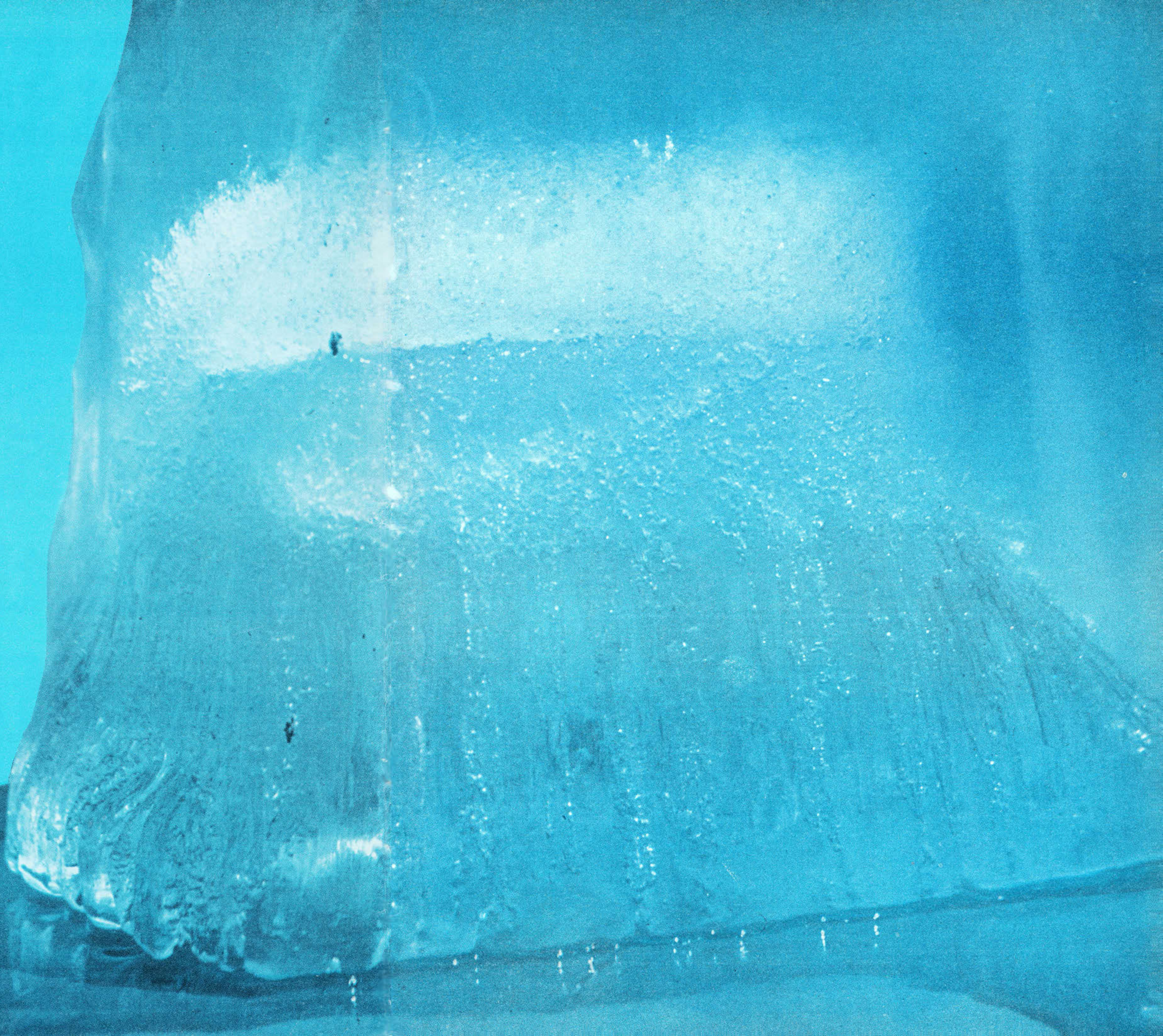
COOL IT!

