AIR CONDITIONING

1955

thru

1961

- THEORY
- DIAGNOSIS
- REPAIR

LINCOLN-MERCURY
RM
REGISTERED MECHANIC

SERVICE DEPARTMENT
LINCOLN-MERCURY DIVISION
Ford Motor Company

Forward

For greater assistance to Dealer Mechanics in Air Conditioning Service, this manual has combined all repair and maintenance information for servicing Air Conditioning Systems installed during 1958-61.

In addition, repair procedures, trouble shooting guides, wiring diagrams, and specifications are included to cover prior models 1955-57 Lincoln and 1957 Mercury.

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PRINCIPLES OF REFRIGERATION

A sound base for understanding the fundamentals of refrigeration or air conditioning includes a reading knowledge of some physical laws and technical details involved in the methods by which we produce artificial cold. Recognition of the conditions which are associated with human comfort in this respect is a good starting point. We must also have an understanding of the relationship which exists between the temperature, pressure and volume of a gas. Finally, we must know what is meant by terms such as energy, heat, molecular motion, units of heat and specific heat. These terms are the common language of the heating and air conditioning trade.

This is a *fundamental* treatment of the subject. We hope that it will stimulate your curiosity enough to encourage you to engage in a more comprehensive study.

We have all heard the remark on a hot, damp day, "it isn't the heat . . . it's the humidity". How many persons who have made this statement understand what humidity really is. It's certainly an important factor in air conditioning, so let's examine it more closely.

As a starting point we can make the statement that "The more heat there is in air, the more moisture it is capable of holding." (By moisture, we mean the water vapor content.)

Another fact which we can accept is that warm air which is holding its maximum vapor content will . . . if it is chilled . . . condense and form drops of water. The temperature at which this condensation occurs is called the "dew point". In percentage figures, the dew point is also known as 100% "relative humidity". (If we define relative humidity, we may say that it is a measured percentage of moisture in the air compared with the maximum amount of moisture the same air could hold at the same temperature.)

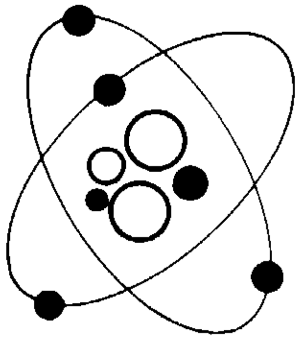
The effect of relative humidity on physical comfort is quite obvious. When it is low, the air can absorb more moisture. As a result, perspiration is quickly absorbed. On the other hand, when the relative humidity is high, the air cannot take on more moisture, so we must endure the discomfort and resort to "brow mopping".

What does air conditioning do to cope with this problem? Two things—first, it cools the air to a comfortable level—then, it lowers the relative humidity to a comfortable percentage below the "dew point". Both of these tasks are performed by the component of an air conditioning system known as the evaporator. The refrigerant inside this evaporator changes from a liquid to a vapor. Thus, it absorbs great quantities of heat from the surrounding air.

As the air gives up its heat, it loses its ability to hold as much moisture as it did previously. In the course of effecting these changes, the dew point is reached and moisture condenses on the fins of the evaporator.

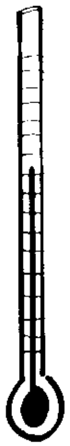
Scientists have long expressed the relationship of pressures, volumes and temperatures of gas. All of us, at one time or another have had to pump up a bicycle tire or inflate a football. As you pumped, the barrel of the pump became warm. Some of you have noticed that tires which are inflated cold and then driven at high speeds which generate heat are again checked, there is a build up of pressure. We are pointing out that the pressure of a gas becomes greater as the temperature increases. And the reversal is also true. As the pressure increases, so also does the temperature. On the other hand, we have seen children squeeze a balloon until it busts. In squeezing the balloon, the volume of the air inside was decreased until the pressure became great enough to break the rubber. From this, we can decide that as the volume of a gas decreases, its pressure increases. These facts become important because we are constantly changing both pressures and temperatures in an Air Conditioning system. We will discuss the importance of this relationship between pressure, volume & temperature later on. But, now let's examine this term "Heat."

Just what is heat? Well, it is a form of energy. Just as energy is measurable and can be expressed in terms of foot pounds, horsepower, watts, etc., so also can heat be measured and expressed. The unit for heat is the British Thermal (Unit) or in smaller measure, the calorie. These units of measure for heat have equivalent values in other forms of energy. For example, 1 B.T.U. = 778 ft. lbs.



