ENGINE & DRIVE-- WHERE SHOULD THEY GO?

In handling and traction tests of conventional, front-drive, mid-engine and rear-engine layouts in four similar cars, we found each to have its own advantages and disadvantages.

PHOTOS JOE RUSZ

(Reprinted from July 1973 Road & Track.)

IN THE BEGINNING it didn't much matter where the engine was, so long as it was near the driving wheels. The important thing was whether or not a car actually moved under its own power, not how fast it traveled or how well it went around corners. But as cars became more sophisticated and people became more sophisticated about cars, controversy arose concerning the inherent superiority of one design over the others. One famous manufacturer of front-wheel-drive cars argued that since no one in his right mind would put the cart before the horse, an engine should be used to pull the car instead of pushing it. These and similar arguments continue, and though automotive design practice has evolved into four basic categories—front engine/rear drive, rear engine/rear drive, front engine/front drive, and mid-engine/rear drive—there is still a general lack of agreement as to which is best.

One area in particular—vehicle stability and handling—has been the subject of some of the most heated debates. Each manufacturer can list any number of reasons why its particular design is superior. That some carmakers have engines and drive trains in more than one location in similar cars and can present equally convincing arguments for each with a straight face leads to further confusion. Better to say that each has its own unique characteristics, advantages and disadvantages.

With that general viewpoint, we set out on this test to find out just what those characteristics, advantages and disadvantages are. Our year-in, year-out experience with cars of the various mechanical arrangements led us naturally to have some preconceptions. Some of these were confirmed by our tests; others were contradicted. Before we go to our tests and their results, let's first discuss the theory and practice of the four layouts.

Front Engine/Rear Drive

DESCRIPTIONS OF the first automobiles as horseless carriages are really quite appropriate. They were literally carriages—short wheelbase, enormous ground clearance, large-diameter wheels and all—with a small engine fitted under the seat. At that time this was adequate for low-speed motoring with two or three passengers. But cars began to grow larger, especially in America, and space for six or seven passengers was demanded. Engines had to be increased in size to pull (or push) these loads and it soon became apparent that locating

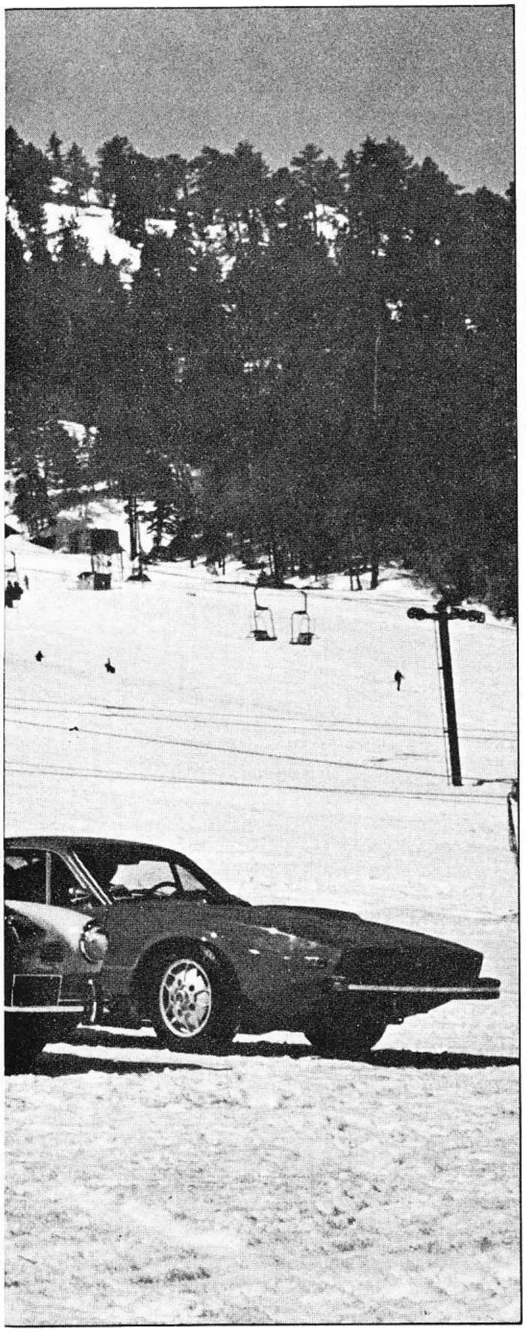
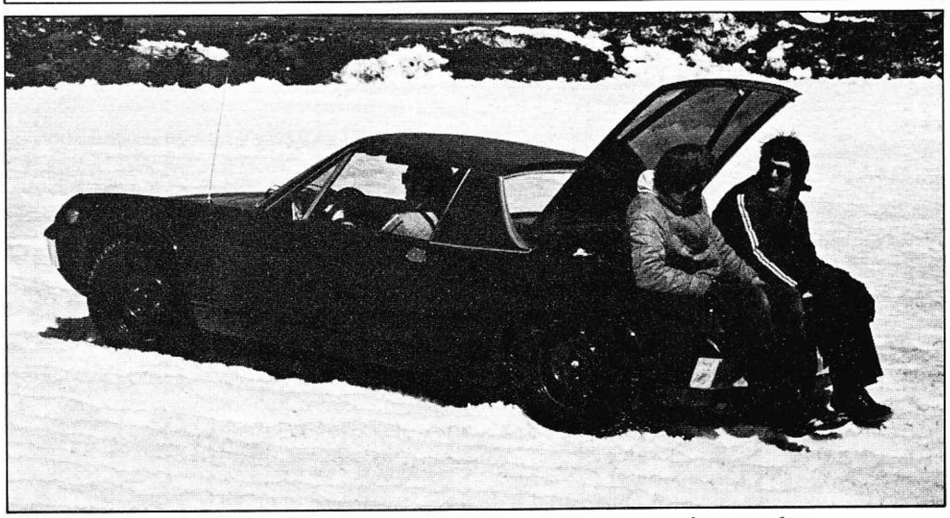


