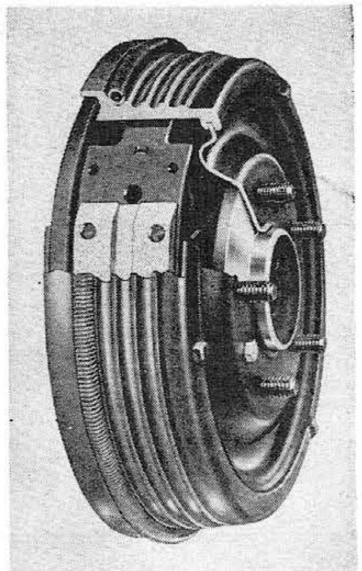


1954 Cadillac brakes feature finned drum and grooved lining for cooling.

POWER TO STOP

BY ROGER HUNTINGTON, SAE

BRUTE HORSEPOWER, torque converters, and low axle gear ratios have done more than you think to "make" the modern Detroit automobile—and to *break* the modern chassis engineer. The push-button driving and feather-bed cruising at 70 or 80 mph which these gimmicks have made possible are driving the brake designers nuts trying to keep up.

The higher cruising speeds and loss of engine overrun drag (due to non-reversing torque flow of the fluid converter) have more than *doubled* the equivalent load on braking systems. Brakes that were adequate on some of our family cars even 4 or 5 years ago are strictly "marginal" today. That's brutal, but true. Meanwhile the brake designers are fast running out of new gizmos on old, economical, established brake layouts that will fill the gap. Big changes may be near.

It's a very interesting technical story . . .

BRAKE FUNDAMENTALS

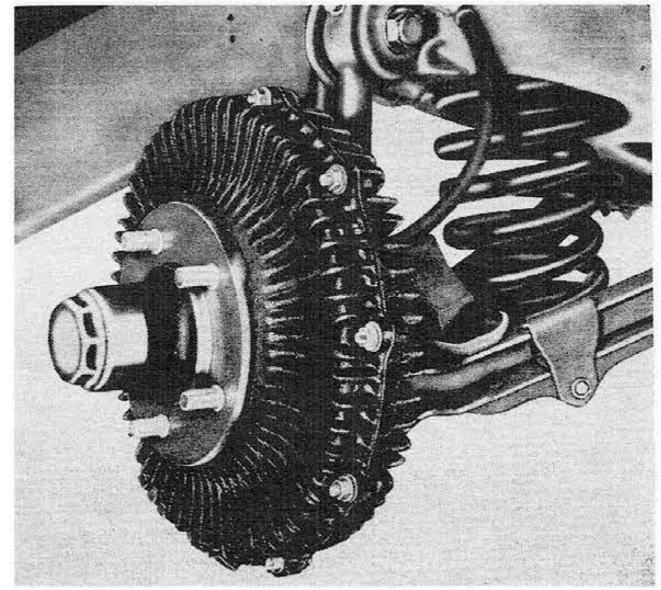
The brake problem is fundamentally a problem of handling *heat*. After all, technically the brakes on an automobile are nothing more than devices for converting the *kinetic energy* of the car's motion into *heat*—and getting rid of this heat to the surrounding atmosphere. If you remember this one simple principle you'll be better able to understand the brake engineer's problems.

There's more heat involved here than you might think. A 4000-pound car traveling at 80 mph has a kinetic energy equivalent to dropping 855,000 lbs. a distance of one foot! The bulk of this energy must be soaked up by the brakes in bringing the car to a stop from this speed. Since one BTU—the amount of heat necessary to raise the temperature of a pound of water 1° F.—has been found to be equivalent to 778 ft.-lbs. of work, then the actual heat absorbed by the brakes in a stop like this would equal 1100 BTUs, or enough heat to boil nearly a gallon of water! This may not sound like a lot . . . but if you were to apply the brakes hard in a "panic" stop, bringing the car down from 80 mph in, say, 7 seconds, the local temperature at the contact surface between lining and drum can quickly flash over *1000° F.*!! (The graph shows some experimental curves from G.M. Research showing the drum surface temperature against time on a fast stop from 70 mph. See page 18.)