Now, let's examine this Term "heat" a little more closely. Heat does many things . . . its presence causes expansion–its absence, contraction. The continued application of heat to a substance, depending upon its intensity, will change the form of that substance . . . it will convert a solid into a liquid, or a liquid into a gas. Scientists explain this phenomenon with the theory of molecular motion.

In a nutshell, this theory supposes that all matter is composed of countless, separate particles called molecules. These molecules are held together by cohesion (mutual attraction) even though they are unattached and in constant motion. The space in which they move is a key-point and it appears that temperature has a lot to do with the amount of this space. As temperature increases, molecular motion is accelerated . . . the increase in speed drives the molecules farther apart. When the space relationship between the molecules is sufficiently altered, the substance changes form . . . it melts–or vaporizes. If heat is being withdrawn, the change might be seen as condensation into a liquid and then, solidification. The point to remember is that temperature increases molecular activity and cold slows-it-down.



The instrument for measuring the intensity of heat (temperature) is deserving of fluting comment.

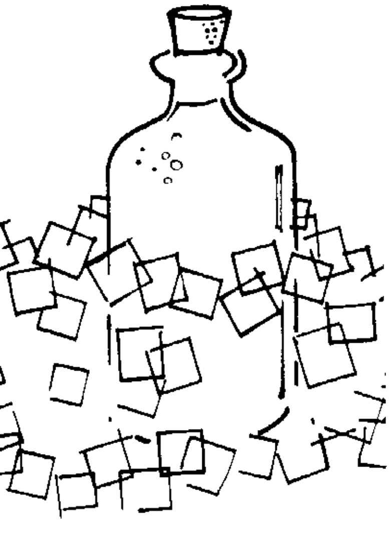
The thermometer is a very commonplace measuring device. In the United States, we use a Farenheit thermometer on which the freezing point is scaled at 32 degrees and the boiling point at 212 degrees. The Centigrade thermometer, a universally adopted device, scales freezing at zero degrees and the boiling point at 100 degrees. The readings on one may be converted to the other by applying the formula: Farenheit Reading = 9/5 Centigrade Reading plus 32, viz.: $100^{o}C \times 9/5 = 180 + 32 = 212^{o}F$.

We have mentioned the B.T.U. as a unit of heat energy. Now let's pursue this unit a step further and relate it to a thermometer reading.

By loose definition the B.T.U. is the amount of heat required to raise the temperature of 1 pound of water 1 degree Farenheit. Thus, to increase the temperature of 1 pound of water from 35 degrees F. to 100 degrees F. we must furnish 65 B.T.U.'s for absorption into the water. To cool the same amount of water the same number of degrees, we must extract 65 B.T.U.'s.

Now, with a brief comment about one more basic theory item, we will be ready to consider the phases of theory which apply most specifically to air conditioning.

Each element and each compound which exists in nature or is manufactured has its own heat characteristics. If we had a shelf-full of miscellaneous items and under laboratory conditions, measured the amount of heat we could remove from each, we would have as many different heat values as there were items on the shelf. This capacity to expel heat, or conversely to absorb heat is known as "specific heat". Water because of its large heat capacity, is the standard around which the specific heat scale has been devised . . . its scale value is 1.00. The specific heat of some other everyday items are: apples–0.92, coal–0.241, air–0.238, glass–0.194, etc. This means that apples, for example, can expel or absorb heat about 92% as well as water.



It is with the aid of these specific heat ratings that refrigeration requirements may be calculated to a given job. (We might add that gaseous substances have specific heat values, but pressure plays an important part in calculating their specific heat value.) A simple example of a specific heat calculation would be the cooling of 1000 pounds of bottled water from 70 to 50 degrees F. assuming that the bottles weigh 75 pounds: 1000 (wt. of water) x 1.0 (Sp. Ht. x 20 (temp. drop) = 20,000 B.T.U. plus 75 (wt. of glass) x 0.149 (sp. ht. of glass) x 20 (temp. drop) =291 B.T.U. or a total of 20,291 B.T.U. To freeze this water, another principle is involved–latent heat.

HEAT TRANSFER AND MEASUREMENT

DIRECTION OF TRANSFER– The transfer of heat is much like the flowing of water. Water flows downhill seeking its lowest level. Heat travels from a substance having a higher temperature to one having a lower temperature . . . This will continue until both substances are at the same temperature.