Fig. 1

TEST CAR SPECIFICATIONS

	Opel GT front engine/ rear drive	Saab Sonett front engine/ front drive	Porsche 914 mid-engine/ rear drive	VW Karmann Ghia rear engine/ rear drive
General:				
Curb Weight, lb	2035	1830	2145	1960
Weight Distribution (with driver), front/rear, %	55/45	60/40	47/53	42/58
Wheelbase, in.	95.7	84.6	96.5	94.5
Track, front/rear	49.4/50.6	48.5/48.5	52.4/54.0*	51.3/52.7
Length	161.9	160.0	159.4	165.0
Width	62.2	59.1	65.0	64.3
Height	47.4	47.0	48.4	52.0
Engine:				
Displacement, cc	1897	1698	1971	1584
Bhp @ rpm, net	75 @ 4800	65 @ 4700	91 @ 4900	46 @ 4000
Torque @ rpm, lb-ft	92 @ 2800	85 @ 2500	109 @ 3000	72 @ 2800
Chassis:				
Wheels	13 x 5	15 x 4½	15 x 4½*	15 x 4½
Tires (original equipment)	165-13 bias	155-15 radial	165-15 radial	6.00-15 bias
Manufacturer's recommended tire pressures, front/rear, psi	19/23	24/22	26/29	18/27
Front Suspension	Independent, Trans Leaf Spring	Independent, Coil Springs	Independent, Torsion Bars	Independent, Torsion Bars
Rear Suspension	Live Axle, Coil Springs	Beam Axle, Coil Springs	Independent, Torsion Bars	Independent, Torsion Bars

* 15 x 5½ wheels are original equipment on 914 2-liter; 15 x 4½ wheels were used for this test and gave test car these track dimensions.



Balanced weight distribution of a mid-engine layout is a disadvantage in the snow, but "dead" weight on the driven wheels can be used to get through low-traction situations.

the engine under the seat was no longer practical.

The geography of the U.S. had an influence on engine placement as well. Long, flat stretches in the midwest and the high mountains of the west required cars with greater horsepower and as metallurgy was in its infancy, increasing power meant larger and larger engines. Displacements of 500 and 600 cu in. weren't uncommon—try fitting one of those monsters under the rear seat!

The effect of racing on automotive design was also strong. Cars that were successful in racing sold well to the public and those early American racers were big, brutish affairs with enormous engines located up front. But even then designers knew something about wheel loadings and the effect of weight distribution on handling, so many of these cars were actually forward mid-engine designs with the engine several inches behind the front axle for better weight distribution.

Over the years a great wealth of know-how about designing cars with front engines and rear drive was built up, and it was cheap and convenient to incorporate a high proportion of well-tried components in each succeeding new model. So the conservative auto industry, especially in the U.S. and Britain, was reluctant to change from the established front engine and rear drive.

There are advantages other than cost and design experience to a front engine/rear drive layout. Size is a major factor. Packaging five or six passengers plus luggage is a more difficult engineering task with a rear engine design and to date it hasn't been done with a midship engine in the current sense. A front engine/rear drive car lends itself to an inexpensive independent front suspension for improvements in ride and steering. A solid axle at the rear cannot offer the first-class ride of independent designs but does have its advantages. One is low cost; the other is the elimination of camber change with its possible extra tire wear and abrupt reversals in handling characteristics.

The effect of ram air through the front grille and forward-mounted radiator makes a front engine relatively easy to cool and accessibility of commonly serviced components is generally better than with mid- or rear-engine designs. Today, safety is an obvious consideration and most designers see in the front-engine layout the only solution to providing adequate crush space (for protecting passengers in a front-end crash) at reasonable cost.

Then there's handling. A noseheavy front-engine car understeers under most conditions and engineers view this as an asset for the average driver. A driver is less likely to get into serious trouble upon entering a corner too fast if the car's front end runs wide than if its tail has a tendency to come around.

There are minuses to a front engine/rear drive layout as well. The driveshaft is a necessary evil of any front engine/rear drive car; it encroaches on passenger space and makes for uncomfortable seating for the middle passengers. An aerodynamic body shape is more difficult to achieve when a designer has to work around a bulky engine up front since it won't let the nose taper as sharply as it might. For racing applications the front-engine car is also at a disadvantage as far as driver comfort is concerned: cockpit heat is a serious concern in most big front-engine race cars. Weight transfer toward the rear when accelerating is an asset in a rear-drive car, but wheelspin can still pose a problem if the proportion of weight on the rear wheels is low. Conversely, weight transfer toward the front during braking unloads the rear wheels too much in a very nose-heavy car to fully use the four tires' friction capabilities.

Front-Wheel Drive

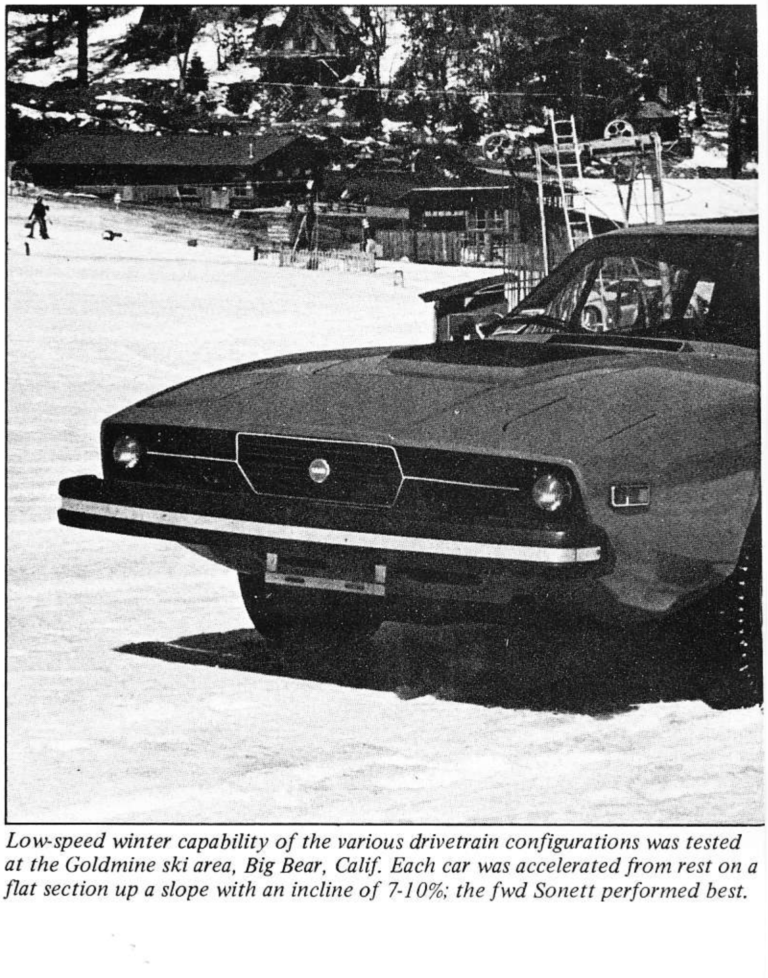
FRONT-WHEEL drive for road vehicles goes back long before the invention of the internal-combustion engine, the most famous ancestor being Cugnot's 3-wheel steamer of 1770. The first car to actually use fwd was patented in 1904 by an American, Walter Christie. He mounted the 4-cyl engine transversely across the frame, a disposition that has gained widespread acceptance, particularly in Europe, over the past decade.

