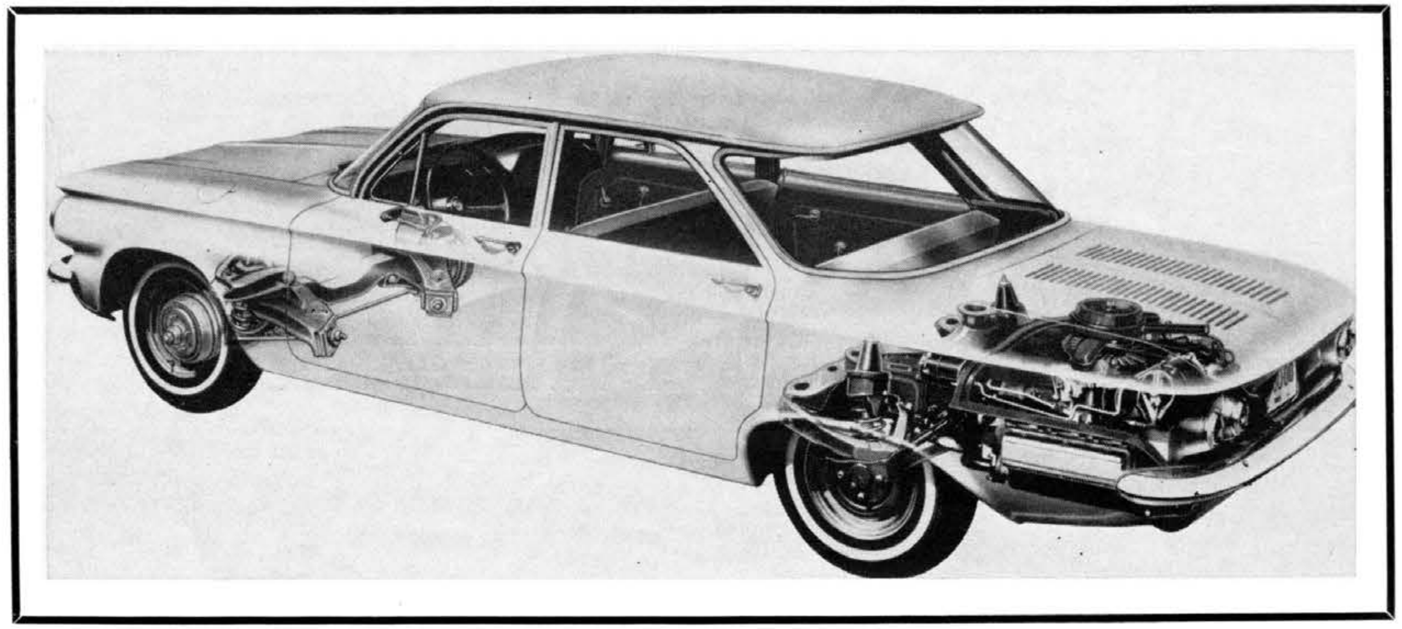
AIR-COOLING FOR CARS?

In Which We Try to Dispel Some of the Hot Air Surrounding Certain Claims

BY ROGER HUNTINGTON

THERE HAVE BEEN just enough successful air-cooled engines down through the history of the automobile to keep engineers and enthusiasts well primed on the possibilities of this simple form of cooling.



ONLY DOMESTIC EXAMPLE of air-cooled passenger car engine design is the Chevrolet Corvair, introduced in 1959 as an economy car. Horizontally opposed 6-cyl. utilizes a cooling fan.

Harry Knox built air-cooled cars without separate cooling blowers in the early 1900s. He called his car the "Waterless Knox." The Franklin people held on longest with air-cooling, building cars up through 1934 and with up to 12 cylinders and 150 bhp. Franklin used some radical longitudinal fin designs and highly developed blowers.

