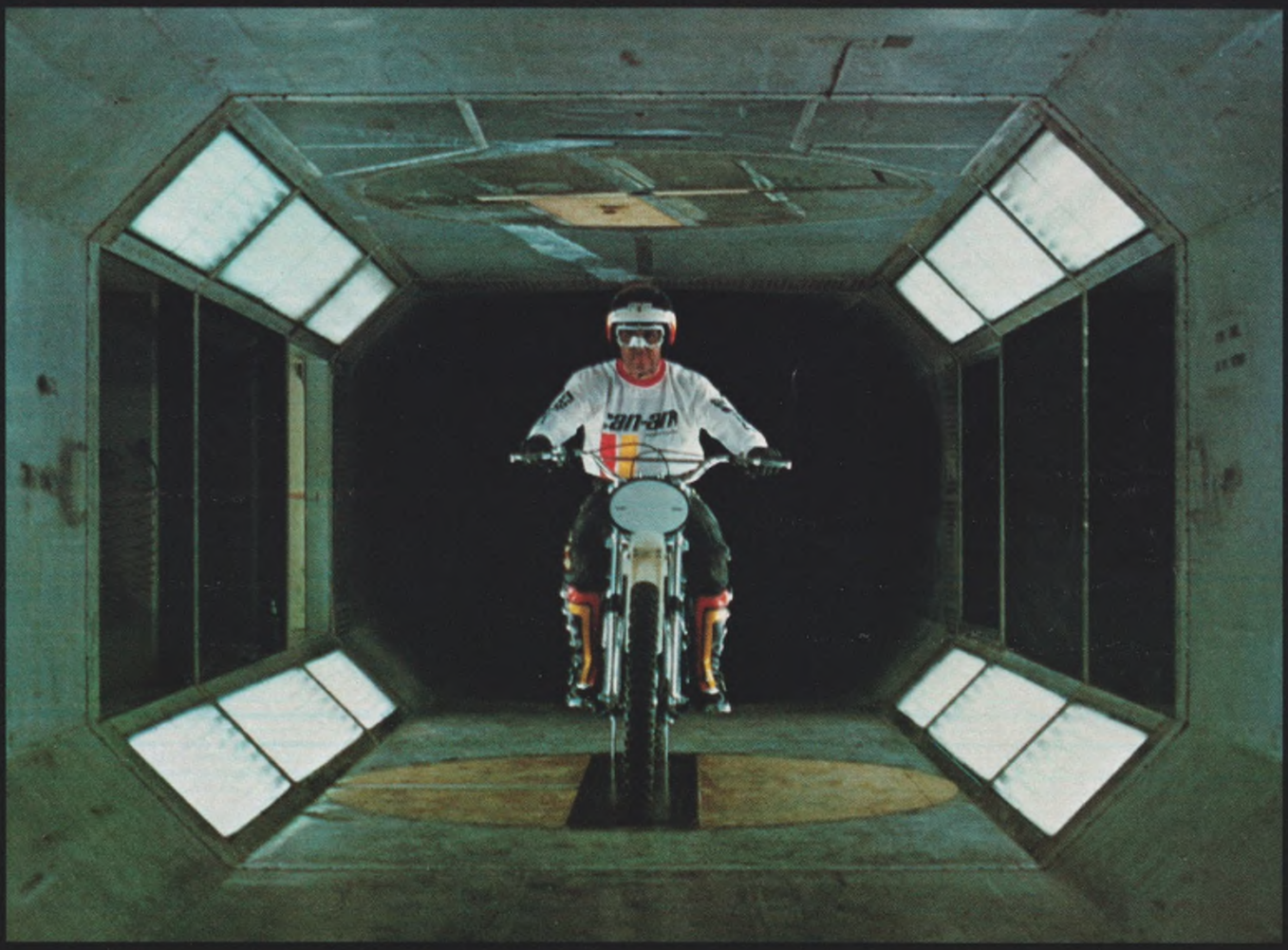
MOTORCYCLE AERODYNAMICS



Here's how a motorcycle's performance, fuel economy, tire and drive chain life and engine reliability can be prevented from disappearing right into thin air.

Text and Photos by
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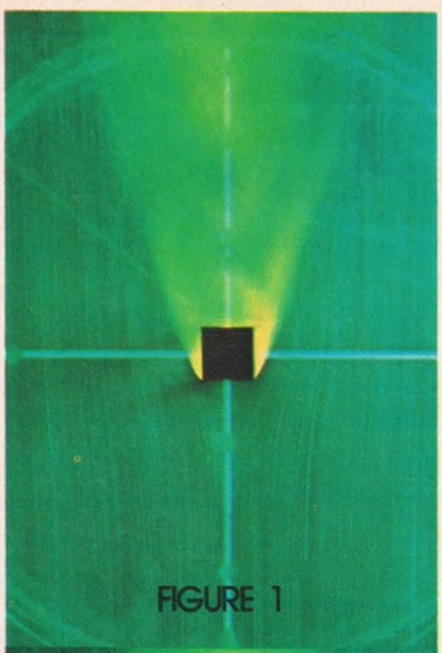