THE EFFECT OF MASS ON HEAT TRANSFER– The temperature of a cup of hot water, immediately after it is taken from a larger container of hot water, is exactly the same in both the cup and the container. We know, however, that the rate of cooling is greatly different. The smaller mass of water in the cup will match its ambient temperature much more quickly than the larger mass from which it was taken.

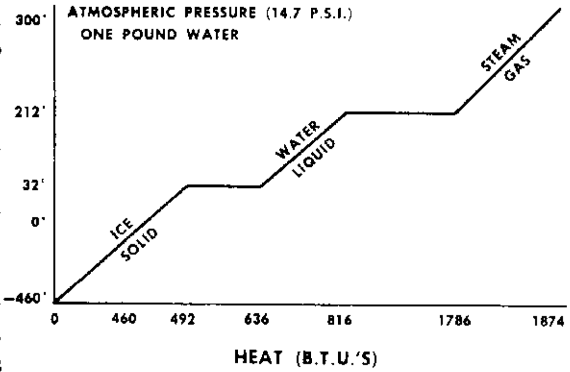
Another example of the effect of mass on heat transfer is the comparative rate at which a small pond and lake will freeze and thaw. The larger body of water takes longer to freeze in the winter and remains frozen for a longer time in the spring. The enormous quantities of heat required to thaw a lake and the equal quantities of heat given up by the lake in the course of its freezing explain why changes in climate are so noticeably tempered in areas near great bodies of water. Again, the greater the mass . . . the greater the heat factor involved.

MEASUREMENT–The British Thermal Unit (B.T.U.) and the Calorie (Cal.) are the units of measurement by which we determine the amount of heat "given up" or "taken on" by any given substance. The B.T.U. by definition, is the amount of heat needed to raise the temperature of 1 pound of water 1 degree Fahrenheit. By example, this means that 1 pound of water requires 180 B.T.U.'s to raise its temperature from 32 degrees to 212 degrees F. Conversly, it must give up 180 B.T.U.'s to drop its temperature from 212 to 32 degrees F.

LATENT HEAT

To illustrate the principle of latent heat, let's use a piece of ice weighing 1 pound and place it in a container over a flame. As the ice melts, place the bulb of a thermometer near the melting ice without touching the ice. You will observe that the water temperature remains at 32 degrees F. until all of the ice is melted. As heating continues you will notice now that the temperature of the water will rise quite rapidly towards its 212 degree F. boiling point. Then when the water in the container boils, it will stay at 212 degrees until the entire contents turns to vapor. This experiment indicates that there are two periods in the ice-to-vapor cycle during which heat was being added without producing a measurable change in the thermometer reading. What became of the heat?

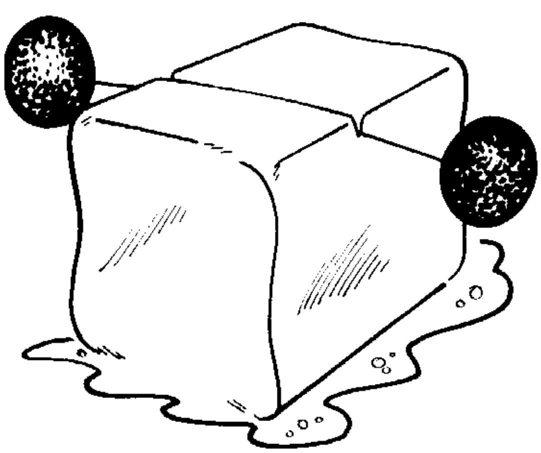
The answer to this question lies in the fact that the original change, if it had begun with the condensation of vapor to water, and then, conversion of the water into ice required that heat to transferred to a colder ambient throughout the cycle to the point where freezing occurred . . . and further . . . that it had to be restored in the same amount until the complete cycle was reversed. During this period of continuous heat replacement, when no temperature change takes place, we are encountering what the scientists refer to as "latent heat". The amount of heat required to melt 1 pound of ice is 144 B.T.U.'s . . . this is known as the "latent heat of fusion". It takes 970 B.T.U.'s to change water into vapor . . . This is known as the "latent heat of vaporization". In both cases this heat is often referred to as "hidden heat".