In the late '30s there were the air-cooled German Volkswagen, the American 2-cyl. Crosley and 4-cyl. White Horse delivery truck. All these used horizontal opposed engines with blowers. Today there is the Volkswagen—plus the Porsche, Citroen, Panhard, NSU, DAF and, of course, the Chevrolet Corvair.

But why hasn't there been more air-cooling down through the years? Is it really as practical as it looks? Are there technical developments on the horizon that can make it more practical in the future? What is its true potential today?

The gas temperatures inside an automobile's engine cylinder vary tremendously, from less than 200° F. on the suction stroke (when fresh fuel-air mixture is being drawn into the cylinder) to over 4000° at the peak of combustion. Tests have shown that the average gas temperature over the four working cycles is on the order of 1200° F. in the combustion chamber (next to the cylinder head) and about 600° in the bore, next to the walls. When one considers the large volume of fuel-air mixture that is being burned in the cylinders in a unit of time, it's obvious that there's a lot of heat to get rid of, in order to control component temperatures.

There are two general ways to do it: Surround the cylinders and combustion chamber with water jackets so that the heat passes through the walls into the water, then is transferred from the water to air in a radiator of some sort. Or, the heads and cylinders can be cooled directly by a blast of air flowing over them. This merely requires that the heads and barrels be cast with fins on them so that they will have sufficient surface area to transfer the heat input from the fuel combustion. It sounds simple and, when everything is right, direct air cooling can be quite efficient—within limitations.

Actually, air flow cools the engine in both cases. With liquid cooling the heat is absorbed in water first, then transferred to the air through the radiator. In both cases there must be a good supply of air to do the cooling. A car's forward motion will put sufficient air through a radiator to do the job; but a fan is needed to draw air in at very low speeds and when idling. Similarly, with direct air cooling, it can be accomplished without a separate blower in an airplane or motorcycle, where the cylinders are out in the open. But in a car, a blower is almost always needed to move the necessary volume of air.

Now, about heat transfer: The thermodynamics textbook says that the quantity of heat that is transferred from one medium to another (air, liquid, metal) depends on the heat-transfer coefficient between the two mediums, the area of surface in contact and the temperature difference between them. Heat transfer increases as any one, or all three, of these factors increase. But there's a special problem in the question of air vs. water cooling: The heat-transfer coefficient between a cylinder wall and the water in a jacket is roughly 100 times greater than between that same wall and a blast of air flowing across it. This means that to transfer the same quantity of heat, the air-cooled engine must have a much larger cooling surface area exposed to the "coolant" and the temperature difference between the surface and the air will be much greater than between a cylinder wall and the water in a cooling jacket.

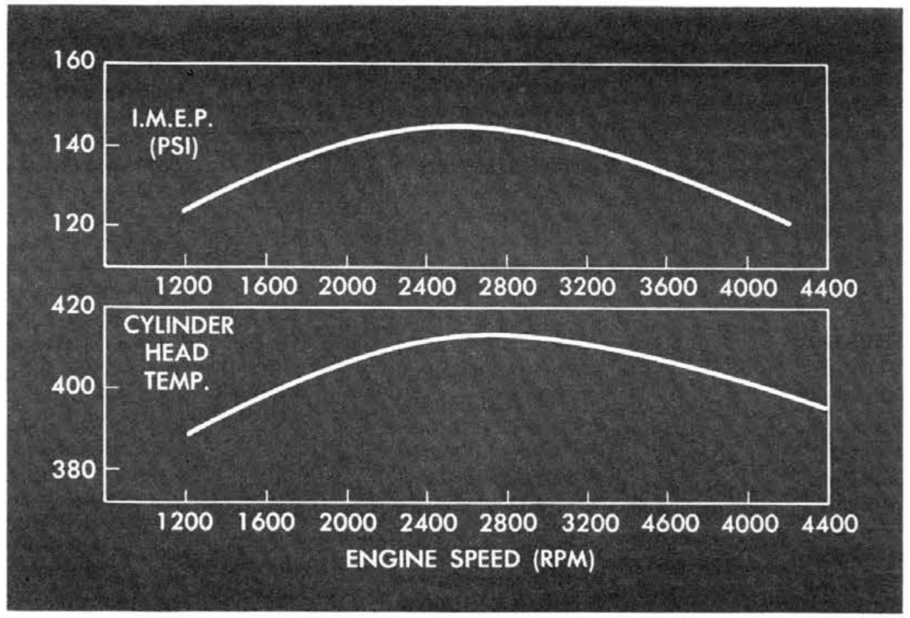
Of course, the large cooling surface area can be obtained by the casting of long, narrow fins around the head and cylinder. An extreme example of this is the huge Pratt & Whitney Wasp Major aircraft engine, which develops 125 bhp from each of its 28 cylinders, each of which has 4300 sq. in. of fin area! This gives an idea of the scope of the problem.