After Christie's racing car, there was a long time before any company used the principle in a series production car. In Germany during the Thirties the low-priced Adler proved popular as did the fwd DKW, and Europeans developed an interest in fwd. Citroen has built nothing but fwd cars since 1936 and in England fwd was given a boost by various Austin and Morris models starting with the Mini. Today companies such as Fiat, Saab, Renault and Audi build fwd cars with technical and commercial success.

In the U.S. fwd is new only to the youthful and forgetful; at least five such cars have been produced in some volume. The last one before WWII was the legendary but relatively short-lived coffin-nose Cord, discontinued in 1937. The first modern American fwd design, the Oldsmobile Toronado, appeared in 1966 and was followed one year later by the related Cadillac Eldorado. Though technically interesting, these cars are successful more for their luxury appeal than the esoteric aspects of fwd.

In Europe and Japan the current trend to smaller urban-type cars has resulted in several fwd designs: Peugeot 104, Renault 5, Honda Civic and Subaru models to name just a few.

Why such interest in fwd? A fwd layout gives maximum interior passenger and luggage space with minimum outside dimensions, particularly when the engine is transverse in the chassis. It's easy to see why. Combining the engine, transmission and final drive into one unit makes for a compact power package. The driveshaft is eliminated, making a flat floor possible, and even a simple beam axle at the rear reduces trunk intrusion to a minimum. There is a drawback to this design sophistication: added cost. Contributing factors include the more costly gearing on a fwd car and the rather tricky front axle system. More money must also be spent to keep noise and vibration from the power unit out of the passenger compartment. But there are offsetting cost savings as well. A beam axle is simpler to suspend than the solid live axle of a rear-drive car (although some fwd cars have independent rear suspension). The driveshaft is also eliminated—another saving.



Low-speed winter capability of the various drivetrain configurations was tested at the Goldmine ski area, Big Bear, Calif. Each car was accelerated from rest on a flat section up a slope with an incline of 7-10%; the fwd Sonett performed best.

Front engine/front drive cars are very noseheavy, 60% or more of the total weight on the front end being common, so excessive front tire wear can be a problem. On large fwd cars a further disadvantage is incurred from the extreme forward weight bias; power steering becomes a necessity rather than a nicety.

Weight bias and the forward driven wheels combine to explain the driving characteristics that are unique to a fwd design. On a steep gradient, for example, weight transfer from the front to the rear wheels helps traction with rear-wheel drive and reduces it with fwd. But the disproportionate successes of fwd cars in rallies and ice racing provide the real answer to suggestions that they lack traction in difficult conditions. With rear-wheel drive the driven wheels try to propel the car along a straight line, resisting efforts to deflect it from its path. Driven front wheels apply their tractive effort in the direction in which they are steered and on slippery roads this is a definite advantage.

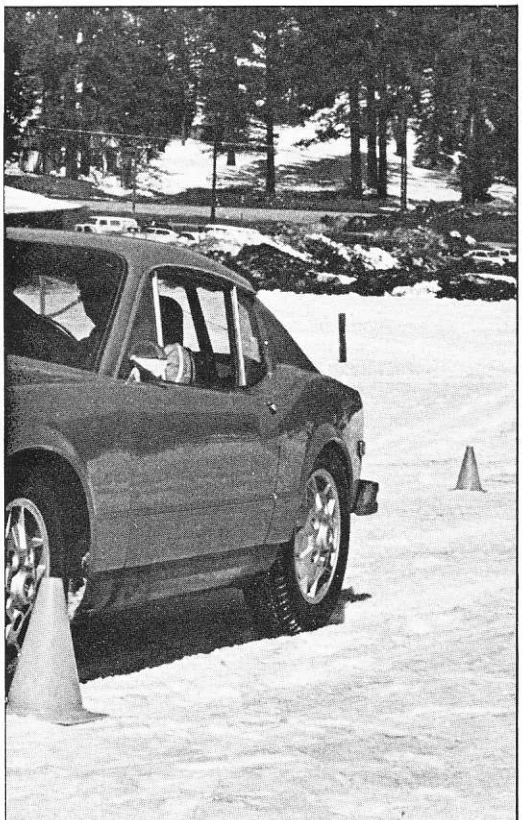
In a fwd car weight transfer to the rear when accelerating reduces traction, and this wheelspin problem led many designers to postulate that fwd was only suitable with low-powered cars. But the Eldorado and Toronado disprove this contention. Under braking the opposite effect occurs—weight is transferred to the front. The same overloading of front brakes and locking at the rear mentioned for front engine/rear drive cars applies, only more so. Modern disc brakes and proportioning systems at least minimize this disadvantage.