FIGURE 1

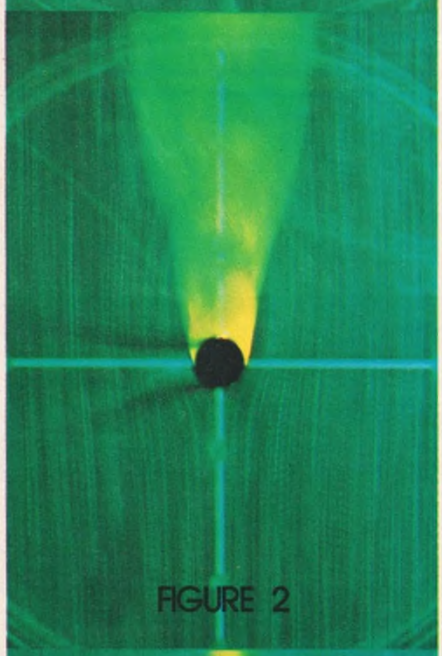


FIGURE 2

FIGURE 3

MOTORCYCLE AERODYNAMICS

● At freeway speeds, the aerodynamic drag of a standard motorcycle is three or four times that of the rolling resistance due to tires and wheel bearings. Wind resistance thus has a significant influence on overall motorcycle performance—top speed, acceleration, fuel consumption and, indirectly, reliability. In addition, the air through which the motorcycle moves generates other aerodynamic forces which affect stability and handling. Most riders are aware of the unpleasant disturbances caused by crosswinds and passing vehicles. And the air stream, flowing over fins or through radiators, provides engine cooling. Motorcycles are very "aerodynamic" devices.

Most motorcyclists are well-versed in the mechanical aspects of their machines, but have little or no understanding of aerodynamics. Aerodynamics is not a black art, as many may suppose, but a highly-developed science founded on well-tested fundamental principles. While mathematical analysis is an important tool in this field, a working understanding of fluid flows can be had by learning only a few basic concepts. With this background, it is possible to discover the sources of aerodynamic drag and devise methods for drag reduction.

We can begin with the *boundary layer,* which plays a dominant role in the aerodynamic characteristics of a body. This layer is the sheet of air immediately adjacent to the body surface, where friction slows the flow down from its full external value to zero velocity. Initially, as the air starts to move around a body, the layer is very thin, the flow in it is smooth, and in this condition it is known as a *laminar* boundary layer. Energy dissipated through internal fluid friction in this region gives rise to a skin friction drag. As the flow continues over the body the boundary layer thickens and eventually becomes unstable, forming a *turbulent* boundary layer. The skin friction is increased for this turbulent flow and the boundary layer thickens more rapidly. Figure ten shows an idealized view of the boundary layer and its development. Skin friction drag is a significant component of the total drag only for highly streamlined shapes.

The location of the point of transition from laminar to turbulent flow depends on body shape, surface roughness, the distance that the flow has traveled over the body and the flow speed. The product of the last two parameters, multiplied by the density of air and divided by the air's viscosity, is an important aerodynamic quantity known as the Reynolds Number. An example of laminar and turbulent flow can be seen in the behavior of a cigarette smoke plume in a still room. Initially the plume rises very smoothly but, after rising far enough, it becomes unstable and begins to oscillate violently. Like the smoke plume, a boundary layer tires as it moves over a body, and eventually becomes sufficiently de-energized to separate from the body surface. The separated flow then continues downstream, forming a turbulent wake. The buffeting you feel when passed by a truck is caused by such a wake.

Variations in surface pressure over a moving body are responsible for the majority of the aerodynamic forces on the body. Air arriving at the body causes a positive pressure force at the leading edge, retarding its motion. As the flow advances past the leading edge the surface pressure rapidly drops, becoming negative, then slowly rises until flow separation occurs. The negative pressures in the separated region pull against the direction of motion, just as the positive pressures push against it. The resultant force is known as *pressure drag* and is the largest component of total drag for un-

Two touring adaptations of a racing fairing: fuel economy would improve 12.4-percent with the taller; nearly twice that in the configuration shown below.

FIGURE 4

streamlined or partially streamlined shapes. Any small local protuberances will have their additional drag components and these are lumped under the term *parasite drag.*

The occurrence of flow separation is bad news. It considerably increases drag, because the region of the base of the body over which the lower, retarding pressures occur is large. Flow separation is a function of many variables, the most important of which is the shape of the body. A concave surface tends to keep the boundary layer attached, whereas a convex surface (as in Figure ten) tends to encourage separation. An analogy of this behavior is provided by a motorcycle approaching a hill. At the base,

FIGURE 5

Unfaired bikes leave a fairly large and highly turbulent wake, as shown by the fluorescent dye cloud behind this model in a water tunnel test.

FIGURE 6

Vertical-slab touring fairings work very well as shields but punch a huge hole in the air and create enough drag to reduce performance.