Then there's the temperature difference. The interior cylinder and combustion chamber surfaces run much hotter on an air-cooled engine. On a liquid-cooled engine these surfaces are only about 50-75° F. above the temperature of the water in the jacket. (The difference is represented by the temperature drop as heat is transferred through the wall.) On a typical air-cooled engine these surfaces will run generally between 400 and 550° at full power—or roughly twice that of the water-cooled engine. This is the temperature difference it takes to transfer the heat input with the available surface area and transfer coefficient.

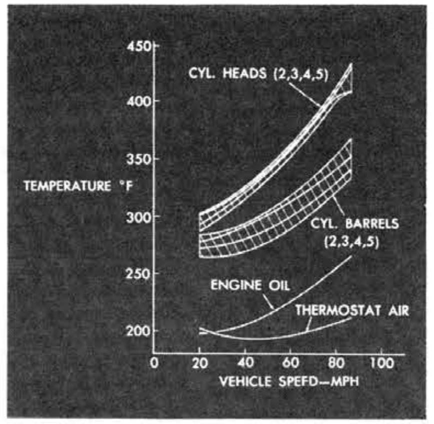
Right here is probably the biggest problem with air-cooling. The high surface temperature in the combustion chamber invites pre-ignition and detonation. Both these combustion phenomena are triggered by high localized temperatures in the combustion area and all interior temperatures will run just that much higher in the air-cooled engine.

In the past these engines have traditionally had to use lower compression ratios with a given fuel octane, other factors remaining equal. The current Corvair and Volkswagen engines, as well as air-cooled aircraft engines, all have relatively low compression. The lower compression, of course, somewhat compromises the fuel economy and potential horsepower per cubic inch.

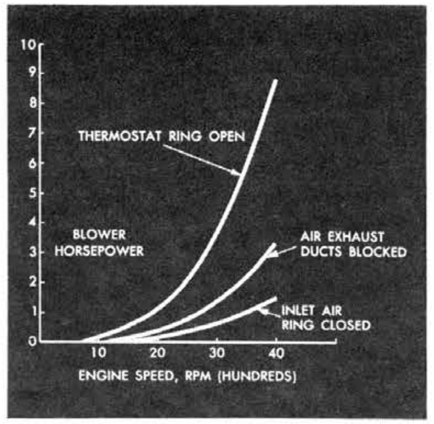
It would be hard to pinpoint the exact effect of this problem, because of the lack of test data on exactly similar engines with air and water cooling, but admittedly the world's air-cooled engines have never been leaders in terms of bhp per cu. in. displacement. (Of course, some of this may be because of less aggressive engineering development. Note that air-cooled military aircraft engines in World War II didn't need to apologize



VARIATION OF cylinder head temperature with rpm of Corvair under full throttle. Note that it is nearly directly proportional to torque output—which depends on IMEP.

