F. | Population |
|---------------------|-------|---------|------------|
| Youngstown | Ohio | 90.8 | 132,358 |
| Dallas | Tex. | 90 | 158,976 |
| Omaha | Neb. | 86 | 191,601 |
| Galveston | Tex. | 85 | 42,000 |
| Jacksonville | Fla. | 82 | 91,543 |
| Atlanta | Ga. | 81 | 200,616 |
| Augusta | Ga. | 81 | 52,548 |
| Cincinnati | Ohio | 80 | 401,247 |
| Birmingham | Ala. | 80 | 172,270 |
| New Orleans | La. | 80 | 387,408 |
| Kansas City | Mo. | 77 | 345,000 |
| Ottawa | Can. | 77 | 112,000 |
| St. Joseph | Mo. | 77 | 77,735 |
| Toledo | Ohio | 76.5 | 243,109 |
| Albany | N. Y. | 76 | 113,344 |
| Washington | D. C. | 75.4 | 437,571 |
| Nashville | Tenn. | 75 | 118,342 |
| Oklahoma City | Okla. | 75 | 91,258 |
| Charleston | S. C. | 75 | 71,500 |
| Providence | R. I. | 74 | 275,000 |
| Columbus | Ohio | 74 | 237,031 |
| Akron | Ohio | 74 | 208,435 |
| Richmond | Va. | 74 | 158,700 |
| Grand Rapids | Mich. | 74 | 137,634 |
| Springfield | Mass. | 74 | 129,563 |
| Decatur | Ill. | 73 | 43,618 |
| Mount Vernon | N. Y. | 73 | 42,726 |
| Pittsburgh | Pa. | 72.5 | 588,193 |
| Cleveland | Ohio | 72 | 796,836 |
| Minneapolis | Minn. | 72 | 380,498 |
| Worcester | Mass. | 72 | 179,741 |
| Pawtucket | R. I. | 72 | 64,248 |
| Buffalo | N. Y. | 71 | 505,875 |
| Waterbury | Conn. | 71 | 91,410 |
| Philadelphia | Pa. | 70 | 1,823,158 |

HOUSEHOLD REFRIGERATION

TABLE CX.—AVERAGE TAP WATER TEMPERATURES—(SUMMER)
FOR CITIES OF UNITED STATES AND CANADA.—(Continued.)

| City | State | Deg. F. | Population |
|----------------------|--------|---------|------------|
| Louisville | Ky. | 70 | 234,891 |
| Oakland | Cal. | 70 | 216,361 |
| Dayton | Ohio | 70 | 153,830 |
| Paterson | N. J. | 70 | 135,856 |
| Winnipeg | Can. | 70 | 135,430 |
| Cambridge | Mass. | 70 | 109,450 |
| Erie | Pa. | 70 | 93,372 |
| Troy | N. Y. | 70 | 78,000 |
| Little Rock | Ark. | 70 | 64,997 |
| Mobile | Ala. | 70 | 60,124 |
| Woonsocket | R. I. | 70 | 43,496 |
| Charlestown | W. Va. | 70 | 39,608 |
| Boston | Mass. | 69 | 749,923 |
| Rochester | N. Y. | 69 | 295,750 |
| New Bedford | Mass. | 69 | 121,217 |
| Somerville | Mass. | 69 | 93,033 |
| Malden | Mass. | 69 | 49,103 |
| Utica | N. Y. | 68 | 94,136 |
| Cedar Rapids | Iowa | 68 | 45,566 |
| Lexington | Ky. | 67.8 | 41,534 |
| Detroit | Mich. | 67 | 993,739 |
| Montreal | Can. | 67 | 466,197 |
| Milwaukee | Wis. | 67 | 457,147 |
| St. John | N. B. | 65.5 | 60,000 |
| New York | N. Y. | 65 | 5,621,151 |
| Brooklyn | N. Y. | 65 | |
| St. Paul | Minn. | 65.5 | 235,595 |
| Des Moines | Iowa | 65 | 126,468 |
| San Francisco | Cal. | 65 | 508,410 |
| New Haven | Conn. | 65 | 162,390 |
| Johnstown | Pa. | 65 | 67,327 |
| Jackson | Mich. | 65 | 48,374 |
| Pasadena | Cal. | 65 | 45,334 |
| Los Angeles | Cal. | 62 | 575,490 |
| Gary | Ind. | 62 | 55,453 |
| Tacoma | Wash. | 60 | 96,965 |
| Elizabeth | N. J. | 60 | 95,682 |
| Lawrence | Mass. | 60 | 94,270 |
| Allentown | Pa. | 60 | 73,502 |
| Portland | Maine | 60 | 69,000 |
| Lincoln | Neb. | 60 | 54,934 |
| Roanoke | Va. | 60 | 50,842 |
| Seattle | Wash. | 60 | 315,362 |
| Rockford | Ill. | 58 | 65,651 |
| Springfield | Ohio | 58 | 60,840 |
| Haverhill | Mass. | 58 | 53,884 |
| East Orange | N. J. | 58 | 50,587 |
| Lowell | Mass. | 56 | 112,479 |
| Davenport | Iowa | 56 | 56,727 |
| Duluth | Minn. | 55 | 98,917 |
| Hamilton | Can. | 55 | 81,881 |
| Peoria | Ill. | 54 | 76,121 |
| Spokane | Wash. | 52 | 104,204 |
| Sioux City | Iowa | 51 | 71,227 |
| Portland | Ore. | 50 | 258,288 |
| Salt Lake City | Utah | 50 | 118,110 |
| Galveston | Tex. | 80 | 42,000 |
| Jacksonville | Fla. | 76 | 91,543 |
| Youngstown | Ohio | 68.7 | 132,358 |
| Augusta | Ga. | 66 | 52,548 |
| New Orleans | La. | 62 | 387,408 |
| Birmingham | Ala. | 65 | 172,270 |
| Charleston | S. C. | 65 | 74,500 |
| Cincinnati | Ohio | 62 | 401,247 |
| Kansas City | Mo. | 62 | 345,000 |
| Atlanta | Ga. | 62 | 200,616 |
| Philadelphia | Pa. | 61 | 1,823,158 |
| Washington | D. C. | 60.5 | 437,571 |