FIGURE 7

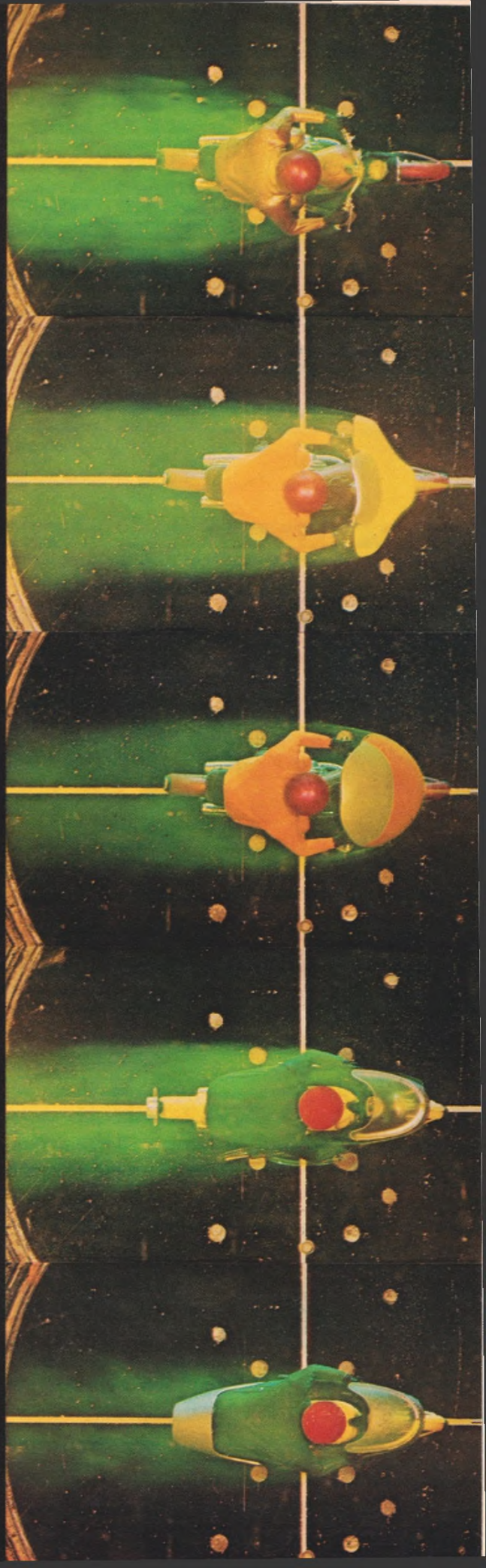
A more rounded touring fairing, offering good protection for a rider, trails a smaller wake and generates less drag than a bare motorcycle.

FIGURE 8

The low, narrow racing fairing leaves a small wake simply because it is small, but may be no better than a bare bike with a crouched rider.

FIGURE 9

Fairing panels behind the rider can be used to keep the flow attached, and produce the smallest turbulent wake and least drag of any partially-faired configuration.



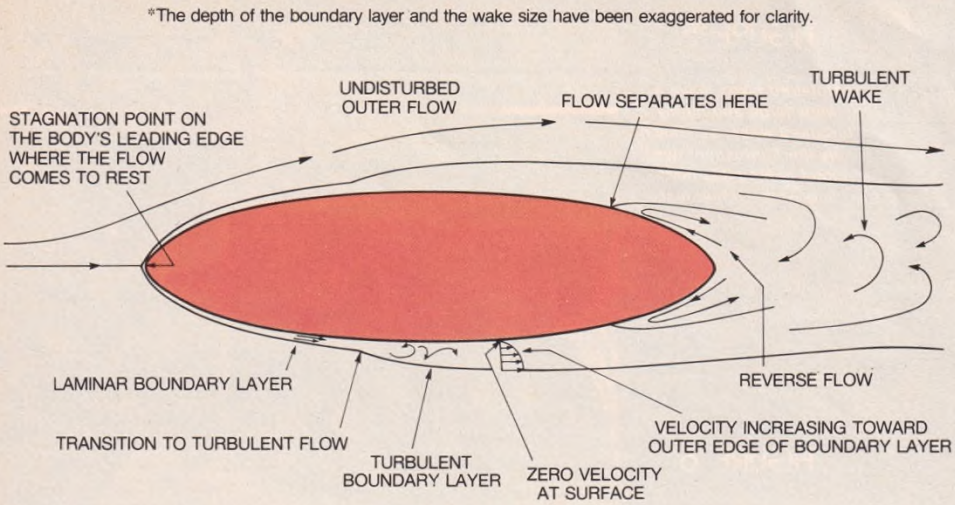


FIGURE 10

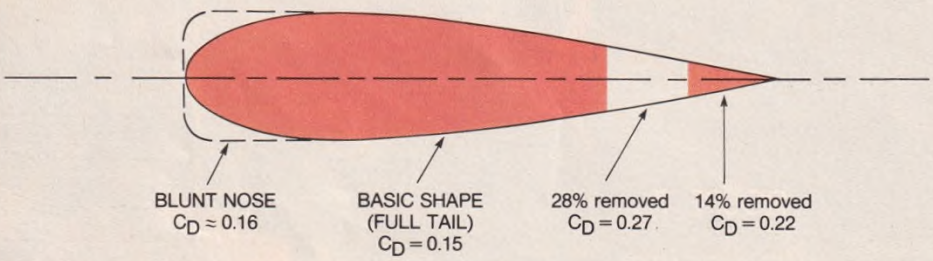


FIGURE 11

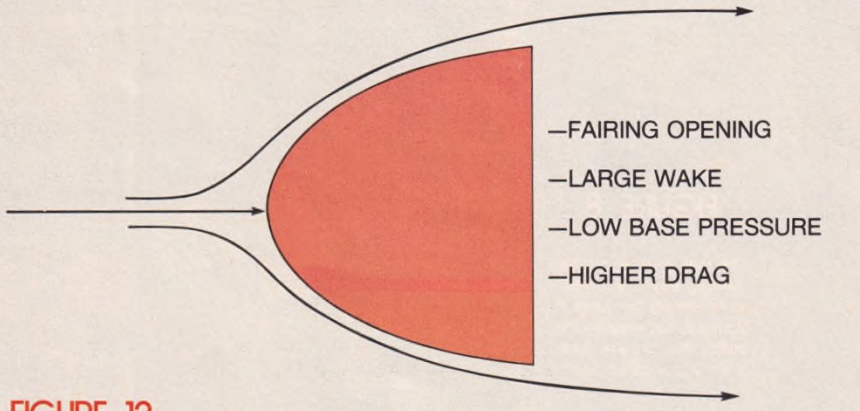
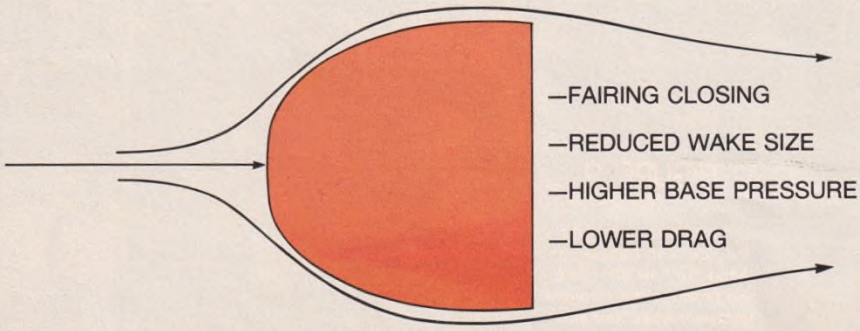


