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ABC OF AIR CONDITIONING

An accurate simplified, technical review of the fundamentals of this latest branch of engineering, including servicing data on present-day units

by Paul D. Harrigan

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Contents

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Preface

This book has been prepared especially for the use of those who are interested in the art of air conditioning, and thus it contains the fundamental principles which underlie all the more practical and commonly used systems. It has been written with the intent to show the application of these principles for the production of comfort, and efficiency, where applied to commercial and industrial installations.

Further study of this subject is of course practically unlimited as there are many branches of air conditioning, and many unknown factors to be worked upon. At the present time, however, there is a dearth of information sufficiently elementary to permit the reader to prepare himself for more intensive study. It is the purpose of this little book to fill that need.

It is the writer's suggestion that you consult the appendix of definitions frequently, as an effort has been made to include therein not merely technical definitions of words, but sufficient explanatory matter to thoroughly familiarize the reader with the term.

PAUL D. HARRIGAN.

CHAPTER 1

The Future of Air Conditioning

ALTHOUGH air conditioning is in its first stage, its progress will be rapid as both science and invention are working on this new device for the comfort and well being of humanity.

Cooling by refrigeration is the obvious method, but we are already using methods of cooling by steam. Although the question of cost is a paramount obstacle, even *that* is being solved by new inventions, as we shall learn later in this chapter. Many of our early inventions were expensive, but have, due to the ingenuity of the inventors, come within the reach of the common man. With new inventions, and with large production, costs are always reduced, and the time will certainly come when we would no more think of renting a home or office that is not air conditioned than we would at present consider a domicile without heating or plumbing facilities.

Air conditioning has already become practical for installation in the home, and will keep an entire house at an even temperature of 70 degrees, or the desired temperature, regardless of whether the outside temperature is zero or one hundred in the shade. The obvious convenience and comfort of such an arrangement is perhaps one of the things which caused the development of air conditioning to be regarded as the greatest invention marking progress in human comfort at the recent Chicago Century of Progress Exposition.

Air conditioning is now awaiting some business genius who will bring it within the reach of the common man, selling and installing the apparatus at a price which will be within the reach of everyone.

As regards air conditioning in factories, the biggest question is, "Will it pay for itself in my own business?" We shall learn from a later chapter of the various process work which is greatly aided by air conditioning, and also of the increased efficiency of the workers under such conditions, but the real problem remains with each individual prospective user. He must figure its installation cost, its possible profits to him, and then determine the advisability of its installation in his plant. It is obviously essential that the installation plans be made carefully, and the cost accounting done with great care and deliberation.

However, when we speak of the cost of air conditioning, we do not mean only the installation expense. There is also the matter of running expenses. For large factories, where the drain upon electric power is great, and also for homes where this unusual constant use of electricity will be required, this cost presents a definite set-back.

At the present time there is being prepared for the market a unit which will take the place of the electric generator to supply the home with sufficient electricity for all purposes, including lighting, cooking, refrigerating, all household uses, and air conditioning. This unit will make air conditioning not only *possible* for the average homeowner, but actually a practical and economical system of heating and cooling. This unit is also being made in sizes which will permit its use for office buildings, hotels, apartment houses, clubs, laundries and all other places which require such additional power.

It is not only an *electric* power unit though, inasmuch as it will have the merits of supplying light, power and heat to all buildings where it is installed.

The experimental unit now in operation consists of a 26 Horsepower Diesel-type engine, connected to a generator. There is a constant voltage delivery by the generator to all loads, without the use of a voltage regulator, due to the construction of the unit. The engine is run with furnace oil, of the type used in the regulation oil burner. It will burn any oil that a Diesel engine will burn, and many that a Diesel engine cannot successfully burn.

This engine will be placed in the cellar, and is fully encased to insure quiet operation. It is specifically mounted to prevent vibration reaching the house itself. Its operation is to be controlled by a house thermostat, similar to those used today for automatically turning oil burners on and off to meet the required need for heat.

It has been proven by laboratory tests that this unit will heat any ordinary house, and burn half the amount of oil used by an oil burner. At the same time it will supply the house with electricity for cooking, household uses, refrigerating, and air conditioning apparatus.

Therefore, the operating cost of air conditioning homes which has been so large a factor in retarding the progress of this type of installation, will be very greatly diminished. This cost has been largely due to the fact that a large amount of electric power was required, and supplying this need ran into enormous figures.

Another field for the future of air conditioning on which experiments are already being made is for use in buses and private automobiles. One manufacturer has announced refrigerating apparatus for buses, trucks and Diesel driven railway trains. Fuel for this apparatus is supplied in tanks in liquid form under pressure. It first creates refrigeration by expansion, which principle is thoroughly explained in the chapter on Elementary Refrigeration, and then passes to the motor. If this proves successful, it will permit truck service for perishable foods.

No one would contend that there is not a difference between conditioned air and the exhilerating air of a fine day in the country. This difference is due to ions, which are in reality infinitesimally small electrical charges.

As a crowd in a room increases, the ions decrease in direct proportion to the number of persons entering that room. Conversely, as persons leave the room, the ion count rises rapidly. The reason for this phenomenon has not yet been discovered. Influence of ions on the body is also still to be fully discovered.

However, it is not necessary for owners to consider these matters, and no one planning an air conditioning installation need delay it for fear of obsolescence because of ionization. When these ions are more fully understood, equipment for their control will be added as a supplement to modern air conditioning installations.

We shall certainly see changes in the future apparatus installed, even though the present apparatus is rather well standardized. Even though these changes may be of a radical nature, it will undoubtedly be some time before they will be under way.

Therefore, we conclude that owners may safely install their air conditioning systems provided two paramount facts are kept in mind: first, the design of the system should be so laid out as to require a minimum of expenditure with the maximum that can be consistently expected in the matter of good service; and second, an ample depreciation allowance should be permitted.

The facts remain that if we are to be comfortable, healthy and modern, we must have air conditioning. When it is installed, ample allowance should be made for future developments.

Air conditioning is not a fad. It is a factor in modern living which is here permanently. It will take its place with heating, and mechanical refrigeration as a sound investment in comfort and health which will pay large dividends over a long period of years.

CHAPTER 2

Uses and Benefits of Air Conditioning

THERE are several distinct functions of a complete air conditioning system, but these are usually divided into two classes, namely those required for summer air conditioning, and those required for winter.

In the winter we must have *distribution* of air, *cleaning* of air, *heating* and humidifying. Distribution of air includes distributing air from the air conditioning apparatus to the various rooms to be so conditioned, the speed of the air in the pipes or ducts which carry it to the various rooms, the movement of the air within each single room and the equalization of air motion in various rooms to prevent stagnant air in one room, and drafts in another.

It is necessary to comfort and health that the air be clean. This requires the removal of dust, soot, odors, pollen and bacteria, which is obtained by passing the air through a filter.

The function of heating the air is understood by everyone, as we have long been familiar with systems of heating during cold weather.

Humidifying simply means to add moisture to the warm air in the building. This is done for two purposes. First, to bring greater comfort and improved health; and second to permit of comfort at lower temperatures than can be enjoyed when insufficient moisture is in the air. Air, like a sponge, can hold only so much moisture. When the air contains less than it can hold, the amount held is stated at its percentage, and whatever this percentage happens to be is called the "Relative Humidity." The ability of the air to absorb moisture, depends upon its temperature. Warm air can absorb more moisture than cold air. Therefore, air which is warmed before adding moisture has a lowered relative humidity. For example, a given amount of outdoor air at a temperature of zero, with a typical relative humidity of 40 per cent will, when heated to 70 degrees, have a relative humidity of only 5 to 6 per cent. This explains why indoor air is too dry in winter, and why it is necessary to add moisture to it.

In the Summer, for air conditioning we must have the same elements of air distribution and cleansing, to which are added the functions of cooling and dehumidifying.

Cooling is accomplished by putting artificially chilled air into circulation. This has been chilled by passing it over coils cooled with cold water, or mechanical refrigeration, or by passing the air over ice, or through a cold water spray.

In the summer, since the uncomfortable condition we wish to combat is the opposite to that which we are attacking in winter—namely *heat* instead of *cold*—we must remove the moisture from the indoor air, by passing the air through a cold water spray, which takes moisture out of the air because it is cold. Or else it can be passed over cold coils, upon which the moisture collects. It can also be done chemically by passing the air through a chemical solution, or bed of crystals, which absorbs the moisture.

In the Temperate Zone, men live on a high plane of energy. They are vigorous which is largely due to the wide changes in climate. In the Tropics and the Orient no such changes occur, and excess energy is not created. Human beings are not capable of standing an unlimited amount of this stimulation of cold and heat, and under too great stress show signs of breaking. Suicides, mental breakdowns and nervous disorders are more frequent in rigorous climates. Thus, the Southerner has the advantage of greater stability of mind and body, but a lower energy, which leaves him more subject to infections. Certain diseases show a tendency to be recurrent in their relation to barometric changes. For instance, acute appendicitis and suicides occur mainly before storms, while colds and pneumonia come with a falling thermometer. Great changes in climate from day to day produce many cases of sinus trouble, arthritis and the like.

These facts as to climate are generally recognized, athough not always thought out. It is generally acknowledged that Florida and California are, due to their climatic conditions, restful climates.

The human body tries to maintain a constant temperature, being aided in winter by clothes and artificial heat. In the summer, we wear less clothes in an effort to counteract that natural heat.

As heat can only flow from a warmer to a cooler substance, body heat *transfer* is reduced in summer. It ceases entirely when *air* temperature reaches body heat. Perspiration, however, produces cooling by evaporation, and by this means our bodies continue to try to maintain an even temperature.

The average body gives off slightly more than 2 lbs. of water per day at 70 degrees. If the temperature rises to 84, this amount is nearly doubled. Meanwhile the body gives off about 400 B.T.U. (which term will be found explained in the section on definitions) when clothes are on, and the body it at rest. If active work is done, this increases to nearly six times this amount.

To persons sensitive to dust, vapor, pollens, or odors which may occasion hay fever, rose fever or sinus trouble, air conditioning comes as a blessing. While air conditioning cannot cure the trouble, as the sensitivity continues when exposed to outside air, it nevertheless permits restful periods of sleep and relaxation, untormented by the affliction.

This problem of dust does not apply only to the home, as there are many industrial processes where dust is prevalent, and particularly dangerous to employees. Various types of filters now available, of water film, centrifugal collector, dry mat, electrical precipitator, or washer construction, which help solve this condition.

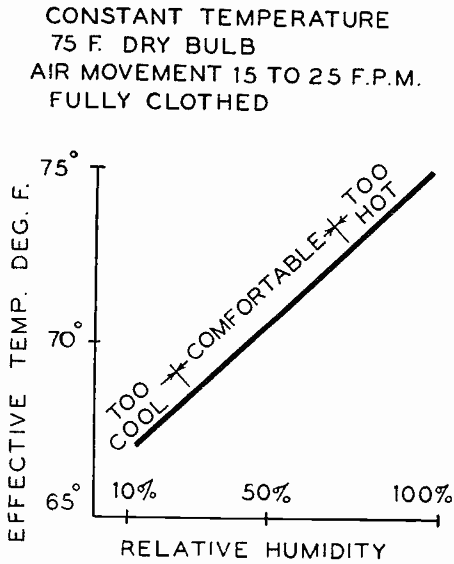
Doctors have complained for years of the heating system used in our buildings, claiming they were largely responsible for the colds we contract. A fluid exists in the mucous membrane of the nose and throat which normally adds moisture to the air, before it reaches the lungs. When the air becomes overly dry, this mucous membrane gradually dries out, due to overuse. This causes irritation to the membranes, resulting in inflammation and swelling. In this area we have a harbor for germs, and the resulting colds, coughs, grip, laryngitis and influenza.

By means of air conditioning this can be eliminated. Although we know that the relative humidity of Death Valley is 23 per cent and that no plant life can exist there, we seldom stop to consider that the average heated home or building has a relative humidity of 15 to 20 per cent, which is dryer than any outdoor air recorded anywhere in the world.

Since this superdry air draws moisture, it absorbs it from the human bodies, leaving them with a lowered resistance, and more subject to disease. Pans of water are placed near radiators in some instances in an attempt to combat this difficulty, but the moisture so obtained is very inadequate.

In the summer, an air conditioning system permits us to keep windows closed, yet enjoy fresh air. This closes out dust. In the congested district of many large American cities, as much as 229 tons of dust rise per square mile, per month. This is mixed with impurities of all kinds. The germ-laden dust drifts into the windows of our homes, offices and factories; each man is estimated to consume 1½ lbs. of dust per year. Naturally the elimination of this factor in our lives, would bring about a more healthy condition.

These closed windows in addition to shutting out dust also shut out noise, which distracts our attention, breaks into the concentrated effort of men



WHAT HAPPENS WHEN THE HUMIDITY RISES

of affairs, and acts as a nerve strain to practically everyone.

One of the interesting phases of air conditioning is its relation to efficiency. In an office there is always an argument as to the lowering or raising of windows. This separates the staff into two warring factions, who, at least for the moment, refuse to cooperate in getting their work accomplished, as well as leaving these two groups preoccupied with their argument.

Executives find it difficult to concentrate in excessively hot rooms. Sometimes meetings are even adjourned until a later date due to the weather, and these delays have upon occasion run into money.

Any appointed job takes twice as long when the weather is hot, and is usually done in a half-hearted manner.

The average person is comfortable at 71 degrees temperature in summer and 66 in winter. Those who are used to a very warm climate will perhaps find that they wish to raise these figures as much as 5 degrees. But it is not the heat, but the humidity, which really makes us uncomfortable. For example, when the thermometer is at 75, note how the effective temperature rises as the humidity increases. Chart No. 1 shows this clearly.

Travelers crossing a western desert where the humidity is slight, say they feel no more heat than in eastern cities with a lower temperature.

	Thermometer	Humidity	Effective Temp.
Western Desert	90	20	77
Eastern City	80	80	78

We used to think that the air in a crowded room became unpleasant due to the inhalation of oxygen and the exhalation of carbon dioxide. This has been proven a falacy. Discomfort is caused by humidity, odors and heat. These cause headache, nausea, and a drowsy sensation. These sensations arise long before the oxygen supply becomes low, or the carbon dioxide high.

This problem of keeping humans comfortable was first recognized by the theatres. Moving picture houses installed air conditioning systems, and found that they no longer suffered a falling off of business in summer. It is today actually more comfortable to sit in an air conditioned theatre than on a sunny porch on a summer afternoon. Acceptance of a cooling system is now quite general in moving picture houses. Some owners of theatres have claimed that it has been a problem to solve what appeared to be a real stumbling block in the advance of the industry—namely the public's indifference to any picture during the summer months. Of 3,000 class A movie theatres in the country, about 300 were air conditioned in 1932. These were mostly located in downtown sections, as neighborhood houses could seldom afford the required investment. Since these theatres vary in the number of persons in attendance at each show, it is essential that their systems be so regulated as to vary to meet changing conditions. There is also the problem of opening and closing doors which necessitate a control to keep the temperatures at an even point.

Hotels have an unusual change recorded as a result of the installation of air conditioning systems. The present lowest priced rooms, which are located facing back air shafts, or at noisy points of the building, can be as comfortable and quiet as any others in the hostelry. This permits a hotel so conditioned to raise the price of the rooms which have previously brought in small revenue. The obvious advantage of a hotel offering a cooled room in which to sleep on a hot night, over one where the rooms are sweltering, need not be commented upon.

Restaurants have also been among the pioneers in the installation of air conditioning systems, and have found that it has greatly increased their summer patronage. The cooler atmosphere in summer has not only drawn persons in, but has stimulated jaded appetites.

Department stores find their trade increased where they have installed a cooling system. In the department selling women's apparel there has been a great decrease in spoilage usually due to excessive perspiration while trying on garments. Department stores are particularly fortunate in making installations in that they usually have a power plant of their own, or are in a position to carry their expense at the reduced rate to which large users of electric current are entitled. Stores also profit by a winter air conditioning system, as it is a well known fact that persons who are comfortabe are easier to sell, more readily pleased, and much less trying upon the sales force.

Office buildings have found that they can rent their offices more readily, and for a higher sum, when air conditioned. A building in the Loop in Chicago was having difficulty in renting space, due to noise. It is now occupied in its entirety, since it has been air conditioned. In one of the eastern cities, a poorly located building is always rented, even when others, more advantageously situated, are vacant. This is due again to the badly located building having air conditioning as an inducement to its tenants.

Extreme dryness of air caused by winter heating is injurious to books, records and paintings, as they become brittle. In summer, the excessive humidity cases molding. Sulpher dioxide from smoke is bad for paper. It is, therefore, obvious that cleaning and control of humidity are the points of greatest interest to the library and museum.

Certainly hospitals should be air conditioned, both for health and a greater comfort to the patients. Unfortunately the cost is almost prohibitive. But it is within possibility to air condition small sections of a hospital, such as delivery rooms, operating rooms, etc., at not too great expense.

Due to the fact that schools are habitually closed during the summer months, cooling systems are not required. But the value and need for winter air conditioning, with its clean, healthy air is generally recognized.

Confectionery makers have always found their products difficult to produce and display in hot weather, due to melting. This condition can be overcome by a cooling system.

Fruits and vegetables are often precooled before loading into cars circulating washed and cooled air through the stacked crates. Artificial ripening by using gas is beginning to be used. This apparatus also includes air conditioning.

Where fruits are canned, air conditioning is a great aid in preventing fruit spoilage, and also in preventing sweating of the cans.

The various processes used in the manufacture and preparation of food of all kinds are greatly benefited by the use of air conditioning in some form or another. A meat packing plant controls the humidity along with its usual refrigeration. Weight shrinkage is stopped, the meat holds its moisture, and the product's appearance is improved as there is no shrivelling.

If the humidity is too high in a flour mill, it causes clogging. On the other hand, if the humidity is too low, the flour loses moisture and weight. The miller loses if the standard moisture content does not remain in his flour. Also high temperatures change the meshes in screens and thus change their sifting capacity. About one ton of air is blown through each barrel of flour that is ground. In order to prevent spoiling, this air must be free from dirt, and from wild spores which might later cause trouble in baking.

Definite temperature must be maintained in order for dough mixing to be right. In order to prevent drying and the formation of a skin, or crust, or holes, the fermenting room must be kept at exactly the right temperature. These conditions can be met with air conditioning.

Breweries and distilleries avoid the contamination of wild yeast with the aid of air conditioning. Formerly the vapors were carried off by admitting large quantities of outside air, but this outside air may be infected. Now the air admitted into the fermenting rooms is also cleaned to avoid contamination. This permits operation during the summer months.

Drug manufacturers condition air for cleanliness and to avoid spoilage of hygroscopic substances.

Fur is extremely sensitive to changes in humidity. The hair cannot absorb dyes if the humidity is high, and if the humidity is low, the hair acquires a permament curl. Aside from the dying process, there is the storage of precious pelts to prevent fading and spoilage by moths. In 1929 over $200,000,000.00 worth of furs were stored in air conditioned rooms.

Vegetables and animal fibres such as cotton, hemp, linen, wool, paper and hair take up moisture from the air, and alter their shape in so doing. Proper humidity in textile mills is, therefore, most important. This peculiar condition is caused by the ability of the fibres to condense water in the pores. When the humidity is too low, it causes dust and creates bad static conditions, which seriously lower the output of the factory. When too dry, the fibres break in carding. Dry air causes fraying and uneven work in drawing and combing. In spanning, the heat from the machines tends to dry the air, and gives poor quality yarn of uneven weight. In weaving, varying temperatures and humidity give varying quality. Yet a certain amount of humidity is necessary to "set the twist" in yarn, to prevent kinking.

Similarly, when paper is too dry the static causes it to stick together, and when it is too wet, it swells and loses shape. Air must be conditioned to a perfectly uniform degree at all times to insure perfect production.

Printers, too, eliminate color registry and static troubles when the humidity is controlled.

In the tobacco industry, air conditioning is used to settle the intolerable dust and keep the tobacco in proper condition. Cigar manufacturers in Philadelphia recognize humidifying equipment as an essential in the production of high quality cigars. In normal summers, due to temperature and humidity conditions in the plant, production fell off from 4,000 cigars per machine per day to 3,600 cigars per machine per day. This was a 10 per cent decrease in production. With complete air conditioning the machines continued to produce at full capacity all summer. Also according to the American Cigar Company, the installation resulted in a general improvement in the health of their employees.

Furniture makers reduce the damage of dust settling on high finishes while drying by means of air conditioning.

Electrical manufacturers need dry air in making certain apparatus, such as condensers, and also for testing purposes.

Air conditioning is equally essential in automobile body plants where dust may play havoc in spraying and finishing chambers.

Railroads today constantly advertise air conditioning on their trains, and its use is generally known. As rapidly as the new equipment can be installed, this particular application of air conditioning is spreading. At the end of 1934 nearly 3,000 cars were so equipped, and the work is still going forward.

Passenger ships which make tropical runs have in a few instances been air conditioned for the comfort of their patrons.

Buses and private automobiles are being experimented with, but have not as yet made much progress.

CHAPTER 3

Elementary Refrigerating Systems

THE ART of cooling bodies below the temperature of the atmosphere is one that has been practiced for centuries. One of the early methods consisted of evaporation of the liquid to be cooled by putting it into porous vessels which were hung in an air stream. This procedure was followed in localities where the atmosphere was warm and dry.

Another early method consisted of the construction of caves and cellars in the ground in which goods were placed to prevent their decaying, as it is possible to obtain a 50 or 60 degree temperature in these underground storage places. Low temperatures were also obtained by the use of freezing mixtures, such as water and saltpetre, snow or ice and saltpetre, etc. In a like manner ice was harvested in the winter, stored in underground caves, and used to preserve food stuffs during the summer months.

It can be seen that until quite recently only the above types of cooling were possible, and it was not until 1775 that the first means of producing refrigeration with machinery were experimented with.

During the next 75 years, many experimental machines were constructed. There were vacuum machines, water machines, sulphuric acid machines, and many others now obsolete.

The real foundation for the development of the compression refrigerating machine was made in 1823, when it was discovered that certain fluids could be liquified after being compressed to a high pressure. To Michael Faraday of England, we are indebted for this discovery. The first real compression machine was developed in 1834, using ether. Although crude, it was the first machine to produce ice, being developed by Jacob Perkin, an American inventor of Massachusetts. In the year 1850 refrigeration by means of a cold air machine was invented by John Dorrie. Five years later, the first absorption machine was invented, by Ferdinand Carrie, of France.

In 1865 the first transparent ice was made from distilled water in New York State. This same year steam coils were used to evaporate ammonia. In the year 1873 to 1875 the first successful ammonia compression machine was introduced by C. E. G. Lindt of Germany, and David Boyle of the United States. During the next 15 years, this system made rapid advances.

Up to this time, little or no use could be found for the manufactured ice. But in 1890 the greatest shortage of natural ice ever experienced occurred in this country. It may be said that from this year on, machine-made ice had an outstanding place in commerce. During the past 45 years, many developments have been worked out and improved upon so that today we have very efficient cooling and ice making machines.

Among the commercial, practical refrigerating systems, the following are the most important and widely used.

1. Natural or manufactured ice.
2. Vapor compression systems, using fluids that can be evaporated and liquified such as Freon, sulphur dioxide, ammonia, etc.
3. Absorption, using liquid ammonia.
4. Steam ejector systems.