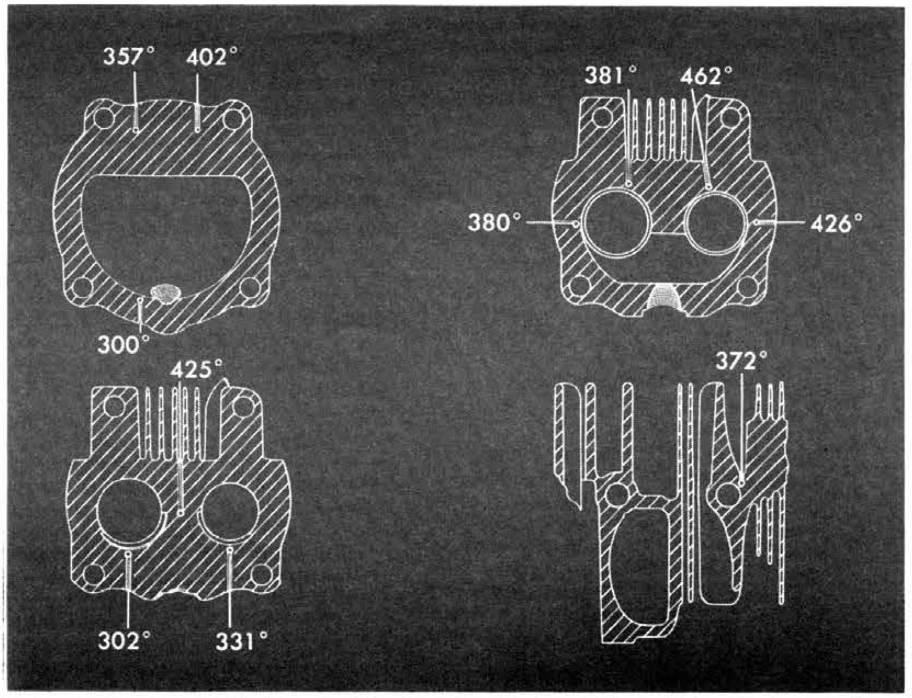


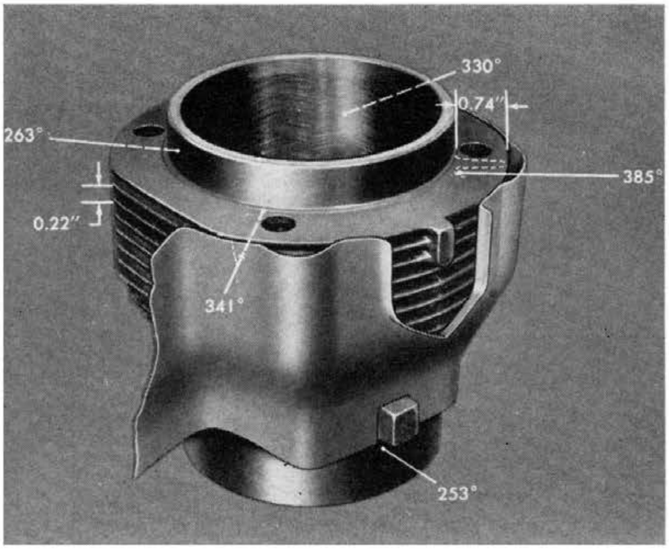
TEMPERATURE readings through Corvair engine at "road load" at various speeds.



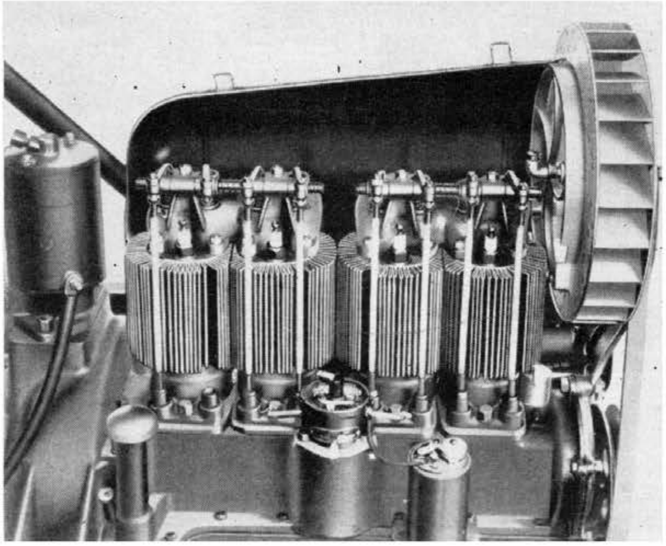
POWER REQUIRED by cooling blower rises sharply as engine speed increases.