FIGURE 12



as the road surface curves upward (concave surface) the machine is pressed down against the road. As it crests the hill and the hill drops away (convex surface) the machine is accelerated away from the road and may become airborne—separated from the road. Bodies which close on themselves are predominantly convex and once the flow nears the point of maximum thickness the boundary layer becomes very sensitive. Surface discontinuities, roughness or too-abrupt curvature will trigger separation. A body which has a large separated wake is termed *bluff* while one with little or no wake is termed *streamlined.*

A visualization of the flow over three different shapes is provided in figures one, two and three. These, and the other flow visualization photographs to be discussed later, were taken in a water tunnel at the Low Speed Aerodynamics Laboratory of the National Aeronautical Establishment (NAE), Ottawa, Ontario, Canada. This tunnel is a closed tube through which water is continuously pumped. Models can be mounted in a glass-walled test section and, by releasing streams of fluorescent dyes or mixing tiny, highly reflective particles in the water, the flow over any shape can be made visible. In the case of figures one, two and three, both dye and aluminum particles are used. The dye is released at the rear of the body, thus staining the turbulent wake. The smooth outer flow is shown in the dashed lines created by reflections from the aluminum particles, which were illuminated by a strobed light source.

The early separations and large turbulent wakes of the square and circular shapes contrast sharply with the small wake of the airfoil (figure three). The drag force on the cylinder (figure two), which has the same thickness as the airfoil, is roughly fifty times greater than the drag force on the airfoil. This, in part, explains the leisurely pace of those old, wire-braced biplanes. The flow around the square (figure one) is even worse. The boundary layer separates at the sharp corners and a very large wake is formed. The resulting drag is greater than for the cylinder. Obviously high drag is associated with separated flows, which are characterized by large wakes.

It is standard practice in aerodynamics to adjust measured aerodynamic forces so that the effects of body size and speed are removed. This allows direct comparison of the aerodynamic characteristics of different configurations and allows results obtained with small models to be extended to full size. These adjusted measurements are called aerodynamic coefficients and the one we are concerned with is the drag coefficient (C_D), defined as

$$C_D = \frac{D}{.0026\ V^2\ A}$$

where D is the aerodynamic drag force in pounds, V is the speed in mph and A is the frontal area of the vehicle in square feet (ft^2). The frontal area, as the name suggests, is the total area presented to the air. The term $.0026\ V^2$ is the pressure the air would exert perpendicular to a flat surface, a plate for example, pushed through the air at V mph.

Thus .0026 V^2A is the force, in pounds, that the air would exert on a flat plate with the same frontal area as the body in question. The drag coefficient could then be interpreted as a measure of how good or bad the body shape is compared to a plate. If the value of C_D is greater than 1.0 then the plate is better aerodynamically. Knowing the values of C_D (from a wind tunnel or coast-down test) you can calculate the aerodynamic drag force for any geometrically identical body of different size, and for any velocity, by inverting the above equation to give

$$D = .0226\ V^2\ C_DA \text{ lb.}$$

The drag force is proportional to the square of speed, to the drag coefficient and to the body size as represented by the frontal area. The product C_DA will, from now on, be referred to as the drag-area.

As an example, assuming $C_D = 0.75$ and $A = 7.2$ ft² the aerodynamic drag at 30 mph would be

$$D_3 = .0026 \times 30 \times 30 \times 0.75 \times 7.2$$
$$= 12.6 \text{ lb.}$$

at 60 mph the aerodynamic drag would be

$$D_6 = .0026 \times 60 \times 60 \times 0.75 \times 7.2$$
$$= 50.4 \text{ lb.}$$

Thus the drag is four times as great at twice the speed (as would be expected from the above equation since $2^2 = 2 \times 2 = 4$).

The drag coefficients of the three shapes in figures one, two and three, and of several other kinds of vehicles, are given below to help place the motorcycle in proper perspective aerodynamically.

Square (figure one)	C_D 1.50
Circular (figure two)	1.20
NACA 64_3-021 airfoil (figure three)	0.024
American sedan	0.40–0.50
Tractor-trailer	0.70–1.10
Golden Rod Land Speed Record car	0.11
Can-Am car	0.35–0.45
F-I or Indy car	0.50–0.60
Jet transport (DC8, 707 etc)	0.06–0.07
Single engine light aircraft	0.10–0.14

The drag coefficient is strongly dependent on body shape, as shown by the examples quoted above. Smooth, slender, tapered bodies have the lowest drag values. The effect of slenderness—the ratio of body length to body width L/W—is further illustrated in figure thirteen. Two situations are shown, one for a highly streamlined body like an aircraft fuselage, and one for a body more characteristic of a motorcycle with partial fairing. As the slenderness increases, the pressure drag decreases, while the skin friction increases due to the larger surface area. Because the pressure term is dominant at low slenderness, the drag initially drops to a minimum value, and then rises with the increasing influence of skin friction. A greater slenderness is required for the higher drag body to reach minimum drag.