Other less common methods of producing refrigeration are:

1. Cooling by evaporation of liquids.
   a. Water.
   b. Ether or the like.
2. Cooling by melting of solids.
3. Cooling by freezing mixtures.
   a. Ice and salt.
   b. Ice and calcium chloride.
   c. Snow and salt.

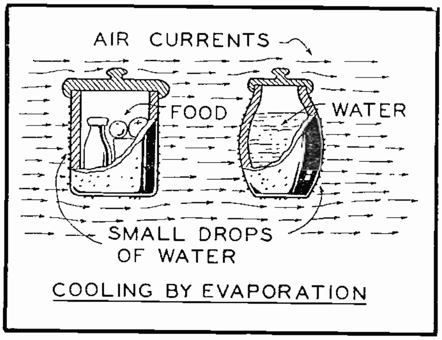


Fig. 1
This method relies on evaporation for cooling.

d. Water and saltpetre.

4. Cooling by sublimation.

a. Carbon dioxide ice.

5. Indirect cooling by evaporation of liquids.

a. Vapor compression.
b. Absorption.
c. Adsorption.
d. Vacuum.

Cooling by Evaporation

As this was one of the earliest methods, it would be well to point out that even today it is being used by tourists crossing Death Valley, and is accomplished by immersing a porous jar in water and then filling this jar with water, or whatever material it is desired to cool, and placing the filled jar in the air current such as the front of an automobile. Thus the evaporation of water contained in the porous walls of the jar is sufficient to lower the temperature of the material inside the jar as much as thirty degrees.

The water held in the pores of the jar was in a liquid form, but when exposed to the air stream, it evaporated. This evaporation required heat, and the heat came from the material stored in the jar. This is illustrated in Fig. 1.

The actual amount of cooling depends solely upon the amount of moisture already in the air, as we know that when the surrounding air is already saturated, there will be no evaporation of water from the earthen jar, and no cooling effect can be produced thereby. However, when the air contains only a portion of the moisture which it is capable of carrying (depending upon the temperature) it is evident that moisture can be added to it from an outside body, such as the porous jar.

A liquid such as alcohol or ether if placed on the body in a liquid form, evaporates, and in doing so produces a cool sensation. This is caused by evaporation of the liquid and absorption of heat from the body to do so.

Cooling by Melting of Solids

In order to change the form of a material from a solid to a liquid, a definite amount of heat must be added to the solid. This is dependent upon the kind of substance used and its temperature and pressure. The heat added to make this change from solid to liquid is called "latent heat," as no change of temperature takes place in the solid.

For instance, a pound of ice at 32 degrees requires 144 B.T.U. (British Thermal Units) to change it to water at the same temperature. Thus, this pound of ice in changing to a liquid form will absorb the 144 B.T.U. from the air, or its surrounding object, thereby producing a cooling effect (see Fig. 2). Obviously cooling below 32 degrees is not possible by this method.

Cooling by Freezing Mixtures

Lower temperatures may be obtained by the use of freezing mixtures, such as ice and salt. The action of the material is such that the temperature of the mixture will be a few degrees below 32 degrees f. The

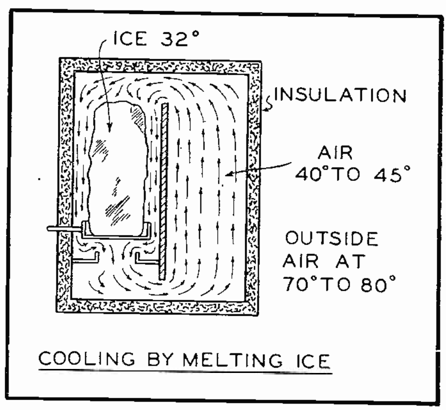


Fig. 2
The common method of cooling by melting ice.

actual amount of cooling depends upon the proportion of salt and ice in the mixture. When the two solids are mixed together, a certain amount of heat is absorbed because both materials change from a solid to liquid due to their being mixed. A brine solution is thereby formed. The heat required to dissolve the salt and ice is taken from the mixture itself, rather than surrounding temperature, so it is possible to cool below the temperature of pure, solid ice. If the mixture contained 15 per cent salt, the resulting temperature would be 11 degrees f.

If two parts of snow are mixed with three parts of calcium chloride crystals, the resulting temperature will be approximately 50 degrees below zero. Or if acetone and solid carbon dioxide are mixed, it is possible to obtain a temperature as low as 70 degrees below zero. This principle is illustrated in Fig. 3.

Cooling by Sublimation

Normally, any solid changing to a vapor or gas must go through a liquid state. However, carbon dioxide changes from a solid to a vapor or gas without going through a liquid state. It has a normal temperature of 110 degrees below zero and the advantage of not wetting containers or materials that are placed in contact with it. Carbon dioxide is commonly known as dry ice, and when changing from a solid to a gas or vapor absorbs latent heat and produces a cooling effect.

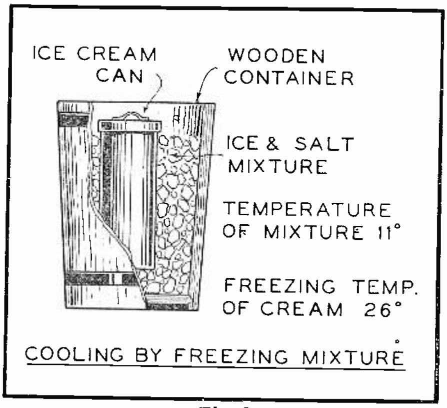


Fig 3
A mixture of snow and calcium chloride produces freezing.

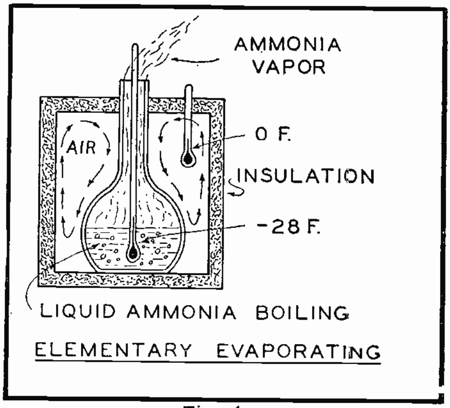


Fig. 4
The vapor absorbs heat producing "cold."

Indirect Cooling by Evaporation of Liquids

All mechanical systems utilize some liquid refrigerant, evaporating at a low temperature. During evaporation, the liquid is changed into a vapor, absorbing heat. An elementary system using a volatile (easily evaporated) liquid is shown in Fig. 4.

The refrigerant may be any of the commonly used ones, such as ammonia. If the ammonia in the container is open to the atmosphere, the temperature of the liquid will be minus 28 degrees, or 28 degrees below zero. At this condition, the container as shown could be cooled to zero degrees, depending upon the construction of the walls of the container and the outside temperature. Although a constant temperature of minus 28 will exist during the process of evaporation in the liquid, the temperature of the container must take other conditions into consideration.

In the case of ammonia liquid at minus 28 degrees, a definite amount of heat is required to change it from a liquid to a gas. Thus, the ammonia absorbs its latent heat at a low temperature and produces a cooling effect. The heat coming through the compartment walls, or materials stored in the compartment, changes the refrigerant into a gas, which escapes through the atmosphere as shown in Fig. 4.

Under certain conditions, it is desirable to use brine, illustrated in Fig. 5.

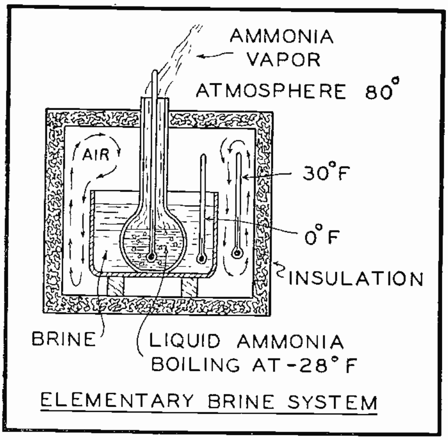


Fig. 5
Refrigerating with a brine solution.

To maintain the insulated compartment at 30 degrees, a vessel containing liquid ammonia, open to the atmosphere, is inserted into a quantity of brine, which would be cooled to approximately zero degrees. The heat from the 80 degree atmosphere is transmitted through the walls into the 30 degree section. This in turn is transmitted by the air to the brine, which in turn imparts it to the ammonia, which is at minus 28 degrees, causing the ammonia to evaporate.

For use in making ice, a system as shown in Fig. 6 is employed.

In this instance a vessel containing liquid ammonia at minus 28 degrees is inserted in a brine solution, which will be cooled to approximately 12 degrees. At this low temperature the water in *cans* surrounded by brine will freeze to a solid. As illustrated, the ammonia vapor is permitted to escape after it has absorbed its latent heat from the brine, which in turn absorbs heat from the water.

Vapor compression is a system that uses a motor-driven compressor, to withdraw the low temperature vapor, as for example from the ammonia container in Fig. 6 which is the evaporator. This gas is then compressed to a high pressure and temperature, so that it may be cooled and condensed back to a liquid by water or air. Thus the complete cycle is divided into four principle parts:

1. Evaporation of liquid at low temperature.
2. Compression of gases or vapors.
3. Condensing of vapor at relatively high temperatures.
4. Controlling liquid supply.

The gases may be compressed by a reciprocating, centrifugal or rotary compressor. Figure 7 illustrates the reciprocating compressor which is the one most commonly used.

To facilitate the return of the lubricating oil, the evaporator should not be installed more than fifteen feet below the compressor, but may be used at any height above the compressor.

In the illustrated system, ammonia is used as the refrigerating medium. With a pressure of 19 lbs. per sq. in. in the evaporator, the temperature of the ammonia will be 5 degrees. So it can be seen that the heat flows from the refrigerator, which is at 30 degrees, into the ammonia, causing it to evaporate. This ammonia vapor is then drawn from the evaporator into the compressor, and a complete cycle is as follows:

The compressor raises the temperature and pressure of the ammonia vapor to a pressure and temperature at which it can be condensed. Thus with a water supply of 70 degrees, and the water passing through the condenser, the water temperature increases to 80 degrees.

It is then possible to condense the ammonia vapor which will have a resulting temperature of 86 degrees, and a corresponding pressure of 155 lbs. Therefore, the compressor withdraws the ammonia vapor from the evaporator as quickly as it is formed

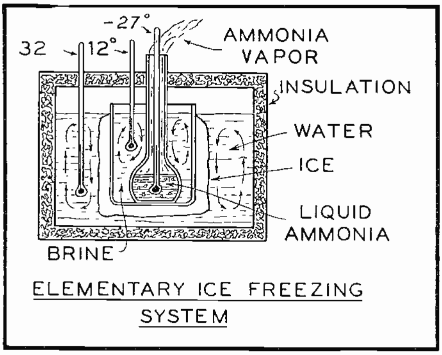


Fig. 6
An elementary method for making ice.

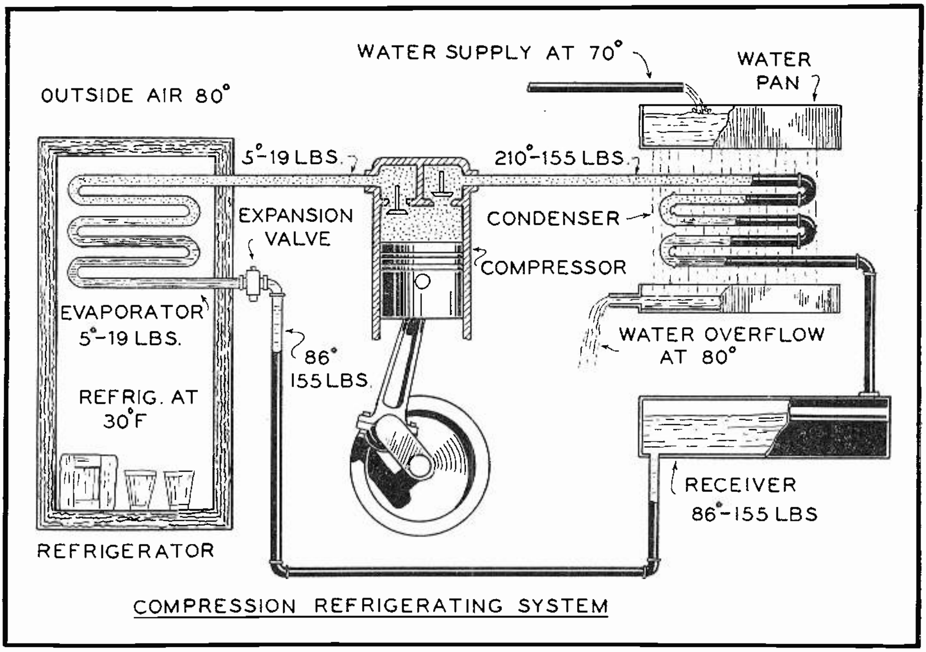


Fig. 7. The fundamentals of refrigerating by compression.

at a pressure of 19 lbs., and compresses this vapor to a pressure of 155 lbs.

It is evident that the pressure and temperature in the evaporator will depend upon the temperature desired in the refrigerated space. The temperature and pressure in the condenser will depend upon the temperature of the water supply. When the evaporating pressure is 19 lbs. per sq. in., the ammonia comes to the compressor in a dry state. The temperature after compression will approximate 210 degrees. Therefore, the condenser cools the hot ammonia gas from 210 degrees to the condensing temperature of 86 degrees, and the heat is absorbed from the ammonia, which is at a high temperature, by the water which is at a lower temperature, until all the refrigerant is condensed to a liquid state.

Then the liquid ammonia at 86 degrees is piped from the condenser to a liquid receiver or storage tank. This tank is connected to the expansion valve, and the condition of the ammonia at the valve will be a liquid at 86 degrees, and 155 lbs. pressure. So the refrigerant expanding from this high pressure to a low pressure of 19 lbs. will have a correspondingly low temperature, and can absorb heat to re-evaporate it so that it may be used over and over again.

This cycle is characteristic of all compression systems of refrigeration. They differ only insofar as the actual refrigerant that may be used, which of course would change the pressures and temperatures correponding to the particular refrigerant, but in no way effect the principle of operation.

Absorption refrigerating machines are used extensively where extreme low temperatures are necessary, and where an ample supply of steam is available. As illustrated in Fig. 8, the essential parts of the system are the condenser, the expansion valve, evaporator and receiver.

These are exactly the same as used in a compression system. The real difference between the two systems lies in the method of abstracting the gas from the evaporator. The vapor coming from the evaporator is dissolved in a weak solution of ammonia and water. This part of the system is called the absorber, as you will note in the illustration. It consists of a shell for retaining the solution of ammonia and water, a device for introducing the vapor from the evaporator into the ammonia solution, a water coil for removing heat from the absorber, and a strong and weak solution.

The ammonia vapor from the evaporator is first condensed and then dissolved in a weak aqua-ammonia solution in the absorber. This change of state gives up heat which is absorbed by water flowing through the cooling coil, and maintains the absorber at a constant temperature, which will always be a few degrees above the average temperature of the water in the coil. The percentage of ammonia which this solution will absorb depends upon the evaporating temperature and temperature that is maintained in the absorber. When the solution has absorbed all the ammonia it can hold at the pressure and temperature, it is then led through a pump which discharges the strong solution into the generator. The pressure of the absorber corresponds closely to the pressure of the evaporator. The pressure of the generator corresponds closely to the pressure of the condenser. The pump is used simply to remove the strong solution from the absorber, and discharge it to the generator. So by applying steam to the heating coils of the generator, it is possible to bring the solution to a boiling point and distil the ammonia.

The temperature of the boiling solution in the generator will be controlled by the condenser pressure, and the percentage of the ammonia in the weak solution, as it leaves the generator, passes through the condenser, and back to the absorber.

The temperature of the steam in the steam coil will always be a few degrees higher than the boiling solution in the generator. Thus heat will flow from the steam into the solution causing it to boil off the ammonia vapor. The ammonia vapor then passes to the condenser where it is condensed to a liquid, and returns to the expansion valve.

Adsorption systems are characterized by the use of Silica Gel, which operates on an intermittent cycle similar to the absorption system. Silica gel is a hard glassy material of extremely porous character, and it is believed that one cubic inch of this material has the equivalent of a total surface area of 50,000 sq. ft. The presence of these minute pores obviously give silica gel a high moisture absorption characteristic. After absorbing moisture, the silica gel can be heated, and the moisture driven out,

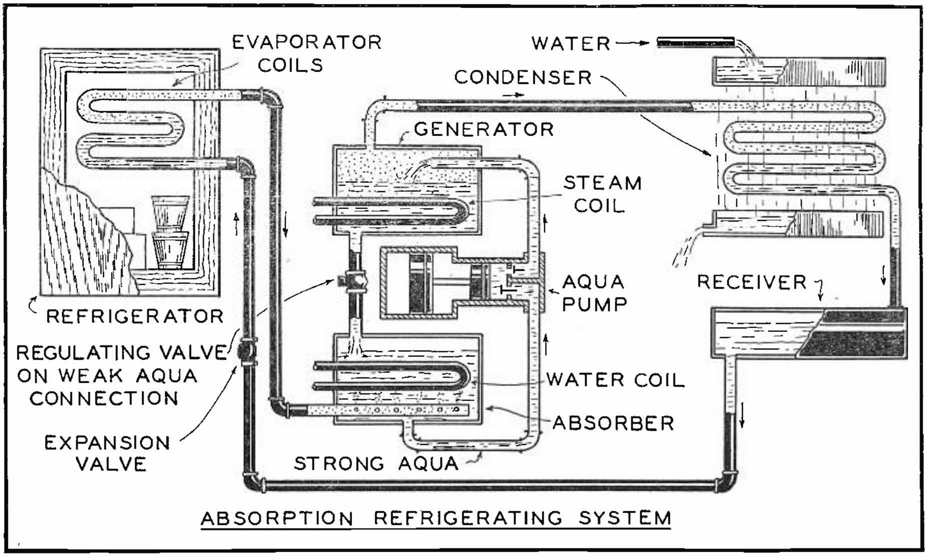


Fig. 9. The principles of refrigeration by absorption.

making it possible to use it over and over indefinitely. No power is required in this system as the heat is applied directly to the silica gel, and the common commercial silica gel will absorb approximately 50 per cent of its weight of water from saturated air. Temperatures of 250 degrees or higher are required to drive off this moisture. This is technically known as reactivating. The operation of this system is illustrated in Fig. 9.

The vacuum, or steam ejector system is based on the principle that water will boil or vaporize, depending upon the extent of vacuum created above it. Thus water at ordinary atmospheric pressure boils at 212 degrees, f. At high altitudes where the atmospheric pressure is reduced, it will boil at 160 degrees, showing that by reducing the pressure, it is possible to boil or evaporate water at lower temperatures.

To obtain a vaporization, or boiling, in the vicinity of 50 degrees, f., it is necessary to provide a constant vacuum of about .36-in. of mercury. This is equivalent to 19 lbs. absolute pressure. The above is a reverse cycle of storing heat in liquids, as in the case of steam generation of 100 pounds absolute pressure, the temperature will be 327.8 degrees. The

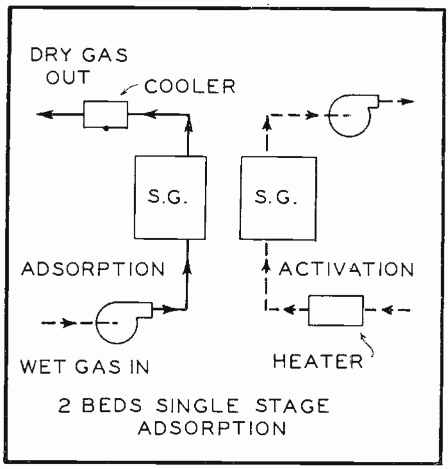


Fig. 9
S. G. in this sketch refers to silica gel.

water and steam being at the same temperature. If a steam valve were opened to the atmosphere, the heat stored in the water would continue to flash into steam until the entire contents were reduced to 212 degrees, and the water would stop boiling. However, if a vacuum is created on the boiler, evaporation will continue depending upon the extent of the vacuum produced.

This process of cooling is illustrated in Fig. 10, in which A is a nozzle

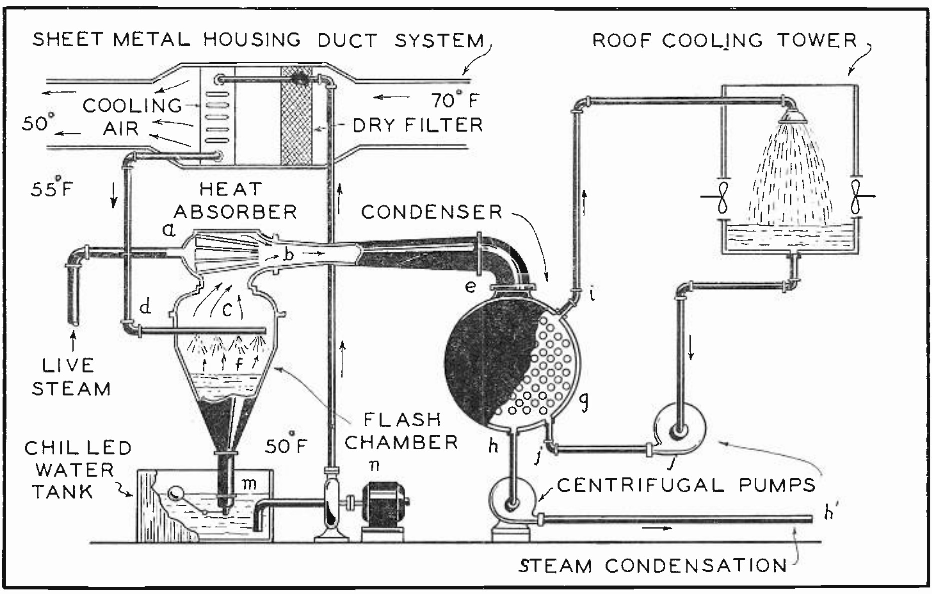


Fig. 10. The steam ejector system in which a vacuum is created to increase vaporization.

containing a series of jets, from which live steam is discharged at a high velocity with pressures ranging from 75 to 300 lbs. per square inch.

As the steam rushes through the contracted tube B, a vacuum is created at the opening C, which opens directly into the chamber F. The water supply line D, from the cooling coil, enters the flash chamber and as the water is sprayed into the low pressure area, some of it naturally evaporates, thus absorbing heat from the particles or drops that do not evaporate. The heated vapor rises into opening C and flows through the venturi tube B to the condenser nozzle E. The object in removing the heat of evaporation is achieved by the low vacuum, and the remainder of the water drops through the flash chamber and then to the storage tank. The steam and water vapor expand as they enter nozzle E, and the steam expands further as it encircles the tube and condenser G. The reason for it expanding is due to the pressure being lower. Water is circulated through these tubes, and the steam flows around them, which is condensed back to water, and is pumped to the high pressure boiler by pipes H and H-1, to be regenerated into steam. Another pump, J, is connected to the condenser tubes which circulate the condenser water to the cooling tower on the roof, where this water is sprayed and caused to evaporate in part. Thus we have a similar partial evaporation to that occurring in the flash chamber, but, of course, the water temperature will not be as low because it is exposed to the atmosphere.