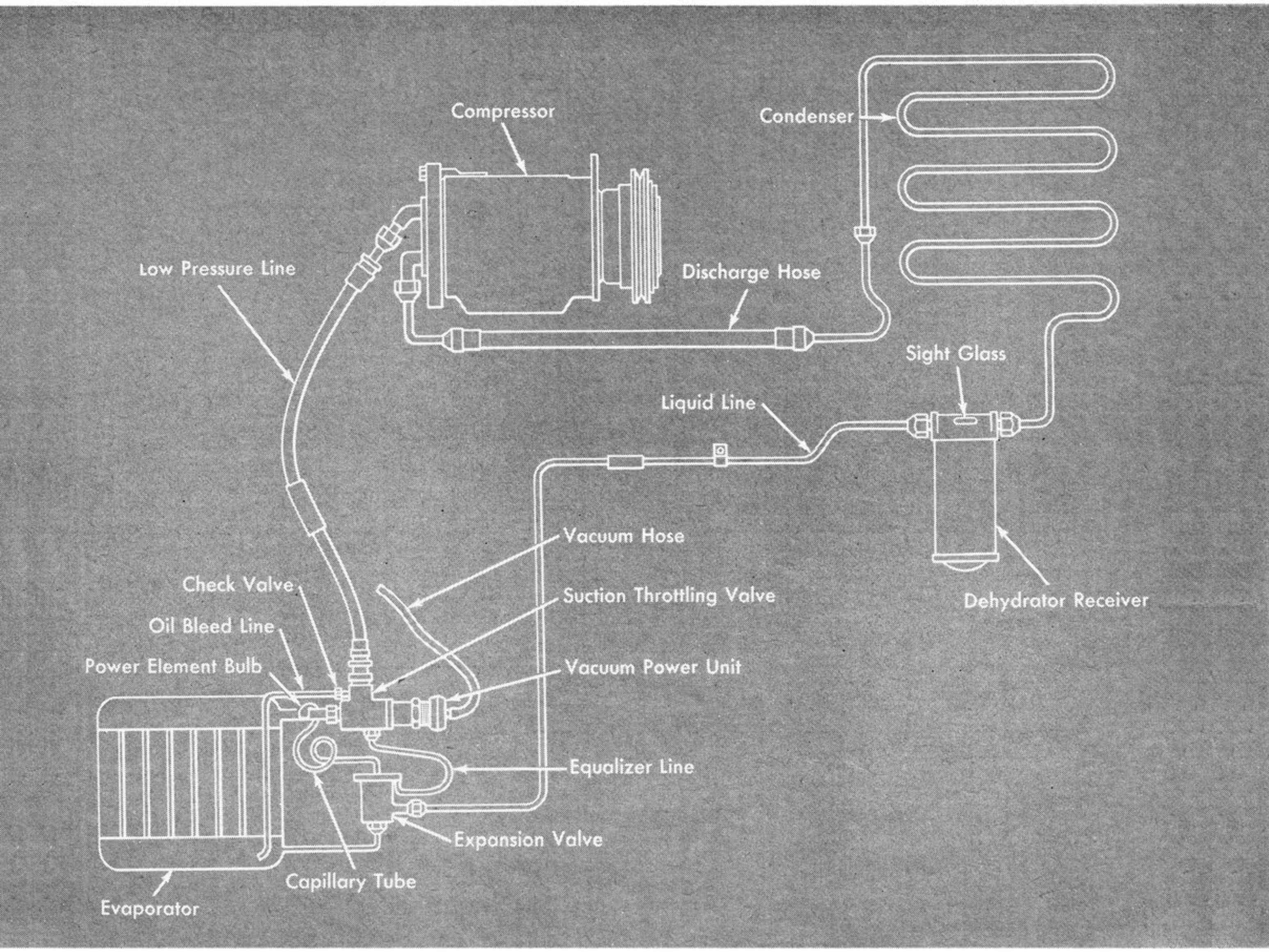
There's a Chill in the Automotive Air

BY ROGER HUNTINGTON

COLD AIR is the hottest item on the car accessory market today. No question about it. In 1960, 7% of U.S. automobile factory production was equipped with air conditioning. Only 5 years later the installation rate had risen to 23% of total auto production. It is predicted that by 1975 more than 50% of all cars will be produced with air conditioning. This growth rate is comparable with that of other popular accessories such as power brakes and power steering. What is remarkable is that these factory air conditioning systems cost from $300 to $500 extra on a new car. It's obvious that a very wealthy car market exists in America, but a great deal of credit for the boom should go to the air conditioning systems themselves. The equipment has been greatly refined in the past few years. Air conditioning offers a great deal for money spent. Air conditioning is a car salesman's dream because the units more or less sell themselves. They're easy to demonstrate to a prospective customer—which is not true of all potentially useful car accessories.

In automotive air conditioning, the basic operating principle, as with any refrigeration system, is that a liquid absorbs a great deal of heat when it changes from liquid to a vapor. This is because molecular motion is greatly increased in the vapor state and energy necessary to generate this motion is absorbed from surrounding materials. The basic problem with a refrigeration system is to find a liquid with a very low boiling point, at which it changes from liquid to vapor. This liquid should require very little pressure to liquefy it in the working temperature range. It should absorb a fair amount of heat as it vaporizes; that is, it should show a high "latent heat of vaporization." And, this liquid should function well with the system plumbing and compressor. The fluid found most prac-





TYPICAL OF air conditioning systems in late model General Motors cars is this one shown in schematic form. Expansion in the evaporator is controlled by both the expansion valve on the inlet and a suction-throttling valve on the outlet.

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tical for small car and home air conditioners is a chlorine/fluorine compound with the trade name "Freon-12." This is not an ideal refrigerant from some standpoints; but it has the important advantages of being odorless, non-poisonous and nonflammable. It boils at about -22° F at atmospheric pressure, and exerts a vapor pressure of 180 psi at 130° F.