TEMPERATURE MEASUREMENTS on Corvair cylinder heads at 4000 rpm with wide-open throttle. Some high-output air-cooled engines run over 500° under full-load conditions.





CYLINDER BARREL temperatures at 3000 rpm for the Corvair. Baffles direct cooling air around back of the cylinders.



ORIGINAL AIR-COOLED Chevrolet was built in 1923, had vertical copper fins welded to steel cylinder barrels.

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to the liquid-cooled engines for their performance. This was because of forced-draft development under wartime conditions. Air-cooled automotive engines could presumably be developed the same way, given a proper stimulus.)

A common criticism leveled against air-cooled engines is the amount of power eaten up by the cooling blower. Admittedly this is a problem. The Corvair blower requires nearly 9 bhp at 4000 rpm engine speed (6400 rpm blower speed). But this is at full power. Corvairs have a thermostatically-controlled throttle ring in the blower inlet that chokes off the air flow when cooling requirements are low on the road, so the average power drain, on the road, would be less than 2 bhp.

The water-cooled engine doesn't get off scot-free on cooling loss, either. The average fan requires 4-5 bhp at 4000 rpm engine speed and the water pump would want another 2 bhp at this speed. Also, there is a definite aerodynamic resistance due to air flow through the radiator core at highway speeds that eats up even more power. (It is significant that the Corvair body, without a radiator, has the lowest coefficient of drag factor of any modern American car.)

Engine noise is a problem with air cooling. The cooling blower moves a lot more air than a radiator fan, and thus makes more noise. Modern acoustic engineering has made progress in quieting these blowers; but they are still audible, while the driver can't hear a radiator fan at street and highway speeds in his water-cooled car.

Another important engine noise angle: Water jackets in cast-iron blocks and heads make excellent sound insulators, muffling a lot of internal engine noise. There is no such shielding with an air-cooled engine. Cast iron has a certain inherent sound-damping quality, but most air-cooled engines have aluminum heads, because of the better heat-dissipating characteristics of the light alloy.

So, there definitely is a noise problem with the air-cooled engine.

Some observers say air-cooled engines are considerably more expensive to build than liquid-cooled designs. The difference probably isn't as large as they think. Admittedly, the head and cylinder casting task is more complex and costly because of the fins. Then there's the additional cost of the elaborate cooling blower and sheet metal baffling around the cylinders. A separate oil cooler is usually desirable, too. But look at the complete liquid-cooled engine installation; there's a separate water pump, radiator and all the associated plumbing. It's still possible that the overall cost of the air-cooled installation would be a little more, but the difference is probably not a killing handicap to the air-cooled engine.

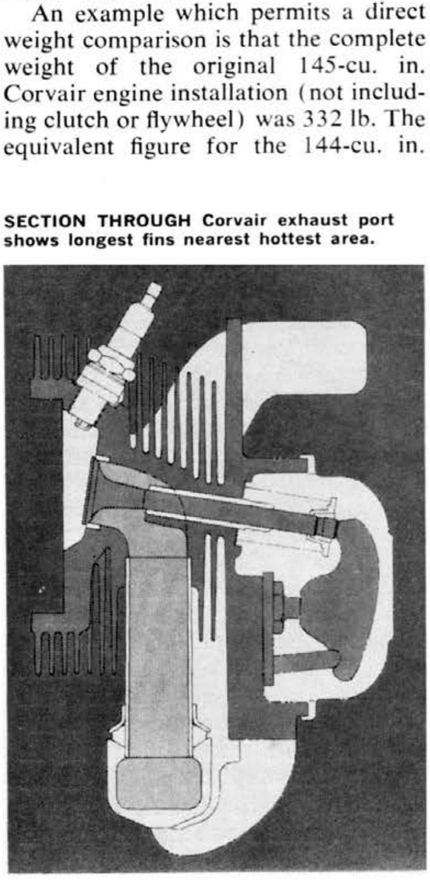
So far the discussion has just been about the disadvantages of the air-cooled engine. How about the good points? There are some important ones.