From the above description, it is evident that cooling is simply the re-

CHART 2

FREON (CCL2F2)					
Temp. °F.	Gauge Press. Lbs./Sq. In.	Density Lbs./Cu. Ft.		Total Heat From -40°	
		Liquid	Vapor	BTU./Lbs.	BTU./Lbs.
32	30.1	87.02	1.10	15.21	66.62
36	33.4	86.55	1.18	16.10	66.17
40	37.0	86.10	1.26	17.00	65.71
44	40.7	85.66	1.35	17.91	65.24
48	44.7	85.19	1.44	18.82	64.74
52	48.8	84.71	1.53	19.72	64.27
86	93.2	80.63	2.57	27.72	59.65
100	116.9	78.80	3.14	31.16	57.46
120	157.1	76.02	4.17	36.16	53.99

CHART 3

METHYL CHLORIDE (CH3CL)					
Temp. °F.	Gauge Press. Lbs./Sq. In.	Density Lbs./Cu. Ft.		Total Heat From -40°	
		Liquid	Vapor	BTU./Lbs.	BTU./Lbs.
32	21.9	59.91	.372	23.4	174.4
36	24.8	59.65	.401	24.9	173.4
40	27.9	59.49	.433	26.5	172.4
44	31.4	59.13	.467	27.9	171.4
48	34.9	58.88	.503	29.5	170.4
52	38.8	58.62	.538	31.0	169.4
86	80.8	56.30	.962	43.9	160.2
100	104.1	55.33	1.17	49.4	156.3
120	144.9	53.94	1.43	57.5	150.6

moval of heat from one place and storage or dissipation in another. The most commonly known refrigerants evaporate or boil at the various temperatures and pressures shown in the following tables. These tables also contain the B.T.U. absorbed by the evaporation of 1 lb. of each substance, at various pressures.

Transferring of Refrigeration

Up to this point, we have discussed the methods of securing refrigeration. We now turn to ways of using the refrigeration so acquired, and Fig. 11 shows a common bunker room, evaporator coils for cooling the air, air circulating fans and connections, between the evaporator surface and refrigerator.

The evaporator coil may be connected to any pipe refrigerating machine that produces a refrigerant at a temperature below the temperature at which the air circulates. Thus the air is cooled in the bunker room and then forced to the space to be cooled, where it absorbs heat, and the temperature of the refrigerator or cooler can be automatically controlled by regulating the amount of air which is circulated through it. As can be seen, no drain connection is provided for in the bunker room because we are not attempting to abstract any moisture from the air. Where indirect cooling by brine is desired, either because of local fire regulations or the possibility of ammonia leak effecting food stuffs. Figure 12 shows a typi-

CHART 4

Temperature Table

SATURATED AMMONIA

Pressure Gauge Lbs. per Square Inch	Temperature °F	Volume of Vapor Cubic Feet per Lb.	Latent Heat B. T. U. per Lb.
0.0	-28°	18.00	589.3
1.3	-25°	16.66	587.2
3.6	-20°	14.68	583.6
6.2	-15°	12.97	580.0
9.0	-10°	11.50	576.4
12.2	-5°	10.23	572.6
15.7	0°	9.116	568.9
19.6	5°	8.150	565.0
23.8	10°	7.304	561.1
28.4	15°	6.562	557.1
33.5	20°	5.910	553.1
39.0	25°	5.334	548.9
45.0	30°	4.825	544.8
51.6	35°	4.373	540.5
58.6	40°	3.971	536.2
66.3	45°	3.614	531.8
74.5	50°	3.294	527.3
83.4	55°	3.008	522.8
92.9	60°	2.751	518.1
103.1	65°	2.520	513.4
114.1	70°	2.312	508.6
125.8	75°	2.125	503.7
138.3	80°	1.955	498.7
151.7	85°	1.801	493.6
165.9	90°	1.661	488.5
181.1	95°	1.534	483.2
197.2	100°	1.419	477.8
214.2	105°	1.313	472.3
232.3	110°	1.217	466.7
251.5	115°	1.128	460.9

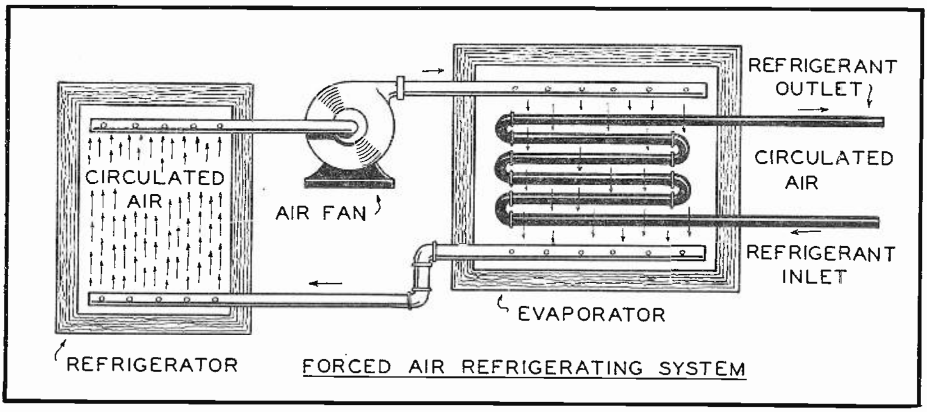


Fig. 11. The "forced air" method of cooling a room or space.

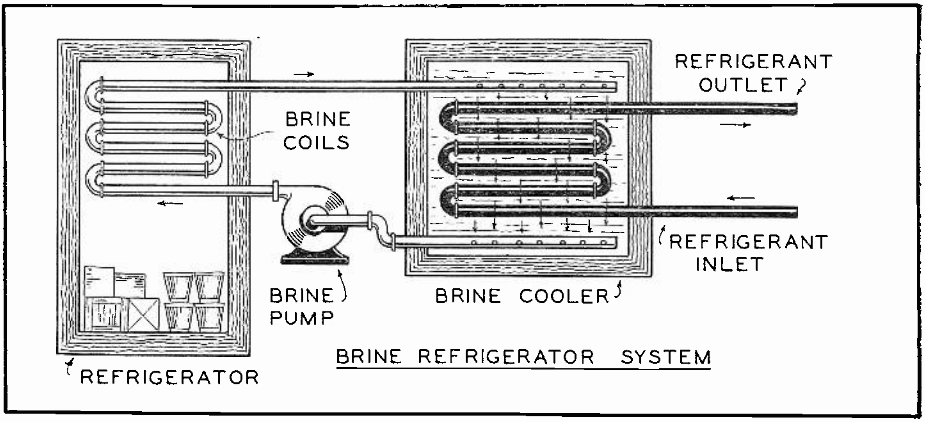


Fig. 12. The "brine cooler" system of refrigeration.

cal installation, which consists of a brine cooler for cooling the brine, the brine coils in the space to be cooled, together with suitable brine connections.

Brine cooler coils may be connected to any refrigerating machine that produces a low evaporator temperature in the coils. Thus it can be seen that heat is transferred first from the air to the brine in the refrigerator or cooler, then from the brine to the evaporating refrigerant in the brine cooler. It is necessary to maintain two different temperatures; first, between the evaporating refrigerant and the brine; and second, between the brine and the room. So it will be necessary to have the brine below the room temperature and the refrigerant below the brine temperature. Although at first this system appears to be large, it offers the advantage of flexible control of operation and safety.

The brine spray system is one in which the brine is sprayed directly in the air being cooled, and is shown in Fig. 13. The system consists of a brine spray header, provided with several spray nozzles, a brine proof bunker, a brine pump, and brine cooler. Discharging from the spray nozzle, the brine is in the form of fine drops, and before they fall to the bunker floor, they are heated a few degrees, the heat coming from the air in the room, or materials stored therein. The air, being cooled, tends to fall to the bottom of the cooler, and the warm air rises to the top and comes into immediate contact with the brine spray, so that a natural air circulation is set up in the room. In this system, the evaporating refrigerant is a few degrees below the temperature of the brine, and the brine is a few degrees below the temperature of the cooler. The brine pump must have sufficient capacity to circulate the required amount of brine and to discharge it at the nozzles at a pressure of not less than 10 lbs. per sq. in., in order to break up the liquid brine and expose more of it to direct contact with the air. The finer the spray of brine, the more area of brine is exposed to the air. This system has its greatest application in meat coolers and packing houses.

Part of a Refrigerating System

Centrifugal compressors find their most important fields of application in systems which operate at low or sub-atmospheric pressure and handle large volumes of gas. They are well adapted to such systems because they can run at high speeds and have no valve to cause trouble. A small unit is capable of large refrigerating capacity. The cost of the unit is low considering the size of the system, and the control is simple. These systems operate best under constant load conditions and therefore are well adapted to large installations like theatres, office buildings, etc., but are not adapted for use in small systems or under fluctuating loads.

Rotary compressors are used quite extensively because of their simplicity of design. They are used in cases where the volume of gas handled is not too large. If the volume of gas to be handled is large, the compressor also must be large, or run at excessively high speed, which brings us to the trouble usually encountered with the use of rotary compressors; this is that the present-day valve design will not stand the high speed required.

Gear pumps are not used to any extent because of the high power consumption and low efficiency under which they operate.

The reciprocating compressor is more widely used today than any of the others especially in the field of air conditioning, and icebox refrigeration. As compared with the other compressors, the reciprocating unit has many advantages, such as the fact that it is easy to service. It operates at low speeds and has a range of sizes to fit any type of installation. Also it is quiet in operation, the principle of operating is easily understood, and it is dependable in performance, having only a few moving parts. The over-all running efficiency is high.

The purpose of the condenser is to discharge to the outdoors the heat which is absorbed by the refrigerant in the evaporator, and such heat as is generated in the compressor. The design of the condenser has a considerable effect on the performance of the system since raising or lowering the condenser temperature has a decided effect upon the efficiency of the system. The two general types are air and water cooled condensers. Since air is not nearly as effective for absorbing heat as water, air condensers are larger than the water cooled type. The air condenser is usually of the fin-tube type, the refrigerant circulating inside the tubes and the air for cooling being blown over the outside surface, which condenses the refrigerant.

Water-cooled condensers are more efficient than air cooled and are generally constructed of one of the three following types. One is the counter flow, double tubed, the refrigerant being circulated through a tube which has a smaller tube in it that carries the water to cool the refrigerant. The water and the refrigerant flow in opposite directions and one tube is inside the other. The shell and tube type consists of a metal shell that has water coils built into it. The water flowing through the coils condenses the refrigerant, which is inside the shell and around the coils. The third type of water cooled condenser is the reverse of the shell and tube type. The refrigerant is inside the tube, surrounded by the water which is inside the shell.

Evaporators are either one of two types,—flooded or dry. The flooded

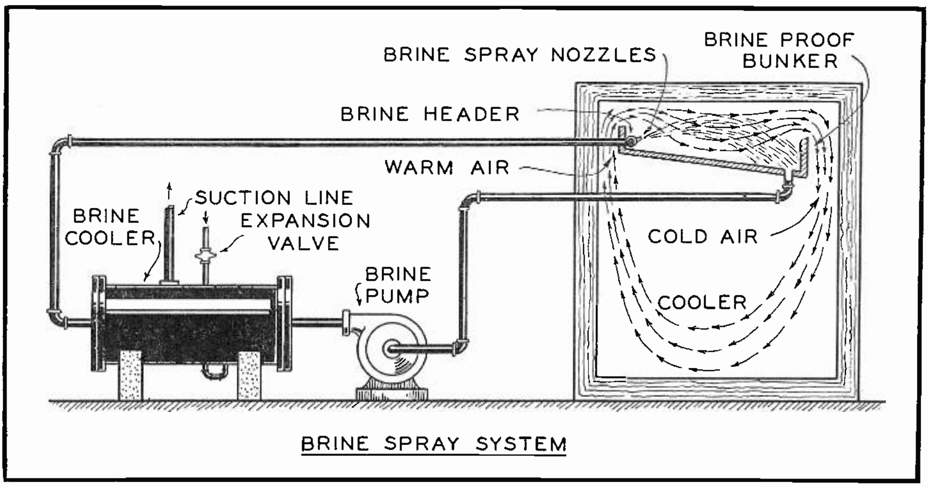


Fig. 13. The "brine spray" refrigerating system using a warm air flow.

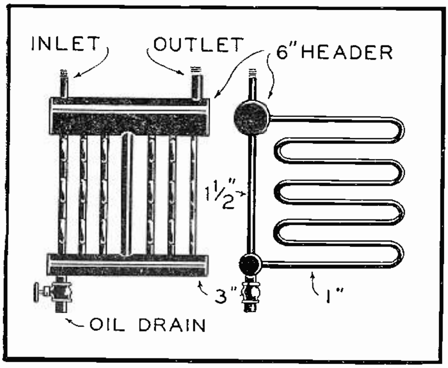


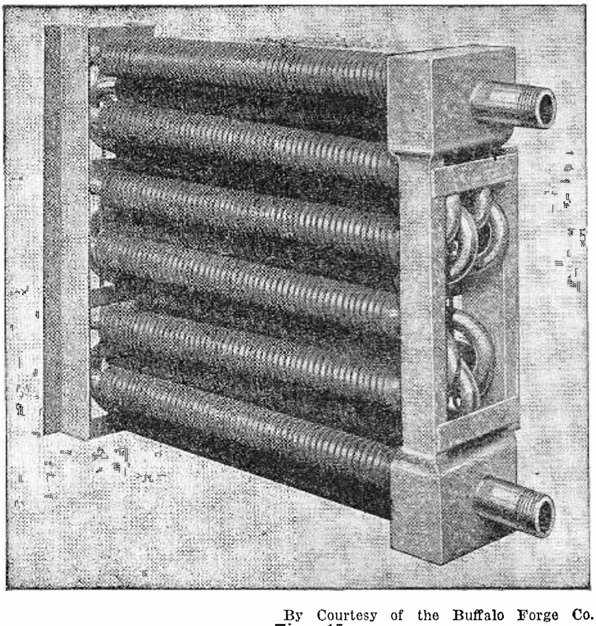
Fig. 14
The header of a flooded type evaporator.

evaporator is generally of the header and tube type and partially filled with liquid, instead of a saturated gas as in the case of dry expansion. The heat transferred through the pipe is greater than that of the dry evaporator. The success of a flooded type evaporator depends on the construction of the header, as there is always a certain amount of dead or flash gas representing about 15 per cent in the case of ammonia. This is brought about by admitting the ammonia to the evaporator or low pressure area and part of it flashing. Since the flash gas can do no work in a refrigerating load, there is no need for pumping it through the entire evaporator, and it is essential that this gas be removed as quickly as it is formed. If it were to remain in the evaporator, it would crowd the liquid refrigerant from the walls of the pipe, and thereby reduce the effectiveness of the flooded sytem.

The flash gas is removed by the use of headers, to which the evaporating tubes are connected. As the refrigerant vaporizes in the tube, the vapor will quickly find its way to the suction header and be pumped back to the compressor. This header also provides for a surge caused by the rapid evaporation of the refrigerant, and the header should have a capacity of from 25 to 50 per cent of that of the evaporator coils. Figure 14 is an illustration of this system.

As in all compressors and methods of refrigeration, the lubricating oil is mixed directly with the refrigerant. So with the flooded type of evaporator it is necessary to provide for an oil return.

Dry evaporators are always of the series tube non-recirculating type as shown in Fig. 15.



By Courtesy of the Buffalo Forge Co.
Fig. 15
A dry type series tube evaporator.

The length of coil used in each system will govern the efficiency and capacity. If the coil is too short, the refrigerant vapor will leave in a wet condition, and result in a loss due to liquid refrigerant returning to the compressor. There is also a possibility of slugs of liquid going back to the compressor and causing untold damage. If the coil is too long, the vapor becomes superheated before entering the compressor. This "superheat" causes an increase in the total cubic feet of refrigerant per-pound perminute to be handled by the compressor, and therefore decreases the efficiency and capacity of the machine.

The purpose of the evaporator is to allow for the expansion of the refrigerant, thereby lowering its temperature and pressure so that heat may be absorbed from the air or water, whichever surrounds it. As the refrigerant enters the coil, it is in a liquid form at a comparatively high pressure. Upon being released into an area where the pressure is low, the refrigerant sprays and is still in a liquid form (minute drops). As these fine drops pass through the tube, heat is absorbed through the surface. The refrigerant is evaporated into a gas, at the same temperature. If we allow this gas to continue further, it will absorb additional heat and its temperature will rise. This higher temperature is called superheat, because it is not in direct contact with wet refrigerant, and the temperature will exceed that of a saturated gas at the same pressure.

An expansion valve is necessary in a refrigerating system to provide some means of controlling the flow of the refrigerant. It is necessary to reduce the refrigerant from the condensing pressure to evaporating pressure, and at the same time regulate the quantity of refrigerant flowing. The simplest form of valve would, of course, be a hand operated device, such as a pressure reducing valve. Starting at the receiver tank, where the refrigerant is stored at a high pressure, it passes through the expansion valve, where the pressure is greatly reduced. Most valves used today are of the thermostatic, expansion type, which are more efficient in operation and offer a method of controlling the amount of refrigerant entering the evaporator. It prevents the return of liquid to the compressor and provides a way of obtaining a completely wetted surface, inside of the evaporator, as well as allowing separate temperature control on each individual circuit of evaporator surface.

The valve is operated by a small amount of superheat in the suction gas as it leaves the evaporator. The valve itself is located in the pipe line at the evaporator inlet, and the bulb is placed on the suction line close to the evaporator *outlet* and inside the refrigerated space.

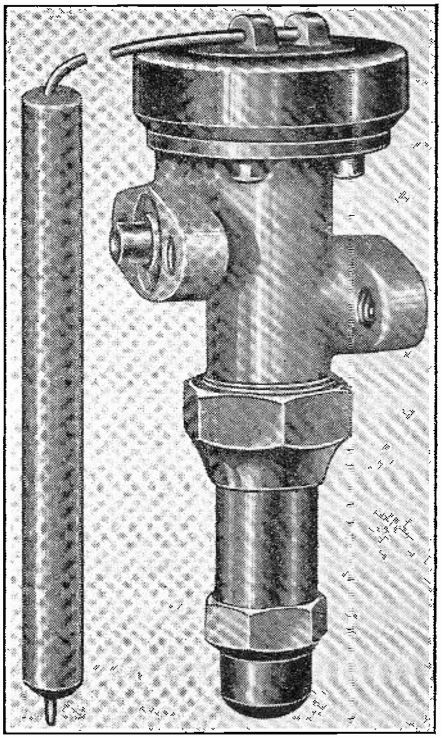


Fig. 16
An expansion valve for controlling refrigerant flow.

The superheat leaving the evaporator causes an increase in the temperature and pressure of the liquid inside the bulb, which in turn exerts force on an inlet orifice disc in the expansion valve. This allows more refrigerant to enter the evaporator. However, if there is no superheat, the temperature and pressure at the suction outlet will be low, and the action of the thermostatic bulb would be to close the expansion valve inlet orifice. As can be seen, this prevents more refrigerant from entering the evaporator, which is the desired result, as we already have as much refrigerant as can be utilized. An illustration of an expansion valve will be noted in Fig. 16.

CHAPTER 4

Types of Winter and Summer Air Conditioning Installations and Their Operation

OUR present-day air conditioning is the outgrowth of the one time popular hot air furnace, which when properly applied did a good job of heating. However, this system gave way to the one-pipe steam system which, in turn was replaced by the vapor and hot water system. As the public in general became educated to the fact that heating alone was not sufficient for ideal comfort, adaptions were then made to the hot air furnace, in an attempt to supply clean, moist air during the heating season, as well as heated air.

When it is realized that during the heating season outside air leaks into the heated rooms at a rate sufficient to change the air in the room from one to three times per hour, it will be evident that moisture must be added to obtain a reasonable degree of comfort. Assuming the outside air to be at 30 degrees, and a relative humidity of 70 per cent, each pound of air at this condition contains 17 grains of moisture. When this air is heated, of course, the same amount of moisture is still in the air, but its relative humidity would drop to 15 per cent, because the heated air can hold more moisture than a 30 degree air.

A unit, as shown in Fig. 17, is being used to filter the air and some form of water pan, or drip screen is installed in the bonnet of the furnace.

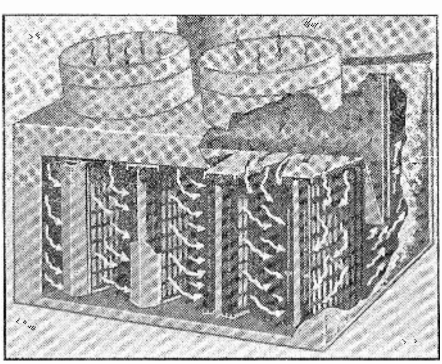


Fig. 17
Flow of air current within the furnace casing.

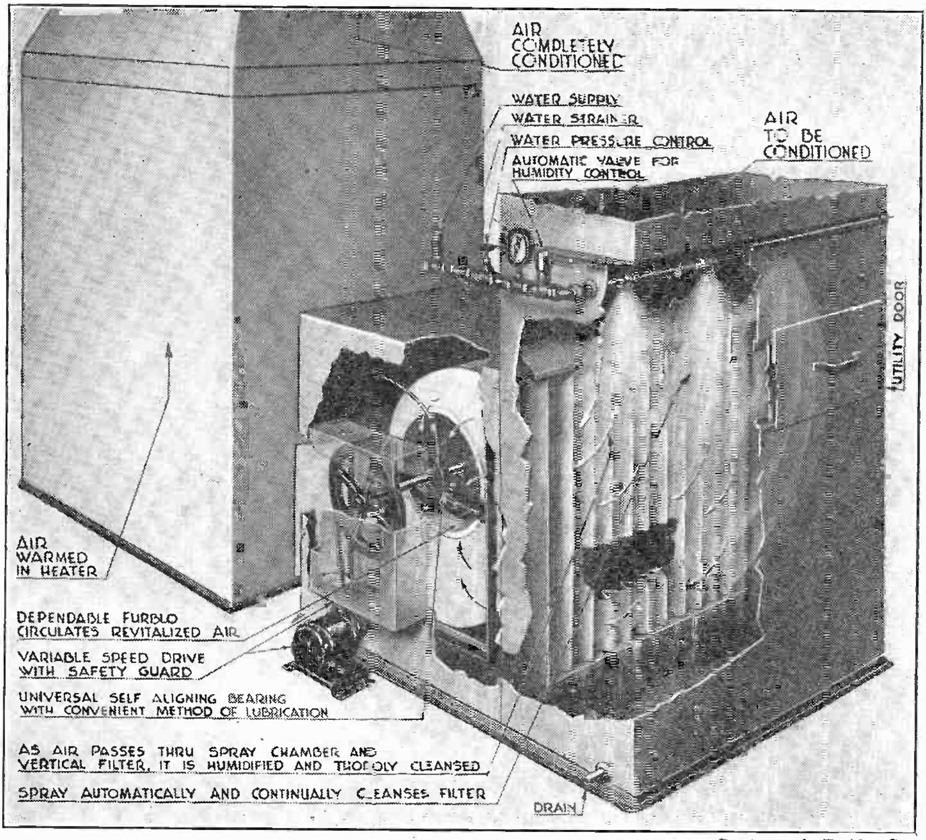
As this type of system does not lend itself to automatic control, it is rapidly giving way to a more complete blower and filter arrangement, as illustrated in Fig. 18.

This type of unit is equipped with water spray nozzle to humidify and partially cleanse the air. The control of humidity is automatic and is accomplished by opening or closing the water valve located in the inlet supply pipe. Baffles, or eliminators, are installed with standard equipment to prevent carrying over water particles in suspension with the air. In insuring adequate humidification, it is usually necessary that the spray water be heated. This is because warm water is more easily vaporized and part of the heat required to evaporate this water will come from the water itself, rather than from out of the air, as is the case when the water is at (or below) the temperature of the air.