The remainder of the system is strictly mechanical. The air is cooled by being blown through an evaporator core similar to a small fin-and-tube radiator. At the evaporator inlet the Freon is a liquid at medium pressure and temperature. An expansion valve releases it to a much lower pressure in the evaporator. This causes it to vaporize and absorb heat from the air going through the core. A tremendous amount of heat can be absorbed with a rise in vapor temperature of only 5 or 10° F, starting with a core vapor temperature of anywhere from freezing to 50 or 60°, depending on control settings. The vapor is drawn out of the evaporator by the compressor, usually a simple piston type. The compressor may be either a V form unit or an axial compressor with four or six pistons moved by a wobble plate. The compressor raises pressure and temperature of the refrigerant vapor to approximate maximums of 300 psi and 200° F, and pushes it along to the condenser located in front of the car's radiator.

This is where the vapor dissipates the heat absorbed from the air going into the car. The condenser is basically a fin-and-tube radiator that cools the hot compressed vapor generally 75 to 100° F, and thus condenses it back to a liquid at medium pressure and temperature. Condensers are not designed to be highly-efficient heat exchangers as are car radiators. The primary job of this component is to condense the compressed refrigerant, but it does dissipate quite a lot of heat. The cooling system designer must carefully consider these factors in laying out a system for an air conditioned car. Generally he must use a special high-capacity fan and radiator, sometimes a greater-than-standard capacity water pump, and the engine idling speed must be raised 100 rpm to provide extra fan and compressor power. Cooling conditions always are critical on air conditioned cars in hot weather. All the heat extracted from air going into the passenger compartment is poured back into the air going through the condenser and car radiator. The inefficiency of the entire cycle causes more than twice as much heat to be returned as is taken out!

From the condenser, the compressed liquid refrigerant goes back to the expansion valve at the evaporator, and the cycle starts again. Another essential item in this circuit is the dehydrator. This is usually a silica gel filter that absorbs any water that may be in the refrigerant. Keeping moisture out of the fluid is essential, of course, to prevent freezing in the lines. And, all air conditioning systems require automatic controls to limit vapor expansion in the evaporator to prevent evaporator temperatures from dropping below freezing. Otherwise the moisture in the air being cooled would quickly freeze and ice would block the evaporator to put the equipment out of service.