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TABLE CX.—AVERAGE TAP WATER TEMPERATURES (WINTER)
FOR CITIES OF UNITED STATES AND CANADA.—(Continued.)

| City | State | Deg. F. | Population |
|---------------|-------|---------|------------|
| Los Angeles | Cal. | 60 | 575,490 |
| Dayton | Ohio | 60 | 153,830 |
| Louisville | Ky. | 60 | 234,891 |
| Omaha | Neb. | 60 | 191,601 |
| Nashville | Tenn. | 60 | 118,342 |
| Oklahoma City | Okla. | 60 | 91,258 |
| Troy | N. Y. | 60 | 78,000 |
| Mobile | Ala. | 60 | 60,124 |
| Springfield | Mass. | 60 | 129,563 |
| Roanoke | Va. | 60 | 50,842 |
| New Haven | Conn. | 58 | 162,390 |
| Des Moines | Iowa | 58 | 126,468 |
| Rockford | Ill. | 58 | 65,651 |
| East Orange | N. J. | 58 | 50,710 |
| Lexington | Ky. | 57.4 | 41,534 |
| San Francisco | Cal. | 57 | 508,410 |
| Allentown | Pa. | 57 | 73,502 |
| Terre Haute | Ind. | 57 | 66,082 |
| New Brunswick | N. J. | 57 | 24,000 |
| Pasadena | Cal. | 57 | 45,334 |
| Springfield | Ohio | 57 | 60,840 |
| Cleveland | Ohio | 56 | 796,836 |
| Toledo | Ohio | 56 | 243,109 |
| Winnipeg | Can. | 56 | 135,430 |
| Albany | N. Y. | 56 | 113,344 |
| Columbus | Ohio | 56 | 237,031 |
| Davenport | Iowa | 56 | 56,727 |
| New York | N. Y. | 55 | 5,621,151 |
| Brooklyn | N. Y. | 55 | |
| Lincoln | Neb. | 55 | 54,934 |
| Akron | Ohio | 55 | 208,435 |
| Pawtucket | R. I. | 55 | 64,248 |
| Utica | N. Y. | 55 | 94,136 |
| Oakland | Cal. | 55 | 216,361 |
| Cedar Rapids | Iowa | 55 | 45,566 |
| Grand Rapids | Mich. | 55 | 137,634 |
| Lawrence | Mass. | 55 | 94,270 |
| New Bedford | Mass. | 55 | 121,217 |
| Mt. Vernon | N. Y. | 55 | 42,726 |
| Boston | Mass. | 54 | 749,923 |
| Ottawa | Can. | 54 | 112,000 |
| St. Joseph | Mo. | 54 | 77,735 |
| Malden | Mass. | 54 | 49,103 |
| Minneapolis | Minn. | 54 | 380,498 |
| St. Paul | Minn. | 54 | 235,595 |
| Waterbury | Conn. | 54 | 91,410 |
| Lowell | Mass. | 54 | 112,479 |
| Sommerville | Mass. | 53.5 | 93,033 |
| Providence | R. I. | 53 | 275,000 |
| Erie | Pa. | 53 | 93,372 |
| Decatur | Ill. | 53 | 43,618 |
| Pittsburgh | Pa. | 52.8 | 588,193 |
| Buffalo | N. Y. | 52 | 505,875 |
| Gary | Ind. | 52 | 55,433 |
| Montreal | Can. | 51 | 466,197 |
| Rochester | N. Y. | 51 | 295,750 |
| St. John | N. B. | 51 | 60,000 |
| Detroit | Mich. | 50 | 993,739 |
| Elizabeth | N. J. | 50 | 95,682 |
| Ft. Wayne | Ind. | 50 | 86,549 |
| Little Rock | Ark. | 50 | 64,997 |
| Johnstown | Pa. | 50 | 67,327 |
| Cambridge | Mass. | 50 | 109,450 |
| Portland | Maine | 50 | 69,000 |
| Paterson | N. J. | 50 | 33,856 |
| Spokane | Wash. | 50 | 104,204 |
| Woonsocket | R. I. | 50 | 43,496 |
| Milwaukee | Wis. | 50 | 457,147 |
| Seattle | Wash. | 49 | 315,362 |

HOUSEHOLD REFRIGERATION

TABLE CX.—AVERAGE TAP WATER TEMPERATURES (WINTER)
FOR CITIES OF UNITED STATES AND CANADA.—(Continued.)

| City | State | Deg. F. | Population |
|---------------------|-------|---------|------------|
| Council Bluffs..... | Iowa | 49 | 36,162 |
| Sioux City..... | Iowa | 49 | 71,227 |
| Superior | Wis. | 47 | 39,674 |
| Salt Lake City..... | Utah | 45 | 118,110 |
| Duluth | Minn. | 45 | 98,917 |
| Jackson | Mich. | 45 | 48,374 |
| Hamilton | Can. | 45 | 81,881 |
| Portland | Ore. | 42 | 258,288 |
| Haverhill | Mass. | 40.7 | 53,884 |
| Tacoma | Wash. | 40.5 | 96,965 |
| Charleston | S. C. | 40 | 71,500 |

TABLE CXI.—DENSITY AND WEIGHT OF WATER.
(Rosetti Table and D. K. Clark Manual).