The effect of nose and tail shape is shown in figure fourteen for a moderately stream-

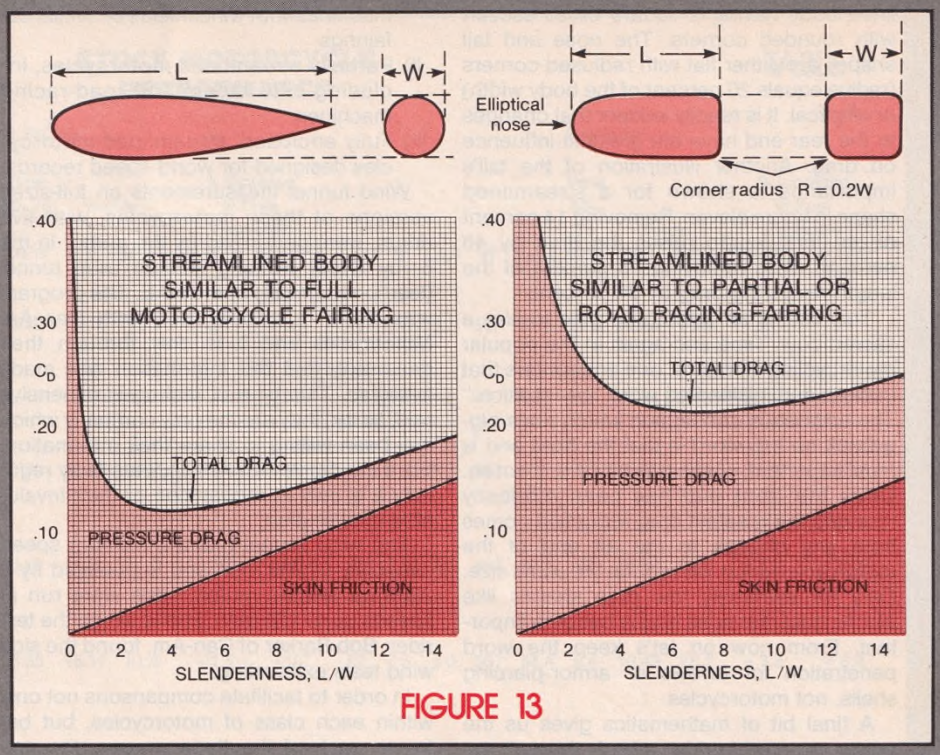


FIGURE 13

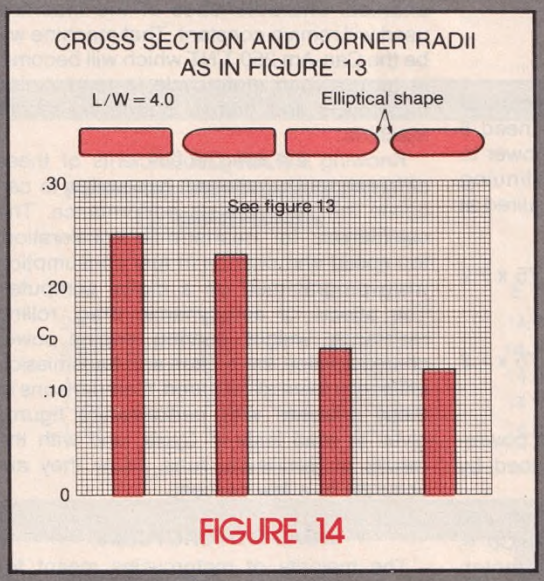


FIGURE 14

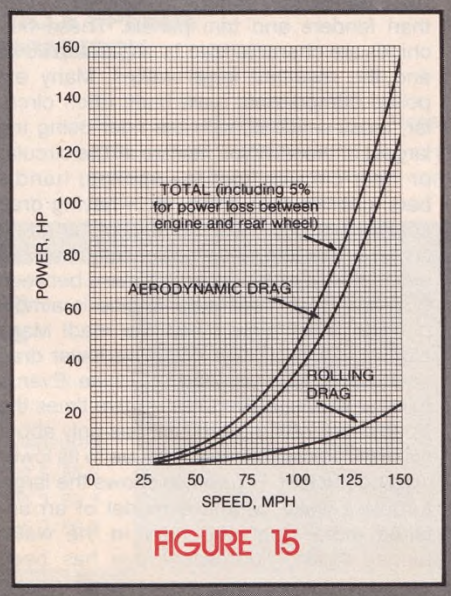


FIGURE 15

lined body having a square cross section with rounded corners. The nose and tail shapes are either flat with radiused corners (radius equals 20 percent of the body width) or elliptical. It is readily evident that changes to the rear end have the greatest influence on drag. Another illustration of the tail's importance is shown for a streamlined shape in figure eleven. Removing 14 percent of the total length raises the drag by 46 percent, while removing 28 percent of the length raises the drag by 80 percent.

This seems an opportune time to slay a sacred cow. Time and again in the popular motorcycling literature, one encounters that useless and misleading word "penetration." The erroneous conception which rides piggyback on this word is that the front end is most important, when in reality this is not so. Once the front end has been modestly rounded the greatest drag reduction comes from any change to the aft end of the motorcycle which will reduce the wake size. Only for extremely low drag shapes like airfoils does the nose shape become important. From now on let's keep the word penetration for arrows or armor-piercing shells, not motorcycles.