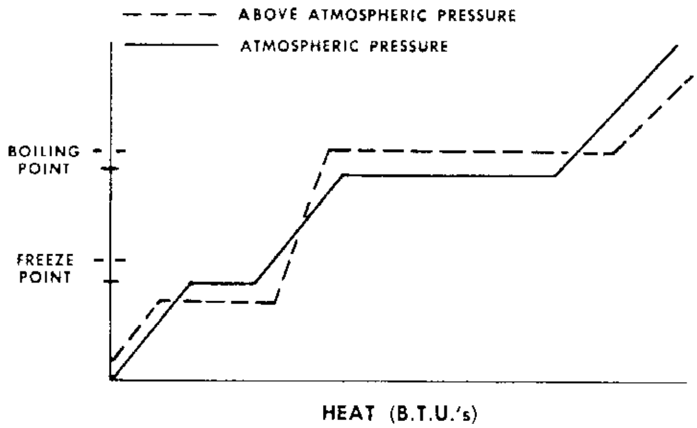
The chart will serve to illustrate this point further. Let's assume that we have 1 pound of ice which we are going to examine under laboratory conditions . . . we'll use a normal atmospheric pressure of 14.7 p.s.i. and a theoretical temperature of 460 degrees below zero (Fahrenheit). This temperature value is known as "absolute zero" . . . it is the theoretical point at which there is absolutely no heat. As we add each B.T.U., we add one measurable degree of temperature until we reach plus 32 degrees F. The next 144 B.T.U.'s which we add have no effect on the temperature, but we do notice that the ice changes to water. The addition of the 145th B.T.U. again raises the temperature 1 degree . . . and so it continues up to 212 degrees. At this point the temperature rise stops until 970 more B.T.U.'s are added. The water by then has turned into a vapor and the temperature again rises with each B.T.U. we add. Conversely, the same amount of heat must be given-off to go from the vapor to ice stage. This tremendous absorption and conversion of heat is the basic principle of conventional refrigeration.

THE EFFECT OF PRESSURE

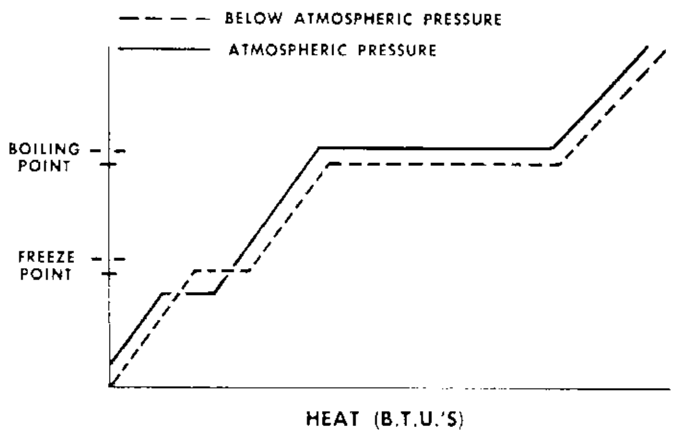
Although many of us are familiar with the experiment in which a cake of ice and a length of wire—weighted at both ends—are used to demonstrate the principle of fusion, we'll review it at this point. As you will note in the cartoon, the strand of wire is hung over the cake of ice and is being drawn down through the ice by the weights. As time passes, the wire creeps toward the bottom of the ice but it doesn't sever the cake. In effect, the weights on the wire are creating two pressure conditions . . . higher along the undersurface of the wire and lower along the upper surface. As a result, the ice melts under pressure on one side of the wire and then refreezes under the lesser pressure above the wire.



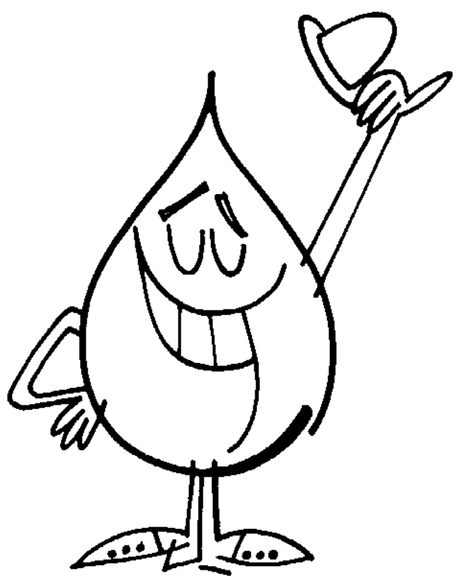
Now let's turn our attention to the chart. The solid line represents a temperature range of water extending from absolute zero to a point beyond vaporization under *standard atmospheric conditions.* The dotted line represents this same condition at a pressure higher than atmospheric . . . the increased pressure *lowers* the freezing point.