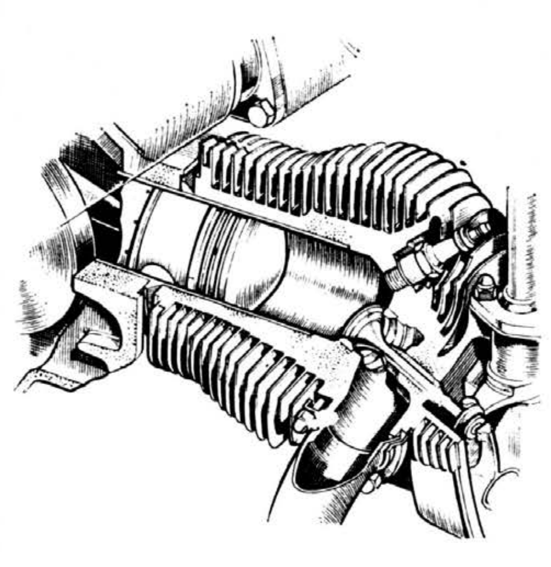
Foremost, of course, is the elimination of cooling system maintenance. There are no problems with water loss or antifreeze, no clogged or frozen radiators, no hoses to replace. About the only attention an air-cooled engine needs is periodic replacement of the fan belt. If an extra one is carried in the car, the driver has almost complete insurance against cooling system failure.

Air-cooled engine installations also are lighter than their equivalent liquid-cooled engines. The heavy water jackets, radiator, plumbing and the 30-40 lb. of water needed to fill the system add a lot of dead weight to the liquid engine installation.

An example which permits a direct weight comparison is that the complete weight of the original 145-cu. in. Corvair engine installation (not including clutch or flywheel) was 332 lb. The equivalent figure for the 144-cu. in.

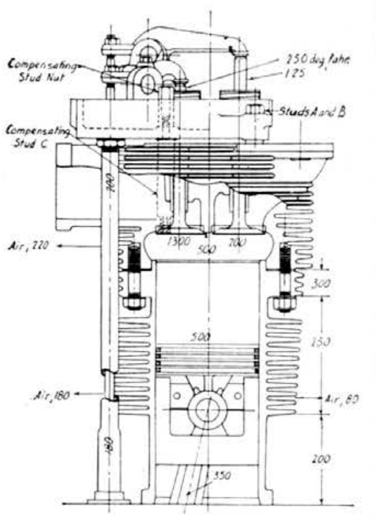
SECTION THROUGH Corvair exhaust port shows longest fins nearest hottest area.



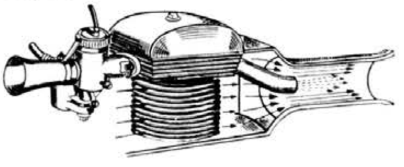


STEEL LINER inserted in aluminum barrels of French Dyna-Panhard engine locates cylinder on crankcase.

FRANKLIN ENGINE design of 1930, showing temperatures at various points. Compensating stud near exhaust valve kept valve clearance nearly constant.



EXTRACTOR effect on this Tatra design has exhaust gases rushing out venturi sucking cooling air out, too.



water-cooled Falcon engine, which came out at the same time, was nearly 100 lb. more. This latter engine also incorporated all the modern weight-saving iron-casting techniques, too.