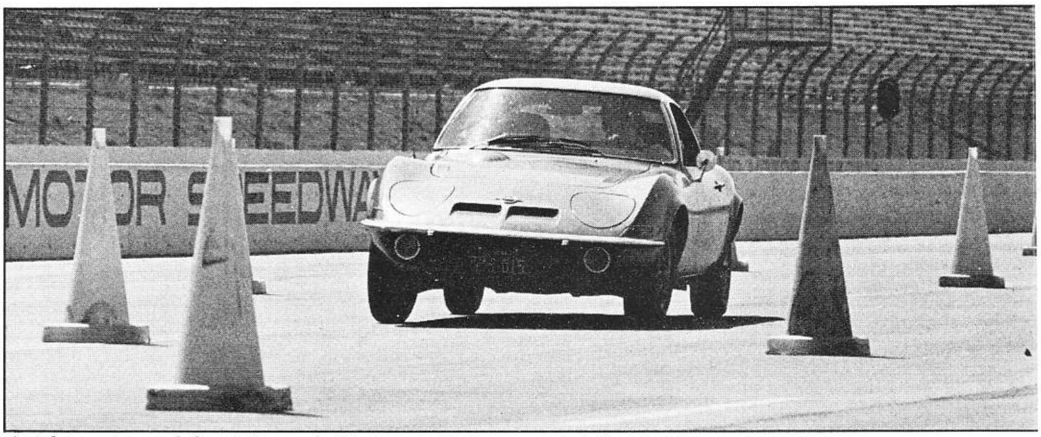
A criticism of fwd cars is that it is necessary to corner with power on, and that if power is taken off the car becomes unstable and oversteers. Fwd cars do corner differently but it's hardly a truism with today's designs that instability when cornering is their basic nature. The reverse is closer to the truth. With almost any car there is some change in cornering behavior when the driver accelerates because a tire which is transmitting power cannot generate as much side force as the same tire when it is rolling freely. So a cornering tire runs at a larger slip angle when also delivering power. With rear-wheel drive, acceleration when cornering increases the slip angles of the rear tires, increasing oversteer (or in the case of most front engine/rear drive cars, reducing understeer). With fwd it is the front tires which run at larger slip angles when cornering under power, so the front end tends to run wide in an understeering attitude with power applied. However, if power is suddenly released the front tires are relieved of their double duty and the car understeers less, assuming the tucked-in nose characteristic of fwd cars under these conditions. Depending upon how much the designers of the particular car have tried to suppress fwd understeer, the result will be simply less understeer or—rarely—some oversteer. But many front engine/rear drive cars also oversteer under the same conditions.

Many manufacturers mention the "arrow principle" in explaining inherently superior straight-line or crosswind stability of fwd. Their reasoning is simple; did you ever try to throw a dart, feathered end first, and hit a target with any degree of accuracy? There is a bit of truth of this "logic," we must admit, as evidenced by the unusually stable behavior most nose heavy fwd cars exhibit in a crosswind. But the reasons are a bit more complex than the simple arrow principle implies.

Rear Engine/Rear Drive

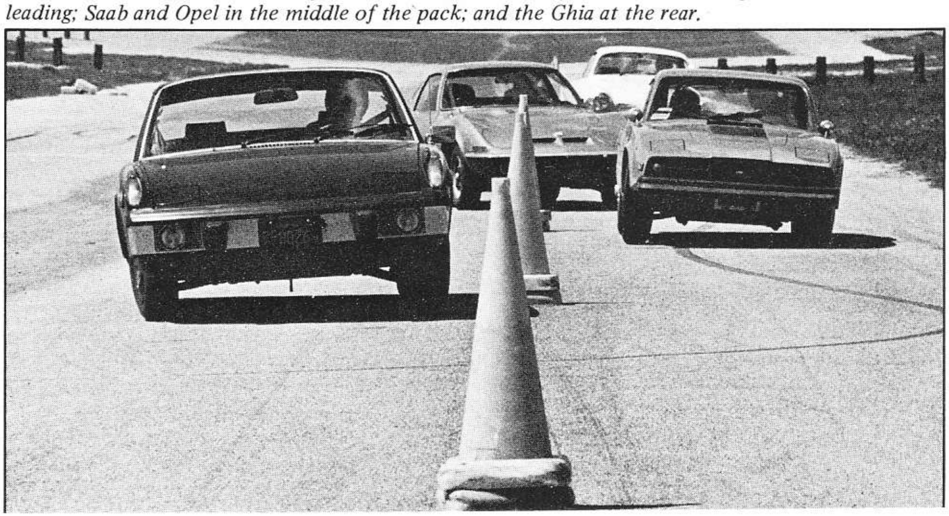
ALTHOUGH REAR-ENGINE cars such as the Julian in the U.S. and the little German Hanomag were produced in the 1920s, it was probably the success of the Auto Union Grand Prix cars in the 1930s that laid the foundation for future mid-engine and rear-engine designs and encouraged Dr Porsche to apply the principle to his VW design. The Auto Union was technically a mid-engine design but the car was so large and the enormous engine positioned so far rearward that a distinction between the two engine locations was hardly ever made. The Porsche 356 which made its debut at the Geneva Show in 1948 broke completely with traditional sports-car design. The conventional front engine sports car of the day had its engine





Quick steering and the ability to hold a controlled power-on drift gained the front engine/rear drive Opel GT a second place in the lane-change maneuver.

Results in the slaloms were as expected: the 914, with low polar moment and good balance, leading; Saab and Opel in the middle of the pack; and the Ghia at the rear.



up front and drive wheels in the back, a ladder-type frame with low torsional rigidity, rock-hard suspension with little roadholding on anything but the smoothest of surfaces, and little or no protection from the elements.

The objective of the Porsche was more along the lines of a high-speed touring GT with due consideration for fast, safe touring in relative comfort. To achieve this goal Porsche used what were basically his VW components—a lightweight, air-cooled engine at the rear, a rigid platform chassis, independent suspension at all four wheels—in an aerodynamic body shape. Compared to conventional sports cars the Porsche had light, responsive steering, smooth ride on all surfaces, a roomy passenger compartment and adequate luggage space, and was incredibly quiet at speed. It also oversteered to an excessive degree because of its rear weight bias, swing-axle rear suspension and skinny tires. And from these early examples grew the notion that all rear-engine cars oversteer in dramatic fashion.