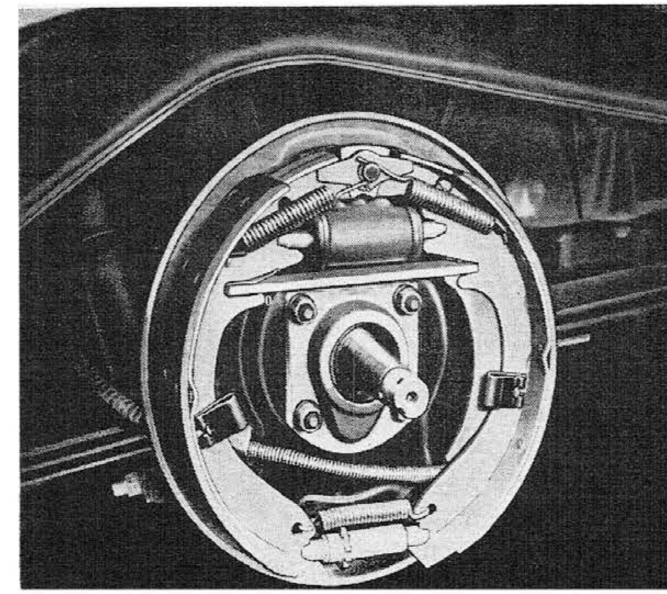
This heat build-up is the big enemy of the brake engineer. Look at it from this angle: The heat absorbed by the brakes on any stop is directly proportional to car weight and proportional to the *square* of speed. A typical 1947 model car might gross 3600 lbs. and cruise at 60 mph; the corresponding 1955 model might weigh 4000 and cruise at 80. This means *twice* as much heat must be absorbed on an average stop from cruising speed on the road—and you must add to this the effect of less engine overrun drag. Anyway you slice it the whole deal adds up to a lot more work for the brakes on our new cars.

What happens when brakes can't handle the heat? Look out!! Frictional characteristics between lining and drum fall off fast above lining temperatures of 450 or 500° F. (due to chemical reactions in the lining material), which reduces the braking force in relation to the pedal pressure. Furthermore, thermal expansion of the drum due to the increase in temperature may cause it to distort in such a way that the lining no longer makes even contact all the way around; this causes a further loss of braking force. We call this brake "fade" and everyone is familiar with it.

The first evidence that all is not well is that you "lose some pedal"—the brake pedal must be pressed closer to the floor before taking effect. Then things get mushy, braking effort is erratic, the linings may grab . . . and finally the pedal goes right to the floor. This would never happen in anything approaching normal operation. But with certain brake designs you can run into some degree of fade even on a single panic stop from 70 or 80 mph; even the best brakes on our American passenger cars will quickly lose their punch if used hard and continuously on a winding road or on a long down-hill run. There definitely *is* a problem here—and a problem that power boosters aren't going to solve.



Only disk brake in American production car use is this one available on the Chrysler Imperial models. Disks may become standard.



Studebaker's improved 1954 brakes feature a keystone-shaped top anchor which makes the braking mechanisms self-centering.

HANDLING HEAT

Obviously the main job of the brake designer is to control the temperature rise in the brake unit under severe operational conditions. Since Mother Nature says we can't reduce the heat *input* to the brakes without reducing car weight or speed, then about the only path left is to design the brake so that it can *get rid* of the heat faster, and thereby maintain a lower operating temperature. Most of the recent brake developments have been aimed in this direction.

There are a number of things you can do to speed up the dissipation of heat from a conventional drum-type brake, though not all the tricks are practical for inexpensive mass-produced cars. The most obvious is to provide positive means for circulating air around the drum and shoes. This can be done either by utilizing the ram due to forward motion of the car acting through scoops and/or ducts; the centrifugal pumping effect of turbine-type blading rotating with the wheel; or even a mechanical blower. All three methods have been used on sports and racing cars.

Positive air circulation can do the job, too. Extensive tests on the '52 LeMans Cunningham, using large finned drums, turbine blades, and scoops for the circulation, showed that the car could be accelerated wide open to 100 mph, braked to a stop at maximum possible deceleration, and the cycle repeated time after time without appreciable fade! Ram air circulation was an important factor . . . because on later tests up to only 60 mph the brakes eventually faded some. While this elaborate and expensive Cunningham braking system might not be practical for your family car, the tests proved that simple, non-mechanical means for positive air cooling could be used to handle very severe braking requirements—far more severe than we'd ever meet in the passenger car field. The latest cooling twist in the competition car field is to take the front brakes away from the shrouding of the wheels and mount them *inboard* near the center of the car, connected to the wheels through U-jointed shafts; this gets them away from the hot tires and right in front of a blast of air from the grille. Mercedes-Benz and Lancia have used this trick to great advantage.

