

The Truth About LIMITED-SLIP DIFFERENTIALS

Our test cars were identical except for the differentials—one standard one antispin. The results will surprise you.

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Chained to each other, the two 4-4-2 Oldsmobiles in Popular Science test pull in opposite directions. Each car has one rear wheel on ice, the other on dry road. Predictably, the car with the antislip axle won the tug-o'-war- pulling the other backwards with both its rear wheels spinning.

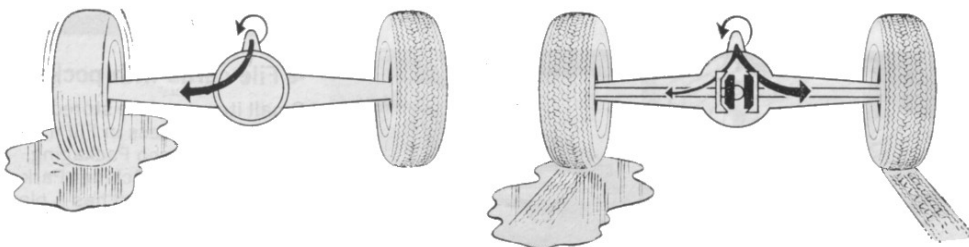
You may have driven cars with limited-slip differentials for many years. Maybe you feel they've gotten you out of spots where a standard axle would have left you stranded. Or maybe you think they don't help you much, if at all. You may even feel that the drawbacks of an antislip unit are greater than the advantages. But what do you *know*?

To get the facts on just what a limited slip differential contributes to mobility under slippery conditions as well as on dry roads, we drew up plans for a series of tests. Not lab tests, nothing theoretical, but full-scale vehicle tests on real ice.

To get positive proof of the effect of an antislip differential, we had to isolate all other factors. That meant getting two test cars, identical except for the differential. Oldsmobile agreed to cooperate, and came up with two 4-4-2 hardtops, weighing within 20 pounds of each other, both equipped with Turbo-HydraMatic transmission.

Both test cars had Firestone F70-14 polyester cord tires. One set was brand new; the other had rolled 1,000 miles. There was no measurable wear on any tire, but this small difference in mileage was to play a critical part in one of our tests.

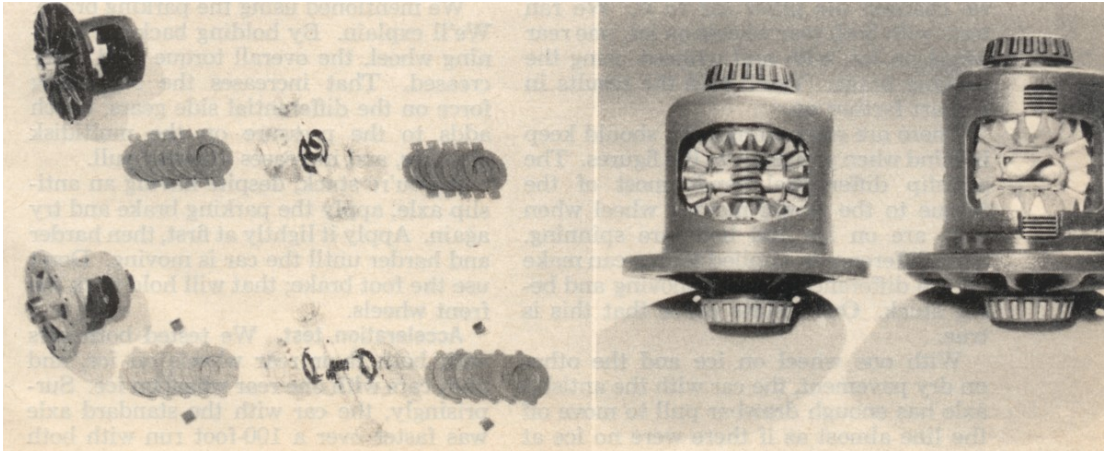
How the axles differ. Before we talk about the test, let's take a quick look at what standard and limited-slip differentials are. In the standard axle, the only connection between the wheels is through the differential side gears. They leave one wheel free to turn at any speed while the other stands still. In the antislip axle, there are multidisk clutches outside the side gears on both sides, connecting the road wheel directly to the final drive, bypassing the differential side gears, whenever wheelspin occurs.