| Temperature Deg. F. | Relative Density | Weight per Cubic Foot |
|------------------------|---------------------|--------------------------|
| 32 | 0.99987 | 62.416 |
| 35 | 0.99996 | 62.421 |
| 39.3 | 1.00000 | 62.424 |
| 40 | 0.99999 | 62.423 |
| 43 | 0.99997 | 62.422 |
| 45 | 0.99992 | 62.419 |
| 50 | 0.99975 | 62.408 |
| 55 | 0.99946 | 62.390 |
| 60 | 0.99907 | 62.366 |
| 70 | 0.99802 | 62.300 |
| 80 | 0.99669 | 62.217 |
| 90 | 0.99510 | 62.118 |
| 100 | 0.99318 | 61.998 |
| 110 | 0.99105 | 61.865 |
| 120 | 0.98870 | 61.719 |
| 130 | 0.98608 | 61.555 |
| 140 | 0.98338 | 61.386 |
| 150 | 0.98043 | 61.203 |
| 160 | 0.97729 | 61.006 |
| 170 | 0.97397 | 60.799 |
| 180 | 0.97056 | 60.586 |
| 190 | 0.96701 | 60.365 |
| 200 | 0.96333 | 60.135 |
| 212 | 0.95865 | 58.843 |
| 230 | | 59.4 (Sat. Pressure) |
| 250 | | 58.7 |
| 270 | | 58.2 |
| 290 | | 57.6 |
| 298 | | 57.3 |
| 338 | | 56.1 |
| 366 | | 55.3 |
| 390 | | 54.5 |

TABLE CXII.—WEIGHT OF VARIOUS SUBSTANCES PER CUBIC FOOT.

| Name | Pounds | Name | Pounds |
|-------------------|--------|--------------------|--------|
| Mercury | 847.7 | Tobacco | 80. |
| Brine | 77.4 | Oil, average | 56 |
| Milk | 64.3 | Eggs | 25 |
| Sea water | 64.05 | Fruit | 22 |
| Pure water | 62.425 | Butter | 58.7 |
| Linseed oil | 58.7 | Fat | 58.5 |
| Whale oil | 57.4 | Oak, white | 48 |
| Sugar | 100.37 | Pine, yellow | 38 |
| Soap | 66.9 | Vinegar | 67.5 |
| Salt | 45. | Beef fat | 57.68 |
| Dry fruits | 45. | Hog Fat | 58.50 |
| Lime | 50. | Hard coal | 85 |
| Olive oil | 57.1 | Stone | 118 |
| Turpentine | 54.3 | Masonry | 143 |
| Petroleum | 54.9 | Sand | 110 |
| Naphtha | 53.1 | Cast iron | 450.54 |
| Alcohol | 57.4 | Wrought iron | 480 |
| Benzine | 53.1 | Brass | 511 |
| Wine | 62 | Charcoal | 18 |
| Ash | 34.3 | Lead | 709.7 |
| Ice | 57.5 | Beer | 64.62 |
| Earth | 93 | Snow | 5.2 |
| Soft coal | 80 | | |

TABLE CXIII.—VOLUME AND WEIGHT OF DRY AIR AT DIFFERENT TEMPERATURES.

Under a Constant Atmosp. Pres. of 29.92 ins. of mercury, the vol. at 32° Fahr. being 1.

| Temp. Deg. F. | Volume | Weight per cu. ft. |
|------------------|--------|-----------------------|
| 0 | .935 | 0.0864 |
| 12 | .960 | 0.0842 |
| 22 | .980 | 0.0824 |
| 32 | 1.000 | 0.0807 |
| 42 | 1.020 | 0.0791 |
| 52 | 1.041 | 0.0776 |
| 62 | 1.061 | 0.0761 |
| 72 | 1.082 | 0.0747 |
| 82 | 1.102 | 0.0733 |
| 92 | 1.122 | 0.0720 |
| 102 | 1.143 | 0.0707 |
| 112 | 1.163 | 0.0694 |
| 122 | 1.184 | 0.0682 |
| 132 | 1.204 | 0.0671 |
| 142 | 1.224 | 0.0659 |
| 152 | 1.245 | 0.0649 |
| 162 | 1.265 | 0.0638 |
| 172 | 1.285 | 0.0628 |
| 182 | 1.306 | 0.0618 |
| 192 | 1.326 | 0.0609 |

*From Hoffman's Handbook for Heating and Ventilating Engineers, published by McGraw Hill Co., Inc.

TABLE CXIV.—SPECIFIC HEATS, WATER AT 32° F. = 1.
(Frick Co.)

| Name | Spec. Heat | Name | Spec. Heat |
|-----------------|------------|--------------------|------------|
| Cast iron | 0.130 | Coal | 0.241 |
| Brass | 0.094 | Sulphur | 0.202 |
| Mercury | 0.033 | Coke | 0.203 |
| Tin | 0.056 | Alcohol | 0.659 |
| Zinc | 0.095 | Oil | 0.310 |
| Chalk | 0.215 | Vinegar | 0.920 |
| Stone | 0.270 | Strong brine | 0.700 |
| Masonry | 0.200 | Ice | 0.504 |
| Oak wood | 0.570 | Water | 1.000 |
| Pine | 0.650 | Air | 0.238 |
| Glass | 0.194 | | |

TABLE CXV.—COEFFICIENTS OF EXPANSION FOR VARIOUS
SUBSTANCES.

| Substance | Coefficient of Linear Expansion in inches per Deg. F. |
|---------------------------|---|
| Aluminum | 0.00001140 |
| Brass | 0.00001040 |
| Brick | 0.00000306 |
| | from 0.00000550 |
| Cement and Concrete | to 0.00000780 |
| Copper | 0.00000961 |
| | from 0.00000399 |
| Glass | to 0.00000521 |
| Gold | 0.00000841 |
| Granite | 0.00000460 |
| Iron, cast | 0.00000587 |
| Iron, wrought | 0.00000677 |
| Lead | 0.00001580 |
| Marble | 0.00000400 |
| | from 0.00000206 |
| Masonry | to 0.00000490 |
| Mercury | 0.00000334 |
| Platinum | 0.00000494 |
| Porcelain | 0.00000200 |
| | from 0.00000400 |
| Sandstone | to 0.00000670 |
| Steel, untempered | 0.00000599 |
| Steel, tempered | 0.00000702 |
| Tin | 0.00001160 |
| Wood, pine | 0.00000276 |
| Zinc | 0.00001634 |