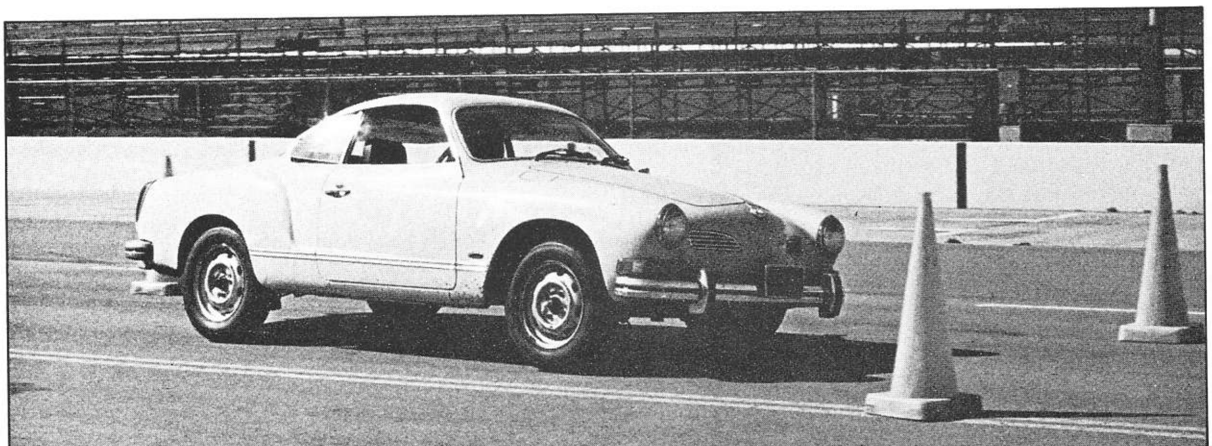
More than 10 years after the introduction of the 356, the first and last modern rear-engine American car appeared: the Corvair. Early examples suffered many of the symptoms of classic oversteer but later models, tamed by better design, were enthusiast's delights. While several companies have built rear-engine cars of modern design today, only the smallest Fiats, France's Alpine-Renault A310, Czechoslovakia's Tatra and various VW models stick with the rear engine placement.

There are several advantages to a rear engine location. As with front drive, there's no driveshaft tunneling through the cabin. With a natural weight bias on the driven wheels, wheel-spin should be reduced and traction improved in slippery conditions, again much as with fwd. Weight transfer toward the rear when accelerating increases the load on the rear wheels and further improves traction; weight transfer to the front during braking tends to equalize wheel loads for more even braking. Clean aerodynamics, as important for fuel savings and quiet cruising with a road car as for top speed and stability in a race car, are easier to achieve with a rear-engine layout. Cockpit overheating, an important consideration with a race car, is less likely to arise when the engine is behind the driver.

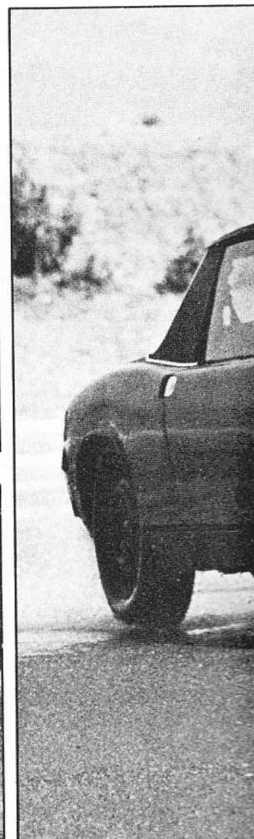
Offsetting these advantages are the problems with adapting this configuration to more than a 2-place or 2+2 design. A full sedan design puts an inordinate amount of weight on the rear end when the back seat is occupied and a station-wagon load in the rear compounds the imbalance. Though a sloping front end is fine aerodynamically, it invariably compromises the front luggage compartment, so rear-engine cars can't always take advantage of the lack of an engine up front in this way. Air is the logical cooling medium for rear engines, although water cooling has been successfully used. Thus the problem of cooling the engine in a confined location out of the direct airstream arises. A front radiator is a possibility but this solution is costly, complex and wasteful of luggage space. The obvious solution is a small, alloy engine which can be adequately cooled by ambient air, fitted to a small car. Sounds like a VW or Porsche, doesn't it? The abrupt oversteer characteristic of early rear-engine cars is not necessarily a problem with later designs: it is possible by judicious juggling of suspension, tires, tire pressures, geometry, etc, to considerably tame oversteering tendencies, but the problem of sidewind stability is more difficult.

Mid-Engine/Rear Drive

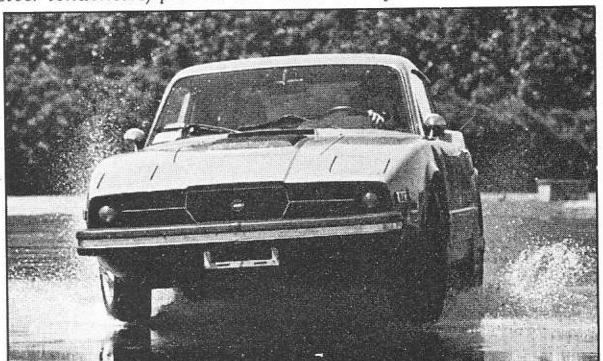
THOUGH MID-ENGINE designs are typically thought of as products of modern racing technology, Gottlieb Daimler placed the engine behind the driver, offset to the left, on his 1886 motor carriage. This was more for convenience than an attempt at design superiority. However, convenience wasn't the reason for the midship engine layout of the Benz Tropfenwagen, also known as the "teardrop car" because of its uncompromisingly streamlined shape. Raced with moderate success in several versions in the 1920s, the Tropfenwagen was overshadowed by the more glamorous supercharged Mercedes and later Mercedes-Benz cars. The significance of this car wasn't lost on Dr



Slow steering, soft front tires, and body roll (concessions to oversteer tendencies) proved the Ghia's downfall in the lane change.



Heavily loaded outside front wheel worked against the Opel.