Brake ventilation is a headache on Detroit designs these days mostly because of styling, and partly costs. The low bodies and heavy shrouding around the front end aren't conducive to a direct blast of air on the drums without special ducting, which would probably be considered too costly right now. Turbine-bladed and vented wheels would be another unwelcome expense. Brake ventilation will come slowly in Detroit. Far as that goes, maybe someday we'll see the trick of putting the brakes *outside* the wheel to get it into the airstream, ala G.M. Firebird!

Another approach to the brake cooling problem, more attractive for production cars, is to merely increase the *size* of the brake unit. Many auto enthusiasts think that simply increasing the brake lining friction area in relation to the car weight will somehow boost the "braking power." But what is this mysterious braking power? No; any brake that can exert sufficient torque force to *lock its wheel* on the road is theoretically 100% efficient . . . and any little 6″ brake could do that!! The real secret of a large brake (and large lining area) is that it has more surface and more beef through which to dissipate heat. It's as simple as that. Obviously a small brake is going to sweat more in swallowing a given heat input than a big one, and it will heat up and fade a lot quicker.

Sports and racing cars have used brakes as large as 16″ in diameter with over 200 sq. in. of lining area per 1000 lbs. car weight; they're almost impossible to fade on size alone! In contrast, a typical Detroiter might have 11″ drums with 50 sq. in. per 1000. Of course, Detroit is severely limited on diameter by 15″ wheels, and may be even more so soon with 14″ wheels. But we're cramming all the brake we can into the space available these days, using *wider* linings as well as more drum diameter. Cadillac, Lincoln, Buick, and Studebaker have recently increased either or both.

One new angle here is the idea of sacrificing some lining area—which means a bit faster wear—to get more air circulation against the inside surface of the drum. As it is, usually with two shoes covering most of the drum area, and since lining material is a very efficient heat *insulator*, much of the heat generated between lining and drum surface has to *pass back through* the drum and be radiated around the outside. Now we're learning that, if we break up the solid lining area a little and try to coax some air against the drum, we can breathe some of this heat out directly. The increase in brake efficiency usually offsets the slight increase in wear rate due to the smaller lining area. One authority states that you can *double* the heat dissipation of a brake by reducing the lining area *one-third* and exposing the rest of the drum to the air! On the '54 Cadillacs they cut a ½″ groove right down the length of the lining (see picture). You may see more of this.

An expensive—but very effective—way to cool the drum is to use an aluminum outer surface chemically bonded to a

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thin iron liner shell (see page 19). The great heat conductivity of the aluminum improves the drum cooling, while retaining the favorable friction and wear properties of iron for the actual rubbing surface. Tests under severe conditions have shown reductions in drum temperature of over 150° F. using "Al-fin" bonded bimetallic brake drums as compared with conventional solid cast iron. A number of sports cars, including Cunningham, have used this layout.