A final bit of mathematics gives us the power required to drive a body through the air. It is

$$P = .0000069\ V^3\ C_DA \text{ hp.}$$

The power required increases as the cube of speed. To double your speed you need 8 times ($2^3 = 2x2x2 = 8$) as much power to overcome aerodynamic drag. Continuing the previous example the power required at 30 mph and 60 mph are

$$P_{30} = .0000069 \times 30 \times 30 \times 30 \times 0.75 \times 7.2 = 1.0 \text{ hp.}$$

$$P_{60} = .0000069 \times 60 \times 60 \times 60 \times 0.75 \times 7.2 = 8.0 \text{ hp.}$$

No wonder fuel consumption and powertrain longevity are drastically reduced by high-speed running.

Figure fifteen shows the power required to overcome aerodynamic drag when C_D = 0.75, a typical value for standard road motorcycles. Also included is an estimate of the power required to overcome rolling resistance (on a salt surface in this case) assuming a tire pressure of 20 psi and a weight of 427 lb. The total power required is the sum of the two as shown. This is the power required at the road, and so an additional amount (5–10 percent) must be added to make up for transmission losses. The dominance of aerodynamics is obvious.

An excellent reference which covers all aspects of aerodynamic drag is the book by Hoerner listed as reference one. The book is written in such a descriptive fashion that a nonspecialist can read around the mathematics and pick up a lot of practical information. The best place to find a copy would be in the library of an engineering school.

Motorcycles can be categorized into one of three aerodynamic groups, depending upon the degree of streamlining present. These groups are:

I) Standard road motorcycles, including machines with windshields or similar tall fairings
II) Partially streamlined motorcycles, including café racers and road-racing machines
III) Fully enclosed, streamlined motorcycles designed for world speed records.

Wind tunnel measurements on full-sized versions of these motorcycles, with live riders, were performed by the author in the 6- by 9-foot working section wind tunnel (lead photograph) of the NAE. The program was done in cooperation with Can-Am Motorcycles and it is only through their generosity that this information was made available. This type of testing is expensive and, so far, they are the only company which has been willing to share their information. So, if the name Can-Am appears fairly regularly it is only in recognition of their invaluable contribution.

The wind tunnel has a maximum speed capability of 230 mph and is powered by a 2000 hp electric motor. Tests were run at speeds up to 170 mph, above which the test rider, Bob Barker of Can-Am, found the side wind tests exhausting.

In order to facilitate comparisons not only within each class of motorcycles, but between each of the three groups, the mechanical characteristics of the machine used will remain constant. That machine will be the Can-Am 250 T'NT which will become, in turn, a road motorcycle, a road racing motorcycle and then a Bonneville record machine.

Knowing the drag coefficients of these different configurations it is possible to calculate the motorcycle's performance. The calculations for quarter-mile acceleration, top speed and change in fuel consumption were programmed on a digital computer. The effects of aerodynamic drag, rolling resistance, weight, gearing, engine power characteristics, tire friction and transmission efficiency were all included. Comparisons of these analyses with performance figures given in road tests in *Cycle,* and with the results of Bonneville runs, show they are accurate to a few percent.

ROAD MOTORCYCLES

The majority of motorcycles meant for road use have no fairings or bodywork other than fenders and trim panels. These machines are characterized by separated flows and the resultant large wakes. Many exposed components have bluff, often circular, cross-sections, with the rider being the largest of these. If you itemize all the circular or near-circular pieces—spokes, handle bars, chassis rails, forks, etc.—having drag coefficients near 1.2, it should come as no surprise that the total motorcycle drag coefficient is high, falling somewhere between 0.70 and 0.80. Your poor engine is almost pushing a flat plate down the road! Many highway tractor-trailer rigs have lower drag coefficients than you and your bike. Even a full-size sedan, having four or five times the frontal area of a motorcycle, has only about twice the aerodynamic drag, due to its lower drag coefficient. Figure five shows the large turbulent wake behind a model of an unfaired motorcycle and rider in the water tunnel. Again, fluorescent dye has been used to visualize the flow. It's easy to see why the standard machine is so poor aerodynamically.

Many riders have added tall fairings or windshields, often attached to the handlebars. These devices serve to protect the rider from small objects, the weather, and air loads, but most seem to do so at the cost of reduced performance. Figure six shows the reason for the performance degredation. The large windshield separates the flow over and around the rider, increasing the wake size and total drag.

It seems appropriate to make a small aside on the effect of fairings on the motorcycle's stability at this point. A certain amount of controversy has arisen concerning the effect of handlebar mounted fairings on wobble or shimmy of the front frame (front wheel, forks etc). I have done some work on motorcycle dynamics and have extended the mathematical model of motorcycle stability developed by Robin Sharp (a lecturer in Mechanical Engineering of the University of Leeds, Leeds, England) to include aerodynamic forces. As has been found in road tests, the theory predicts that mass added to the steerable portion of the motorcycle, increasing the front fork's moment of inertia, reduces stability. If a particular machine has weak wobble stability (and some have), this introduces the possibility of serious wobble problems at high speed. However, I don't believe that the problem is sufficiently widespread for one to avoid this type of fairing. In fact, I believe it should be possible to design and place a handlebar fairing so that it will cause little or no deterioration in stability. If this is done, the handlebar fairing has some definite advantages. It is simple, light, relatively inexpensive and quite easily installed. Because of its proximity to the rider it can offer better protection than a frame-mounted fairing of the same size, or as much protection with smaller size, and hence lower drag.