As shown in the illustration, the air to be conditioned enters the top and all dust and dry particles are washed out by direct contact with the water. As these particles settle on the eliminator plates, they are washed down to the bottom and find their way to the drain.

This type of unit is equipped with a silent, belt driven, multivane fan, which forces the required amount of air through the system, by means of duct work, as illustrated in Fig. 20.

Any number of outlets may be provided, each equipped with its own automatic temperature regulator, thus making it possible to hold different temperatures throughout the various sections of a building. This plan is commonly known as zone control, and is essential in such cases where the heat loss varies in different parts of a building. Such a condition would



Courtesy of Furblo Co.

Fig. 18. A complete blower and filter system for automatic control.

exist if a cold North wind were blowing on one side of the house, and the sun shining on the other. In other words to accomplish this, it is necessary that each section be provided with a thermostat which opens its corresponding damper, and starts the blower motor and heat generating unit.

The air is delivered to the heating unit in a clean, moist condition, where it is heated to the proper temperature, ranging from 100 to 150 degrees f., depending upon the design and location of the register outlets. The heater itself may be a specially designed warm air furnace

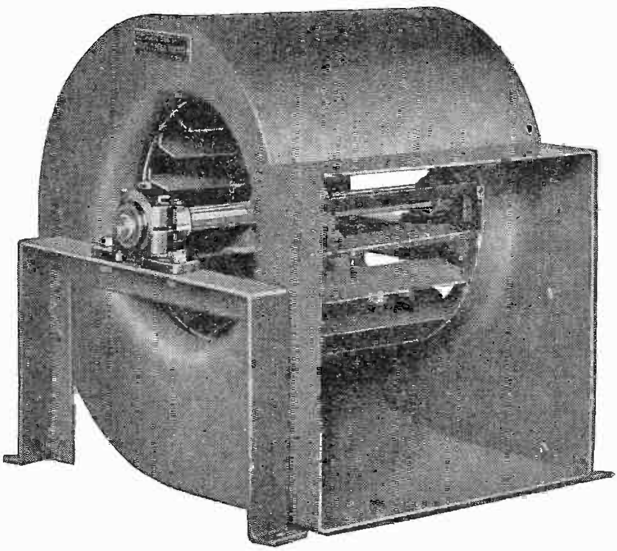
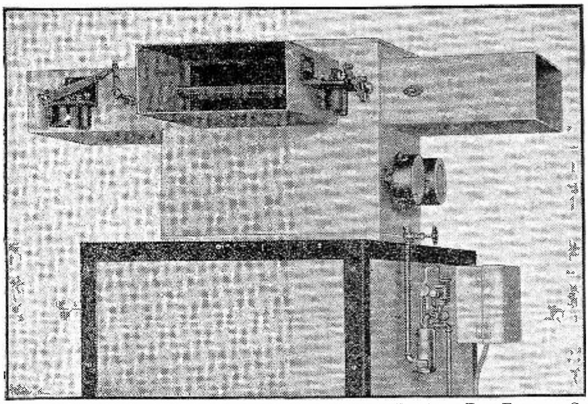


Fig. 19
A multi-vane blower for air circulation.



Courtesy Fox Furnace Co.

Fig. 20
The duct system for distributing conditioned air.

type, using any kind of fuel, or it may be indirect in which steam coils are installed and the air blown over them.

The operation of this system illustrated in Fig. 18 is as follows: When moisture is required in the space being conditioned, an electrical type humidistat automatically opens the water valve, provided the blower is running. A thermostat located near the humidistat starts the blower motor when the room temperature falls below the setting of the thermostat. A second thermal switch is usually placed in the heating element to insure the delivery of warm air, and prevents the blower from operating unless there is heat or steam in the heating element. It naturally follows that if the thermostat calls for heat and the secondary switch is not closed, indicating that there is no heat, the blower motor will not start until heat is furnished to close the secondary switch.

An electric relay is also used to open or close dampers, regulate a gas valve, or turn on an oil burner at the same instant the thermostat calls for heat.

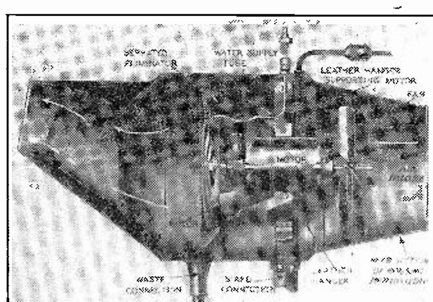
This type of unit has its greatest market in the domestic field, as it is especially designed for this work, and priced within reason.

Figure 21 illustrates a specially designed factory type humidifier, which finds its widest application in the textile mills, and research laboratories. Because of its compactness and high efficiency, any number of units may be used to supply the required amount of moisture.

The humidifier consists of a revolving rotor directly connected to a small electric motor and fan. Water for evaporation is led through a small copper tube to a pin just back of the rotor. In this way the water is sprayed into the revolving rotor, and is thrown by centrifugal force, against the eliminator, which breaks up the drops and spray into a very fine mist. Air is drawn through the rear of the unit by the motor-driven fan and as it is forced forward, carries the fine mist and fog out through the mouth of the humidifier. Any heavy particles of moisture are arrested by the specially designed uneven passage in the forward section, which prevents any solid drops of water being blown out with the moist humidified air.

These small units have the ability to condition spaces ranging from 2,000 to 40,000 cubic feet of volume, depending, of course, upon the amount of moisture required in the air and the prevailing outside conditions.

The control is automatic in that a magnetic valve shuts off the supply water to the head, or turns it on, as the humidity rises or falls. A predetermined percentage of relative humidity may thus be maintained in the room. A feature is that the motor and fan continue to run even after



Courtesy of American Moistening Co.

Fig. 21
Cross section of Amtex Humidifier.

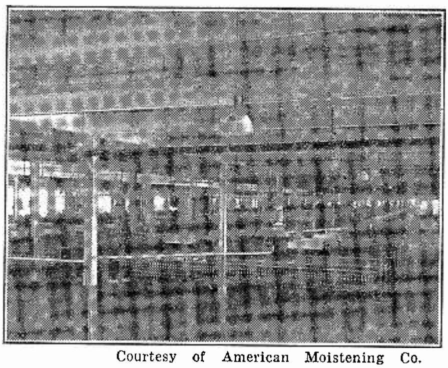
the water supply is shut off, so as to maintain an air circulation in the room at all times.

Figure 22 shows a typical installation of humidifiers in a large textile mill.

Figure 23 illustrates an indirect winter-air conditioner, equipped with blower, motor and water sprays,—also heating surface is installed in the upper section of the unit as shown through which steam or hot water may be circulated to heat the air as it passes through the fin surface.

Moisture may automatically be supplied by opening and closing a water valve in the line of the spray nozzles. Dry-type filters are usually installed in the return duct connection just above the blower motor. This unit may also be equipped with zone control as illustrated in Fig. 18.

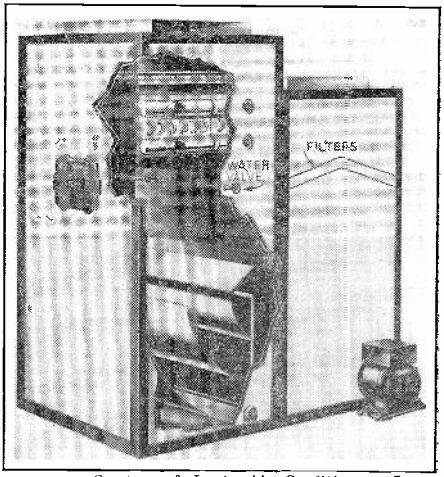
In the above types of systems it is possible to obtain (during the "heating season") air circulation, control of temperature, control of humidity, and filtering. Provision should be made for the introduction of fresh air to the spaces being conditioned. The most practical arrangement is a duct connection from the outside directly to a point near the filter. In doing this an adequate supply of fresh air can be obtained and forced into the rooms being conditioned. This scheme will prevent the infiltration of cold air around the window frames and tend to build up a pressure within the conditioned space. This will eliminate drafts around windows and along the floor which are usually ex-



Courtesy of American Moistening Co.

Fig. 22

A typical humidifying installation in a textile mill twisting room.



Courtesy of Lewis Air Conditioners, Inc.

Fig. 23

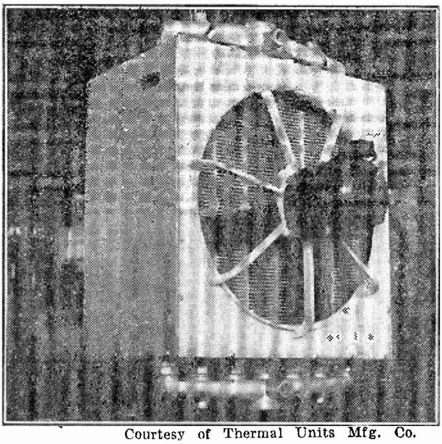
Construction of heat exchanger-humidifier.

perienced on cold days. The small air pressure which is built up in this matter causes air to be forced out of the cracks or openings in the construction of the air conditioned space rather than permitting the natural leakage of air through these crevices into the spaces which are now conditioned.

The following pages describe simple methods of cooling and dehumidifying, particularly for comfort. As explained in a preceding section, it is necessary to add moisture during the heating season to maintain a condition of comfort. However, during the summer we must reverse this principle and take moisture out of the air to allow for normal moisture evaporation from the body. It is also essential to cool the air to enjoy a comfortable temperature.

In summer it is not unusual to have an outside air temperature of 95 degrees, and a 50 per cent relative humidity, which represents a very uncomfortable condition. One pound of air as mentioned above contains 124 grains of moisture, and in cooling this air to 80 degrees and 50 per cent humidity, it is necessary to abstract from the air sensbile heat to lower its temperature to 80 degrees together with 47 grains of moisture per pound, the moisture representing the latent heat of the air.

Figure 24 illustrates a unit con-



Courtesy of Thermal Units Mfg. Co.

Fig. 24
A cooling unit for direct expansion.

structed of copper or aluminum fin surface through which cold water or a refrigerant may be circulated, and by means of electrically operated fans, air is forced over this surface and cooled to a temperature below the saturation or dew point temperature. In doing so, some of the moisture will be condensed out of the air.

This type of unit is obtainable in any number of sizes, and for all types of refrigerants. Control of operation can be made automatic by the use of an electrically operated valve in the cooling medium supply line, whether it be water, brine or refrigerant. Application is limited only by the size of the space to be cooled. It is essential that units of this kind be installed high in the conditioned room, and the discharged air directed in such a manner as to prevent drafts or blow directly upon any person or persons who may be in the room.

Figure 25 illustrates the typical connections that are required to use a cooling unit such as shown in Fig. 24, for direct expansion. The actual distance between the condensing unit and the evaporator surface may be any length although it is advisable to keep them within 50 ft. of each other. The reason for this requirement is to reduce the amount of friction in the pipes caused by the velocity of the refrigerant. The direction of the refrigerant in the suction and liquid lines is indicated by arrows. The control may be automatic by using a plain "room thermostat" to stop or start the condensing unit, as occasion may require. Although the fan in the cooling unit will operate during such periods when no cooling is required.

This diagram illustrates the simplest form of cooling and dehumidification of air. A vapor compression machine is used in conjunction with this unit room cooler and for the most part our study will be on this type of refrigeration.

Figure 26 clearly shows a water cooled, shell-tube, condensing unit and its component parts, all of which

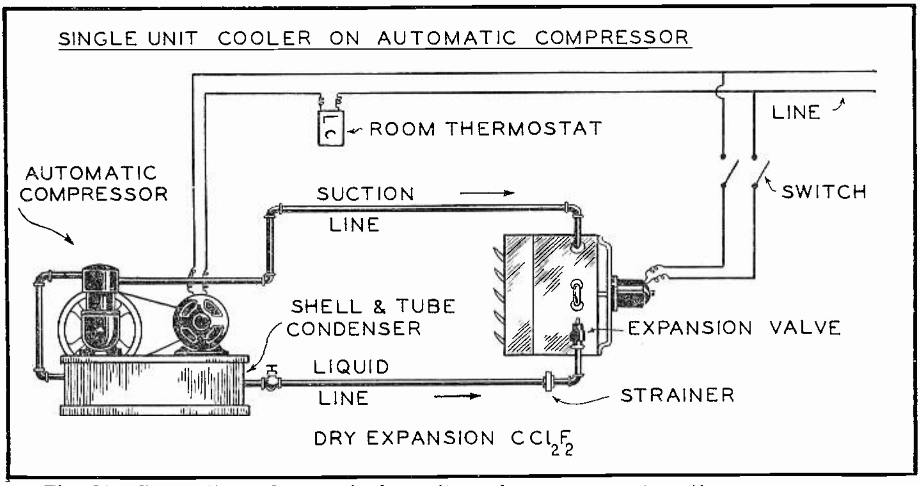


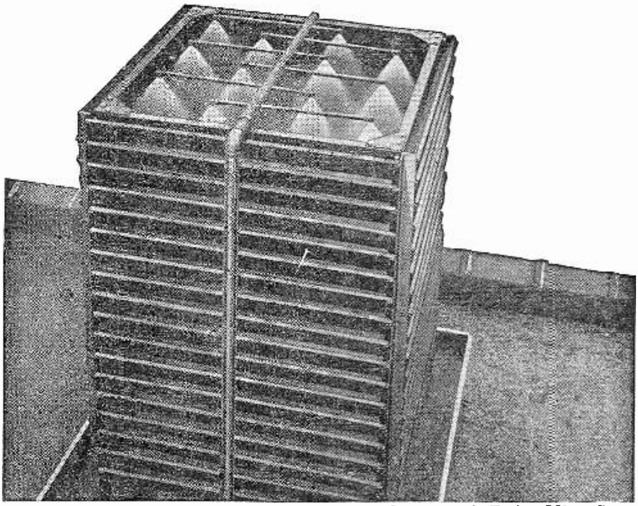
Fig. 25. Connections for a single unit cooler to an automatic compressor.

have been explained in detail in various sections of the book.

In localities where the cost of water is prohibitive to the operation of large condensing units, a water cooling tower is generally used, the type of which is shown in Fig. 27. This particular unit is termed an atmospheric cooling tower and derives its name from the fact that no fans are required to force the air through, or over the water.

As shown in the illustration, the condenser water is sprayed downwards and natural air is circulated through the sides, which are partially open. The spraying of this water in the air cools the water because a part of it evaporates into the air, and the heat for evaporation comes from the water itself. The air that comes in contact with the water becomes saturated and is carried away by the slightest natural air motion.

The sides of these towers are usually made of clear redwood, although in some cities local ordinances prohibit the use of wooden towers. In such cases, the same design may be obtained in metal.

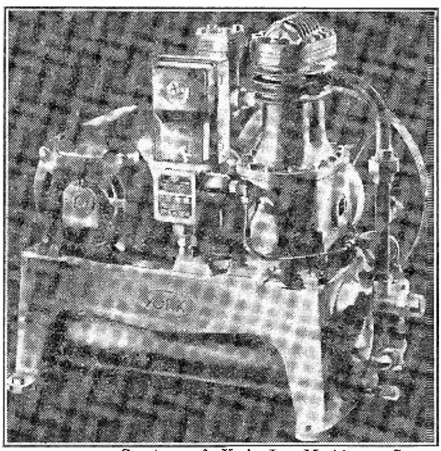


Courtesy of Binks Mfg. Co.

Fig. 27
A water cooling tower for condensing.

Under ordinary operation less than 2 per cent of the water handled is lost by driftage, the balance being returned to the condenser unit to again absorb heat and be resprayed in the tower.

Figure 28 shows a typical circuit of the condensing unit and tower. A by-pass is provided around the con-



Courtesy of York Ice Machinery Corp.

Fig. 26
A water-cooled shell-tube condensing unit.

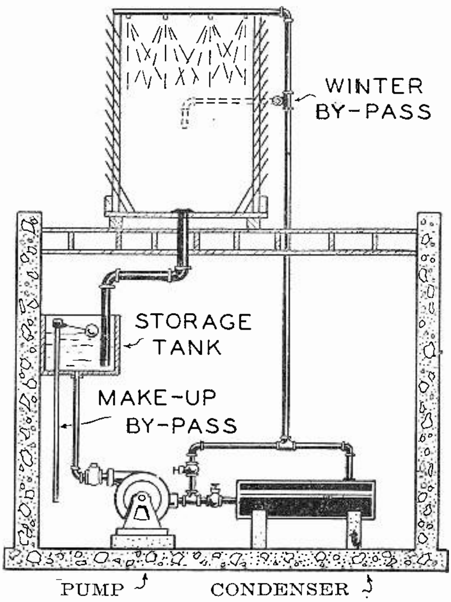
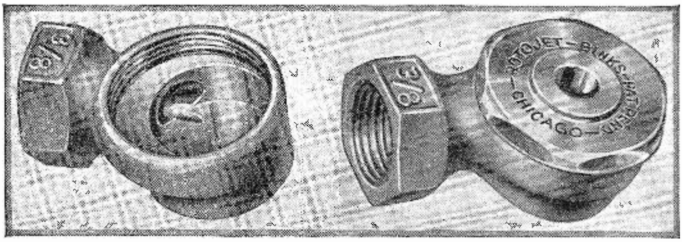


Fig. 28
Circuit of a condensing unit and tower.

denser and is necessary because the water pumped to the tower is usually two times that which could be economically pumped through the condenser. A water circulating pump pumps water through the condenser to the tower. A storage tank is used, as shown on the illustration, only in such cases where cooling during freezing weather is desired. On an installation where the machine will not operate during the cold weather, a pan arrangement is installed directly in the bottom of the tower, which may hold as much as 6 ins. of water. A service connection is made to the city water supply line to a ball float arrangement to maintain a constant level. The principle of this is similar to that of a toilet ball and float arrangement, and will automatically make up for such water as is carried away by drift.

The water in the cooling towers is sprayed from nozzles as illustrated in Fig. 29. The construction of these nozzles is such that they do not become clogged either from lime, sediment or other foreign matter, usually encountered in air conditioning systems.

In cases where it is impractical to install a cooling tower on the roof, a device similar in characteristics may be installed in the basement and connected to a blower that draws in outside air, forces it through the tower and exhausts it outside. In this plan the water is cooled by evaporation as with an atmospheric roof tower, and requires only the addition of a fan and motor to accomplish the same results. Figure 30 illustrates the connections between the condensing unit and the forced-draft tower, together with the necessary valve arrangement to provide the use of city water to cool the condensing unit during such times as repairs are being made to any part of the tower.



Courtesy of Binks Mfg. Co.

Fig. 29

The type of spray nozzle used for circulating water in a water cooling tower.

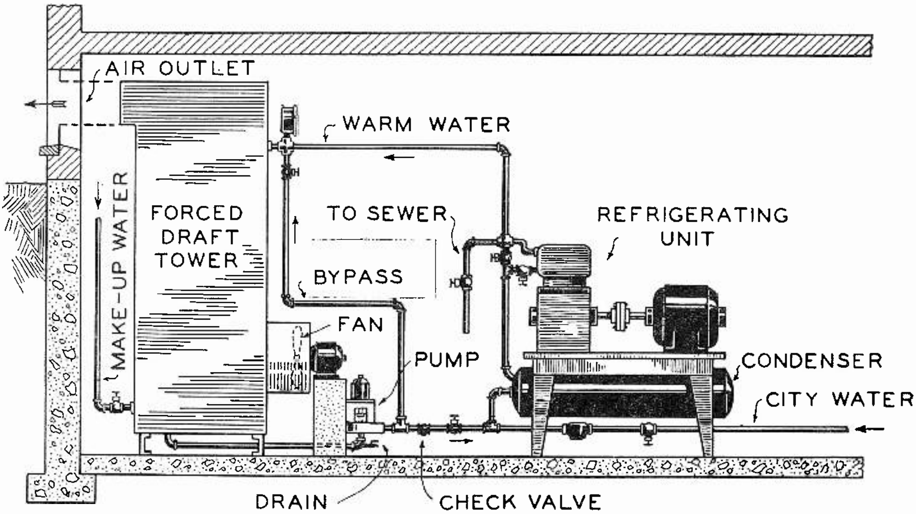


Fig. 30. Connections between the condensing unit and a forced-draft tower, with all valves.

Figure 31 is a cross section of this type of forced draft cooling tower.

As a general rule, it is advisable to allow the fan and pump to continue operation during such periods as the condensing unit is shut down due to the conditioned space being brought to the desired temperature. This scheme will allow the water which lies in the bottom of the tower and that which is in circulation to be cooled slightly below the normal operating temperature.

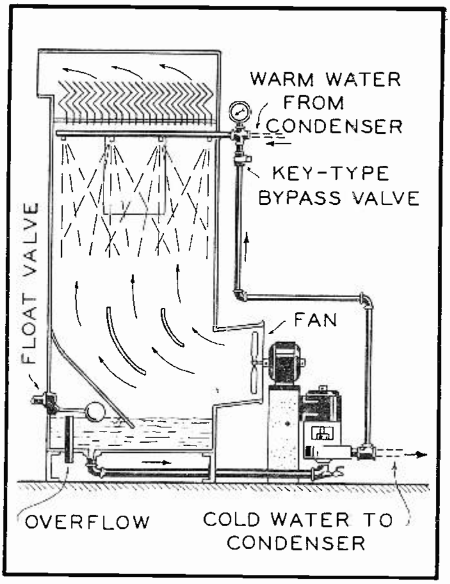
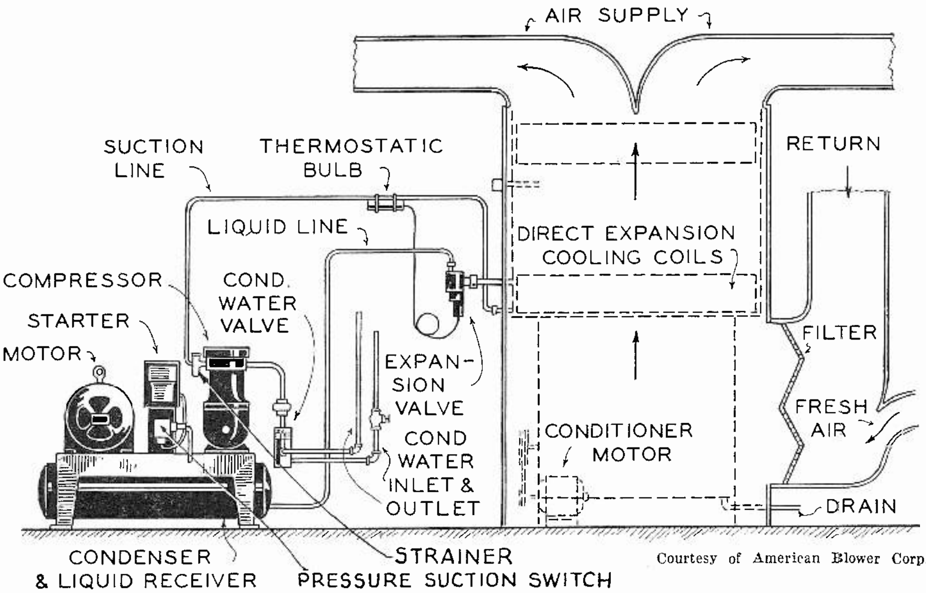


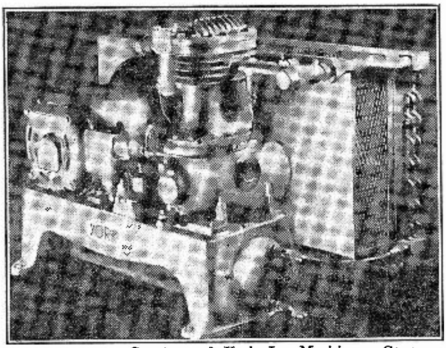
Fig. 31
A cross-section of the unit shown in Fig. 30.