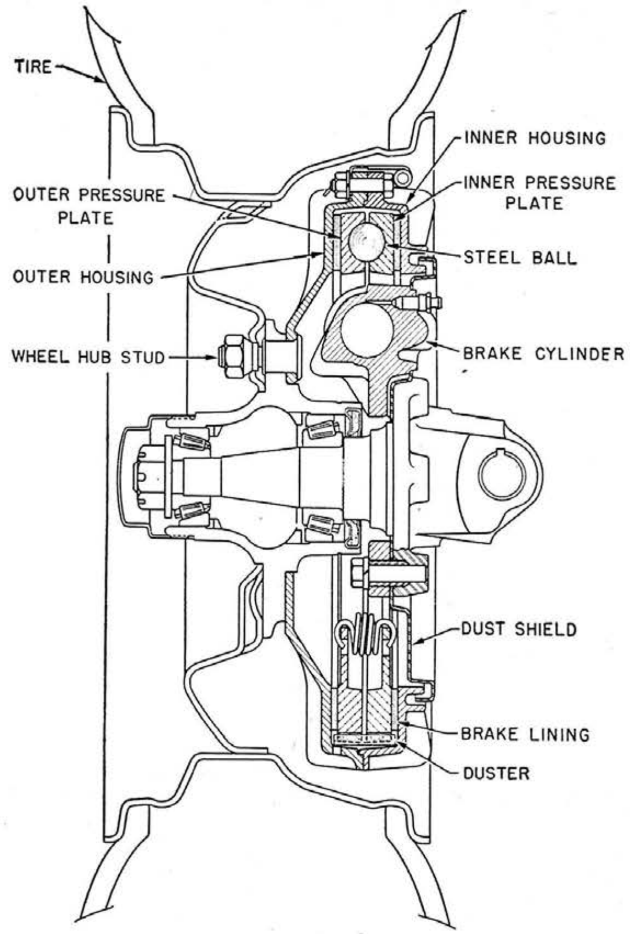
A very simple trick that will help drum cooling to some extent is merely putting *fins* on the outside surface, just as you'd put fins on the cylinders of an air-cooled engine. This is common in the competition and sports car field, and Cadillac is now doing it in our industry. *Water*-cooling of brakes has even been tried! One of the '54 LeMans Cunninghams had jacketed drums, positive water circulation by pump, and two special radiators in the fenders—all at a cost of about 200 lbs. of extra car weight. Results were so-so.

And, of course, don't forget the possibility of the negative approach to cooling—design the brake so that it can stand higher temperatures without fading. Some results have been had here. Nobody has yet come up with a low cost, long-wearing lining material that can take much over 500° without losing a lot of its friction. In the truck field sintered *metallic* linings (powdered metal fused into a porous mass by heating) show much promise, but they're pretty expensive for cars. Other tricks here are ribbing the drum to control thermal distortion, using flexible brake shoes to conform to a badly distorted drum, using *four* shoes per brake for better contact all around, etc. Any of these could be a future key to better brake performance.

BALANCED BRAKING

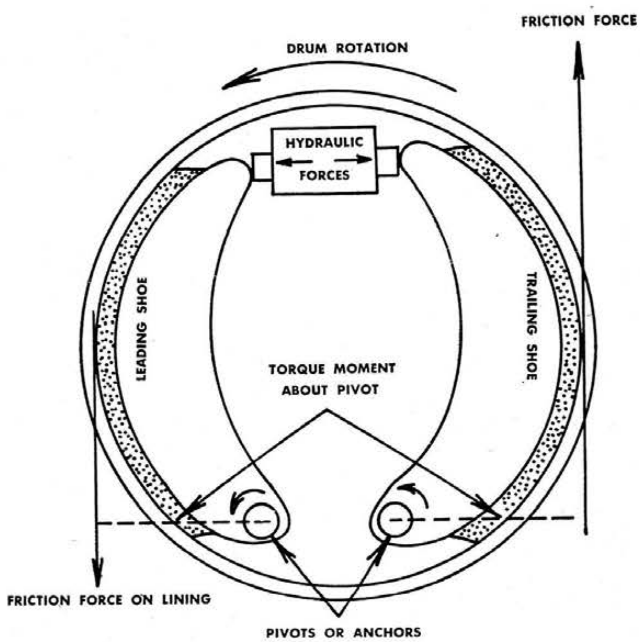
If you can't make each wheel carry its fair share of the total braking job, all the lining area and drum cooling in the world won't give a clean, quick stop. This item is often forgotten in brake discussions, but it's as important as any factor in the picture.

Here's the deal: You all know that the actual retarding force on the car itself is produced through friction between the tires and road; the more total friction the quicker the stop.