Air conditioning systems for passenger cars have an interesting technical history. They've been around probably longer than one might think. Packard offered the first optional factory-installed system on its 1938 models. Chrysler and Cadillac developed similar systems before World War II. Lincoln offered air conditioning soon after the war. By the early 1950s, Nash and all GM divisions, except Chevrolet, offered factory-installed systems. By the mid-1950s air conditioning was available with nearly all full-sized American cars.

However, air conditioning never really caught on with the mass market in these early years. The systems were very crude by today's standards and owners paid a great deal for what value was received. For one thing, early units didn't have electromagnetic clutches on the compressors to disconnect them from the belt drive when the system was not in use. The compressors would "idle" with no load which added to drag on the engine and wore out compressors faster. Car owners were instructed to remove the compressor drive belts in winter. This inconvenience was not popular.

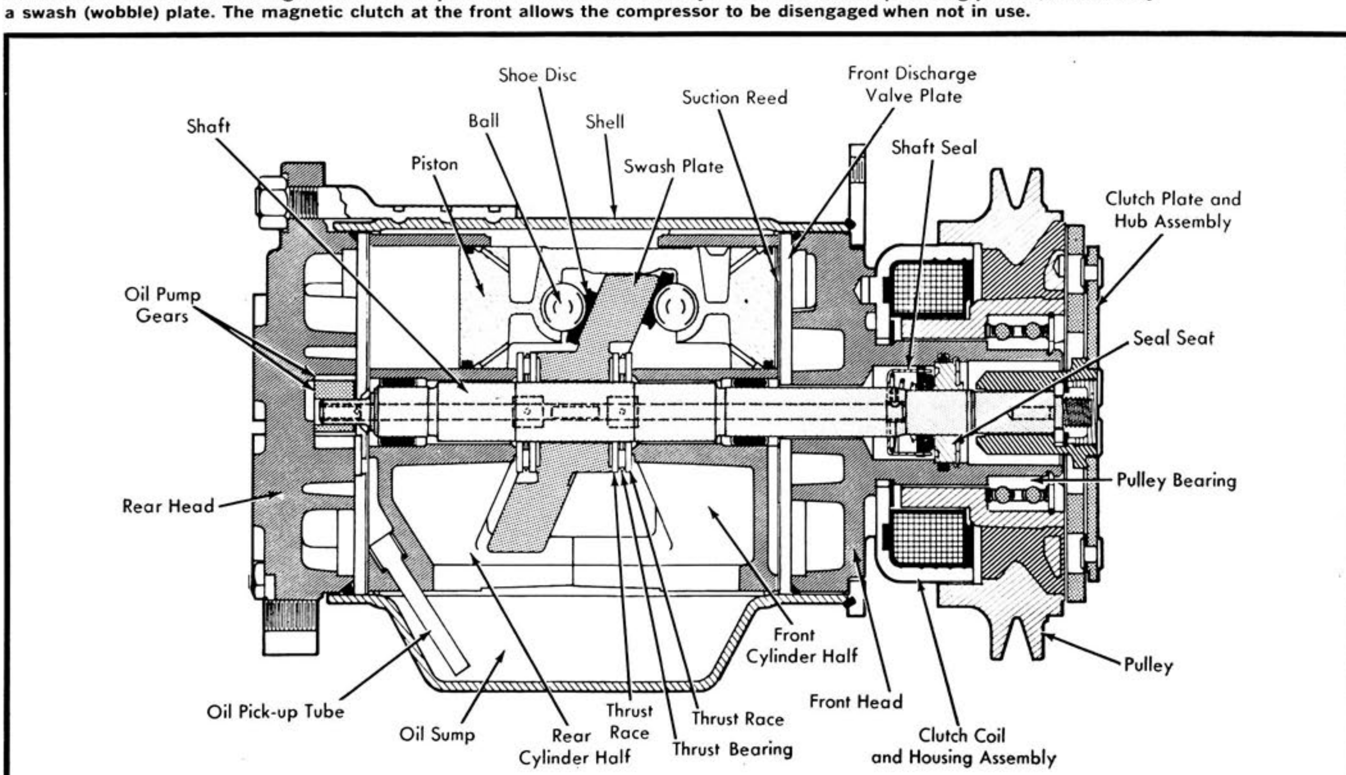
ANOTHER EARLY problem was that evaporator and blower assemblies were very bulky; locating them was a problem. The best place was in the luggage compartment, with the cool air blown forward along the roofline from behind the rear seat. Some cars had plastic ducts that ran along the edge of the ceiling to bring the cool air directly to the front seat compartment. This was a little better, but front seat passengers would have preferred to have the cool air flowing back at them from the dashboard area. Also, the plumbing required between the evaporator in the trunk and the compressor and condenser in the engine compartment was complex and vulnerable. Those early trunk-located air conditioning systems added nearly 300 lb. to the weight of the car!