Figure 32 shows a typical arrangement of a central plant for summer conditioning, for which the refrigerant is produced by a water cooled condensing unit, connected to direct expansion cooling coils in the air conditioning compartment, that is generally made up of heavy gauge metal and equipped with low speed multivane blowers, and blower motor, together with a sufficient amount of filter surface to filter the mixed return air and fresh air. As the air is taken into the conditioner through the fans, it is forced over the cooling coil where dehumidification and cooling is obtained and the air when exhausted out of the top to a duct distribution system, which conveys the conditioned air to any number of rooms or spaces where it is required. A thermostat placed in the space being conditioned will stop or start the condensing unit but the fan will continue to operate to insure an adequate supply of fresh air, which is usually brought in at the rate of ⅓



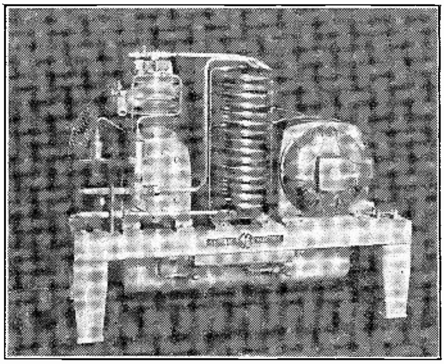
Courtesy of American Blower Corp.

Fig. 32. A typical central plant for summer air conditioning.



Courtesy of York Ice Machinery Corp.

Fig. 33
An air cooled condensing unit.



Courtesy of General Elec. Co.

Fig. 34
A counter-flow water cooled condenser.

of the total air distributed by the system. The indicating arrows show the direction of flow of air to the conditioner, and also the direction of water in and out of the condensing unit as well as the flow of refrigerant to and from the coil surface.

While the accompanying illustration, Fig. 32, shows a water cooled conditioning unit, it must not be construed that only a water cooled unit will work on such a system. It is also practical to use an air cooled condensing unit such as illustrated in Fig. 33 or a counter flow double tube water cooled condenser unit as shown in Fig. 34 can be used. Although the air cooled units can be obtained in the larger sizes, they are more readily adapted to systems requiring in the neighborhood of 2 horsepower. The extended-fin type surface and U turns is the condenser, through which the hot refrigerant is circulated and the heat absorbed from it by room air, which is circulated over the surface by means of a fan directly connected to the driving motor shaft.

The principle types of filters used in air conditioning systems are as follows:

1. Dry type, pre-oxydized steel-wool enclosed in a steel frame. These filters may be cleaned when necessary by removing them from the conditioner and spraying water through them or using a vacuum cleaner.

2. Spun glass wool which is furnished in a light weight cardboard frame and partially saturated with an adhesive solid. This type of filter must be discarded when it becomes filled with dirt and dust.

3. There is also the oil dipped steel, or copper wool enclosed in a metal frame which may be cleaned by application of steam or a caustic water and re-used.

These, of course, are not all types of filters which are on the market but these three types represent the majority of kinds which are popular in air conditioning installations. The exact effectiveness of each type of filter is covered entirely by the application

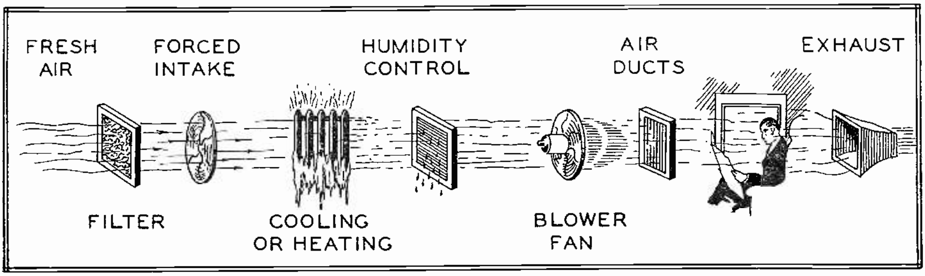


Fig. 35. The functions of an air conditioner shown in sections.

to which it is put, and it is recommended by all manufacturers that the air velocity through filters shall not exceed 300 F.P.M., or feet per minute.

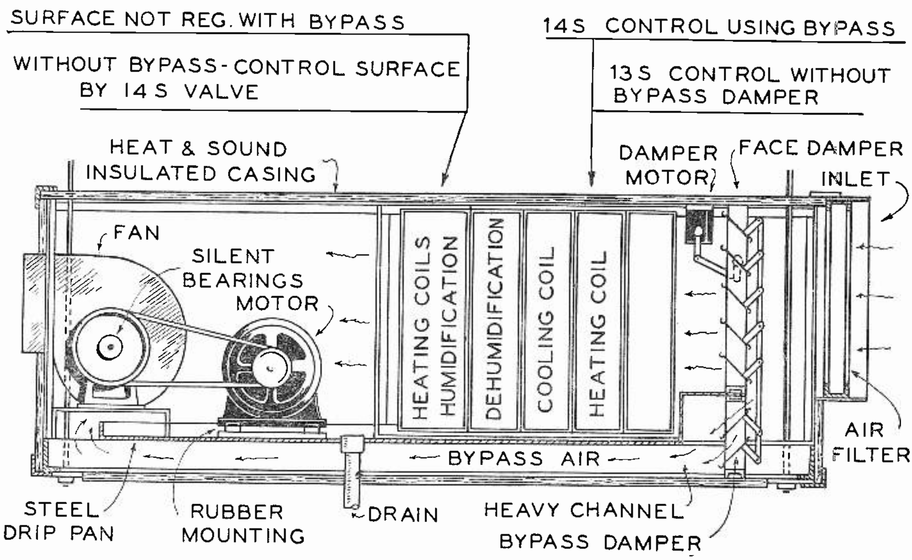
Up to the present time we have discussed in detail methods of winter air conditioning and simplified methods of summer conditioning. In this section, the study of a complete winter and summer system will be taken up.

It is evident that in most sections of the country it is just as important to have the complete combination of winter and summer air conditioning as to have either part alone. However, it is worth mentioning here that the term air conditioning to most people represents simply a cooling system. With a little study it is definitely proven that ALL functions are necessary to have the maximum of efficiency and comfort. To accomplish this result, such a unit as illustrated in Fig. 36 can be installed.

This type of unit may be located directly in the space being conditioned, or in an adjoining room or basement. It takes fresh air from outdoors together with recirculated air from the conditioned space and mixes them in a sheet metal duct connections at the filter end of the unit. As the air enters the unit it passes through filters and is drawn through a set of automatic dampers which are controlled by a room thermostat during the cooling period. During the heating season they are controlled by a room thermostat together with a pilot thermostat (see Fig. 36—13-S) located in the duct distribution system, to prevent the discharge of air at an uncomfortably low temperature.

Electrically the damper motor and the steam supply valve (see Fig. 36—14-S) are arranged in parallel to open or close simultaneously on call for heat by either the pilot thermostat or the room thermostat, so that while neither the thermostat or the pilot thermostat in the duct system is calling for heat, the face dampers will be closed and the air bypassed through the bypass damper section. The exact angle or the degree to which the face dampers are closed may be adjusted to give an economic balance and overcome the intermittent opening and closing of both the dampers and the steam supply valve.

(This scheme may be adopted by anyone for heating, but it cannot be used to bypass air around a cooling coil unless permission is obtained



Courtesy of American Blower Corp.

Fig. 36. A small air conditioner which can be made to suit varying conditions, as explained.

from the owner of the patent rights for such a system.)

After the air passes through the dampers, it is directed across extended heating-coil surface through the dehumidifier and cooling coils, which would be valved off during the winter time. Then the air enters the section indicated by heating coil or humidifying device, where moisture will be added to the air by any of the approved methods explained elsewhere in this book. The air now enters the fan and motor section, where it is taken in from both sides of a double inlet, double width blower and discharged to the outlet and duct distribution system.

Figure 36 shows this in a small installation, but the same principles apply regardless of the size of the area to be conditioned. It will work just as efficiently in large or small installations.

For summer, the fresh and recirculated air is again mixed just outside the unit, and taken through the filters and damper arrangement, where some of the air may be directed into the bypass air channel and the balance taken directly through the cooling surface where it is cooled and dehumidified. Both operations take place on the same coil surface. As both the bypassed air and the cooled air must mix at the blower, it can be seen that in the event that the cooled air is at a temperature too low to be delivered into the conditioned spaces its temperature can be raised by regulating the amount bypassed or mixed. The final mixed air is taken through the blower and discharged to the duct distribution system.

Another of the advantages of the bypass damper is that when the room thermostat is satisfied and the room is cool enough, instead of having the condensing unit or supply of refrigerant closed off, this would remain open or in operation and the face damper would partly close while the bypass damper would be open. Further, a small amount of air will thus continue to pass through the coil surface and be cooled and dehumidified. As only a small portion is passing through the surface, it will be easily reheated when mixed with the bypassed air. But due to the low velocity across the cooling surface as compared to the velocity when the total air supply is directed over the surface, extreme dehumidification will result and control of the relative humidity may be accomplished during the cooling season. As shown in the diagram, a drain connection is provided to carry away the water which is condensed out of the air during the cooling season, or to take away water that is not evaporated during the process of humidifying during the heating season. After careful study, it will be evident that the pilot thermostat will be an electric arrangement rather than the Fig. 36—13-S type.

Where an air conditioning system is installed and a unit similar to Fig. 36 is used without the bypass dampers, the sequence will be as follows: Fresh air and recirculated air are mixed in a duct connection and drawn through the filter surface where, as in the other scheme, from 90-95 per cent of the dust is removed. The total air supply will pass through the first heating coil, ordinarily termed a preheater, so that during the heating season the mixed air will be heated and controlled by a valve as explained in Fig. 36—13-S. The air then passes through the cooling coils which are closed off and then goes through the main heater which is controlled by a valve similar to Fig. 36—14-S. Immediately after leaving this heating surface, the air is brought in contact with warm water furnished either with spray nozzles or drip screens. Of course in the case of the spray nozzles, eliminator plates must be used in the space between the motor and the spray nozzles, while drip screens do not require these eliminators, as little or no water is carried over with the air. We now have warm, moist, clean air, ready for duct distribution at the fan outlet.

During the cooling season, the air passage is the same as during the heating season up to the first heater coil. This does not have steam in it as the steam supply is shut off. As the air passes through the dehumidifying and cooling coil, its temperature is lowered below the dew point temperature for the air at that condition and moisture is condensed out of the air and finds its way to the drain. Then the cooled air is drawn through the main heating coil which is also turned off and the humidification section which of course is not in operation. At this point, the air enters the motor and blower section and is discharged to the duct system or directly to the room being conditioned in case the unit is installed in the conditioned area.

In ordinary comfort cooling systems where the ratio of latent heat to total heat is one-third, sufficient dehumidification can be obtained by the use of a refrigerant whose temperature ranges between 30 and 40 degrees. As the air leaving the cooling surface may be 60 or 65 degrees, it can be delivered to the room at this temperature. However, without the use of a bypass, and where the ratio of latent and total heat is greater than one third, it may be necessary to cool the air to a temperature of 50 degrees and then use the heating coil to heat the air from 50 degrees to a possible 65 degrees so that it may be delivered to the conditioned space at a temperature which will not create discomfort and drafts.

Illustration Fig. 37 is an elevation drawing of either a complete year-round air conditioning system or simply a humidifying or dehumidifying scheme, depending entirely on the temperature of the spray water that is delivered to the unit. While this system has been in use for many years, particularly in theatres, its application is usually confined to the larger buildings when performing all the functions of a year-round air conditioning system. From the illustration, it can be seen that fresh air and recirculated air are mixed, and drawn through tempering coils and dry type filters then through the diffuser plates that are installed to evenly distribute the air through the spray chamber, where it is in direct contact with the water, which may be well water, recirculated water, or precooled water. It is evident then that if the temperature of the spray water is below the dew point temperature of the entering air, the air will be cooled and dehumidified in exactly the same manner as when it passes over a cold evaporator surface. The cool, dehumidified air is then drawn through the eliminators that serve to arrest any solid particles of water that might be carried in the air by mechanical suspension.

From this point, the air travels through the reheater surface and fan

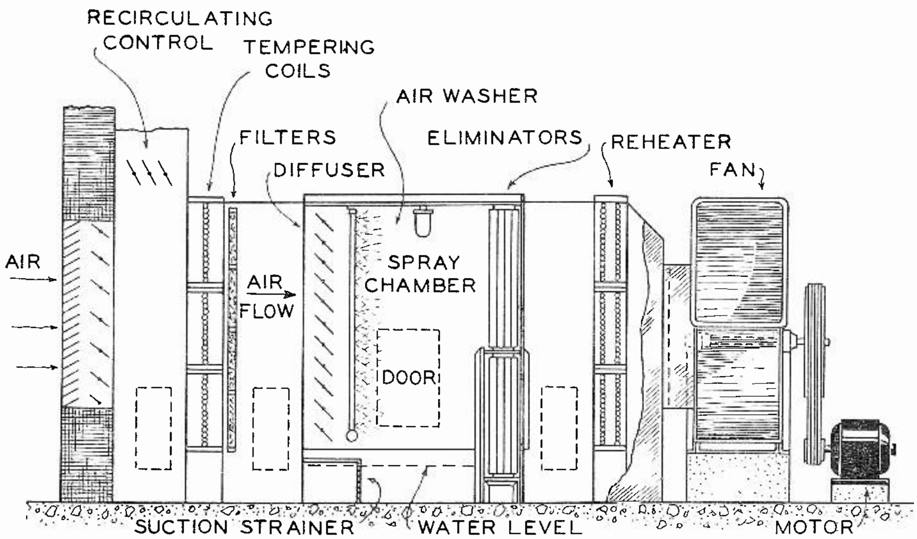


Fig. 37. An elevation drawing of a device which may be used as a complete year-round conditioner or as a humidity control.

to be discharged into the duct system, going back over the same course for winter operation, where humidification is desired, the tempering coils are used to raise the temperature of the incoming air to 45 degrees. This air, passing through the spray chamber, with water at a temperature of 70 degrees or higher, becomes *saturated* at a temperature of 45 degrees. In this plan, the heat for evaporation comes from the water itself. The air is then directed through the eliminator plates, and the reheater surface, where it is usually heated to 70 degrees, and delivered to the conditioned rooms. When 45 degree saturated air is heated to 70 degrees without adding or subtracting *additional* moisture, it will have a relative humidity of 40 per cent.

In the case of recirculating water, that is by maintaining a definite level as shown by the water line, and making up for only such water as is vaporized into the air, a water pump is used to force the spray water through the nozzles, pick up that which is not vaporized and recirculate it. This method is commonly known as cooling by evaporation and may be used quite successfully in sections of the country where the wet bulb temperature and relative humidity is low, so that the heat required for evaporation is abstracted from the air, and its temperature lowered, but at a sacrifice of increasing the wet bulb temperature and relative humidity in the conditioned spaces and delivery air.

Under some conditions this type of system is very satisfactory. But where the outdoor relative humidity is high, this scheme has an adverse effect by further raising the relative humidity and causing a feeling of oppressiveness, thereby defeating the purpose for which it was installed.

Another possible combination adaptable to this type of sytem is to place in the spray chamber and water tank blocks of ice over which *water* is sprayed, thereby cooling and dehumidifying the air passing through the chamber.

From the above descriptions it can be seen that this system offers at least a dozen combinations to treat air for any conceivable condition.

It will be noted in the illustration that dry-type filters are used before the air enters the washer. This is because it has been definitely proven that an air washer removes only 50 per cent of the carbon particles present in the air. However, the air washer will remove soluble odors and gases, which of course easily pass through the filter, so that each has its individual purpose in the system, and where a choice must be made the selection will be governed by the kind or type of impurities in the air.

CHAPTER 5

Service and Control Applied to Air Conditioning Systems

IN AIR conditioning and refrigerating systems, the service and control are as important as the original design. It is essential that the service man know all the functions and operations of the various controls and, in this way, it will be possible for him to quickly analyze trouble without having had any previous experience on the particular control involved. On the following pages are pictured illustrations of well known control units together with service *"hints,"* which will be helpful to the service man who wishes to familiarize himself with the ever increasing popular vapor compression system. The expansion valve is used on practically all types of air conditioning systems and may cause trouble in the entire system if not properly installed or adjusted.

The valve itself does not need to be installed directly in the conditioning unit or refrigerated space but the bulb must be inside and the valve installed as near as possible to eliminate frosting of the line between valve and evaporator, and to prevent building up of false pressures after the valve. The valve will be more sensitive if installed close to the evaporator. In the case of a system operating for some time with a lack of refrigerant it has been found that the valve seat will cut and score because of the high velocity gas passing through the valve seat instead of liquid. This, of course, can be remedied only by adding more refrigerant and replacing the valve seat.

Figure 38 illustrates the proper location of a thermostatic expansion valve as used on a dry-type of evaporator. It is important that a good contact be made between the bulb and pipe to insure the sensitiveness of this valve. If the bulb is installed as shown by the dotted lines in the illustration it would remain cold during the shut-down period and when the compressor starts up it must first pump the accumulated refrigerant out of the pocket before the bulb will warm up and because of this the bulb operation would be sluggish and erratic. On the majority of valves there is only one adjustment which varies the compression of the balancing spring and after the system has been in operation for one hour it may be adjusted to permit more refrigerant to go through if the suction refrigerant temperature is too high. In case the suction line frosts, it will be necessary to reduce the amount of refrigerant entering the evaporator. The importance of keeping dirt out of the valve cannot be over- emphasized and it is essential that a strainer be installed as close to the valve as possible to prevent pipe scale and foreign material from entering the valve. When putting a new job into operation it is advisable to blow out any foreign matter by bypassing the expansion valve or leaving an open connection. The service man must be sure that there is no water in the system as it would freeze at the expansion valve so it is

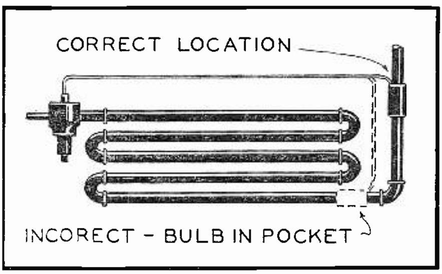


Fig. 38

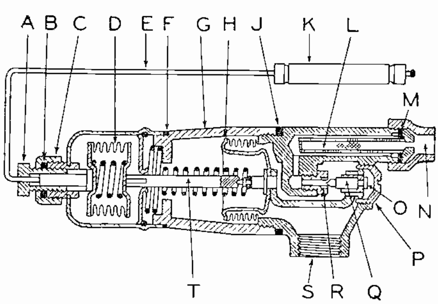
Correct and incorrect positions for a thermostatic expansion valve used on a dry-type evaporator.

advisable to use a dryer installed in the liquid line not as a permanent connection but only during the testing and adjusting period.

If the valve fails to open and remains closed at all times, it has lost its charge and this may be caused by a broken diaphragm, a split in the connecting tube or bulb or a badly welded joint in the bulb. It will be necessary to replace the valve assembly.

If a valve fails to close and refrigerant can be heard going through it during the shut-down period it is evident that the seat has been damaged and a replacement will be necessary.

Lack of refrigerant in the system will be indicated by warm liquid lines, warm evaporator, low suction pressures, low head pressures and a *decided* hissing of the expansion valve; the hissing noise will be the first evidence of low refrigeration.



A ADJUSTING SCREW
B MOISTURE-TIGHT PACKING AROUND ADJUSTING SCREW
C PACKING NUT
D THERMOSTATIC POWER
E FLEXIBLE CAPILLARY TUBE
F MOISTURE-TIGHT JOINT
G BAKELITE EXTENSION
H BELLOWS SEAL
J MOISTURE-TIGHT JOINT
K THERMOSTATIC BULB
L STRAINER SCREEN
M COPPER GASKET
N INLET CONNECTION FOR 1/4" COPPER TUBE
O NEEDLE SWIVEL
P SOLDER-SEALED PLUG
Q STEEL NEEDLE (STAINLESS)
R STAINLESS STEEL SEAT
S OUTLET CONNECTION
T BAKELITE PUSH-ROD

Fig. 39
The cross section detail of a typical expansion valve for thermostatic control. The action can be easily understood.

Figure 39 clearly illustrates a cross section of a typical expansion valve.

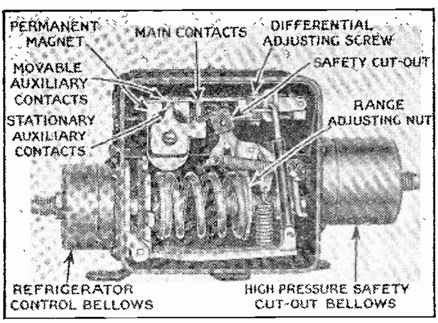
An oversupply of refrigerant will be indicated by a high head pressure, due to the liquid refrigerant collecting in the condenser decreasing the volume and effectiveness of the condenser tubes. The first symptom will be short cycling of the condensing motor which will cut out on high head pressure.

Figure 40 illustrates a back pressure control which is standard equipment and necessary on nearly all types of condensing units. The operation is such that if the suction pressure at the condensing unit is too low it will automatically interrupt the electrical circuit to the compressor motor causing it to stop. Under conditions of a light load at the evaporator, it is necessary to stop the condenser motor otherwise, a very low suction temperature would be obtained resulting in frost at the evaporator surface and restricting the air flow over the evaporator. Ordinarily a small copper tube connection is made between this control and the compressor crank case which is open to the suction line. In the same illustration there is shown a high pressure safety cutout which is connected to the head of the compressor by copper tubing, and in event that the head pressure becomes too high, pressure is exerted on the bellows which in turn trip the main contacts and stop the compressor motor. These controls are always equipped with a differential adjustment so that the unit may operate over a range of pressure to provide a normal running range.

In the case of a unit stopping and starting too frequently, the range adjustment should be set to give a greater differential between the "on" and "off" period. Most of these controls have a minimum differential of 3 lbs. and a maximum differential of 25 lbs. and, for the standard air conditioning system a 20 lb. difference is usually sufficient to compensate for the varying loads. This applies only to the suction pressure. The high pressure cutout does not need adjustment beyond the point that it will stop the unit at a predetermined high pressure and allow it to restart at approximately 30 lbs. below the high pressure.

If trouble is experienced in either the contact spring or adjustment the remedy will be obvious and repairs can be made but, if either the low pressure bellows or high pressure bellows are ruptured or leak it will be necessary to replace with new ones.

Figure 41 illustrates a standard service connection valve. These valves when used on the suction line are attached directly to the crank case of the compressor and, from the diagram, it will be noted that by bringing the valve stem back or out we close the opening port to the service plug connection which is usually ⅛ in. pipe thread made especially to receive a pressure gauge. When the valve is back seated in this manner, a direct opening will then be made between the refrigerant connection and the compresser crank case. With the valve stem in this position, a gauge can be installed without losing refrigerant — now — by turning the valve stem in a few turns a direct connection will be made between all three points; that is, the refrigerant line, crank case and pressure gauge. Should it ever be desirable to close off the refrigerant connection, it may be done by turning the valve stem in or front seating it as the name applies. During normal operation, the stem should be back seated and the sealing nut made tight to prevent the escape of gas. Never leave the pres-



Courtesy of General Elec. Co.