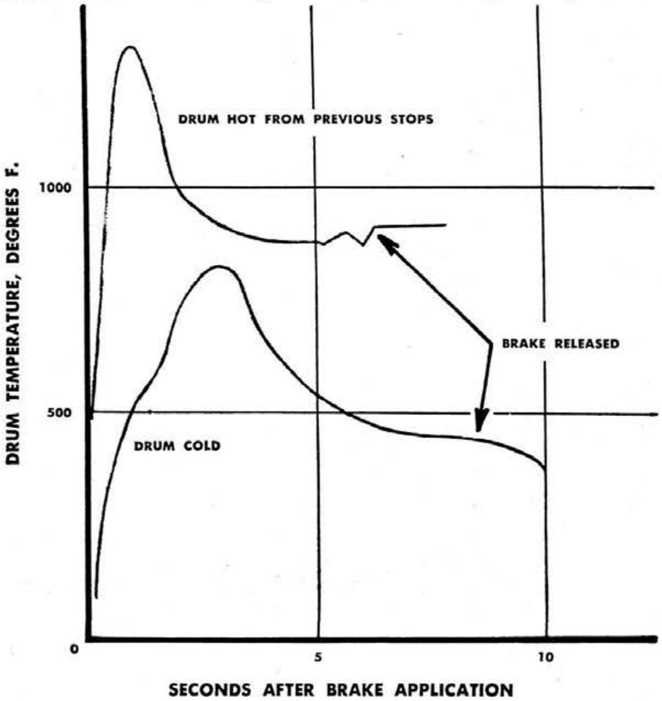


Based on Lambert design, Chrysler disc brake section drawing shows ball and ramp arrangement which gives brakes servo action.

Schematic drawing illustrates self energization in shoe-type brake. The left shoe is self-energized, or "leading." Both shoes would be leading shoes if they were pivoted at opposite ends.



Tests made at the General Motors Research Laboratories showed a temperature build-up on the surface of typical cast iron brake drums under hard braking at 70 mph with 55 pounds pressure.



Now since friction force depends on the force pressing two surfaces together, it will be obvious that, for best possible braking, the braking force (or torque) on each wheel should be *exactly proportional* to the instantaneous weight on that wheel! This is not as simple as it sounds. The weight on the four wheels will vary widely with the number of passengers and luggage. Even greater variation in front-rear weight distribution is caused by simple *inertia* or momentum. When the car is decelerated the moment of the center of gravity above ground level (CG is generally about 25" above ground level on a stock car) pushes the front end down and lifts weight off the rear. For instance, if you have, say, 55% of your car weight on the front end when traveling at constant speed, a panic stop will increase this momentarily to around 69%! And the clincher is that this "inertia weight transfer" varies with the rate of deceleration—so every different type of stop gives a different front end loading.

How are you going to nail it down? You don't. Detroit can only compromise and "balance" their front-rear braking for a normal load and normal stop on dry pavement. The '54 models vary anywhere from 53 to 65% of the total braking force on the front wheels (done by using different lining area and hydraulic forces). But, of course, this leaves the rear brakes doing practically nothing in a panic stop on wet pavement or ice, while the fronts lock up.

The answer is obviously some sort of compensating system in the brake hookup that will automatically control the front-rear brake proportioning (probably through the hydraulic line pressure) to keep any one wheel from locking before the rest. Such a device has been developed in the truck field to keep trailers from jack-knifing on ice; space won't permit a discussion of the gimmick here, but we may someday see something like this in the auto field. Meanwhile brake balancing must be a tough compromise on the drawing board, and on any stop you may have available only part of the inherent efficiency of your braking system because of this problem.

DISK BRAKES

We've been hearing a lot about disk brakes ever since an experimental set of Dunlops cinched the 1953 Le Mans race for Jaguar. That race was a great victory for modern brake science. The disk-braked Jags were able to go 100 yards farther into the corners before backing off than the other 150-mph cars, and they did it for 24 hours without a trace of fade!