TABLE CXVI.—SPECIFIC HEATS OF GASES.

| Name of gas | Specific Heat | |
|-----------------------|-------------------|-----------------|
| | Constant Pressure | Volume Constant |
| Air | 0.23751 | 0.16902 |
| Carbon dioxide | 0.21700 | 0.15350 |
| Carbon monoxide | 0.24500 | 0.17580 |
| Hydrogen | 3.40900 | 2.41226 |
| Nitrogen | 0.24380 | 0.17273 |
| Oxygen | 0.21751 | 0.15507 |

TABLE CXVII.—COEFFICIENTS OF EXPANSION AND COEFFICIENTS OF TRANSMISSION OF SOLIDS AND LIQUIDS.

| Substance | Coefficient of Expansion | Coefficient of Transmission |
|--------------------------|--------------------------|-----------------------------|
| Antimony | 0.00000602 | 0.00022 |
| Copper | 0.00000955 | 0.00404 |
| Gold | 0.00001060 | ..... |
| Wrought Iron | 0.00000895 | 0.00089 |
| Glass | 0.00000478 | 0.0000008 |
| Cast Iron | 0.00000618 | 0.000659 |
| Lead | 0.00001580 | 0.00045 |
| Platinum | 0.00000530 | ..... |
| Silver | 0.00001060 | 0.00610 |
| Tin | 0.00001500 | 0.00084 |
| Steel (soft) | 0.00000600 | 0.00062 |
| Steel (hard) | 0.00000689 | 0.00034 |
| Nickel steel 36% | 0.00000003 | ..... |
| Zinc | 0.00001633 | 0.00170 |
| Brass | 0.00001043 | 0.00142 |
| Ice | 0.00000375 | 0.000024 |
| Sulphur | 0.00006413 | ..... |
| Charcoal | 0.00007860 | 0.000002 |
| Aluminum | 0.00002313 | 0.00203 |
| Phosphorus | 0.00012530 | ..... |
| Water | 0.00008806 | 0.000008 |
| Mercury | 0.00003333 | 0.00011 |
| Alcohol (absolute) | 0.00015151 | 0.000002 |

*From Hoffman's Handbook for Heating and Ventilating Engineers, published by McGraw Hill Co., Inc.

TABLE CXVIII.—COEFFICIENT OF EXPANSION AND COEFFICIENTS OF HEAT TRANSMISSION OF GASES.*

| Substance | Pressure constant | Constant Volume | Coefficient of Cubical Expansion at 1 Atmosphere | Coefficient of Trans- mission |
|---------------------|----------------------|--------------------|---|-------------------------------------|
| Air | 0.23751 | 0.16847 | 0.003671 | 0.0000015 |
| Oxygen | 0.21751 | 0.15507 | 0.003674 | 0.0000012 |
| Hydrogen | 3.40900 | 2.41226 | 0.003669 | 0.0000012 |
| Nitrogen | 0.24380 | 0.17273 | 0.003668 | 0.0000012 |
| Superheated steam | 0.4805 | 0.346 | 0.003726 | ..... |
| Carbonic acid | 0.2170 | 0.1535 | ..... | 0.00000122 |

*From Hoffman's Handbook for Heating and Ventilating Engineers, published by McGraw Hill Co., Inc.

TABLE CXIX.—STRENGTH OF MATERIALS.

| Material | Elastic Limit | | | Ultimate Strength | | | Factory of Safety | | |
|--------------|---------------|-------|---------|-------------------|-------|---------|-------------------|----------|-------|
| | Tension | Comp. | Shear | Tension | Comp. | Shear | Steady | Variable | Shock |
| Brick | | | | | 3000 | 1000 | 15 | 25 | 30 |
| Stone | | | | | 6000 | 1500 | 15 | 25 | 30 |
| Timber | | | L. 600 | | | L. 600 | | | |
| Cast Iron | 3000 | 3000 | T. 3000 | 10000 | 8000 | T. 3000 | 8 | 15 | 15 |
| Wrought Ir. | 6000 | 20000 | 20000 | 15000 | 80000 | 20000 | 6 | 15 | 20 |
| Struct. Stl. | 25000 | 25000 | 40000 | 50000 | 50000 | 40000 | 4 | 8 | 10 |
| Cast Stl. | 35000 | 35000 | 50000 | 60000 | 60000 | 50000 | 4 | 8 | 10 |
| | 50000 | 50000 | 80000 | 70000 | 70000 | 60000 | 5 | 8 | 15 |

TABLE CXX.—PHYSICAL CONSTANTS OF METALS.