Fig. 40

A back pressure control which automatically turns off the compressor if the suction pressure at the condenser is too low.

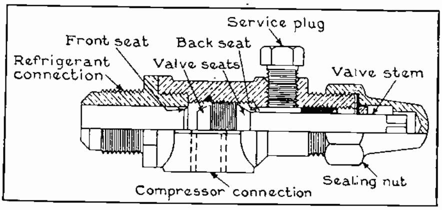


Fig. 41

A service connection valve to permit servicing without losing refrigerant.

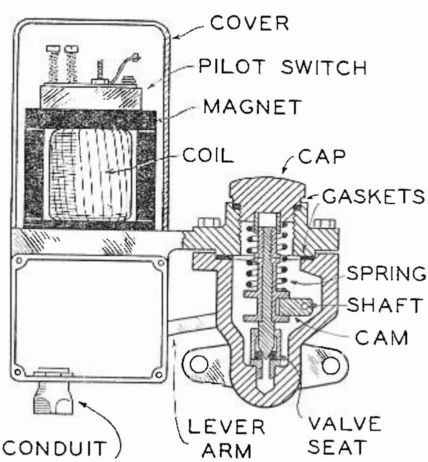
sure gauge on longer than is absolutely necessary.

This same type of valve as described above is used on the head or discharge of the compressor as well as on the low pressure suction side. Rarely if ever will any trouble be experienced with this part of the equipment but, it is well to know the positions in which the valve seat can be placed.

Figure 42 shows the cross section of a magnetic liquid valve more often called a solenoid valve. This valve finds its greatest application where more than 1 such unit as illustrated in Fig. 24 is used and connected to a single condensing unit and it is desired to hold different temperatures in the spaces being cooled by the Fig. 24 unit. Thus, by the application of a thermostat in each room connected to a magnetic valve, we can regulate the flow of refrigerant to each unit by opening and closing the valve as called for by the thermostat. While there are many types of magnetic valves it is essential that they all be installed in a vertical position in a horizontal pipe and the one illustrated is equipped with a pilot switch that can be used to operate some mechanical device, as a condensing unit. The valve illustrated is of the lever type and the solenoid plunger operates the valve indirectly so that when the coil is energized due to action of the thermostat, the plunger is pulled up in the center of the solenoid and makes a firm contact on the pole face of the laminated solenoid frame. As the plunger travels upward it opens the valve and when it reaches the frame, the valve is wide open. As long as current is passing through the coil, the plunger is held in this position in the center of the solenoid and the valve remains open. When the space being conditioned reaches the cooled temperature desired the thermostat acts to de-energize the solenoid and the plunger drops out and closes the valve by its own weight and the assistance of the top spring automatically closing off the supply of refrigerant to the air conditioned unit. Trouble may be experienced with these valves if they are not installed in a vertical position; in case the solenoid coil is burned out; or the seat is damaged, thus permitting the valve to leak.

Ordinarily a line voltage with a variance not greater than 10 per cent above or below the rated voltage will not affect the continued operation. However, a steady over-voltage may eventually cause the coil to burn out. An under voltage for an extended length of time reduces the pull of the magnet; the plunger will not lift up completely, and the coil may burn out.

The valve itself should never be installed where frost is likely to accumulate as this may penetrate the magnet coil and short circuit causing a burned out coil. Moisture may also freeze on the lever arm causing it to bind and prevent the plunger from moving far enough up into the solenoid eventually causing the coil to burn out.



Courtesy of Alco Valve Co.
Fig. 42
A magnetic liquid valve or solenoid valve for individual control of temperature.

In the type of valve where a packing is used, care must be exercised in tightening the gland nut as this additional resistance may prevent the plunger from lifting.

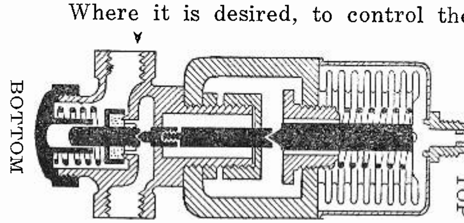
It is not uncommon for these valves to hum whenever the current is on. Generally this is due to the fact that the valve is tilted a little. This hum may be overcome by loosening the valve and selecting a better position —vertically. It is possible to obtain these valves for any type of service or voltage.

Water Regulating Valve

Figure 43 clearly shows the cross section of a water regulating valve such as is used on all water cooled condensing units. Its function is to automatically regulate the supply of water being delivered to the condenser and is actuated by the head pressure of the compressor. For example, when the unit is not running, the heavy spring shown in the bottom section of the valve holds the valve seat closed preventing the waste of water and with the unit running the pressure on the head of the compressor exerts force on the bellows shown in the upper part of the illustration. This pressure compresses the bellows and forces the center pin down and the valve from its seat permitting water to pass through to the condenser. This valve is adjustable over a wide range and should be set to open at pressures recommended by the manufacturer of the condensing unit. Ordinarily these valves do not give rise to any special trouble although it is recommended that a strainer be placed in the line before the valve.

Immersion Thermostat

Where it is desired, to control the



WATER REGULATING VALVE
Fig. 43
A water regulating valve used on all water cooled condenser units to regulate the water supply.

temperature of brine or water an immersion type electric thermostat may be used to complete the circuit by stopping and starting a condensing unit. Figure 44 covers the working parts and its operation is as follows: parts 1, 2 and 3 are filled with an expanding liquid so when the bulb is heated the expanding liquid generates pressure in the system overcoming the tension of the loading spring, 4, and the bellows, 3, expands actuating the switch, 5.

This control may be used within the limits of minus 50 degrees F. to 600 degrees F. although field adjustment is limited to 50 degrees above or below the factory calibration. Adjustments may be made by turning screw 6 to the right for a higher temperature and left for a lower temperature. The adjustment may be locked by the nut 7. The wiring connections are made through opening 8 to terminals 9.

Little or no trouble will be experienced with this control and in the event of failure the cause would be evident upon removing the cover. Typical wiring diagrams are shown in Fig. 45.

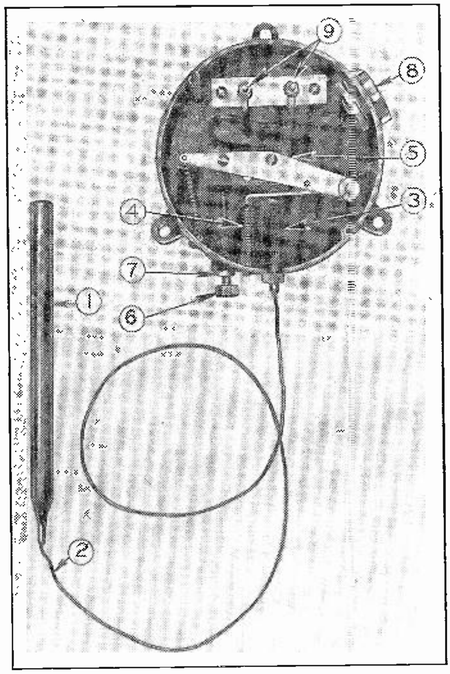


Fig. 44
An immersion-type electric thermostat for controlling the temperatur of water or brine.

Humidistat

Where it is desired to control the amount of moisture in the air of the space being conditioned, it is necessary to have some control device which will be effective by the presence or absence of moisture in the air and in turn make or break an electrical circuit. Such a device is illustrated in Figs. 46 and 47 and is calibrated to operate on a percentage of the

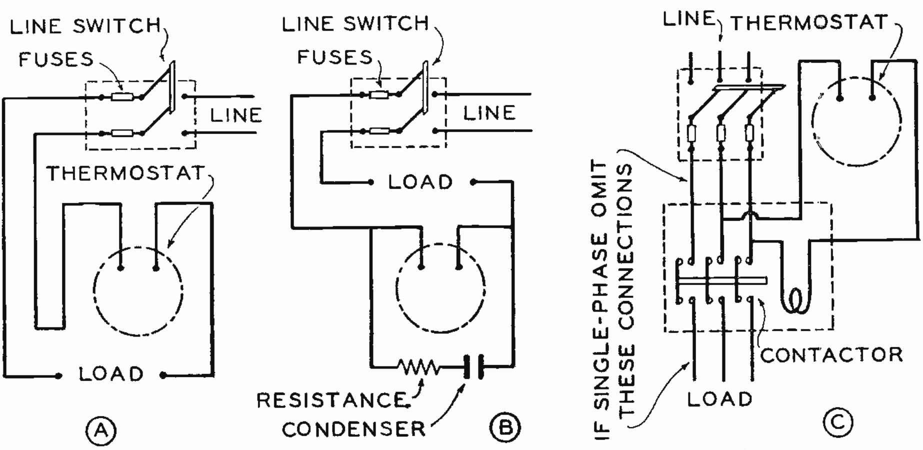
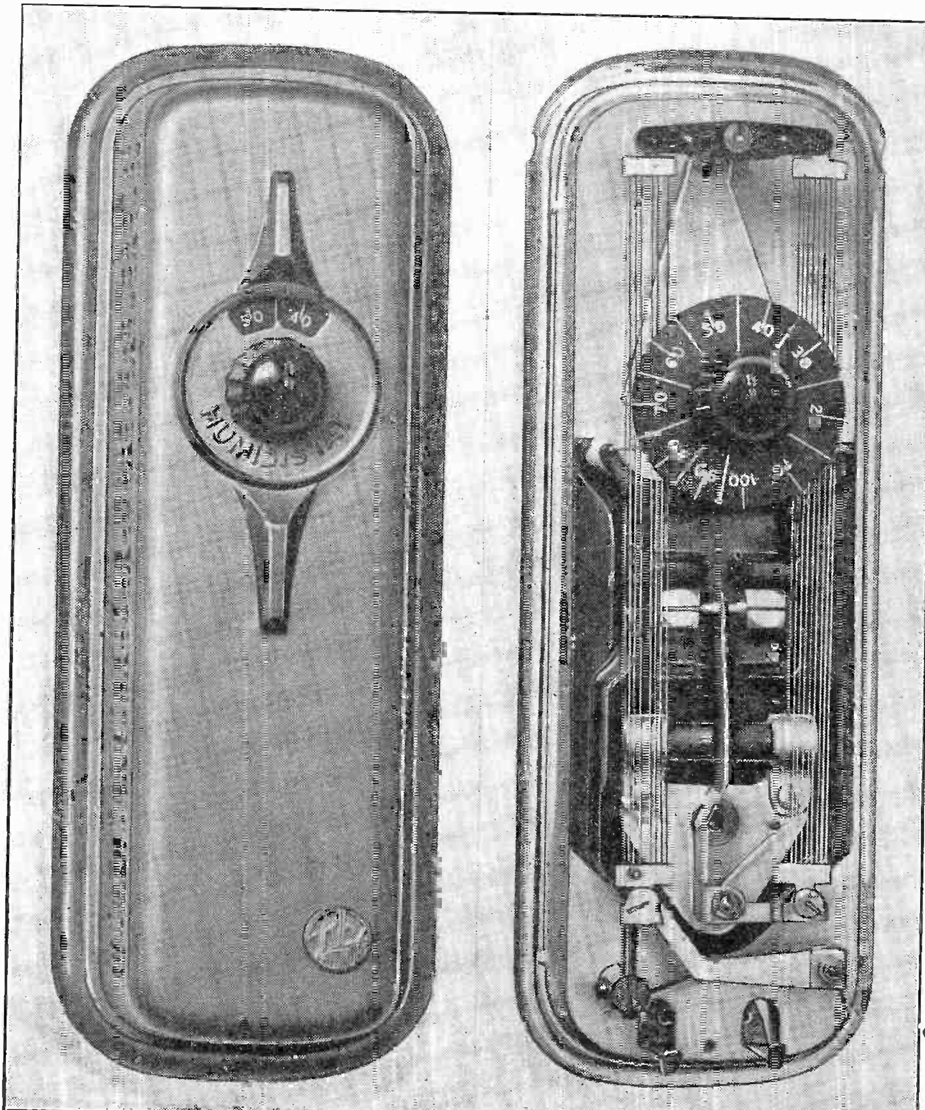


Fig. 45. Three circuits for the immersion thermostat.
A—Shows its use for 110 or 220 volts A.C. single phase.
B—shows its use for 110 volts D.C. load not exceeding 4 amps.
C—shows a single or split phase circuit for heavy loads—A.C. or D.C.

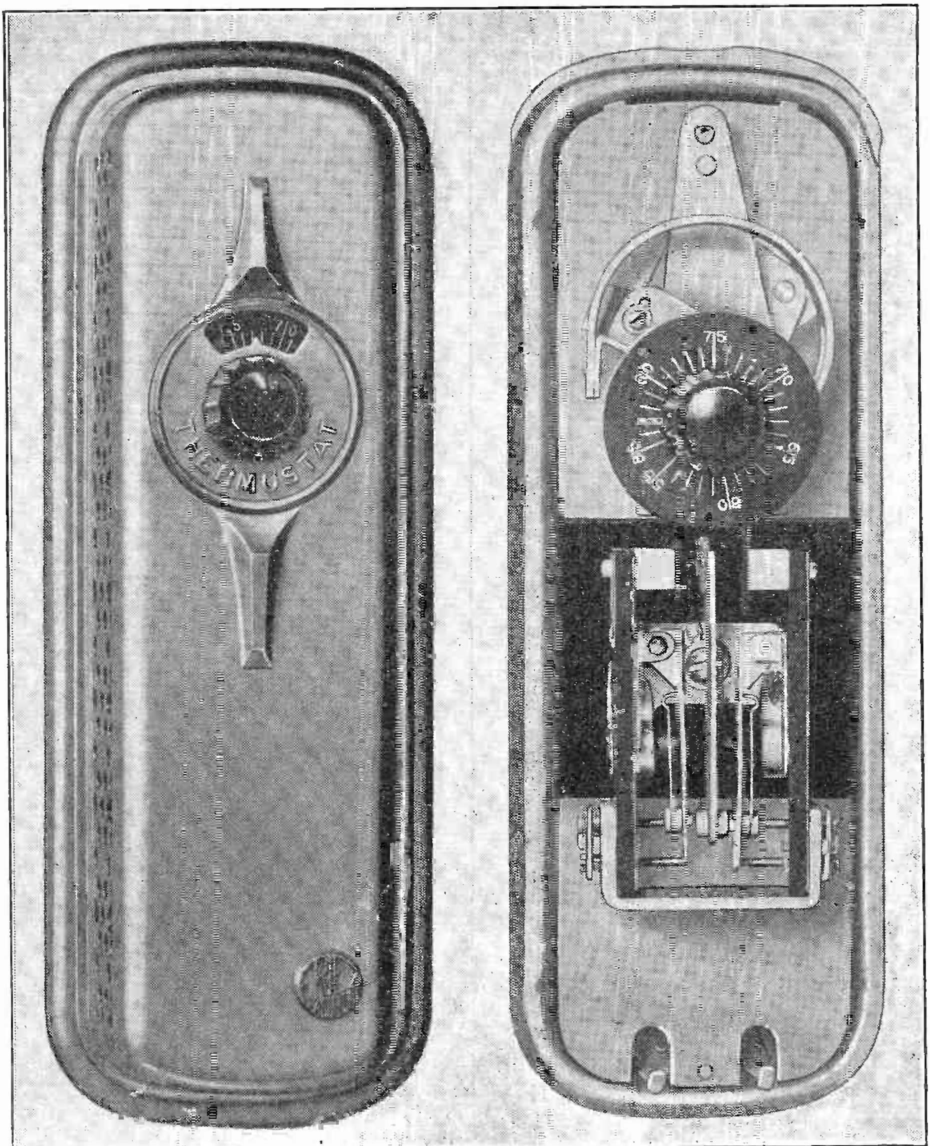
amount of moisture in the air. The indicating dial is graduated from 10 to 100 per cent which is a direct reading of the relative humidity. The humidistat as shown in illustration 46 consists of a set of actuating levers connected to two multiple groups of human hair which expand or contract as the amount of moisture present in the air changes. The action of the hair on the levers make or break an electrical circuit which would open or close a solenoid water valve in the case of a winter air conditioning system, or for a cooling system it may be used to operate dampers, refrigerant valves or stop and start a condensing unit.

The maximum load that may be carried by this control is 110 volts



Courtesy of Friez Instrument Co.

Fig. 46 and 47. A Humidistat inside and out—a device for controlling the moisture in the air.



Courtesy of Friez Instrument Co.

Fig. 48. A conventional thermostat—inside and out—for controlling air temperature.

and 50 watts and with the exception of a small solenoid valve or damper regulator, a relay and transformer will be necessary to operate heavy equipment such as motors, condensing units, etc.

No attempt should be made to check the factory calibration of this instrument until it has operated in the conditioned room for several hours and becomes entirely acclimated to its new condition nor should any check be made unless the humidity has been held constant for several hours with a general air circulation over the control. If, after several hours, of operation it is found that the control needs adjustment it may be accomplished by turning the large slotted screw just inside the enlarged opening in the bottom left hand corner of the cover. Moving this adjustment screw clockwise gives a higher control point and for a lower control point it should be turned counter-clockwise. A sling psychrometer together with a temperature humidity chart should be used in checking the humidistat.

Thermostat

Figure 48 shows a conventional type thermostat with outside cover on and with the cover off exposing the thermostatic element which is affected directly by any change in air temperature. With proper application these thermostats will operate on a one degree differential total and successfully break loads up to 100 watts without recourse to relays and, of course, where heavier loads have to be handled the thermostat would then be used as a pilot switch to operate magnetic starters, etc. The dial graduation is in degrees, f. From the illustration it will be observed that the center metal strip is a continuation of the curved bi-metal strip just over the indicating dial and as this bi-metal strip is made up of two dissimilar expanding metals any change in the air temperature surrounding it causes it to change shape slightly thus moving the center strip either to the right hand lower contact or left hand lower contact automatically completing or breaking an electric circuit, as the condition may require.

Where it is necessary to make adjustments, it must be borne in mind that these instruments are very sensitive so the utmost care must be used. The operation will be affected if the contact points become dirty in which case they can be cleaned with a very thin piece of clean cardboard such as a calling card or, in event that they become pitted due to excess voltage, and amperage, the contacts may then be polished and used while the new set is being ordered.

The accompanying electrical diagrams (Fig. 49, A to H) illustrate the various uses or methods of installing and connecting either the humidistat as described or this thermostat and, it will be noted that they may be obtained to operate either on the high voltage or the ordinary 16 or 25 volt control system.

Automatic Defrosting

It may be necessary where an air conditioning unit is used in connection with a brine circulating system or direct expanded refrigerant whose temperature is below 25 degrees F. to provide some means of automatic defrosting because with this low temperature refrigerant the moisture

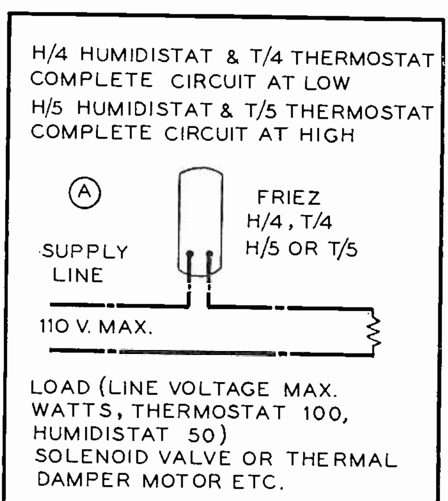


Fig. 49A

Connections for a humidistat or thermostat to 110 volt line.

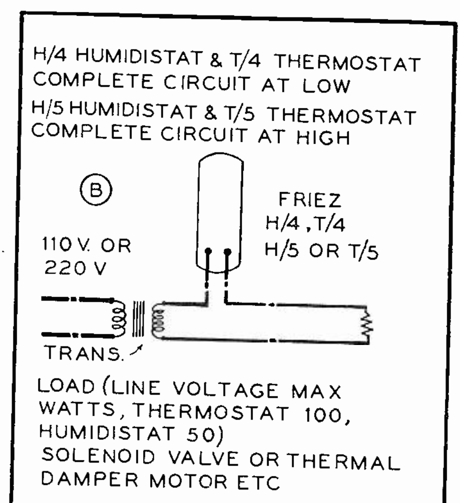


Fig. 49B

Connections for humidistat or thermostat to line at either 110 or 220 volts.

which is condensed out of the air as it passes over the surface freezes to such an extent that the air passage between the fins of the evaporator surface becomes clogged with ice.

In order to overcome this objection, and where it is impossible to raise the refrigerant temperature, a small electric air switch and magnet valve may be installed as shown in

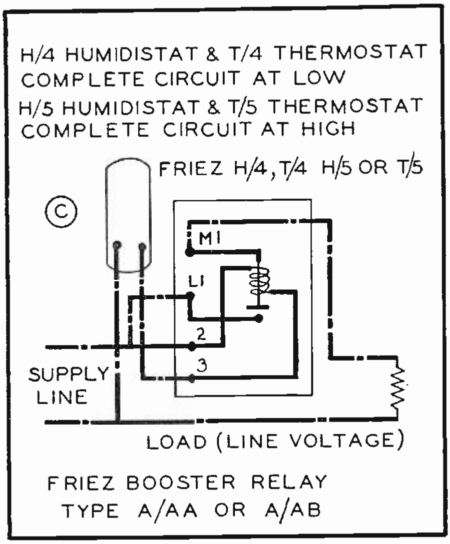


Fig. 49C

Connections for a humidistat or thermostat with a relay for heavy loads.

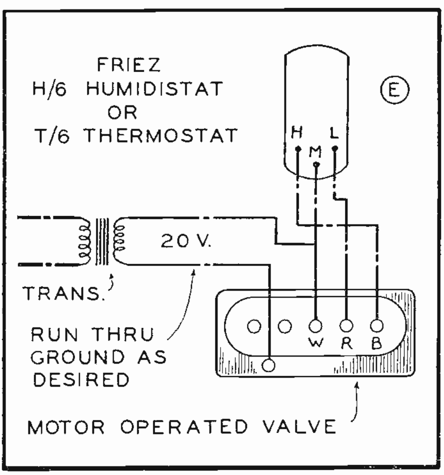


Fig. 49E

Connections for a 1-wire control by humidistat or thermostat by use of a ground connection at 20 volts.

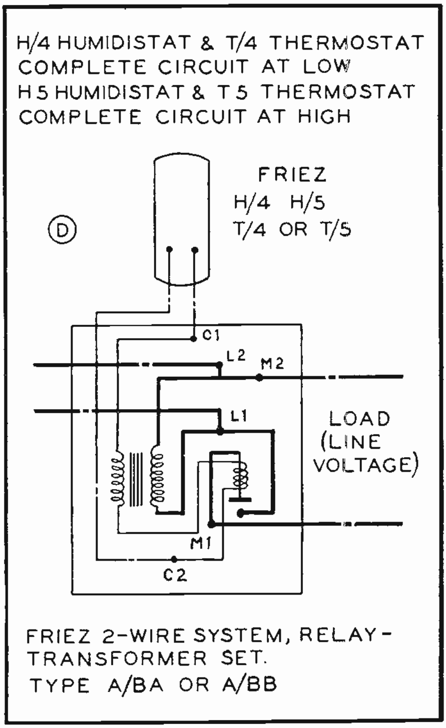


Fig. 49D

Connections for humidistat or thermostat with a relay and transformer.