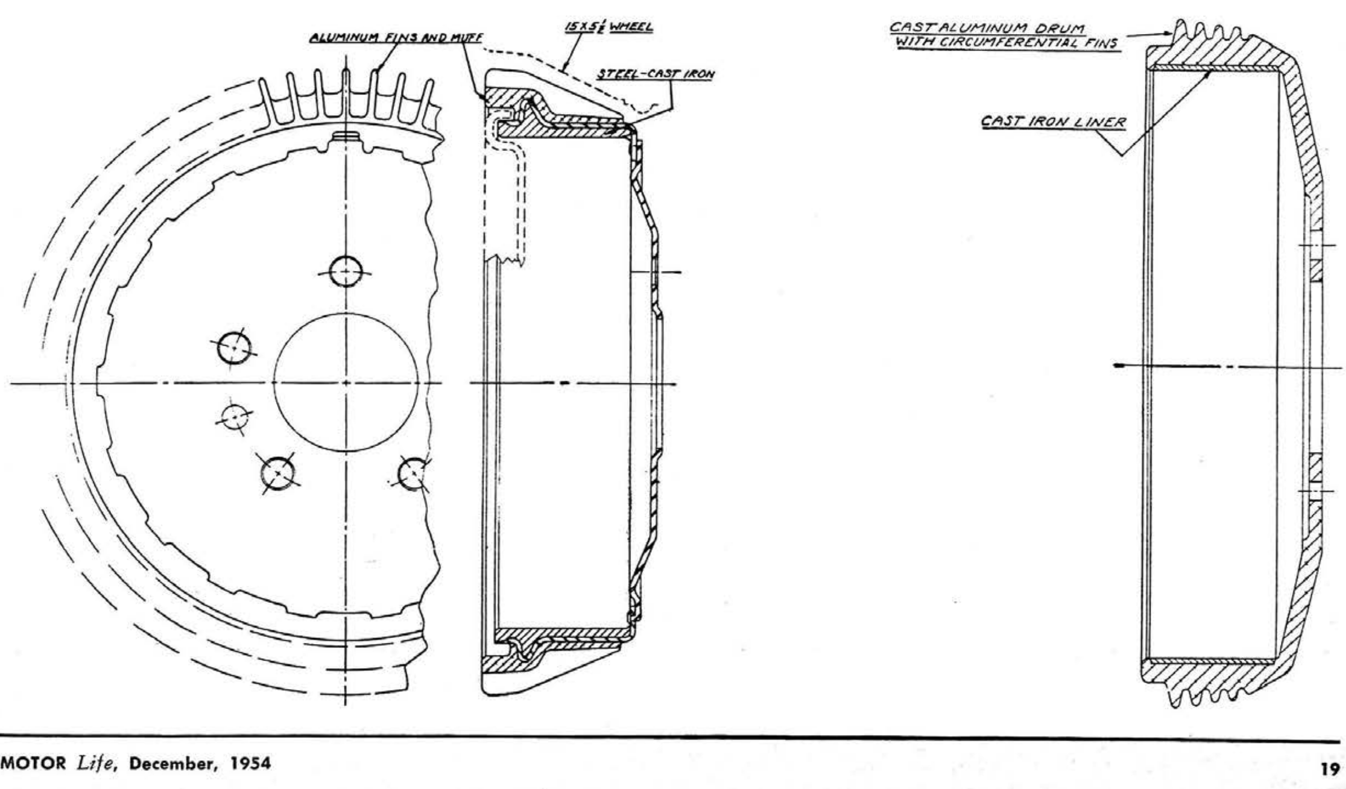
As you know, the principle of the disk brake is to use a flat disk rotating with the wheel instead of a drum, and press the friction material squarely against the disk in an *axial* direction. Some layouts use friction contact clear around the disk on one or both sides, while others use one or more small circular pads pressed against the disk, generally on both sides. Principle is the same, of course. The advantages of the disk brake layout are obvious: You have no pivoted shoes, so contact is even at all points; there is no thermal distortion to vary the contact force (expansion of the disk is even and has no effect on friction pressure); cooling is much better, especially on the "pinch" brakes with small pads where most of the disk is rotating in open air; the brake can be made considerably lighter (less unsprung weight) and more compact. Main disadvantages are high cost and fast wear on the small friction pads with the pinch brake.

Probably the general disk brake layout most likely to see future use in our auto industry operates something like a plate clutch, with friction over most of the circumference of the disk (on both sides), and operating in an enclosed casing. Chrysler is presently putting this type on their large Imperial models (see pictures). A unique and important feature here is the provision for "servo" action—that is, it's arranged so that the friction torque acts to *increase the force* pressing the disks together; this is done by allowing a slight rotation of the stationary disk and having balls acting in ramps to "cam" the parts together. It works very efficiently.

It may be a little premature to say that the disk brake is the next step in our auto industry. There is still lots to be done with the old drum brake to make it work better . . . and the disk *is* very expensive by today's standards. But low weight and heat dissipation will become more vital as time goes on. This could sell it. We'll see.