| Metal | Specific Gravity | Specific Heat | Melting Point Degrees F. |
|------------|------------------|---------------|-----------------------------|
| Aluminum | 2.56 | 0.218 | 1216 |
| Antimony | 6.71 | 0.051 | 1166 |
| Arsenic | 5.67 | 0.081 | 1472 |
| Barium | 3.78 | 0.047 | 1562 |
| Bismuth | 9.80 | 0.031 | 518 |
| Cadmium | 8.60 | 0.056 | 610 |
| Caesium | 1.87 | 0.048 | 79 |
| Calcium | 1.57 | 0.170 | 1481 |
| Cerium | 6.68 | 0.045 | 1152 |
| Chromium | 6.50 | 0.120 | 2741 |
| Cobalt | 8.50 | 0.103 | 2714 |
| Columbium | 12.70 | 0.071 | ----- |
| Copper | 8.93 | 0.093 | 1981 |
| Gallium | 5.90 | 0.079 | 86 |
| Glucinum | 1.93 | 0.621 | ----- |
| Gold | 19.32 | 0.031 | 1945 |
| Indium | 7.42 | 0.057 | 311 |
| Iridium | 22.42 | 0.033 | 4172 |
| Iron | 7.86 | 0.110 | 2768 |
| Lanthanum | 6.20 | 0.045 | 1490 |
| Lead | 11.37 | 0.031 | 621 |
| Lithium | 0.54 | 0.941 | 367 |
| Magnesium | 1.74 | 0.250 | 1204 |
| Manganese | 8.00 | 0.120 | 2237 |
| Mercury | 13.59 | 0.032 | —38 |
| Molybdenum | 8.60 | 0.072 | 4532 |
| Nickel | 8.80 | 0.108 | 2642 |
| Osmium | 22.48 | 0.031 | 4530 |
| Palladium | 11.50 | 0.059 | 2822 |
| Platinum | 21.50 | 0.032 | 3191 |
| Potassium | 0.86 | 0.170 | 144 |
| Rhodium | 12.10 | 0.058 | 3452 |
| Rubidium | 1.53 | 0.077 | 100 |
| Ruthenium | 12.26 | 0.061 | 3270 |
| Silver | 10.53 | 0.056 | 1762 |
| Sodium | 0.97 | 0.290 | 207 |
| Strontium | 2.54 | ----- | 1472 |
| Tantalum | 10.80 | 0.036 | 5252 |
| Tellurium | 6.25 | 0.049 | 825 |
| Thallium | 11.85 | 0.033 | 578 |
| Thorium | 11.10 | 0.028 | ----- |
| Tin | 7.29 | 0.055 | 450 |
| Titanium | 3.54 | 0.130 | 3362 |
| Tungsten | 19.10 | 0.034 | 5432 |
| Uranium | 18.70 | 0.028 | 4352 |
| Vanadium | 5.50 | 0.125 | 3182 |
| Yttrium | 3.80 | ----- | ----- |
| Zinc | 7.15 | 0.094 | 786 |
| Zirconium | 4.15 | 0.066 | 2700 |

TABLE CXXI.—DIMENSIONS OF STANDARD PIPE.