Air conditioning started to come of age in the mid-1950s with advent of compressor clutches and cowl-located cooling units. GM's Harrison Division pioneered such a system for 1954 Cadillacs and Pontiacs. The evaporator was located in the rear of one or both of the front fender sections, with the blower in a separate housing between the evaporator and cowl intake. It wasn't a truly integrated system because the air conditioner wasn't incorporated with the heater, though they both used the same blower. The arrangement was far superior to the old trunk-located systems. It was more compact, simpler, cheaper and interior cooling was more efficient with the cool air coming from ahead of the passengers. In this case the cool air was discharged upward in the dashboard cowl area. It worked fairly well, though admittedly it was bulky and complex as compared with today's systems.

Nash and Hudson introduced the first true integrated air conditioning system in 1956. The evaporator was combined with the heater, under the cowl, and both used the same blower system. The layout was much like today's units, which, of course, are even more compact, cheaper and more efficient. Another important point is that integrated systems add only 150 lb. or less to the weight of the car, so very little acceleration performance is lost. This was an important technical development that must be credited to one of the "little guys" in the American auto industry. It wasn't long before the Big Three made similar systems available to auto buyers.

About this time the low-price volume ▶

CUTAWAY DRAWING shows Frigidaire axial compressor. The unit has three cylinders and six reciprocating pistons, actuated by a swash (wobble) plate. The magnetic clutch at the front allows the compressor to be disengaged when not in use.



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lines (Chevrolet, Ford, etc.) started to offer "hang-on" air conditioning units. There wasn't enough demand for this particular convenience in those days to warrant re-tooling these high-volume lines for integrated cowl systems. Hence manufacturers developed very compact evaporator units for attachment under dashboards. Sometimes these dash units had their own blowers. In other cases, with special ducts, they used the heater blower. They were quite efficient, and sold for $100 to $150 less than integrated systems on the higher-priced cars. They did seriously reduce legroom in the center of the front seat and they didn't appear integrated. It is significant that hang-on air conditioners for low-priced cars have only started to disappear in the past few years, as production installation rates on low-priced cars began to climb over 20%. Manufacturers can't afford to integrate optional accessories into volume lines until they're very sure the options have a real future.

The most recent vital technical breakthrough on car air conditioning systems is the "re-heat" principle, introduced on senior GM models in 1963. Very simply, all inlet air goes through the evaporator and is cooled to near freezing temperature, then the temperature of the air discharged into the passenger compartment is controlled by routing part or all of the cooled air through the heater core. The evaporator is kept at near freezing temperature at all times and the heater core is kept at 180–200° F at all times. Inlet air is first cooled and then re-heated, or not, as the temperature may require. On earlier systems the inlet air could be selected through either the evaporator or heater core, but not both. Temperature of the cooled air was controlled by varying the amount of vapor expansion in the evaporator by a manually-controlled valve—so the evaporator temperature might vary from 30° to perhaps 60° F or thereabouts.