I think it is very important to ensure that your machine is in good condition if you use a fairing of this type. Poor rear shocks, worn forks, worn or poor-quality tires, or play in the steering head or swingarm bearings are probable causes for wobble problems much of the time. If, in spite of everything, your bike is one of the unfortunate few which have a predisposition to wobble it might be possible to effect a solution using one of the steering dampers found on some machines.

It is also possible that there are some aerodynamic effects due to the fairing itself which might cause wobble. The drag force acting on the fairing will probably make the motorcycle more stable. However, there are several types of unsteady aerodynamic excitation which *could* (and I stress that this is only speculation) lead to unstable behavior. The word unsteady is the key, as the forces to be discussed change with time either due to the nature of the flow or due to motorcycle motion.

The first possibility would be the phenomenon known as vortex shedding, where bursts of rotating air rather like weak tornados are released alternately from either side of a bluff body at a rate which increases with speed. While this phenomenon may sound innocuous it has led to the destruc-

STOCK MOTORCYCLE PERFORMANCE

TABLE 1

	1 RIDER										2 RIDERS									
Can-Am 250 MX	C_D	A	C_DA	W	V_{max}	Time 50–75 MPH	¼-mile E.T.	¼-mile MPH	% Increase in Fuel Economy 25 MPH	% Increase in Fuel Economy 55 MPH	C_D	A	C_DA	W	V_{max}	Time 50–75 MPH	¼-mile E.T.	¼-mile MPH	% Increase in Fuel Economy 25 MPH	% Increase in Fuel Economy 55 MPH
Rider(s) sitting upright	.71	7.2	5.1	427	85.7	6.40	15.15	82.5	0	0	.76	7.5	5.7	567	81.6	10.6	16.46	75.4	0	0
Rider(s) leaning forward	.68	6.3	4.3	427	89.8	5.10	15.03	87.1	+7.3	+11.9	.73	6.5	4.7	56 7	85.7	7.6	16.03	80/4	+7.9	+13.3
Rider(s) upright, fairing and tall windshield	.59	7.2	4.2	452	90.5	5.90	15.00	84.2	+5.1	+12.4	.63	7.5	4.7	592	85.7	9.0	16.43	77.4	+5.9	+12.6
Rider(s) leaning, fairing and tall windshield	.58	7.2	4.2	452	90.5	5.85	14.98	84.4	+5.0	+12.4	.63	7.2	4.5	592	86.4	8.7	16.39	78.0	+7.5	+15.3
Rider(s) upright, fairing and short windshield	.69	7.2	5.0	447	86.4	6.65	15.17	81.6	−1.5	+0.7	.67	7.5	5.0	587	84.4	9.4	16.49	76.7	+3.8	+8.8
Rider(s) leaning, fairing and short windshield	.56	6.3	3.5	447	94.6	4.95	14.61	88.4	+11.8	+23.1	.62	6.5	4.0	587	89.1	7.2	16.36	81.5	+11.7	+22.1

ROAD RACE FAIRING PERFORMANCE COMPARISON

TABLE 4

Fairing	Cd	A	CdA	W	V max	¼-Mile E.T.	¼-Mile MPH	Mosport Lap Times
1972 Can-Am	.61	4.5	2.75	447	100.7	14.42	90.6	1:50.43
350 Yamaha	.45	4.5	2.03	447	107.5	14.23	93.71	1:48.67
1973 Can-Am	.27	4.5	1.23	452	119.0	14.06	97.4	NA
1973 Can-Am*	.35	4.5	1.58	452	113.6	14.14	95.8	1:47.69
Advanced Can-Am	.30	4.0	1.20	452	120.8	14.02	98.2	1:46.90

*Road Racing Trim

MEASURED/ESTIMATED BONNEVILLE SPEEDS COMPARISON

TABLE 3

Motorcycle	Cd	A	CdA	Speed Estimated	Speed Measured
1972 Can-Am	.61	4.5	2.75	109.8	111.6
1973 Can-Am	.27	4.5	1.22	143.0	136.5

MEASURED/ESTIMATED ¼-MILE PERFORMANCE COMPARISON

TABLE 2

Motorcycle	E.T./MPH Estimated	E.T./MPH Measured
Can-Am 250	15.03/15.04	82.5/85.2
Honda CB-450	14.70/14.40	85.3/89.3
Suzuki T-500	15.00/14.70	85.0/89.3

MOTORCYCLE AERODYNAMICS

tion of large suspension bridges, has caused untold millions of dollars damage to high voltage transmission line cables and has led to the failure of many tall stacks, towers and other structures. It could cause problems for motorcycles if the frequency of shedding was the same as the wobble frequency (about 8 to 10 cycles per second for many machines). This could occur at about 60 to 80 mph for a two foot wide fairing—if shedding can occur at all on such a truncated shape.

Another possibility is that the steering motions of the motorcycle, in response to bumps or wind gusts, could lead to a changing aerodynamic force which would make the frame wobble. This is more likely, and would be very much dependent on the shape of the fairing. I hope to do some work in the future to investigate these possibilities. The frame-mounted fairing, of course, is not attached to the fork and so avoids the problem. Both kinds of fairings may increase the response to side winds and passing vehicles somewhat, although this does not seem to be a major problem.