| Nominal, in. | Diameter. | | Thick-ness, in. | Circumference | | Transverse areas. | | Length of pipe per sq. ft. of | | Length of pipe containing one cu. ft. | Wt. per length, lbs. | No. of threads per in. of screw. | Con-tents in ft. of length. | Wt. of water per ft. of length, lbs. |
|--------------|----------------------|----------------------|-----------------|---------------|---------------|-------------------|-------------------|-------------------------------|-----------------------|---------------------------------------|----------------------|----------------------------------|-----------------------------|--------------------------------------|
| | Actual external, in. | Actual internal, in. | | External, in. | Internal, in. | External, sq. in. | Internal, sq. in. | External, sq. in. | Internal surface, ft. | | | | | |
| 1/4 | .405 | .27 | .068 | 1.272 | .848 | .129 | .0572 | .0717 | 9.44 | 14.15 | .241 | 27 | .0006 | .005 |
| 3/8 | .534 | .364 | .088 | 1.696 | 1.144 | .229 | .1041 | .1249 | 7.075 | 10.49 | .42 | 18 | .0026 | .021 |
| 1/2 | .674 | .494 | .091 | 2.121 | 1.552 | .358 | .1917 | .1663 | 5.547 | 7.73 | .559 | 18 | .0057 | .047 |
| 3/4 | .814 | .623 | .109 | 2.639 | 1.957 | .554 | .3048 | .2492 | 4.547 | 6.13 | .837 | 14 | .0102 | .085 |
| 1 | 1.055 | .824 | .113 | 3.299 | 2.589 | .866 | .5333 | .3327 | 3.537 | 4.635 | 1.115 | 14 | .0230 | .190 |
| 1 1/4 | 1.315 | 1.048 | .134 | 4.131 | 3.292 | 1.358 | .8626 | .4954 | 2.904 | 3.645 | 1.668 | 11 1/2 | .0408 | .349 |
| 1 1/2 | 1.566 | 1.38 | .14 | 5.215 | 4.335 | 2.164 | 1.496 | .668 | 2.301 | 2.768 | 2.244 | 11 1/2 | .0638 | .527 |
| 2 | 2.067 | 1.811 | .145 | 7.461 | 5.061 | 2.835 | 1.961 | .797 | 2.01 | 2.371 | 2.678 | 11 1/2 | .0918 | .760 |
| 2 1/2 | 2.875 | 2.067 | .154 | 9.032 | 6.494 | 4.43 | 3.356 | 1.074 | 1.608 | 1.848 | 3.609 | 8 | .1632 | 1.356 |
| 3 | 3.575 | 2.468 | .204 | 10.996 | 7.753 | 6.492 | 4.784 | 1.708 | 1.328 | 1.547 | 5.739 | 8 | .2550 | 2.116 |
| 3 1/2 | 4.275 | 2.967 | .217 | 12.566 | 9.036 | 9.621 | 7.887 | 2.679 | .955 | 1.245 | 7.536 | 8 | .3673 | 3.049 |
| 4 | 5.068 | 3.548 | .225 | 14.137 | 10.146 | 12.566 | 9.887 | 3.243 | .991 | 1.077 | 9.001 | 8 | .4998 | 4.155 |
| 4 1/2 | 5.863 | 4.045 | .239 | 15.708 | 11.146 | 15.904 | 12.73 | 3.174 | .849 | .948 | 10.665 | 8 | .6528 | 5.405 |
| 5 | 6.658 | 4.645 | .259 | 17.417 | 12.648 | 19.635 | 15.961 | 3.674 | .764 | .848 | 12.34 | 8 | .8263 | 6.851 |
| 6 | 7.655 | 5.445 | .281 | 20.813 | 15.849 | 24.306 | 19.99 | 4.316 | .587 | .757 | 14.502 | 8 | 1.029 | 8.500 |
| 7 | 8.652 | 6.045 | .301 | 23.965 | 19.054 | 34.472 | 28.838 | 5.584 | .501 | .634 | 18.762 | 8 | 1.2312 | 10.312 |
| 8 | 9.652 | 7.023 | .327 | 27.096 | 22.063 | 45.664 | 38.738 | 6.926 | .443 | .544 | 23.271 | 8 | 1.499 | 12.312 |
| 9 | 10.652 | 8.037 | .344 | 30.238 | 25.076 | 58.426 | 50.04 | 8.386 | .397 | .478 | 28.177 | 8 | 1.777 | 14.750 |
| 10 | 11.652 | 9.019 | .366 | 33.412 | 28.076 | 72.76 | 62.73 | 10.03 | .355 | .427 | 33.701 | 8 | 2.065 | 17.500 |
| 11 | 12.652 | 10.019 | .375 | 36.690 | 31.477 | 90.763 | 78.839 | 11.924 | .318 | .382 | 40.065 | 8 | 2.360 | 20.000 |
| 12 | 13.652 | 11.019 | .375 | 39.968 | 35.343 | 113.098 | 99.402 | 13.696 | .299 | 1.436 | 45.95 | 8 | 2.665 | 22.500 |
| 14 | 15.652 | 13.019 | .375 | 46.035 | 41.7 | 137.677 | 113.098 | 14.579 | .268 | 1.04 | 48.985 | 8 | 3.288 | 27.500 |
| 16 | 17.652 | 15.019 | .375 | 52.102 | 47.626 | 153.938 | 137.88 | 16.051 | .253 | .903 | 52.922 | 8 | 3.933 | 32.500 |
| 18 | 19.652 | 17.019 | .375 | 58.169 | 53.474 | 176.713 | 159.485 | 17.23 | .255 | .868 | 57.893 | 8 | 4.603 | 37.500 |
| 20 | 21.652 | 19.019 | .375 | 64.236 | 59.322 | 201.062 | 182.635 | 18.407 | .250 | .816 | 61.77 | 8 | 5.293 | 42.500 |
| 22 | 23.652 | 21.019 | .375 | 70.303 | 65.170 | 223.706 | 203.164 | 20.164 | .247 | .768 | 66.66 | 8 | 6.003 | 47.500 |
| 24 | 25.652 | 23.019 | .375 | 76.370 | 71.018 | 249.14 | 223.12 | 21.7 | .241 | .719 | 71.57 | 8 | 6.733 | 52.500 |
| 26 | 27.652 | 25.019 | .375 | 82.437 | 76.866 | 275.457 | 245.477 | 23.477 | .239 | .666 | 76.47 | 8 | 7.483 | 57.500 |
| 28 | 29.652 | 27.019 | .375 | 88.504 | 82.714 | 302.81 | 269.832 | 25.332 | .239 | .619 | 81.37 | 8 | 8.253 | 62.500 |
| 30 | 31.652 | 29.019 | .375 | 94.571 | 88.562 | 330.16 | 295.174 | 27.282 | .239 | .572 | 86.27 | 8 | 9.043 | 67.500 |
| 32 | 33.652 | 31.019 | .375 | 100.638 | 94.410 | 357.51 | 320.518 | 29.232 | .239 | .525 | 91.17 | 8 | 9.853 | 72.500 |
| 34 | 35.652 | 33.019 | .375 | 106.705 | 100.258 | 384.86 | 345.862 | 31.182 | .239 | .478 | 96.07 | 8 | 10.683 | 77.500 |
| 36 | 37.652 | 35.019 | .375 | 112.772 | 106.106 | 412.21 | 371.206 | 33.132 | .239 | .431 | 100.97 | 8 | 11.533 | 82.500 |
| 38 | 39.652 | 37.019 | .375 | 118.839 | 111.954 | 439.56 | 396.550 | 35.082 | .239 | .384 | 105.87 | 8 | 12.403 | 87.500 |
| 40 | 41.652 | 39.019 | .375 | 124.906 | 117.802 | 466.91 | 421.894 | 37.032 | .239 | .337 | 110.77 | 8 | 13.293 | 92.500 |
| 42 | 43.652 | 41.019 | .375 | 130.973 | 123.650 | 494.26 | 447.238 | 38.982 | .239 | .290 | 115.67 | 8 | 14.203 | 97.500 |
| 44 | 45.652 | 43.019 | .375 | 137.040 | 129.498 | 521.61 | 472.582 | 40.932 | .239 | .243 | 120.57 | 8 | 15.133 | 102.500 |
| 46 | 47.652 | 45.019 | .375 | 143.107 | 135.346 | 548.96 | 497.926 | 42.882 | .239 | .196 | 125.47 | 8 | 16.083 | 107.500 |
| 48 | 49.652 | 47.019 | .375 | 149.174 | 141.194 | 576.31 | 523.270 | 44.832 | .239 | .149 | 130.37 | 8 | 17.053 | 112.500 |
| 50 | 51.652 | 49.019 | .375 | 155.241 | 147.042 | 603.66 | 548.614 | 46.782 | .239 | .102 | 135.27 | 8 | 18.043 | 117.500 |
| 52 | 53.652 | 51.019 | .375 | 161.308 | 152.890 | 631.01 | 573.958 | 48.732 | .239 | .055 | 140.17 | 8 | 19.053 | 122.500 |
| 54 | 55.652 | 53.019 | .375 | 167.375 | 158.738 | 658.36 | 599.302 | 50.682 | .239 | .008 | 145.07 | 8 | 20.083 | 127.500 |