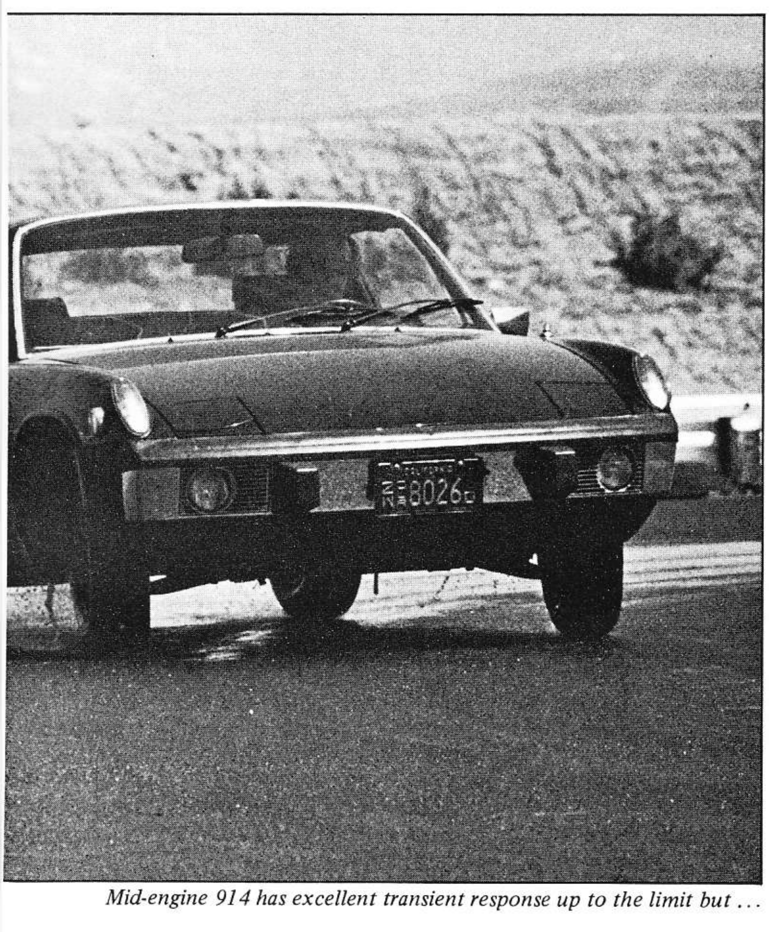
Understeering Saab was easiest to control in oil/wet skid pad.

Porsche, who made the midship engine/transaxle configuration work successfully in the Auto Union Grand Prix cars. Later, Porsche designed the mid-engine 550 Spyder, the first racing Porsche not derived from the 356 series, which enjoyed a fantastic competition record and is a forerunner of such successful Porsche racing models as the 904 coupe, the 908 and the turbocharged 917/10.

Cooper pioneered the first truly modern mid-engine Grand Prix cars in the mid-1950s and built one of the earliest sports-racing cars, the Monaco. Following Cooper came a succession of successful mid-engine designs—the indecently quick Lotus 23, Lola 70-Chevrolet, Ford GT, Ferrari 250LM and the much-copied McLaren designs of the late 1960s and early 1970s.

Production mid-engine cars have lagged behind their racing counterparts. One of the first was the Rene Bonnet Djet, later called the Matra Djet, introduced in the early 1960s. The Djet was a somewhat ungainly-looking 2-seater sports car—an inauspicious beginning for mid-engine designs to follow—expensive 2-seat luxury GTs like the De Tomaso Mangusta and its replacement the Pantera, the Ferrari Dino, the Lamborghini Miura (first with a transverse mid-engine) and the thoroughly modern Maserati Bora. These are cars that have ushered in a new era in automotive design, and for those with more down-to-earth budgets there are now the Lotus Europa, Porsche 914—the first mass produced mid-engine car—and the recently introduced Fiat X1/9.

The almost complete takeover of racing by cars with a mid-engine configuration can be explained by the term *polar moment of inertia.* For illustration, consider two bowling balls attached at the ends of a weightless bar. If you lift the bar in the middle and try to turn it you will find that the weight of the balls at each end make movement difficult to initiate and stop. Now, however, if the bar is shortened so that the two balls are placed next to each other the system is much easier to rotate, without a decrease in total weight. The polar moment of inertia has been decreased. When the driver, engine, transmission, fuel



Mid-engine 914 has excellent transient response up to the limit but . . .

tank, etc, are all placed between the wheels, the polar moment of inertia of the car about the center of gravity is low; thus the tires can more easily alter the course of the car. Steering is usually responsive and sensitive too. There are other benefits as well: the majority of weight is again on the driving wheels but the distribution isn't so extreme as with the rear engine or front drive; cornering power can be at a maximum; handling characteristics can be tailored with few compromises. Aerodynamic considerations are an important factor. Unhindered by an unwieldly chunk of cast iron at the front end, designers have far more latitude in shaping the nose and overall body shape for minimum drag with maximum downforce.

But if the driver can easily move the car out of a straight line, so can other kinds of forces, such as a bump or a sidewind. So the mid-engine car gives but it also demands. In exchange for higher cornering power, the mid-engine design asks for a driver with a high degree of competence. Mid-engine cars don't break away easily but when they go, they go suddenly. Drivers who are accustomed to tire squeal or body roll as signs of imminent danger often have difficulty in predicting the breakaway of mid-engine cars because they approach their limits so undramatically.

In racing, where lower lap times alone are the telling factor, a designer may often compromise some areas of the car to reach this goal. Road cars, however, must meet more complex automotive needs. So there are several problems which have kept the mid-engine car from achieving the popularity one might expect. Cost is a primary consideration. Innovation usually costs money, at least until economical solutions to basic problems are achieved.

Because the engine sits right behind the driver in a mid-engine car, such a layout is really only adaptable to 2-seat sports and GT cars. Attempts that have been made to provide extra seats, as in the Lamborghini Urraco, are incomplete solutions at best. For a mass-produced car serviceability is a definite consideration, and accessibility is not a strong point of most mid-engine designs. Add to this heat and noise from an enclosed engine compartment close to the passengers, and you have problems that make even strong engineers cringe. Finally there's the question of rearward vision. No mid-engine car yet with the possible exception of the Porsche 914 has come up with a successful solution to that problem.

The Test Cars

MATCHING FOUR cars of such varying designs for our testing was not the difficult task one might imagine. The Porsche 914 and the Saab Sonett (mid-engine and front-drive categories) were easy choices as they're the only examples available to us at the moment. Our 914 was the 2-liter variety and therefore the most powerful car in our group, but this was of little consequence as none of the tests we planned placed any emphasis on engine performance. Selecting a conventional sports car required a bit more thought, but the choice was finally narrowed down to the Opel GT which fit within the weight, power and dimensional specifications of the previous two choices. Picking a rear-engine sports car was the most difficult. There's the Fiat 850; but it's considerably smaller and lighter. At the other end of the spectrum is the Porsche 911, a heavier car with power and sophistication that clearly set it apart from the basic nature of the rest of our group. Right between these two, however, is the VW Ghia—not a sports car in the strict sense of the term but right as far as size, weight and uncomplicated design were concerned.