Preliminary wind tunnel tests by Can-Am on fairings for road machines suggest that both adequate rider protection and reduced drag are possible. Two fairings which combine drag reduction and adequate protection are shown in figure seven. They are characterized by fairings around the engine and windshields which curve to bring the separating flow skimming past the rider, rather than throwing it out snow-plow fashion. The drag coefficient for both machines tested was less than without the fairings, yet both offered significant rider protection. Admittedly, these are not the best-looking fairings around, but their appearance could be improved without sacrificing performance. Table one provides details of the drag coefficients, frontal areas and drag areas for these motorcycles for two different riding positions. In one case the rider was sitting upright; in the other he was leaning forward as he would if using clip-ons and rear-sets. The presence of a passenger generally increases the drag. It would seem that the drag coefficient is lowest when the rider's position allows the flow to pass from the fairing to the rider's body rather than separating around him. The rider's body now acts as an extension of the fairing. As we shall see later, this concept is of greatest importance for racing machines. This behavior is shown for the flow around an improved handlebar-mounted road fairing in figure eight. The fairing is curved so that the sides are parallel to the flow direction, and its shape is such that it just clears the contours of the rider's body when viewed from in front, yielding the minimum increase in frontal area. The stable bubble of separated air provides excellent protection over the rider's upper body.

The quarter mile terminal speeds and E.T.s are also included in the table, as is the passing time required to accelerate from 50–75 mph. The weights assumed for each case are shown. A transmission efficiency of 95 percent and a tire pressure of 20 psi were used. In some cases, with the fairings in place, quarter mile times are slightly increased. This is caused by the increased weight reducing low speed acceleration. Above about 20 mph, acceleration is increasingly improved by the fairings, as shown by the 50–75 mph acceleration times. The reduced passing exposure would enhance safety by reducing passing risk. A one-second reduction would remove about 100 ft. from the distance required to pass.

An indication of the accuracy of the acceleration analysis can be obtained by comparing the quarter mile speeds and E.T.s for a few of the motorcycles tested previously by *Cycle,* using the published weights, engine power outputs and gear ratios. Table two gives the comparisons between my calculations and the road test results. Note that the 240 T'NT performance gives the best result—this was the machine for which the aerodynamic forces were measured. The small differences remaining between calculation and measurement could be readily accounted for by track temperature, rider technique and the riding position assumed during the run.

Fuel consumption changes are shown for 25 mph and 55 mph—speeds representing city and freeway driving. The changes are given as the percentage increase (+) or decrease (—) relative to the 250 T'NT with one or two riders (as is appropriate) sitting upright at the same speed. The fuel savings can be considerable, even in city traffic, and are larger at freeway speeds.

The improvements in acceleration and fuel consumption are results of lower power required to propel the motorcycle. Since the drive line—engine, transmission, chain, rear tire—are generating and transmitting reduced power, these components should have longer lives. It would also be possible to raise the final drive ratio while maintaining as much, or slightly more, top end acceleration than for the unfaired vehicle, allowing reduced cruising rpm.

From Table one it can be seen that the greatest performance increases occur with the low windshield and leaning rider. However, the best overall performance was obtained with the tall windshield, as it was less sensitive to the number of riders or the riders' position.

Even if a fairing is not desired, cleaning up a few of the larger bluff components will yield useful results. Simple fairings on the fork legs, nine inches long, would lower the drag coefficient by 1.25 percent. This would result in a fuel consumption improvement with a single rider of 1.2 percent at 55 mph and yet would only cost a few dollars. If a similar clean-up were carried out on other small components such as the headlight-instrument grouping, handlebar, and front fender, a worthwhile saving could be made, perhaps on the order of 4–6 percent in fuel consumption, for virtually no cost. Acceleration (especially at highway speeds) and top speed would increase accordingly.

All in all, a properly-designed fairing is potentially of great advantage to the motorcyclist. Some of these advantages, as I see them, are:

I) Protection from wind blast, rain and cold, and a reduction in wind noise.
II) Protection from small flying objects.
III) An improvement in fuel consumption and the reduction in passing exposure due to lower drag.
IV) An improvement in engine life, chain life and rear tire life due to reduced power requirements resulting from lower drag.
V) A reduction in engine noise levels to the rider and to all others if a lower fairing (figure four) is used and lined with a sound absorbing material.
VI) An improvement in visibility to others which makes it less likely that you will be hit, or have a pedestrian suddenly step in front of you.
VII Convenient storage for small items.

PARTIALLY STREAMLINED MOTORCYCLES

From the last section we can see that the addition of a good road fairing can provide valuable performance improvements, particularly at higher speeds. It would be expected that the improvements to partially streamlined road racing or record motorcycles would be even greater. At first sight one might think that, since these motorcycles already have fairings, there is little more to be done. This is not the case.

Most fairings that are run on racing motorcycles very strongly suggest the word *afterthought.* They look like something slapped on after the fact, based on the supposition that anything will do. After all, how important can aerodynamics be? Even the fairings that appear to have had some development have suffered from the "it's what's up front that counts" syndrome.

My first contact with motorcycle aerodynamics came when Can-Am asked me to develop a fairing for a partially streamlined class and had set two world records which they now wished to raise. Can-Am felt that the old fairing could be improved—in fact had to be improved—as the new engine had only two bhp more.

It was obvious that the major drag source would be the large separated flow over the rear of the motorcycle. Accordingly, an attempt was made to reduce the wake size. To accomplish this objective it seemed a good idea to use the rider's body as a continuation of the fairing—matching fairing and rider so that the flow would pass from the fairing and remain attached to the rider. A close reading of the AMA rules showed that a small fairing was allowed behind the rider.

The approach just outlined was accomplished by:

I) Lowering the rider's forebody because the slope of his back on the previous machine, as on most current road racers, was too steep to allow the flow to remain attached.
II) Using a large seat and additional fairing panels behind the rider, adjusted so that the flow remained attached after clearing the rider.
III) Carrying out a general clean-up, including disc wheel fairings, fork fairings, and

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