TABLE CXXII.—DIMENSIONS OF EXTRA AND DOUBLE EXTRA STRONG PIPE.

| Diameter. | | | Thick- ness, in. | Nearest wire gauge, No. | Circumference. | | Transverse area. | | | Length of pipe in ft. per sq. ft. of | | Nomi- nal wt. in lbs. per ft. |
|-----------------|-----------------------------|-----------------------------|------------------------|----------------------------------|------------------|------------------|----------------------|----------------------|-------------------|---|----------------------|--|
| Nominal, in. | Actual, exterior, in. | Actual, interior, in. | | | External, in. | Internal, in. | External, sq. in. | Internal, sq. in. | Metal, sq. in. | External surface. | Internal surface. | |
| $\frac{1}{8}$ | .405 | .205 | 1.23 | 12½ | 1.272 | .644 | 1.29 | .033 | .086 | 9.433 | 18.632 | .29 |
| $\frac{1}{4}$ | .54 | .294 | 1.27 | 11 | 1.696 | .921 | .229 | .068 | .161 | 7.075 | 12.936 | .54 |
| $\frac{3}{8}$ | .675 | .421 | 1.27 | 10½ | 2.121 | 1.323 | .358 | .139 | .219 | 5.657 | 9.07 | .74 |
| $\frac{1}{2}$ | .84 | .542 | 1.49 | 9 | 2.639 | 1.703 | .554 | .231 | .323 | 4.547 | 7.046 | 1.09 |
| $\frac{3}{4}$ | 1.05 | .736 | 1.57 | 8½ | 3.299 | 2.312 | .866 | .452 | .414 | 3.637 | 5.109 | 1.39 |
| 1 | 1.315 | .951 | 1.82 | 7 | 4.131 | 2.988 | 1.358 | .71 | .648 | 2.904 | 4.016 | 2.17 |
| 1¼ | 1.66 | 1.272 | 1.94 | 6½ | 5.215 | 3.996 | 2.164 | 1.271 | .893 | 2.301 | 3.003 | 3.17 |
| 1½ | 1.9 | 1.494 | .221 | 6 | 5.969 | 4.694 | 2.835 | 1.753 | 1.082 | 2.01 | 3.556 | 3.63 |
| 2 | 2.375 | 1.933 | .221 | 5 | 7.461 | 6.073 | 4.43 | 2.935 | 1.495 | 1.608 | 1.975 | 5.02 |
| 2½ | 2.875 | 2.315 | .28 | 2 | 9.032 | 7.273 | 6.492 | 4.209 | 2.283 | 1.328 | 1.649 | 7.67 |
| 3 | 3.5 | 2.892 | .304 | 1 | 10.966 | 9.085 | 9.621 | 6.569 | 3.052 | 1.091 | 1.328 | 10.25 |
| 3½ | 4 | 3.358 | .321 | 0 | 12.566 | 10.549 | 12.566 | 8.566 | 3.71 | .955 | 1.137 | 12.47 |
| 4 | 4.5 | 3.818 | .341 | 0 | 14.137 | 11.995 | 15.904 | 11.449 | 4.455 | .849 | 1 | 14.97 |
| 5 | 5.563 | 4.813 | .375 | 00 | 17.477 | 15.120 | 24.306 | 18.193 | 6.12 | .887 | .793 | 20.54 |
| 6 | 6.625 | 5.75 | .437 | 000 | 20.813 | 18.064 | 34.472 | 25.967 | 8.505 | .577 | .664 | 28.58 |

| DOUBLE EXTRA STRONG PIPE—Table of Standard Dimensions. | | | | | | | | | | | | |
|--|-----------------------------|-----------------------------|------------------------|----------------------------------|------------------|------------------|----------------------|----------------------|-------------------|----------------------|----------------------|--|
| Nominal, in. | Actual, exterior, in. | Actual, interior, in. | Thick- ness, in. | Nearest wire gauge, No. | External, in. | Internal, in. | External, sq. in. | Internal, sq. in. | Metal, sq. in. | External surface. | Internal surface. | Nomi- nal wt. in lbs. per ft. |
| $\frac{1}{8}$ | .84 | .244 | .298 | 1 | 2.639 | .766 | .554 | .047 | .507 | 4.547 | 15.687 | 1.7 |
| $\frac{1}{4}$ | 1.05 | .422 | .314 | 1 | 3.299 | 1.326 | .866 | .139 | .727 | 3.637 | 9.009 | 2.44 |
| 1 | 1.315 | .587 | .364 | 00 | 4.131 | 1.844 | 1.328 | .139 | 1.087 | 2.904 | 6.508 | 3.65 |
| 1¼ | 1.66 | .885 | .388 | 00 | 5.215 | 2.312 | 2.164 | .615 | 1.349 | 2.304 | 4.317 | 5.2 |
| 1½ | 1.9 | 1.083 | .406 | 000 | 5.969 | 3.418 | 2.835 | .93 | 1.905 | 2.01 | 3.511 | 6.2 |
| 2 | 2.375 | 1.491 | .442 | 0000 | 7.461 | 4.884 | 4.43 | 1.744 | 2.886 | 1.608 | 2.561 | 9.02 |
| 2½ | 2.875 | 1.755 | .560 | ½ | 9.032 | 5.513 | 6.492 | 2.419 | 4.073 | 1.328 | 1.673 | 13.68 |
| 3 | 3.5 | 2.284 | .608 | ½ | 10.966 | 7.175 | 9.631 | 4.097 | 5.524 | 1.091 | 1.406 | 18.56 |
| 3½ | 4 | 2.716 | .642 | ½ | 12.566 | 8.533 | 12.566 | 5.794 | 6.772 | .955 | 1.217 | 23.75 |
| 4 | 4.5 | 3.136 | .682 | ½ | 14.137 | 9.952 | 15.904 | 7.724 | 8.48 | .849 | 1.217 | 27.48 |
| 5 | 5.563 | 4.063 | .75 | ¾ | 17.477 | 12.764 | 24.306 | 12.965 | 11.34 | .687 | .940 | 38.12 |
| 6 | 6.625 | 4.875 | .875 | ¾ | 20.813 | 15.315 | 34.472 | 18.666 | 15.896 | .577 | .784 | 53.11 |