In the second chart, the solid line again represents water under standard atmospheric conditions (14.7 p.s.i.) and the dotted line shows the effect of a lower pressure. We see here that the lesser pressure raises the freezing point of the water and lowers its boiling point. This is a condition which exists many places in nature . . . the city of Denver, Colorado is one example. At the high altitude in which Denver is situated, the atmospheric pressure is 12.2 p.s.i. The boiling point of water under this pressure is 203 instead of 212 degrees F.



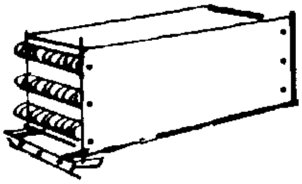
With this basic information, we are ready to proceed to the consideration of commercial refrigerants. It is perhaps obvious that water is an impractical refrigerant. Such tremendous reduction of pressure is required to lower the boiling point from 212 degrees F. to a point in its surrounding atmospheric pressure where it will attract heat, that it becomes an uneconomical method of producing refrigeration. A good refrigerant has certain desirable properties. Among them we can include: a low boiling point . . . a high latent heat value . . . an ability to operate on a positive pressure instead of a vacuum . . . a tendency to liquefy easily at moderate pressure and temperature. In addition, it must be safe, non-toxic, mix well with oil, have no effect on moisture, and have a non-corrosive effect on metal. FREON is this type of refrigerant. Its boiling point is minus 21.7 degrees F. . . . its latent heat value is 68.14 B.T.U.'s/pound at 18 degrees F. . . it is under positive pressure at its boiling point . . . it liquefies at 75 p.s.i. . . . and finally, it meets all other requirements for a good refrigerant.



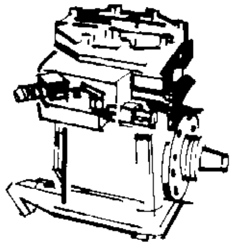
THE REFRIGERATION CYCLE

We are now going to consider a complete refrigeration cycle. By "cycle" we mean the series of operations in which heat is absorbed by the refrigerant, turned from a liquid into a vapor, compressed, and then forced into a condenser where the heat in the refrigerant is given-off into circulating air and then, the refrigerant is restored to its liquid state. We will be bringing together most of the basic theory we have discussed earlier in this booklet, as well as a little more detail on vaporization and condensation.

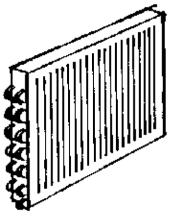
As we have shown in the diagram and suggested in the preceding paragraph, refrigeration is accomplished in four phases . . . vaporization, compression, condensation and pressure reduction.



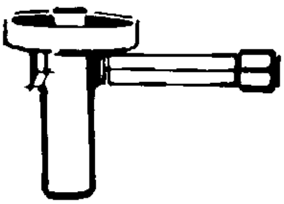
Phase 1 – The refrigerant at low temperature and low pressure is in the evaporator. Here it absorbs the heat from its surrounding atmosphere and from objects in this atmosphere. In the course of performing this work, the liquid turns into a gas. The physical law involved is the "latent heat of vaporization".



Phase 2 – A compressor draws the heat laden vapor out of the evaporator through the compressor inlet line. (The compressor, in most commercial applications is a reciprocating device . . . a piston type unit which performs its intake capacity under suction pressure, compression in one or more stages, and then discharge under pressure.) As the result of compression, the temperature of the refrigerant is increased and is now ready to be discharged into the condenser.



Phase 3 – When the high temperature refrigerant vapor enters the condenser, it is under pressure. It remains under pressure while it changes from a vapor to a liquid. It also remains under pressure when it leaves the condenser for storage in the receiver.