The benefits of this new re-heat principle are obvious. By pre-cooling the inlet air to near freezing all moisture can be condensed from it. Then, by re-heating the system delivers warm, dry air in the car on cool, damp days. This adds measurably to passenger comfort. Condensed moisture keeps the evaporator coils wet, which permits these coils to act as a very efficient filter for inlet air. Particles of dust, smoke and pollen will cling to the wet coil surfaces and be drained off under the car with condensed water. The air going into the car is both de-humidified and filtered. Best of all, this condensing trick is effective at outside air temperatures as low as 40 or 45°. Air conditioning becomes an accessory that can be used almost year 'round by merely re-heating the cooled and de-humidified air.

This re-heat principle has caught on quickly throughout the industry. As of the 1966 model year, it has been adopted on the Dodge Polara and Plymouth Fury lines, Chryslers, Lincolns, on the Ford Fairlanes, Comets and Falcons, plus all the GM full-sized car lines and A-body compacts. Notable hold-outs are Ford, Mercury, and the junior Dodge and Plymouth automobiles.

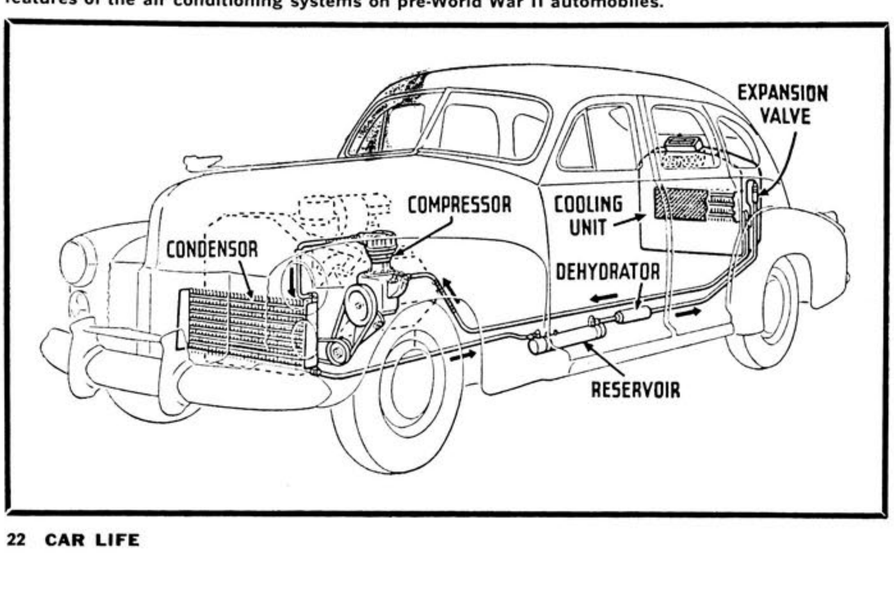
The majority of car owners with air conditioning wish to know just how much the cooling costs them in extra fuel consumption. Actually, engine power required to drive the compressor varies widely with rpm of the compressor, which determines its friction loss, and the pressure output. These factors, in turn, depend on car speed and outside air temperature. The compressor "head pressure" is determined automatically by the air temperature. The expansion valve and suction throttling valve on the evaporator are attempting to maintain the evaporator temperature at near freezing (on re-heat systems). This requires greater vapor expansion and higher inlet pressure as the temperature of the air going through the evaporator rises. Also, less cooling occurs in the condenser with higher air temperatures going through it, which means higher condenser inlet and outlet pressures. The result is that compressor head pressure may vary from 275 psi in an ambient air temperature of 100° F to only 130 psi when the outside air temperature is only 50–60°. This makes a tremendous difference in the power required to drive the compressor.

