located in front of the radiator. This adds air restriction to the engine fan system and raises the air temperature entering the radiator. The most crucial conditions for the engine cooling are at idle or slow traffic conditions in temperatures over 100 F. Temperature-to-boil when operating at various loads is one way of evaluating the radiator cooling. Another method and somewhat simpler is to determine the time that an engine with air conditioning in operation can idle before the radiator reaches the boiling point (243 F when a 14 psi pressure cap is used), in 105 or 110 F ambients.

An air conditioner added to a car will, of course, require a portion of the available engine power. This may be as high as 7 hp at 100 mph, but at normal driving speeds the power needs will be reduced approximately 3–4 hp. The gasoline economy is not reduced appreciably, however, because the extra drag from open windows is eliminated when air conditioning is used. When the conditioning is not required, approximately 2 miles per gallon can be saved by disengaging the compressor. Use of a clutch reduces battery load for starting the engine.

Care must be exercised in adapting the compressor to the engine. It must be mounted so that undesirable vibrations are not introduced to the car. Usually the compressor should be very rigidly mounted to the engine mass so that the compressor pulsations are absorbed by the entire engine weight, thus reducing the amount transmitted into the car proper. In general, the compressor should be applied without affecting the operation of the engine or any of the accessories.

Styling

So far the requirements for the functional design and application of the automobile air conditioner have been discussed. The importance of styling and appearance cannot be overlooked. Some of the factory installed units are not readily visible so only the controls must be blended into the dash panel of the car. Some of the field installed units available at the present time are mounted in the open under the dash, and must be attractively styled to conform with the distinctive dash panels used in the automobiles.

Cost Considerations

It is important that the unit be designed and manufactured to give the customer a good value. The continued development and higher volumes have reduced the unit price to a reasonable level. Standardization of parts from one model to another as much as possible is desired to help reduce the unit cost, but at the present time this is not a controlling factor in unit design. The space limitations on each individual model are much more significant at the present time. As the demand for car air conditioning increases it will receive more consideration in the overall automobile design details.

DESIGN REQUIREMENTS FOR SPECIFIC COMPONENTS

The general design requirements for automobile air conditioners cover many new and variable phases that do not arise in the usual air conditioning applications. The wide range of operating conditions, peculiar air distribution problems and extreme space limitations make it necessary to design components specially suited for automotive air conditioning use. Some of the special considerations in design and selection of compressors, condensers, evaporators, and controls will be discussed in the succeeding paragraphs.

Compressors

A great deal of development work has been carried out in the past several years to make available compressors suitable

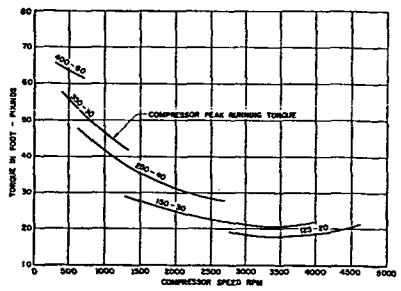


Fig. 4 .... Peak Torques Required to Drive Typical Compressor

for car cooling use. The modifications of commercially-available compressors that were first tried were found to be too large and noisy and incapable of holding up at the high speeds. A number of factors have to be considered in the design of an automotive compressor.

1. Displacement. The compressors used today have displacements of 9.0 to 10.5 cu in. per revolution. They are belt driven from the crankshaft at ratios ranging from 0.85 to 1.30. In order to improve pull-down and slow speed performance there is a demand for displacements of 12 to 13 cu in.

2. Physical Size. With increasing engine size and number of accessories under lower hoods, compressor size is most important. Length and height are particularly limited. Today's compressor requires approximately 0.2 cu ft of space for about 10 cu in. displacement. The larger displacement compressor being demanded cannot be any larger and preferably should be smaller.

3. Speed Range. Since compressors today are driven directly from the engine via pulleys and belts, they must withstand speeds up to 6000 rpm and must still be smooth and quiet down to 500 rpm. Unless some means for controlling compressor speed is developed, the top speeds may go even higher in order to improve low speed performance.

4. Torque Requirements. The instantaneous or peak torque requirements directly affect belt loads, clutch torque needs, and smooth and quiet operation. The fact that these torque and vibration problems are so closely tied together eliminates the possibility of using an economical single cylinder compressor because its peak torque and belt loads would be a maximum. A single cylinder compressor is also difficult to adequately balance for smooth operation and the large quantity of gas handled with each stroke makes muffling of gas noise difficult. Most of the compressors available today have two cylinders. The large displacement being considered may require three or four cylinders to be sufficiently smooth and quiet. The peak torques on some two-cylinder compressors operating at idle conditions with high head pressures may go as high as 70 lb ft. At these speeds there is no benefit gained from fly-wheel effect. Fig. 4 shows peak torques for a typical compressor operating at various conditions. The clutches must be designed to transmit these peak torques.

5. Weight. The weight factor is not of prime importance at the present time but as more and more engine and accessory weight is added to the front of the car, limitations will be imposed on the compressor. The compressors today weigh 16 to 32 lb.