A more obscure advantage of the air-cooled engine, which came to light only during the recent Corvair program, is an apparent reduction in bore wear under similar operating conditions. The air-cooled engine just seems to last longer before excessive oil consumption due to ring and bore wear. Chevrolet engineers have noticed this about the Corvair (though they hesitate to quote specific figures).

The reason for this is obvious: Most ring and bore wear comes when the engine is running cold. Lubrication is marginal at this time, clearances are tight, there is much scuffing and much of the wear is due to corrosion from condensed acids. But the air-cooled engine warms up much faster because there isn't the cold water in the jackets to absorb the heat. The engine runs with cold cylinder walls for a much shorter time and thus has a slower wear rate.

The problem of the car heating system is the toughest problem and is very controversial. Many Detroit engineers say it's nearly impossible to develop an efficient interior heating system using hot cooling air from the engine. The problem is further aggravated when the engine is in the rear: There's plenty of warm air available from the engine, but the problem is to duct it efficiently to the passengers with sufficient force and without engine odors. Corvair engineers started out with a separate gasoline heater but have since developed an efficient hot air system. Volkswagen engineers have never developed a decent heating system in all the years the car has been built.

There are several promising areas where air-cooled engines might be radically improved for future passenger cars.

For one thing, new precision casting techniques, such as shell molding, might permit more square inches of fin area per cubic inch of displacement on heads and barrels and thus reduce surface temperatures in the combustion chamber. This would permit higher compression on a given fuel octane. It also has been found that a very rich fuel-air mixture is quite effective in reducing head temperatures, due to the heat absorbed by the fuel when it evaporates on the compression and suction strokes.

WARTIME AIRCRAFT engines used very rich mixtures and water injection to get "liquid cooling" during bursts of full power. Automotive engines might do the same thing.

Water or alcohol injection might be considered too elaborate, but it should be easy enough to calibrate carburetors to feed a little richer mixture on full throttle than would be used for the equivalent liquid-cooled engine. Thus, better finning and a richer mixture might permit half to one point higher compression ratio on a given fuel—and then the air-cooleds would be back with the liquid-cooled engines on bhp/cu. in.

Air-cooling protagonists have always dreamed of a system whereby the jet extractor effect of the exhaust gas flow through a venturi could be utilized to draw cooling air over the fins so the need for a separate blower would be eliminated. This looks good on paper. Carl Doman of Franklin, now Service Engineer for Ford, showed such a design in 1945. Fletcher Aviation, in 1954, took up the idea during development work with a Porsche engine.

This ultimately led to a new engine, the Fletcher Flair, a flat 4-cyl. of 65 bhp which weighed only 185 lb. It never got into production, but it had no fan—it relied on Fletcher's patented jet-cooling system. This system eliminated the cost and power absorption of the cooling fan but Fletcher never explained what it used for mufflers. Obviously a very low back-pressure would be required to make jet-cooling practical for application to every-day passenger cars.

More efficient blowers and cylinder baffling would also help a lot on noise. There are lots of possibilities in this area. Keep in mind also that fin design can be related to the problem of noise; that is, with more efficient finning, the cooling air flow could be cut down, which would reduce noise. Further insulation of the car body also would help.

The problem of car heating, however, will remain. Cutting down the cooling air flow will reduce the heat available for the car. Of course, if the air-cooled engine was placed in the front of the car, the problem would be greatly eased. Shorter, more direct heat ducting would work better. Otherwise, perhaps auxiliary gasoline heat will be necessary for very cold climates. A combination heating system, using part engine air and part auxiliary gasoline heat, might do the job with a minimum drain on fuel economy.

So those are some of the problems of the air-cooled engine. Its true potential is hard to judge. It is hard to imagine big luxury cars using air-cooled engines—they're probably most practical for smaller economy cars. The current Corvair and Volkswagen engines in this class are highly successful designs which are practical in every way, although even they could be improved with some concentrated engineering development. ■