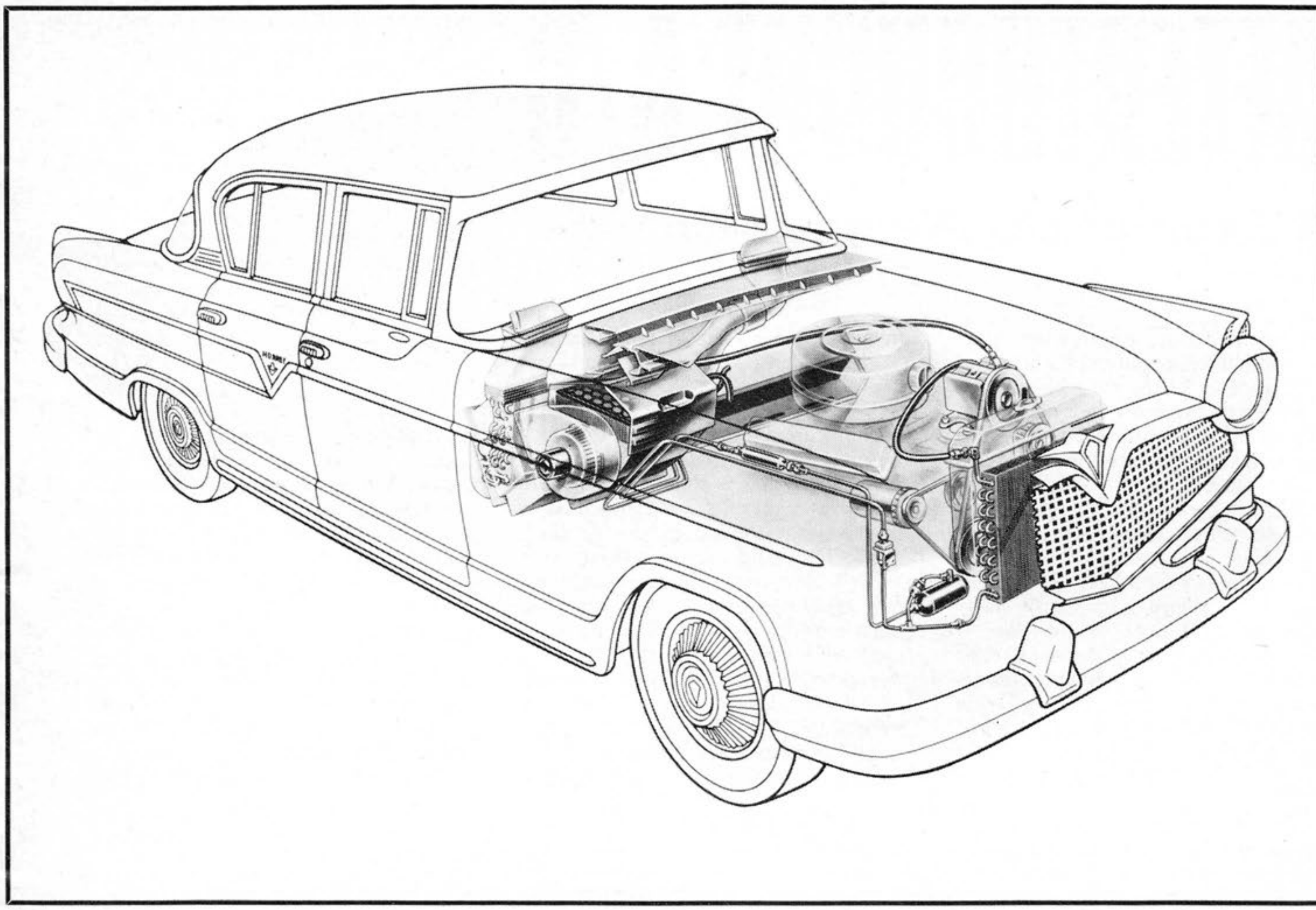
AT 60 MPH road speed, when the ambient temperature is 100° F, the compressor will pump 275 psi head pressure and require 6 bhp to drive it. This drag on the engine will consume 1 gal./hour of fuel. If the car delivers 14 mpg at 60 mph without air conditioning it would lose between 2 and 2.5 mpg with the system in operation. Most carmakers claim a loss of about 2 mpg under these conditions. However, if the ambient temperature is only 60° F, the compressor head pressure is 130 psi and thus only 3.5 bhp is required to drive it. Under these conditions the loss in mileage is only 1–1.5 mpg. The worst conditions for mileage loss with air conditioning is at very high road speeds of 80 and 90 mph in 100° temperatures. Here the friction losses in the compressor are high and can easily sap 8–12 bhp. The result is additional fuel consumption of 2 gal./hour.