6. Refrigerant. The compressors today use Refrigerant 12. Some Refrigerant 22 was used in the past to gain the additional refrigerating effect for a given displacement, but with Refrigerant 22 the high discharge pressures (up to 650 psi) at idle and slow car speeds were very undesirable and pressure pulses which generate vibrations were more severe. The higher pressures and temperatures also caused more compressor seal problems. With Refrigerant 12 the pressures reach 400 psi at the idle conditions and the impulses are of lower magnitude.

7. Ambient Temperatures. The under-hood temperatures where the compressor is normally located can reach 200 F. Cooling the seal under these high temperatures becomes a problem, especially since a clutch is usually applied as close to the compressor body as possible and obstructs effective air circulation in the seal area.

8. Lubrication. Splash systems have been satisfactory on auto compressors, but a forced-feed lubrication system is preferred for more positive bearing lubrication, better seal cooling and because the crankcase oil is agitated less, thus reducing the oil carry-over. Little loss can be afforded from the small oil supply, small because the sump size is dictated by space limitations.

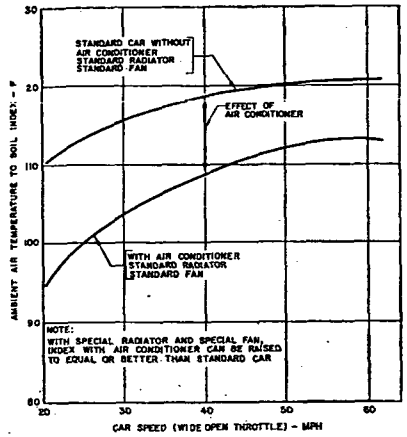


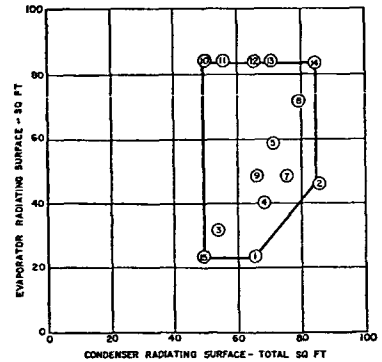
Fig. 5 .... Effect of Air Conditioning on Engine Cooling

Compressor Drives and Mounts

The compressors today are driven by one or two belts from the engine crankshaft pulley or water pump pulley. Magnetic clutches are commonly used so that the compressor can be disengaged when air conditioning is not required and in many cases is cycled for temperature control. A 5 or 6 in. diameter clutch pulley is required in order to have adequate belt wrap to drive a 10 cu in., 2-cylinder compressor. To avoid belt slap the belts should not have long unsupported spans. The pulleys, clutch, and belts must be balanced to avoid vibration problems. Compressor drives and mounts must be carefully designed to avoid objectional vibration periods between the compressor and engine and its accessories. The compressor should be mounted as solidly to the engine as possible so that it is an integral part of the engine. There is an urgent need for small, economically feasible and reliable means for controlling compressor and engine fan speed within at least a 4 to 1 speed range (1000 to 4000 rpm), and preferably lower (1000 to 2500 rpm).

Condensers

The condensers have on occasions been described as probably the biggest trouble maker and least engineered of any component in the auto air-conditioning system. Although the curves of Fig. 5 are not representative of the latest cars, they describe the effect of air conditioning on engine cooling, one of the important engineering problems in condenser design and application. The condenser pressures often are not held to a reasonable level at critical speeds—i.e., slow speed and idle. Actually considerable development work has been done to improve condenser surface design and construction but there are still condenser and radiator heat rejection problems. Further condenser system design is not as much a matter of determining or developing an optimum condenser surface as it is to somehow obtain adequate air flow at low speeds. There are several specifications that can be set up to guide the condenser design and its application to a car in front of the radiator.



* *Condenser radiating surface and corresponding evaporator radiating surface used on various systems having Refrigerant 12 compressors of approximately 10 cu in. displacement.*

Fig. 6 .... Coil Surface Areas for Factory and Field-Installed Automobile Air Conditioners*

1. The condenser surface should be sufficient to balance out a little below a normal air cooled condensing temperature for 110 F ambient. When traveling at 25 mph in an 110 F ambient, this would be on the order of 140 F condensing temperature.
2. The face area should be large, the depth shallow and the coil construction free on the air side to keep the restriction of condenser and radiator air to a minimum. An ideal condenser coil and condenser-radiator air system would provide the required condensing capacity and yet keep the engine cooling as good as it is on the car without air conditioning. This can only be done by increasing the radiator air flow when applying air conditioning.
3. At least 75 percent of the engine radiator air should pass through the condenser.
4. Recirculation of air from the engine compartment back through the radiator should be prevented as much as possible. Use of extra seals and baffles may be required to improve the cooling at idle.
5. The coil should have corrosion resistant treatment since it is often subjected to salt laden road sprays. Steel or aluminum fins and steel or copper tubes with proper corrosion treatment have been used successfully.

Evaporator

The evaporator section design is influenced by many of the normal requirements of compactness, low air restriction, uniform refrigerant distribution, etc., but there are some specifications that are peculiar to an evaporator for automotive use. The design point is quite difficult to establish because of the varying conditions and duty including: (1) the evaporator is to balance the capacity of a compressor-condenser combination that is changing from ¼ ton or less at idle speeds and high ambients to 2½ tons at high speeds and average ambients; (2) evaporator is frequently called upon to pull down the conditioned space, since there is no possibility of keeping the unit