The weight distribution of each of these cars pretty well fits the classic definition: the front-engine Opel with 55% up front, the 60/40 distribution of the Sonett, the aft-heavy Ghia with 58% on the rear wheels and the 47/53 distribution of the mid-engine 914.

To eliminate any inherent unfair advantage the 914 might enjoy because of wheel width (the stock 15 x 5½-in. wheels of the 914 2-liter are the widest in our group) the stock cast alloy wheels were replaced with the identical 15 x 4½ steel rims used on the Ghia or 1.7-liter 914. And since original-equipment tires vary considerably between the four cars, we standardized the tires. To be sure we were testing configurations and not tires, we obtained a spare set of wheels for each of the cars and fitted each with Pirelli Cinturato CF67 radials of 165-mm section width. Besides the tires, Pirelli supplied one of their top tire engineers, Clive Castell, from their Reno, Nevada test office. His technical advice, recommendations and physical assistance were of great value in our testing. To eliminate tire pressure as a factor in our tests, all tires were inflated to the manufacturer's recommendation for light loads. Pertinent specifications of the four cars are given in Fig. 1.

The Tests

THE NUMBER and variety of tests planned meant several testing sites were needed. We started at the Goldmine ski area in Big Bear, Calif., jumped to the Bondurant School of High-Performance Driving at Ontario Motor Speedway for three days, and finally went to Orange County International Raceway in Irvine for low-traction skidpad evaluations.

Fred Goldsmith, owner of the Goldmine ski area, offered R&T the use of his facilities to test low-speed winter traction capability of the various configurations. Each of the cars was accelerated from rest around a gently curving flat section. At the point where the curve ended and the slope began a marker was placed, beyond which the land sloped gradually upward to an incline of 7–10%. Each car was timed to the marker and the distance driven up the hill past the marker recorded.

Snow condition was hard packed, with a light crust affording maximum traction for this sort of surface. Theory points to the superiority of the rear-engine car in these conditions with front-wheel drive about equal on the flat sections but falling behind on the slopes. Mid-engine and front engine/rear drive cars, particularly, should be at a disadvantage and would be expected to be pulling up the rear of the pack. Over several runs the Saab surprised us by achieving a better time to the marker and running farther up the hill. Several factors explain the Saab's performance. First, the lower portion of hill wasn't unusually steep, so adverse weight transfer off the driving wheels was not an important consideration. Look back, however, to the tire pressure entry in the table of general specifications. Notice that the front pressure for the Saab is 3 lb less than the rear pressure for the Ghia. Our counterparts at *PV4* Magazine have proved the benefit of reduced tire pressures for traction in the sand, so the Saab has an advantage here. As a quick check we reduced pressures in the front of the Saab and the rear of the Ghia to 15 psi, and now the Ghia motored right past the Saab. We intend to pursue the question of tire pressure vs traction next winter in much more detail.

The 914's superior weight balance worked against it here, and it also suffered from the highest tire pressure on the driving wheels of any of the cars. The Opel's poor showing was expected and can be attributed almost entirely to its 55/45 weight distribution.

Short and Long Slaloms

TRAVELING TO warmer weather, we arrived at Ontario Motor Speedway. Here we devised two tests of transient response: a high-speed lane-change maneuver and low- and high-speed slaloms. Purposes of the slaloms were to determine if transient response of the cars varied with speed and to pick out "overshooting oscillations," if any, leading to instability and oversteer. Pylons were positioned in a straight line 50 feet apart for the low-speed course and every 100 ft for the high-speed slalom. The time from first pylon to last was recorded and later converted to the speed figures listed in the results, tabulated in Fig. 2.

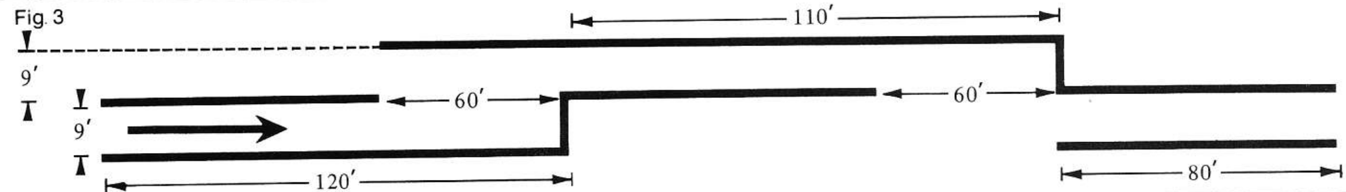
Here the results substantiate theory. The mid-engine 914 with its low polar moment, quick and precise steering and good weight balance proved superior at both speeds. Through the

Fig. 2

TEST	Opel GT f/r	Saab Sonett f/f	Porsche 914 m/r	VW Karmann Ghia r/r
Short Slalom (pylons spaced 50 ft apart, measured distance=500 ft): speed, mph	27.7	27.8	**28.7**	27.2
Long Slalom (pylons spaced 100 ft apart, measured distance=700 ft): speed, mph	50.2	51.7	**52.0**	47.5
Lane Change: speed, mph	62.5	61.4	**65.2**	59.5
Snow Traction:				
Time to marker (standing start), sec	20.67	**13.05**	18.78	16.50
Distance driven past marker up incline, ft	10	**143**	24	101
Steady-State Cornering (low traction oil/wet skidpad):				
Speed on 85-ft radius, mph	22.4	**23.4**	23.1	22.7
Lateral acceleration, g	0.396	**0.432**	0.419	0.405

All tests conducted on Pirelli Cinturato CF67 tires, 165-mm section

Fig. 3



low speed course the excellent caster action of the 914's steering was an important factor in its quickness, and through the long course its balance came into play. It achieved good bite front and rear, with the tail end hanging out slightly.