TABLE CXXIII.—COPPER TUBES.
Weight per Lineal Foot.

| Gauge No. | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Wall Thickness Inches | 0.095 | 0.083 | 0.072 | 0.065 | 0.058 | 0.049 | 0.042 | 0.035 | 0.032 | 0.028 |
| Outside Diameter of Tube Inches | | | | | | | | | | |
| $\frac{1}{8}$ | | | | 0.048 | 0.047 | 0.045 | 0.042 | 0.038 | 0.036 | 0.033 |
| $\frac{3}{16}$ | | | 0.101 | 0.097 | 0.091 | 0.082 | 0.073 | 0.065 | 0.060 | 0.054 |
| $\frac{1}{4}$ | 0.178 | 0.168 | 0.155 | 0.146 | 0.135 | 0.120 | 0.106 | 0.091 | 0.084 | 0.076 |
| $\frac{5}{16}$ | 0.250 | 0.231 | 0.210 | 0.195 | 0.178 | 0.156 | 0.138 | 0.118 | 0.109 | 0.097 |
| $\frac{3}{8}$ | 0.322 | 0.294 | 0.265 | 0.245 | 0.223 | 0.193 | 0.169 | 0.144 | 0.133 | 0.118 |
| $\frac{7}{16}$ | 0.395 | 0.357 | 0.319 | 0.293 | 0.267 | 0.231 | 0.202 | 0.171 | 0.157 | 0.139 |
| $\frac{1}{2}$ | 0.466 | 0.420 | 0.374 | 0.342 | 0.311 | 0.268 | 0.233 | 0.197 | 0.182 | 0.160 |
| $\frac{5}{8}$ | 0.610 | 0.546 | 0.483 | 0.441 | 0.399 | 0.342 | 0.297 | 0.250 | 0.230 | 0.203 |
| $\frac{3}{4}$ | 0.754 | 0.672 | 0.591 | 0.540 | 0.486 | 0.416 | 0.360 | 0.303 | 0.278 | 0.245 |
| 1 | 1.04 | 0.92 | 0.81 | 0.73 | 0.66 | 0.57 | 0.48 | 0.408 | 0.376 | 0.330 |

NOTE: Stubs or Birmingham gauge used.

Formula for determining the proper thickness of copper tubing is given as follows:

$$T = \frac{P \times D}{6,000} + .0625$$

Where T = thickness in inches

P = working pressure

D = Inside diameter of the tube in inches

This was prescribed by Board of Supervising Inspectors of Steamboats. (1911).

TABLE CXXIV.—SHEET METAL DIMENSIONS AND WEIGHTS.
Wt. per sq. ft. in lbs.

| Decimal Gauge | Iron 480 lbs. per cu. ft. | Steel 489.6 lbs. per cu. ft. | U. S. Gauge numbers |
|---------------|---------------------------------|------------------------------------|------------------------|
| 0.002 | 0.08 | 0.082 | |
| 0.004 | 0.16 | 0.163 | |
| 0.006 | 0.24 | 0.245 | 38-39 |
| 0.008 | 0.32 | 0.326 | 34-35 |
| 0.010 | 0.40 | 0.408 | 32 |
| 0.012 | 0.48 | 0.490 | 30-31 |
| 0.014 | 0.56 | 0.571 | 29 |
| 0.016 | 0.64 | 0.653 | 27-28 |
| 0.018 | 0.72 | 0.734 | 26-27 |
| 0.020 | 0.80 | 0.816 | 25-26 |
| 0.022 | 0.88 | 0.898 | 25 |
| 0.025 | 1.00 | 1.020 | 24 |
| 0.028 | 1.12 | 1.142 | 23 |
| 0.032 | 1.28 | 1.306 | 21-22 |
| 0.036 | 1.44 | 1.469 | 20-21 |
| 0.040 | 1.60 | 1.632 | 19-20 |
| 0.045 | 1.80 | 1.836 | 18-19 |
| 0.050 | 2.00 | 2.040 | 18 |
| 0.055 | 2.20 | 2.244 | 17 |
| 0.060 | 2.40 | 2.448 | 16-17 |
| 0.065 | 2.60 | 2.652 | 15-16 |
| 0.070 | 2.80 | 2.856 | 15 |
| 0.075 | 3.00 | 3.060 | 14-15 |
| 0.080 | 3.20 | 3.264 | 13-14 |
| 0.085 | 3.40 | 3.468 | 13-14 |
| 0.090 | 3.60 | 3.672 | 13-14 |
| 0.095 | 3.80 | 3.876 | 12-13 |
| 0.100 | 4.00 | 4.080 | 12-13 |
| 0.110 | 4.40 | 4.488 | 12 |
| 0.125 | 5.00 | 5.100 | 11 |
| 0.135 | 5.40 | 5.508 | 10-11 |
| 0.150 | 6.00 | 6.120 | 9-10 |
| 0.165 | 6.60 | 6.732 | 8-9 |
| 0.180 | 7.20 | 7.344 | 7-8 |
| 0.200 | 8.00 | 8.160 | 6-7 |
| 0.220 | 8.80 | 8.976 | 4-5 |
| 0.240 | 9.60 | 9.792 | 3-4 |
| 0.250 | 10.00 | 10.200 | 3 |

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