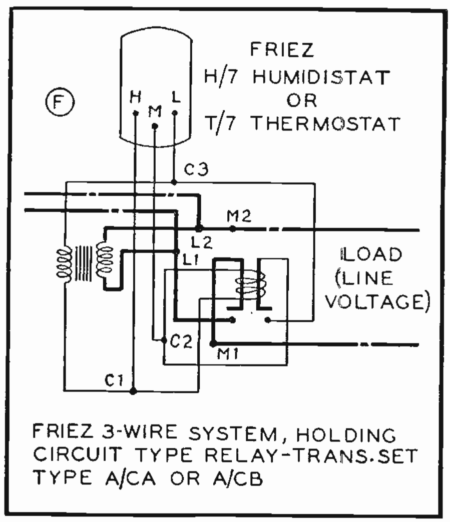


Fig. 49F

Connections for a 3-wire system with holding circuit relay and transformer.

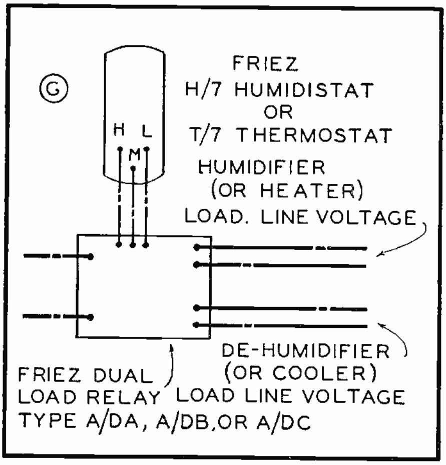


Fig. 49G
Connections for a humidistat or thermostat for heater and cooler control.

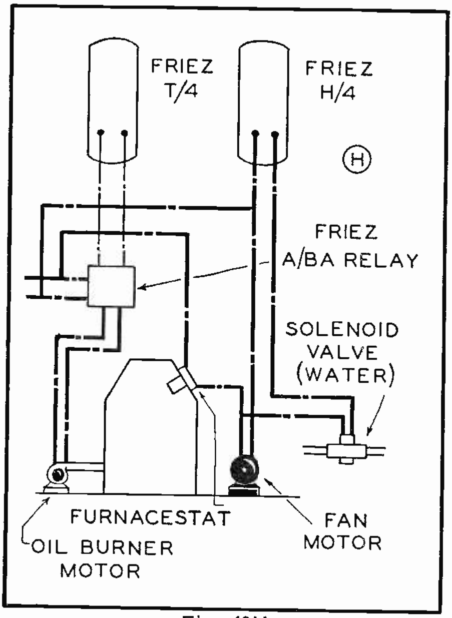


Fig. 49H
Connections for a humidistat and thermostat with a "furnacestat" for complete control.

Fig. 50 mounted inside the cabinet assembly with a vane in the path of delivered air from the unit. This air current holds the switch closed energizing the magnet valve, and keeping the refrigerant line open. As frost collects on the evaporator the amount of air passing through will be reduced because of the restrictions

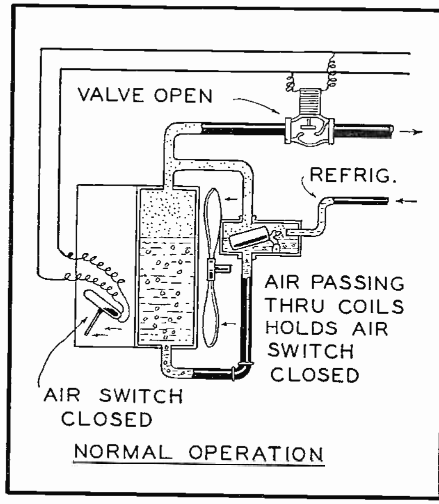


Fig. 50
An air switch and magnet-valve for automatic defrosting.

and the vein of the air switch drops automatically opening the magnet valve preventing further circulation of refrigerant. As the fan remains in constant operation, the ice and frost soon melt, air will pass through the surface, and the cycle begins again. Figure 51 shows this operation during defrosting period. While this device is illustrated on a flooded type unit cooler, it may be adapted to cold storage rooms where the temperature does not go below 33 degrees and also may be used on an ordinary central plant air conditioning system.

The following electric diagrams Fig. 52 show the application of an automatic defrosting air switch.

Where a year around air conditioning system is installed, similar to the unit shown in Fig. 36 of the preceding chapter, some method of controlling the temperature of the delivery air during the heating season must be provided. Where steam or hot water is available, a valve as shown in Fig. 53 is ordinarily used to control the amount of steam or water delivered to the heating surface. The valve mentioned is equipped with a long flexible tube D and thermostatic bulb A. The valve itself is installed in the steam or hot water line and the bulb A and B is installed in the air stream that is being delivered to the room or space being conditioned. Section A of the bulb contains an expansible hydrocarbon oil which, on being heated, generates a pressure that is transmitted through copper tube D to tube G which is the control element where it moves a packless piston to operate the valve K. The corrugated tube B in the thermostatic bulb is controlled by the adjusting screw C and serves solely to vary the temperature at which the regulator valve functions. This is accomplished by changing the adjusting screw C and the relative length of the corrugated tube B. It will be observed that if its length is increased the oil in A has less space for expansion and the valve will be operated at a lower temperature.

The control tube G contains corrugated tubing F which is exposed to the expansive force of the liquid in A. This force is transmitted through D and acts through piston H to move valve stem I and open or close valve as desired. The spring J is opposed to the direction of expansion and tends to keep the valve K open so that when the valve is exposed to temperatures above that for which it was designed to operate, it will be closed.

Ordinarily, this control valve should be set to close the supply of heat when the delivery air temperature is 65 degrees as at this temperature the air can be delivered to the conditioned space without causing the discomforts of drafts in the area being conditioned.

When it is found that this type valve is not operating properly, and cannot be made to do so by turning

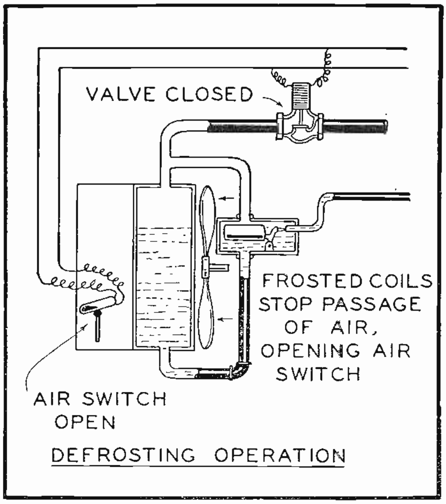
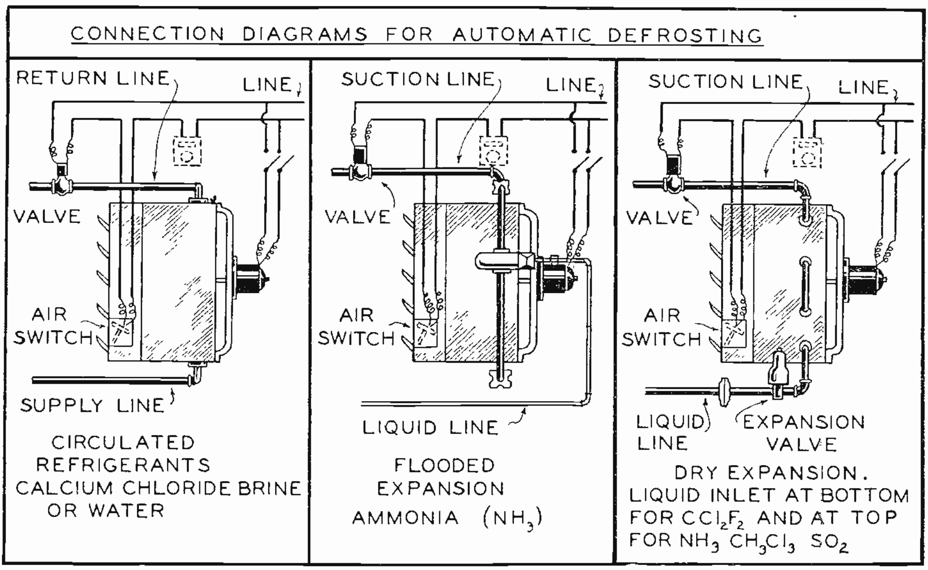
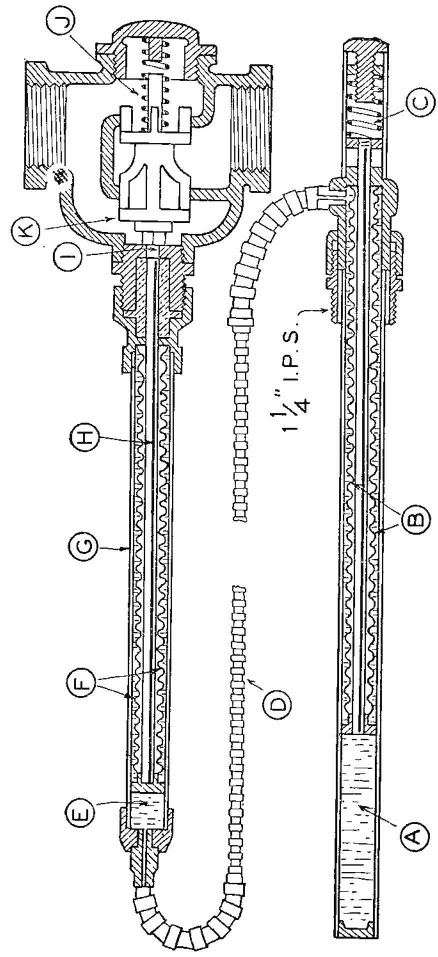


Fig. 51
The action shown in Fig. 50 is illustrated during the defrosting period of the cycle.



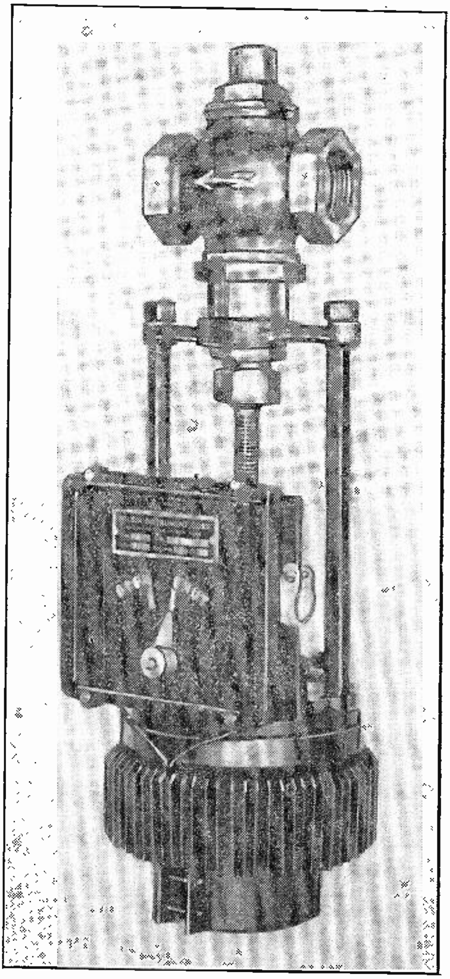
Courtesy of Thermal Units Mfg. Co.

Fig. 52. Connections for automatic defrosting. A—for circulated refrigerant; B—for flooded expansion; and C—for dry expansion systems.



Courtesy of Sarco Co.

Fig. 53
A pilot thermostat used to prevent extremely cold air from being delivered by the air conditioner.

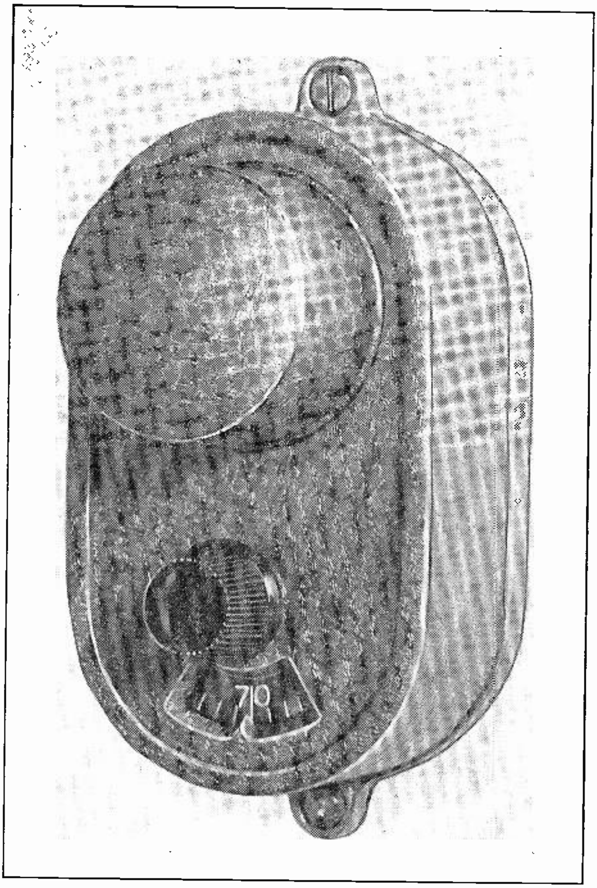


Courtesy of Wilbin Instrument Corp.

Fig. 54
Control valve used with thermostat shown in Fig. 55 for supplying hot water or steam to heater in Fig. 36.

the adjustment screw C, the only remedy is complete replacement. In the above statement, however, it is assumed that there is a definite supply of steam or hot water available at temperatures or pressures for which the control valve was specified. The control described and illustrated in Fig. 53 does not have any connection with the temperature of the room or space being conditioned and is used merely as a pilot thermostat to prevent the discharge of extremely cold air so it will be observed that a room thermostat, additional heating surface and control valve will be necessary to automatically maintain a comfortable temperature in the conditioned space during the cold weather. While there are many such valves available only one will be illustrated and described below. Figures 54 and 55 show the control valve and thermostat that will automatically supply steam or hot water to the heating surface of Fig. 36 in the preceding chapter. The thermostat is installed in the room being conditioned and, as the temperature drops or raises, it opens or closes the valve which is installed in the heat supply line to the heating surface on the fan side of the dehumidifying and cooling coil. The operation of this control device may easily be understood if reference be made to Fig. 56 in which the thermostat is shown as No. 1 which has a chamber two completely filled with liquid. Arranged in this chamber is the flexible bellows 3 having its lowered end closed and the upper end sealed to the top of chamber. Attached to the inside of the bellows is the plunger 4 which actuates the snap switch 5 which is normally closed and opens with a rising temperature. The valve 6 which the thermostat 1 controls is the reverse acting type and is opened by the action of the thermostat and closed by the spring 7. Suspended below valve 6 is the heat motor and chamber 8 to which an electric resistance heater 9 is strapped. A flexible bellows 10 has the lower end closed and the upper end sealed to the top of the pressure chamber 8. The valve operating plunger 11 is fastened to the bottom of the bellows which is held expanded by the spring 12. When current is permitted to pass through, by the operation of the thermostat, the heater 9 vaporizes a portion of the volatile fluid with which chamber 8 is partially filled. This builds up a pressure in chamber 8 which compresses bellows 10 and moves the valve plunger 11 upwards thus opening valve 6. In the control box mounted on the valve motor is a crank mechanism 13 actuated by the travel of the plunger 11. This crank operates two switches arranged in the control box. Switch 14 is connected in series with the thermostat 1 and is normally closed so that when the plunger 11 is at the top of its stroke the crank 13 opens switch 14 and interrupts the flow of current to the heater.

Chamber 8 immediately starts to cool assisted by the radiating fins and plunger 11 begins to travel downwards. Switch 14 closes again so that the valve is held in the wide open position as long as the thermostat switch 5 remains closed. When the temperature surrounding the thermostat 1 reaches a point at which it is set the plunger 4 opens switch 5 and interrupts the current to resistor 9 and the liquid in chamber 8 cools rapidly and the plunger travels downward until valve 6 is closed. A slight further downward movement of the plunger causes crank 13 to close switch 15 and this switch is shunted



Courtesy of Wilbin Instrument Corp.

Fig. 55

This thermostat is used with the valve in Fig. 54 to control the flow of steam to the heating surface of the unit shown in Fig. 36.

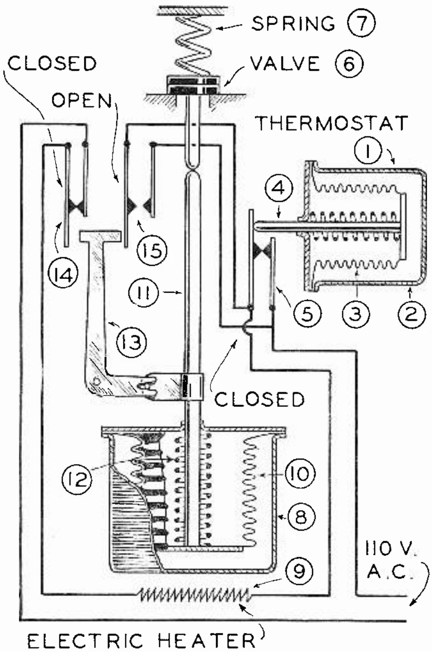


Fig. 56

The connections for the parts of the control described here.

across the thermostat connections and is normally opened. Closing switch 15 puts current momentarily on the heat resistor causing a slight movement back and forth of the valve plunger without actually opening the valves. This keeps pressure in chamber 8 so that it is instantly ready to open the valve when the thermostat calls for more heat. The above cycle is then repeated. This valve may be used on 110 volt A.C. or D.C. and trouble will be experienced if the voltage varies greatly beyond that for which it was designed and plainly marked on the face of the control box. The presence of dirt or dust on contact 5 may interfere with the successful operation and may be cleaned as described elsewhere in this book.

It is advisable to install a strainer in the supply line ahead of this valve. A strainer should also be installed in the line of valve (Fig. 53) to prevent scale or foreign material from accumulating on the valse seat.

Filters

On a call for service on an air conditioning system where filters are used almost invariably the first place to look for trouble is the filters, regardless of the type used as most people believe the place in which they live or work is clean and that filters are something that merely go to make up an air conditioning system they do not bother to check the filters or clean them. While it is true that a system will operate without filters, one of the greatest benefits derived from air conditioning would be sacrificed if they were removed or not kept in proper order.

Starters and Switches

On the larger type air conditioning systems, where motors of 5 H.P. or over are used, there is a general requirement by the local power companies that a reduced voltage starting control be used, so that when the condensing unit starts only about 70 per cent of the normal starting current will be drawn. There will also be a corresponding reduction in r.p.m. of the motor. This is accomplished by the use of a telechron time limit switch built into the automatic starting compensator and, after about 10 seconds of reduced voltage operation, the action of the time switch closes the main line contacts allowing the condenser motor to quickly pick up speed and full load operation. These compensators are equipped with overload heaters that will automatically interrupt the main supply in event of a continual overload and, after cooling off, the sequence can be restarted after pushing the reset button although an inspection should be made to determine the cause of the overload to prevent further interruptions which are most likely to occur at the most inopportune times.

The small magnetic switches as used to start fans etc., are also equipped with overload heater units but do not have the timing mechanism or the reduced starting voltage feature.

The proper size overload heater coil is ordinarily indicated on a chart inside the cover of the control and, it is advisable to check the manufacturer's recommendation against the size of the coil used for the particular job.

Every effort has been made to have the explanation of the various service problems complete, and the control schemes adequately described. However, it must be obvious that a small book cannot contain information covering all possible combinations of heating and cooling equipment. We feel that with the information contained herein thoroughly assimilated, it will not be difficult for the reader to obtain and understand more advanced or complete data, as he may require it.

CHAPTER 6

Ventilation Data For Air Conditioning

(Figuring the Infiltration and Heat Load to suit given conditions)

PRACTICALLY all rooms and buildings in which men live have a certain amount of natural ventilation, termed infiltration. Air seeps through cracks in the floors, walls, around windows and door frames and amounts to a surprising number of cubic feet per hour. Of course, the majority of air entering a room or structure finds its entrance via the cracks around doors and windows, for some space is necessary for windows and doors to open easily.

Tables of infiltration intended for use with air conditioning apparatus involve recognition of the fact that conditioned rooms are maintained at a lower pressure than the outside conditions and that the air leakage is naturally greater. The most practical method of estimating infiltration is to base it upon the cubical contents of the room. This is fundamentally wrong, but until accurate data are available it will constitute the only means of arriving at a proper estimate.

The velocity of the air has a great deal to do with the amount of air which enters the rooms or structures, for during certain seasons of the year the velocity of the air will be high and more air will naturally pass through the cracks than in other seasons.

For the average home, office and small shop where only a limited number of persons gather, natural ventilation is generally satisfactory.

The following table gives the changes which may be expected for normal construction. The structure should be examined so that some idea of infiltration may be determined.

CHART 5

Infiltration

Exposure of room	No. of changes per hour
One side	½ to 1
Two sides	¾ to 1½
Three sides	1 to 2
Four sides	1 to 2
Inside room	½ to ¾

Heating engineers have made available considerable data given the magnitude of air leakage through walls and windows, but it should be noted that such infiltration tests were applicable to rooms not having a mechanical air supply, so that this data cannot be used without modification.

At the present time the most satisfactory method for estimating infiltration appears to be based on the size of the room or space to be conditioned. While this is fundamentally wrong, since the true leakage is largely determined by the size of cracks about doors, windows and the porosity of the walls, besides the pressure differential, no entirely satisfactory data have been advanced.

Where infiltration data are attempted by the estimation of infiltration through cracks the results are usually valueless and less accurate than the estimate based on the cubic feet exposure basis.

The following may be used as a guide for ordinarily tight structures of average construction:

CHART 6

Natural Air Changes for Rooms Under Different Exposures—Per Hour

Exposure	No. of Changes Per Hr.
Inside	½
No windows or outside doors	¾
1 side	1
2 sides	1½
3 sides	1¾
4 sides	2

Another fault found with improperly installed apparatus or equipment carelessly operated, is that drafts are detected. In drying and processing work rapid air movement is imperative, but where human comfort is concerned the conditioned air must be evenly and thoroughly distributed without sign of draft. In many cases the operators shut down certain of the ducts, which increases the pressure at all of the open distributors and results in noticeable drafts.

Estimating Infiltration Load

If it is desirable to estimate the sensible heat load of a room it may be computed by use of the following simple formula:

$$H = \frac{V \times (t_o - t)}{n \times 3360}$$

where

H—Sensible heat in B.T.U. per minute from infiltration.

V—Volume of room in cubic feet.

t_o—Outdoor dry bulb temperature assumption.

t—Indoor dry bulb temperature.

n—Number of hours required to effect one complete change.

Latent Heat Load of Infiltration

If the latent heat load is to be estimated it can be determined by use of the following formula:

$$H1 = Ht - H_s$$

where

H1—Latent heat load.

Ht—Total heat load.

H_s—Total sensible heat load.

Refrigeration Demand for Cooling Air and Moisture Condition

Chart 7 which follows may be used for the calculation of the *refrigeration demand* requiring for the cooling of air and condensation of excess moisture.