In a virtual tie for second place through the 50-ft course were the Opel and slightly quicker Sonett. Though the positions remained the same in the high-speed event the margin of separation opened up considerably in favor of the Saab. The Opel's quick rack-and-pinion steering allowed the car to be precisely positioned from pylon to pylon, but working against it was body roll and weight transfer to the outside front wheel. This became very apparent at higher speeds as the noseheavy Opel scrubbed off speed with each reversal of the steering wheel. Perhaps a better-handling front/rear car would have done better.

The Saab's fwd pulled it around the pylons into a second place finish. There is an obvious noseheavy feel to the Saab, but understeer never became excessive. That the Sonett's cornering attitude can be controlled by the throttle played a part in its quickness around the pylons: by proper applications and reduction of throttle the Saab could be aimed from pylon to pylon with precision.

The Ghia ran dead last. Its slow steering, excessive body roll and soft front tires (compromises to reduce oversteer) work against it all the time. The helm does not readily answer the call when asked to reverse direction abruptly, so one must drive slowly to keep from getting caught up without enough steering lock. The heaviness of the tail is evident but never a problem; when it starts to slide it goes very slowly and in a controlled fashion. There is no "dreaded oversteer" with the Ghia, but perhaps if there were it would have done better in this test.

Lane Change

THE LANE-change maneuver was another matter entirely, and though final results are identical to those in the slaloms with one exception, some previously undetected handling characteristics surfaced. This was a test at freeway speeds that stimulated a car's behavior in moving around an object that suddenly blocked its path. Braking was not allowed. Each car was driven between a row of pylons set 9 ft apart. At the end of a 120-ft straightaway marking the entry lane the car had to be jogged left into the adjacent 9-ft lane, then following a short straight section driven back into the original lane (Fig. 3). The time through the course was recorded and later converted to the speeds given.

In the slaloms the quickest times were recorded with smooth driving; early mistakes had a tendency to become magnified later in the course. For the lane-change maneuver proper positioning was less of a concern; avoiding "an accident" was the primary consideration. As a result, as entrance speeds increased, some interesting cornering attitudes appeared. The 914 was again quickest, but not before giving the drivers a few bad moments. The mid-engine car tends to be quick but sneaky: if a driver isn't careful, the limit of adhesion creeps up on him and before he realizes it he finds himself motoring backward. Transient response and balance are excellent up to the limit, but one step beyond and you've got trouble—it takes a skilled and sensitive driver to realize he is approaching the limits of the car, but it should be remembered too that the mid-engine's limits are higher.

In second place, but quite a bit slower than the Porsche, was the Opel GT. Quick steering allowed the Opel to be driven fast down the entry lane and abruptly jogged to the left. A bit of speed was scrubbed off by the heavy front end but by staying on the power we could drift the rear end out in a gentle curve. As the car approached the limit the tires started to squeal and the driver could sense the rear end starting to break traction. By letting up on the throttle slightly we could maintain the drift down the short straight and then reverse for a quick exit.

The Saab could be driven into the first turn with wide-open throttle; once onto the straight section reduced but constant power was required to straighten the car for the quick right. Full power caused the front end to drift wide, resulting in the driver's clipping pylons on return to his original lane. Releasing the throttle to induce an oversteer attitude like the Opel's didn't work; precious tenths were lost as the car slowed down.

Pulling up the rear was the Ghia—a poor fourth. Slow steering, soft tires and body roll were the Ghia's downfall once again. Steering response is so leisurely there just isn't time for it to catch up with itself after the initial input. The tail meanwhile is swinging out gently, leaving the driver inadequate distance to correct and prepare for returning to the original lane unless he reduces speed. The Ghia oversteers, but in slow motion, so even an unskilled driver can hardly fault its "high-speed" handling.

Low Traction Cornering

THE ADVANTAGE of fwd in limited-traction situations was again proved on the oil/wet skidpad at Orange County International Raceway. An 85-ft-radius circle was laid out and each car driven around as fast as possible. The Saab's steering is without much feel on center but the car maintains an understeering attitude under power at all times, which contributes to ease of control. Other factors also contribute to the Sonett's speed: driven front wheels apply traction in the direction in which they are steered. This and weight on the driven wheels are definite assets in slippery conditions.

The 914 exhibited the same traits here as in the lane-change maneuver—neutrality up to the limit but abrupt oversteer beyond. It places second here because its better front-to-rear balance when cornering imparts an advantage that wasn't usable when driving in the snow.

The Ghia has rear-wheel drive and a decided rear weight bias on its side in this test. But it comes in third for the same reason the 914 does well—balance. Its typical cornering attitude was with the tail hung out; completely catchable, but keeping it caught took valuable time.

There was no quick way to drive the Opel. With the low weight it has on the rear wheels, driving it was a constant battle between understeer with light throttle and oversteer if a bit too much power was applied. The tail didn't come around quickly like the 914's but the constantly changing attitude resulted in slewing and slow lap times.

Side-Wind Evaluation

ONE OTHER test, a side-wind evaluation, turned out to be more subjective than objective because the wind machine R&T rented turned out to be more of a bust than a gust. Luckily a brisk wind gusting to 70 mph at times (no kidding) blew in from the desert for a few days while we had the cars. Our subjective judgments: the front-heavy Sonett with fwd pulling it along was most stable. Next came the also nose-heavy Opel. The 914 was fairly wind sensitive, not a great surprise considering the Porsche's low polar moment of inertia and slight rearward weight bias. Rear-engine cars with light front ends are typically affected more by winds than other configurations, and the Ghia did not disappoint us.

The winner? There is none. This was a test of configurations, not cars; and as our testing proved, each design has specific strong points and limitations. We've laid a few myths to rest: namely, that rear-end cars oversteer drastically and also have better traction in difficult conditions. On the other hand it was satisfying to see many theories proved out by actual testing.

In conclusion, a few conclusions. If you want ultimate handling for driving fast on winding roads—entertainment and pure speed, particularly on dry roads—the mid-engine layout is for you. If you have a need for top traction in the snow where you live, a front-drive or a rear-engine car makes sense and the edge seems to go to the front-drive car. The conventional front-engine car with rear drive seems not to have any compelling advantages, but there are plenty of these cars with more-than-acceptable handling—and you just may have to settle for one anyway, since there are no mid-engine sedans and only one front-drive sports car.