The above figures are for a typical V-8 engine. An economy Six, however, has a lower specific fuel consumption and will show a somewhat lower fuel mileage loss even with the same compressor under otherwise equal conditions.

Car owners should not expect too much of their air conditioners under extreme cooling conditions. Cooling capacity is by no means unlimited. The designer must select a rated capacity and draw the line there. For example, with most systems the evaporator can be kept near freezing temperature in ambient air temperatures up to 80–85° F, with an adequate flow of air through the condenser. This will discharge air from the cooling outlet nozzles in the passenger compartment at around 40° minimum. The outlet

MASSIVE WEIGHT, complex plumbing and inefficiency were the outstanding features of the air conditioning systems on pre-World War II automobiles.





AMERICAN MOTORS offered the first fully integrated air conditioning system on the 1956 Nash Rambler and Hudson. Heating and cooling systems, combined in one dash unit, used the same blower. Weight was reduced to approximately 150 lb.

temperature does not reach freezing because the evaporator is not 100% efficient as a heat exchanger and some heat is picked up in the air tubes. But, conditions get rougher at higher ambient temperatures. In 100° air the automatic control valves may not keep the evaporator temperature below 40° F and the air discharge temperature will be 20° higher because of inefficient heat transfer at the higher temperature ranges.

And air conditioners must operate in even more severe conditions. High humidity reduces cooling capacity because of the heat absorbed in the evaporator when water condenses out of the air, the opposite effect of latent heat of vaporization. In 100° F ambient air at 90% relative humidity when the weather is unbearably "muggy" the evaporator temperature may run 60° at a compressor head pressure of 350 psi and the air temperature discharged into the passenger compartment may be over 80°! But it will be dry and this will make it feel cooler. Another tough cooling condition is when the car is standing still with its engine idling. There just isn't enough air flow through the condenser for very much cooling capacity even allowing for higher idling speeds and high-capacity fans. Under 100°, humid conditions, the air conditioners can't be expected to produce. The engine will overheat soon. Car manufacturers just haven't designed air conditioning systems to cool effectively under these conditions. They could, but the systems would be much more bulky and expensive and that capacity would not be needed 99% of the time. Hence, carmakers recommend either turning off the unit under such conditions or, if the car is moving at slow speed, to run in first or second gear to keep the fan speed up.

THE NEW all-weather heating/cooling systems now are being delivered with GM senior and Lincoln cars. With these systems the desired car interior temperature is selected with a dial and the system automatically maintains this temperature year 'round, delivering cooled or heated air as required. The operating principle of the cooling system on these cars actually is the same as described earlier for the re-heat system. The temperature is controlled by mixing hot and cold air and the evaporator and heater core are maintained at minimum and maximum temperatures, respectively, at all times. There's nothing new in the mechanical part of these systems. The key is in the electronic controls and electric and vacuum servos that actually mix the hot and cold air to maintain the preset interior temperature. These represent some brilliant thinking, plus a lot of hard work to induce function to follow theory.

Is this the direction that future car air conditioners will take? There's no question that this is the general design trend. Cars are becoming more automatic in every way, requiring less and less attention from the driver. There's no reason to believe the interior air conditioning system will be any exception. But it must be emphasized that a great deal of development must be done on these all-year systems. Current versions, frankly, are not reliable. They require frequent service attention because of their complex design. It will be some years before such systems are the standard air conditioning option in all price classes. ■