In the table given previously a number of air changes were listed, depending upon the exposure. For very excellent construction the minimum infiltration figure may be employed and for poor or old construction the greater or maximum factor should be used. For ordinary work the table given herewith should be employed. The estimator is cautioned to exercise judgment in employing any infiltration estimate, for *a refrigeration unit costs considerably more than a heating unit* and an under-estimated or over-estimated job will represent a costly error.

The previous table may be used for estimating the cooling and condensation load by using the number of changes of the room in accordance with its exposure and multiplying this by the volume of the room and then multiplying by the factor given in Chart 7, which gives the refrigerating effect required per cubic foot. Or, taking the cubic feet required per hour and multiplying by the factor in the Chart provides a very convenient method of determining the total load for any room.

Maintainance of Humidity

Moist or properly humidified air serves to prevent colds, bronchitis and pneumonia, so far as a health safeguard is concerned. Further, paper, wood, plaster, rugs and cloth are maintained with a proper moisture balance, so that such materials are kept in proper condition. Dehydration increases the fragility of all products and in many cases causes a change in texture and color.

Under ordinary conditions, when the outdoor temperature makes it

CHART 7

Refrigeration Load For Air Cooling

Temperature Reduction, °F.

Relative Humidity %	5	6	7	8	9	10	11	12	13	14	15	16	17	18
40	.045	.085	.120	.155	.195	.235	.280	.320	.365	.415	.460	.510	.560	.615
45	.123	.165	.205	.245	.290	.335	.383	.428	.482	.530	.580	.640	.695	.757
50	.200	.245	.290	.335	.385	.435	.485	.535	.590	.645	.700	.765	.930	.900
55	.280	.352	.377	.425	.480	.528	.585	.642	.703	.765	.825	.895	.965	1.038
60	.360	.410	.465	.515	.575	.630	.685	.750	.815	.885	.950	1.025	1.100	1.175
65	.438	.488	.543	.598	.663	.720	.783	.850	.918	.990	1.170	1.155	1.235	1.313
70	.515	.565	.620	.680	.745	.810	.875	.950	1.020	1.905	1.175	1.260	1.350	1.450
75	.587	.648	.703	.763	.833	.895	.968	1.055	1.125	1.202	1.295	1.390	1.485	1.580

The above load, expressed in B.T.U. per Cubic Foot of Air cooled, is the refrigeration demand for air cooling and moisture condensation.

imperative to use the heating system, materials in the home and office, give up their moisture to the air. This is shown by the condensation on windows during the frosty days of the heating season. During the heating season, rugs, plaster, and wood give up a certain portion of their moisture content, for in building provided solely with heating means, a slow acting dry kiln effect is created.

Where humidification apparatus is started toward the end of the heating season it will be observed that it is difficult to maintain the proper humidity, for the wood, plaster, paper, rugs, concrete, etc., begin to drink in the moisture lost during the dehydrating period. Just as soon as the humidity is raised a few per cent, the materials take up some more. Eventually they arrive at the proper balance, so that they neither take up or give off moisture.

Regain

The absorption, and especially the reabsportion of moisture by materials is known as the "moisture regain." This is of such importance to the manufacturers of certain products that a great deal of experimental work and study has been devoted to it. Regain curves have been developed, especially in the rayon, silk, wool, paper, and cotton trades.

If, for instance, a manufacturer of woolen materials, placed the air conditioning system in operation late in the winter, so that the relative humidity was raised from 40 to 50 per cent, the wool would absorb 1.7 per cent of its bone dry weight in additional moisture. Paper, under similar conditions would absorb about 1.3 per cent, while cotton would absorb about 0.8 per cent in additional moisture. In production these additional weights represent a considerable loss if the materials are sold without regain.

Condensation on Windows

Where the proper indoor relative humidity is maintained in the winter months, condensation or frosting occurs on the windows. Windows that "steam up" are objected to, especially in homes, offices and factories, for natural light is prevented from entering and the windows are left spotted or streaked when dried. If the condensation occurs in appreciable amounts over extended periods, it will destroy the finish and create rust or rot. Usually the putty suffers and may require attention every season.

Of course, condensation can be prevented by maintaining a lower relative humidity, but this is one of the objectives of the air conditioning system and in manufacturing forms one of the prime essentials in the production of the finished materials. In homes and offices, health and comfort, require the higher relative humidity. Condensation, and incidently the load on the system can be cut down or eliminated by the use of double or triple windows.

The formation of moisture on windows is the same manifestation of the "dew point" mentioned before.

In the case of a single glass window, the condensation appears like drops of dew, just as it does on a pitcher of ice water. If however, the outdoor temperature is below the freezing point, the condensation will freeze and result in a frosted condition.

Double and Triple Windows

Double glass for windows, with an air space between the panes, will result in the inner glass being maintained at a higher surface temperature than where a single glass is employed, so that no condensation will occur under normal conditions. In industrial applications where high humidities must be maintained triple glass is used.

Manufacturers of store display cases and counters have employed double and triple glass for a number of years, realizing that the display must not be hindered by condensation. These manufacturers early learned that the space between the panes must be sealed with an air tight and waterproof material, otherwise moisture would enter and precipitation occur in time.

The University of Illinois conducted a series of tests and evolved the chart given below, which lists the temperatures of the glass at which condensation will take place. Inasmuch as the air within the air conditioned room is usually in considerable motion, the glass surface is slightly warmed by the warmed air flowing over it, so that the temperatures and humidities given in the Chart can be assumed to be the critical points, beyond which condensation will occur.

CHART 8

Percentage of Relative Humidity at which condensation forms.
Single Windows

Outdoor Tempera-ture	Temp. of Inner Surface of glass	Relative humidity at which conden-sation forms on glass
-10	13	12
0	20	18
10	28	23
20	34	30
30	42	38
40	48	48
50	55	64
60	62	80
70	69	99

Double Windows

Outdoor Tempera-ture	Temp. of Inner Surface of glass	Relative Humidity at which Conden-sation forms on glass
-10	46	45
0	49	49
10	52	54
20	54	60
30	57	68
40	60	75
50	63	83
60	66	91
70	69	99

Glass Door and Window Coefficients

The values of K, expressed in B. T.U. per hour per degree temperature difference per square foot, are given below for all glass doors and windows not exposed to the direct rays of the sun.

CHART 9

Unexposed Windows and Doors

Thickness of glass	K
1	1.13
2	.46
3	.29
4	.21

Exposed Windows and Doors

Where windows have a south-east or western exposure, they should be provided with awnings or venetian blinds. Otherwise the direct rays of the sun will permit a large amount of heat to enter the conditioned space—ranging from 20 B.T.U. per square ft. to 190 B.T.U. per square ft., besides the normal transfer of heat through the glass due to temperature differances between the inside and outside.

Where awnings are used over windows and doors, the standard glass coefficient as given in Chart 9 should be used (which is for each degree difference per square ft. of surface) and the result must be doubled or Chart 10 may be used to determine the amount that would pass through without awnings, and reduce the total amount that would pass through without awnings and reduce the total amount by 75 per cent for 1st floor and 85 per cent for other than 1st floor levels.

When calculating the heat load due to solar radiation, it should be kept in mind that the sun's rays do not strike the east, south and west windows at the same time. However, some means must be found to determine which side has the greatest load. Also determination must be made as to the possibility of these loads occurring at the peak load period (as at 12 o'clock noon in a restaurant or 3 p.m. in an office).

To aid in selecting the load and time of day, Table 10 has been developed. This is by no means complete, as this particular factor involves pages of data from experiments for both windows and doors.

CHART 10

Exposed Windows

Exposure	B.T.U. Trans-mitted per Sq. Ft.	Time of Day	Horizon-tal Sur-face
East	165	9 a.m.	180
S. East	140	9 a.m.	180
South	20	3 p.m.	180
S. West	140	3 p.m.	180
West	165	3 p.m.	180
N. West	70	3 p.m.	180

This chart is given only to illustrate the magnitude of sun effect and while the B.T.U. transmitted for horizontal surface is given as 180, it so happens that for these two time settings, the B.T.U. figures are the same. Actually, this factor varies from 35 at 6 a.m. to 255 at 12 noon, then down to 20 at 6 p.m. for the locations at 40 degrees north latitude, only.

From the above, it can be seen that this part of air conditioning heat gain calculation is a study in itself and does not come within the scope of this book. It will, however, show the reader some of the intricate problems encountered in scientifically figuring the requirements for cooling and heating for any given building.

In many cases awnings cannot be employed due to the design of the building. In such cases light colored shades and other light impervious materials may be used to cut down the effect of solar radiation. Where shades or screens are employed a reduction of 50 per cent of the heat load of exposed glass areas may be used.

CHART 11

Solid Wooden Doors

Nominal thickness inches	K
1	0.69
1¼	0.59
1½	0.52
1¾	0.51
2	0.46
2¼	0.42
2½	0.38
2¾	0.35
3	0.33

The above coefficients are based on a wind exposure of 15 miles per hour and on 1 degree f. difference between the outside and inside temperatures.

Ordinary office and residential doors consisting of thin panels or provided with glass, should be estimated as having a coefficient of K= 0.9 per sq. ft. per degree of temperature difference per hour.

Motor Heats

All motors generate heat and where installed or contemplated in air conditioned rooms must be included in estimating the total heat load.

CHART 12

Motor Heat Load

H. P. Motor	B. T. U. Generated per hour
1/20	425
1/10	680
1/8	750
1/6	817
1/4	1020
1/3	1290
1/2	1870
3/4	2750
1	3410

Electric Appliances

Electric lights dissipate approximately 3.42 B.T.U. per hour for every watt consumed and the heat load in every room is easily determined by a survey of the lamp sizes.

Many rooms only make use of electric lights on dark days. In such cases the reduction in solar radiation compensates for the heat generated by the electric lights.

Electric toasters, waffle irons, hot plates and urns also dissipate considerable heat. In estimating the heat evolved through the use of these devices the watts ratings on each of the units should be noted and a study made of the length of time each is employed. Most of these devices will only be in constant use during the rush or peak load and may be used but little during the remainder of the day.

CHART 14

Heat Dissipated by Human Beings

Activity	B.T.U. per hour
Seated, at rest	400
Standing, at rest	430
Seated, light work	500
Standing, light work	575
Moderate work	800
Heavy work	1,500
Dancing	1,000
Musician	1,000
Carpenter	850
Tailor	500
Walking, 2 m.p.h.	700
Walking, 3 mp.h.	1,050
Walking, 4 m.p.h.	1,400
Walking, 5 m.p.h.	2,500

Gas Heated Devices

Many of the heating devices used in restaurant work, for example, make use of gas as a source of heat. There is a material difference when such devices are provided with a hood and are ventilated.

The following table refers to gas heated percolators. A good rule of thumb to follow on gas heated appliances is to base the heat load on the number of cubic feet of gas burned. For natural gas allow 1,000 B.T.U. per cubic foot and about 500 B.T.U. for manufactured gas. This allowance can be made for all gas heated devices, including percolators, water heaters and steam plates. It is important to obtain the hours of operation, for in many cases where more than one device of each kind may be used during the rush hours, only one may be used during the remainder of the day.

CHAPTER 7

Definitions Used In Air Conditioning

THROUGHOUT this book, certain terms are used and are not explained in detail. We suggest that reference be made to the following pages for such information.

Air Conditioning

The science of controlling the temperature, humidity, motion and cleanliness of the air, within an enclosure, to maintain conditions most suitable for health, comfort or commercial process work.

Atmospheric Pressure

Atmospheric pressure equals 14.7 lbs. per sq. in. at sea level, or 30 ins. of mercury which means that the air is exerting a pressure of 14.7 lbs. per sq. in. This will balance a column of mercury 30 ins. high, provided the vacuum is first created in the top of the mercury tube. To prove this, take a common tin can with a small amount of water in it, and apply heat until steam is generated. This will force the existing air out of the can, and if the heat is removed and the can sealed, the steam will soon condense into water, creating a vacuum in the can. It is at this point that we can prove the presence of air pressure, by the fact that the can will collapse from the pressure of the surrounding air.

Barometric Pressure

Same as atmospheric pressure.

B.T.U. (British Thermal Units)

Since heat is not a substance, it cannot be measured in pounds or pints, but, like energy, it may be measured by the work it performs. Therefore, a B.T.U. is a measurement of the amount of heat required to raise the temperature of 1 pound of water from 62 to 63 degrees. For all practical purposes, the same amount of heat will raise the temperature of 1 pound of water from 180 to 181 degrees. Actually it takes slightly more heat to do this, for temperature below 62 degrees require a slightly smaller amount of heat. Therefore, it is customary to use as a basis, one B.T.U. will raise the temperature of one pound of water one degree F. and other substances are raised a varying amount by one heat unit. For instance 4.2 pounds, or approximately 55 cubic feet, can be raised one degree by the application of one B.T.U.

Dew Point

The temperature at which moisture will be condensed out of the air. If a mixture of air and humidity is cooled, it will ultimately reach a point where it can no longer hold the amount of moisture present, and any further lowering of the temperature will cause the moisture to be condensed out. In air conditioning systems, the cooling surface is at a temperature below the Dew point temperature of the air, so that air coming in contact with this surface is cooled to a temperature below the saturation point, and moisture is condensed out of the air, and finds its way to the drain pipe.

Dry Bulb

The reading obtained from an ordinary thermometer. See "Sensible Heat."

Fahrenheit

Method of calibrating or marking off a mercury column to register the temperature. This was named after its inventor. Our ordinary thermometers are marked off on the Fahrenheit scale.

Grains of Moisture

Moisture in the air is ordinarily stated as being so many grains. This means the weight of water vapor or humidity in the air, at the conditions mentioned. It requires 7,000 grains to weigh 1 lb.

Heat Gain

That heat which is transmitted through the walls of a structure from the outside where the temperature is high to the conditioned space. Heat gain also applies to such heat generating devices as electrical appliances, steam tables, human beings, etc.

Heat Loss

The transfer of heat from inside an enclosure to the surrounding outside air. Heat always flows from an area of high temperature to a low temperature area.

Humidity

This comes from the Latin word humidus, meaning moist. Air at all conditions contains a certain amount of moisture, which is really steam or water vapor. The presence of this moisture in the air affects it in three ways. First, it increases its capacity for heat. Second, it decreases its weight per cubic ft. and makes it more buoyant. Third, it reduces the amount of oxygen contained in a cubic ft., thus imparting its value for purposes of respiration. When the atmosphere contains the maximum quantity of steam or humidity that can exist at the temperature, the air is said to be saturated. Should the air temperature be lowered, moisture will be condensed out of the air.

Latent Heat

The amount of heat required to change a body or substance from one condition to another without changing its temperature. For example it requires 144 B.T.U. to melt a pound of ice at 32 degrees, to water at the same temperature. The pound of water so produced may be heated to the boiling point, 212, by the addition of 180 B.T.U., sensible heat. To change the water at 212 into steam at the same temperature requires 971.7 B.T.U., latent heat which does not change the temperature but merely evaporates it to vapor steam. Steam so generated is mixed with the air and does not register on an ordinary thermometer.

Refrigeration

The process of cooling which is really the removal of heat. It is the process by which the temperature of a given space or substance is lowered below that of the atmosphere or surrounding materials. It is accomplished by transferring the heat from one substance to another. When applied to air conditioning, refrigeration generally means the cooling of air or water.

Relative Humidity

The amount of moisture that is in the air at the condition given, as compared to the amount the air could hold if saturated at the same temperature. For example, if the relative humidity is 50 per cent and the temperature if 80 degrees, the air is carrying only half as much moisture as it is possible for it to carry. The air does not really hold moisture, or "carry" it. The moisture exists in a vacuum space as well as in the atmosphere.

Sensible Heat

The intensity, rather than the amount—the more sensible heat a body possesses, the hotter it is, and the more sensible heat that is taken away from it, the colder it is. This is indicated by the word temperature. So if we raise the temperature, we increase the sensible heat. It can, therefore, be recorded on an ordinary thermometer.

Sling Psychrometer

An instrument that has an ordinary thermometer and a wet bulb thermometer attached to it, as illusstrated in Fig. 57. It is used to obtain the wet bulb temperature.

Specific Heat

All substances require a certain amount of heat to change their temperature, and with the exception of hydrogen, they require less heat to raise a pound one degree than does water. Therefore, the specific heat of water is taken as 1, while the specific heat of air is .24 and mer-

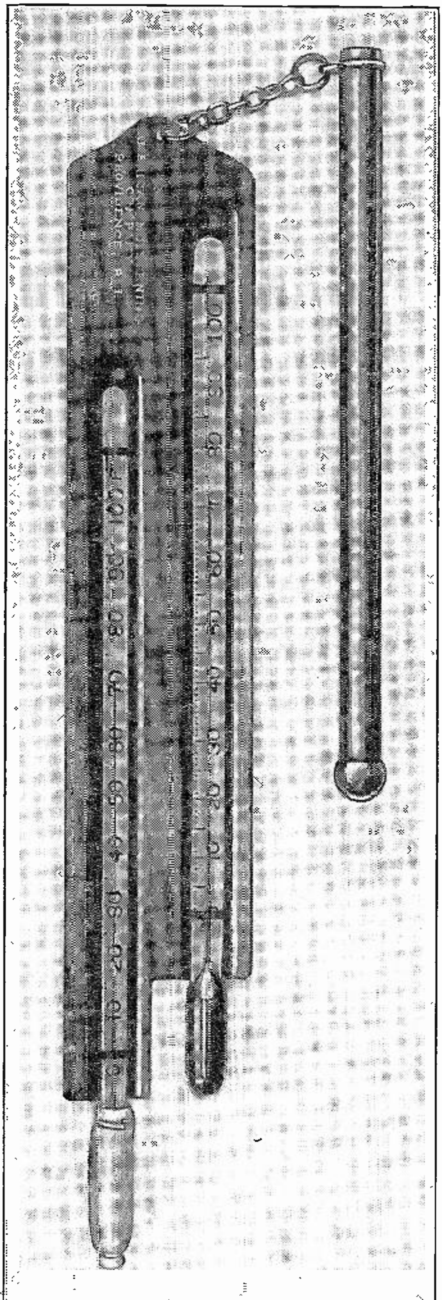


Fig. 57

This combined unit of wet and dry bulb thermometers is used in calculating air conditioning needs and conditions.

cury is .033, which means that 1 B.T.U. will raise the temperature of 4.2 pounds of air one degree, or 30 pounds of mercury 1 degree. Variour substances have definite specific heats and are always compared to water.

Ton of Refrigeration

The amount of heat which must be abstracted from 2,000 pounds of water at 32 degrees F. to convert it into ice at the same temperature, and, since the latent heat of the ice is 144 B.T.U. per pound, the ton is equivalent to 144 times 2,000 pounds, or 288,000 B.T.U. As an element of time is considered for this absorption, the 288,000 B.T.U. divided by 24 hours gives a B.T.U. rating of 12,000 per hour. A rated ton refrigerant machine will absorb 12,000 B.T.U. in one hour, or make one ton of ice in 24 hours.

Total Heat

The amount of sensible heat in the air together with the amount of latent heat at any given condition.

Vapor

A substance that at ordinary temperatures is a liquid or a solid but when heat is applied, or the pressure surrounding it is lowered, becomes a gas. For example, mercury may be in all three conditions. At ordinary temperatures, mercury is a liquid, at 40 degrees below zero it becomes a solid by freezing, and it can be vaporized to a gas at 600 degrees F. above zero.

Velocity

The speed at which air is moved through a duct system. For example, a duct 12 ins. on each side has an area of one sq. ft. or 144 sq. ins., and air passing through at the rate of 1,000 ft. per minute (F.P.M.) would deliver 1,000 cubic ft. in a minute, expressed as cubic ft. per minute (C.F.M.). From another angle, assume the same 12 in. duct to be 1,000 ft. long. If we place a square piston at one end and push it completely through in one minute, the air in the duct would travel at a velocity of 1,000 F.P.M. The volume of the duct being 1,000 cubic feet, the delivery would then be 1,000 cubic feet in one minute. If we had a duct 24 ins. wide and 12 ins. high, or deep, the area will be 2 sq. ft. It is required to pass 6,000 cubic feet of air through in one minute. The actual air velocity inside the duct would then be 3,000 F.P.M. If the duct is increased to 24 ins. square, the same amount of air could be delivered at a velocity of 1,500 F.P.M.

Volatile

Easily vaporized liquid at normal conditions, as associated with air conditioning or refrigeration.

Volume

See velocity.

Ventilation

The continuous removal of foul air from a room, used for either habitation or manufacturing purposes, and the constant introduction of fresh air to take its place.

Wet Bulb

The reading obtained from an ordinary thermometer that has a mercury bulb enclosed in a moist cloth sack, and whirled through the air for 15 or 20 seconds, holding it away from the influence of any external heat. The final temperature will be lower than a dry bulb thermometer if the air is not completely saturated because moisture will be evaporated out of the cloth and absorb heat from the mercury in the thermometer. In the event that the air is already saturated, no moisture will be evaporated from the cloth and this reading would then be the same as an ordinary dry bulb thermometer. The drier the air is when the reading is taken, the greater will be the depression of the wet bulb thermometer.

CHAPTER 8

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Heating, Piping and Air Conditioning.
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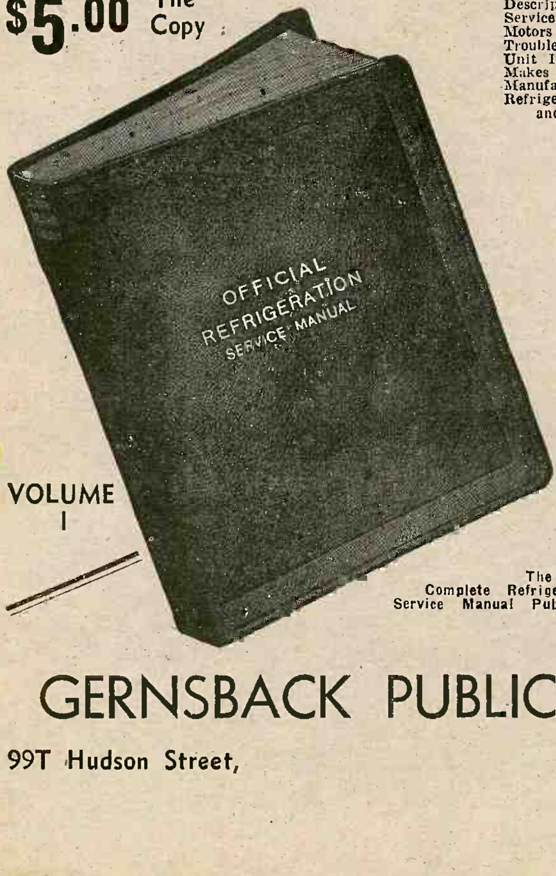

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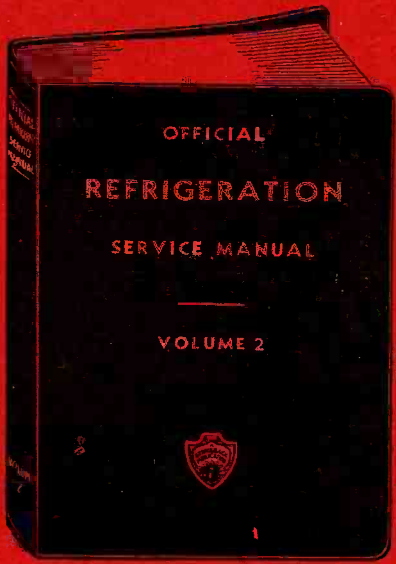

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