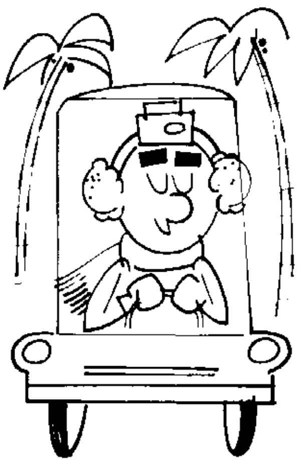


Phase 4 – As the compressor draws refrigerant from the evaporator (Phase 1), a fresh supply of low pressure refrigerant must be available to enter the evaporator and continue the heat absorption process. To meet this need for low pressure liquid, an expansion valve is placed between the receiver and the evaporator. In addition to serving as a pressure reduction device, the expansion valve is also the flow control valve for the system, separating the high and low pressure segments of the system.

Our home refrigerators employ the four phases outlined above. They are the same type of two-sided system . . . on their high pressure side we find an electric drive-motor, compressor, condenser and receiver. This is often called the condensing unit. Quite often these components are mounted on a common base. The low pressure system picks-up the balance of components . . . the expansion valve, evaporator and low pressure lines between the outlet side of the valve and the inlet side of the compressor.

A compression-type refrigerating unit is a highly efficient piece of machinery . . . so much so that it is now being used to heat as well as cool by merely reversing its cycle.

REFRIGERATION IN AUTOMOBILES



The basic automotive air conditioning system operates much the same as the home refrigerator, that is it transfers the heat from inside the passenger compartment to the outside.

The evaporator is exposed to air flow from the passenger compartment through a motor-driven blower. The expansion valve releases liquid refrigerant into the evaporator coils, the heat from the air is absorbed by the boiling refrigerant and disappears in the refrigerant vapor. The refrigerant vapor containing the hidden heat, is pumped out of the evaporator by the compressor and forced under high pressure to the condenser which is located in front of the radiator. In the condenser, the refrigerant vapor condenses back to a liquid and the heat, that was absorbed from the passenger compartment and hidden in the vapor, now reappears and passes off into the air stream. We have changed the state of the liquid refrigerant in two places, inside the passenger compartment and in front of the radiator. Heat was required to change state inside the passenger compartment and the same heat was given off by the refrigerant when it changed state outside.

The liquid refrigerant under high pressure, now passes from the condenser to the receiver where it is stored for reuse and to insure a solid column of refrigerant to the expansion valve. The liquid refrigerant will not boil while it is stored in the receiver because it is under high pressure which maintains the boiling point of the refrigerant above the temperature of the surrounding air. Thus, no heat can transfer from the outside air to the refrigerant in the receiver.

The receiver is connected to the expansion valve at the evaporator where the cooling cycle starts over again. When the expansion valve is opened, the high pressure liquid refrigerant from the receiver passes through an orifice in the expansion valve which meters the refrigerant into the evaporator at a greatly reduced pressure.

As the refrigerant enters this low pressure area, it will immediately begin to boil and its temperature will drop to that corresponding with the low pressure.

For instance, if the pressure inside the evaporator is 30 p.s.i., the temperature of the refrigerant will drop to 32° F.; and it will begin to boil by absorbing heat from the surrounding areas. The following chart indicates the pressure-temperature relationship of Freon (Refrigerant 12):

GAUGE PRESSURE (Pounds Per Square Inch)	0	8.2	30.1	84.1	168.6
TEMPERATURE (Degrees Fahrenheit)	−21.7	0	32	80	125

This relationship is often to be found on the faces of the gauges used in air-conditioning work.

The liquid refrigerant passing through the evaporator will continue to boil at 32° F. until all of the liquid has vaporized. The flow of the refrigerant is regulated by the expansion valve so that it will remain in the evaporator long enough to completely vaporize.

It may seem difficult to understand how heat can be transferred from a comparatively cooler car passenger compartment to the hot air outside. The answer lies in the difference between the refrigerant pressure that exists in the evaporator and the pressure that exists in the condenser. In the evaporator, the expansion valve releases the refrigerant to a lower pressure area thereby reducing the boiling point below the temperature of the passenger compartment. Thus, heat transfers from the passenger compartment to the boiling refrigerant. In the condenser, the compressor raises the condensation point above the temperature of the outside air. Thus, the heat transfers from the condensing refrigerant to the outside air. The expansion valve and the compressor simply create pressure conditions which, by following the physical laws described earlier, provide refrigerant and cooling.

We have now seen the basic components of an automotive air-conditioning system. There are several variations of systems in use today, but they are all based upon the same law of nature: THAT HEAT IS EITHER ABSORBED OR GIVEN–OFF WHEN A GIVEN MATERIAL CHANGES ITS STATE.