(*Continued on page 62*)

Al-fin brake design has been popular in racing. Here are two examples of experimental "Al-fin" bimetallic brake drum types.



POWER TO STOP

(*Continued from page 19*)

TO SELF-ENERGIZE OR NOT?

Another angle of this servo business that I think is quite significant today has to do with "self-energization" in a drum brake. You're all familiar with this feature, though maybe not by its technical name. By pivoting the brake shoe so that it rotates in the same direction the drum is turning, the friction force between lining and drum sets up a torque about the pivot which tends to rotate the shoe more, pull the lining down harder, and increase the braking force in relation to the pedal pressure. The drawing shows how this works. The British call this a "leading" shoe. This is a very important effect in brake performance.

Obviously to have both shoes self-energized you would have to pivot them at *opposite* ends and use two hydraulic pistons to operate them. Chrysler products (and many foreign cars) have featured this layout for years. The other manufacturers find it more economical to have only one shoe self-energized, and use a dual-expanding piston unit at one end to operate both shoes. Theoretically the Chrysler cars should require somewhat less pedal pressure for a given stop, but there seems to be little practical difference on the road.

But here's the point I'm getting at: The very latest thinking on improving brake efficiency under severe conditions is that *neither* shoe should be self-energized, with a power boost added to make up for the loss of force multiplication!! With a self-energized brake most of your braking is actually being done, not by pedal pressure, but by friction on the lining pulling it against the drum. Then obviously any appreciable drop in lining friction, such as when the brake heats up, is going to cause a terrific loss in braking force in relation to pedal pressure.

The new theory is to use *brute force* (through a vacuum power unit) instead of friction to apply the shoes to the drum; it requires about *three times* the force at the shoe tip for a given braking torque. . . but a big loss in lining friction will have very little effect on the performance of the brake. The linings will literally *burn up* before they'll fade appreciably! The Girling Company in England has recently come out with a "two-trailing-shoe" brake, and it's now being used as standard equipment on the Mk. VII Jaguar sedan. Works beautifully. What with the general adoption of power boosters in this country, you might see this over here someday.

BRAKE TIPS

In conclusion, a few tips for the owner and enthusiast:

Your brakes are your best life insurance—so baby 'em. Check frequently for wear, adjustment, and fluid level. There's been a rash of accidents lately traced to cheap brake fluids that are flooding the market; they have a low boiling point, and under severe braking conditions the heat may boil the fluid in the lines and cause sudden, complete brake failure. Use only reliable, established brands when adding brake fluid. Same deal with some cheap linings. Their friction coefficient drops off at a lower temperature than the established brands, so you can run into serious fade under only moderately severe braking conditions. Saving a buck or two on brake work may prove to be poor economy!

To the home-builder who is working up his own sports car for fast road work, I would re-emphasize the importance of *brake cooling*. When building your own car it's not much of a job to provide for some ventilation around the brakes. Scoops and ventilating holes in the backing plates are good. And in regard to the important brake balancing, you might experiment with greater braking force on the rear than the Detroit version has, since your weight distribution and weight transfer will be a lot different.

And that about covers—or at least skims—the brake story. *Heat* is the big bug. If we can control it—and balance the braking work somewhere near evenly between the four wheels—our troubles are over. Ettore Bugatti once joked that he built his cars to go, not stop . . . but when you're threading down a crowded highway these days with 200 hp iron going in all directions, it's kind of nice to know you can pull your neck in when you want to!! •

WINTER TARGET

(*Continued from page 27*)

may be clogged. Both should be flushed to get complete value out of the operation. If your car has a hot water heater make sure it is flushed and reverse flushed as well. A clogged heater might very well be the weak spot in the cooling system.

Once you're satisfied that the system is in good operating condition, select the anti-freeze you've decided to use this winter. A great percentage of drivers who live in areas where cold weather is unpredictable, always select the permanent type anti-freeze for its dependability. Run the engine of your car until the temperature is higher than sufficient to open the thermostat. At this stage, drain the system completely by opening the drain petcocks at the radiator bottom and the engine sides. (NOTE: Be sure to turn off the engine before draining.) Either measure the amount of liquid you have drained (providing the system was full) or check your car's owner's manual to learn the capacity of the cooling system. Close the

(*Continued on page 65*)