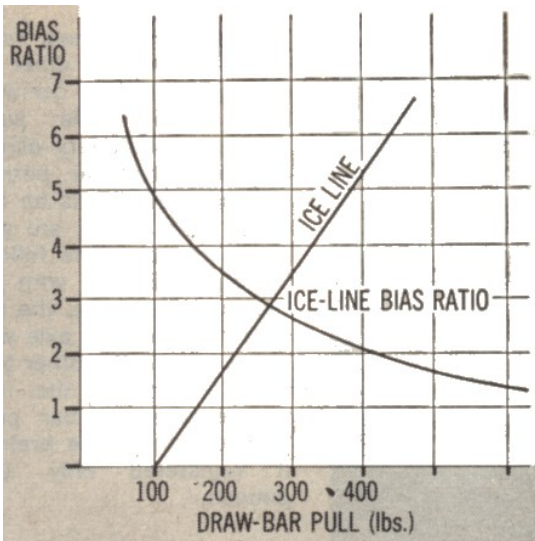
With standard differential (above), a car with one driving wheel on ice fails to move ahead because wheel with good grip transmits no more torque than the spinning one—and that can be zero. With limited-slip differential (right), gripping wheel gets more torque than spinning wheel, and car moves.

If one wheel in a standard axle loses traction, it will start to spin, and no more torque can be applied to it or to the opposite wheel. With an antislip differential, the clutch on the side of the gripping wheel will engage as soon as the other wheel starts to slip, and the gripping wheel will get *more torque* than can be applied to the spinning wheel.

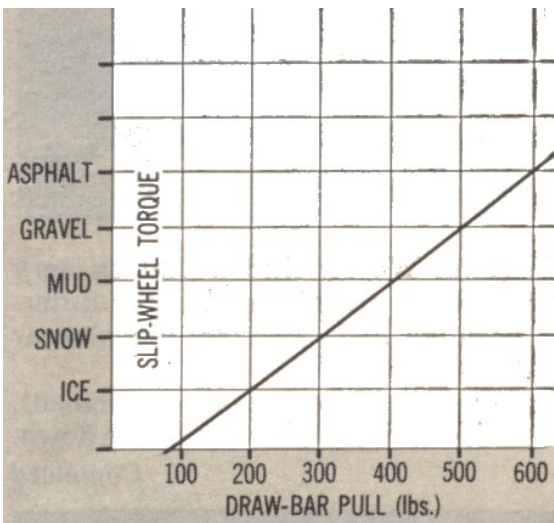
Engineers often call the antislips "torque-bias" differentials. The bias ratio is the torque difference between the two wheels, expressed as a multiple of the torque applied to the spinning wheel (slipwheel torque).



Two types of GM limited-slip differentials are shown in the photos above: at left, with parts laid out; at right, assembled. Both differentials have multiplate clutches outside the side gears. The Olds type has an S spring between the side gears to provide a preload on the clutches-the other has coil springs. When one rear wheel slips, a side thrust is exerted by the side gear, and the clutch will engage, limiting the slip. When both wheels grip, side thrust is relieved and clutches disengage.



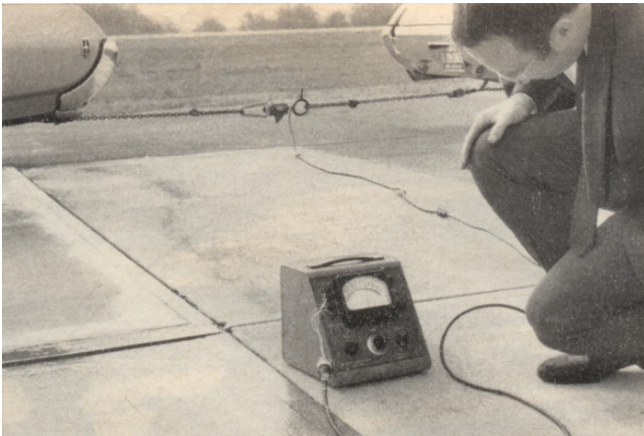
Bias ratio is torque in the gripping wheel divided by torque in slipping wheel. Drawbar pull is torque of both driving wheels combined. Ice line represents rise in drawbar pull possible with higher bias ratios. Normal ice-line bias ratio is 2.8:1.



Slip-wheel torque is an expression of the tractive force between the road surface and the tire. It is determined by the coefficient of friction; the firmer and more abrasive the road surface, the higher this torque. Drawbar pull increases in proportion.

Now, on to the testing. We were given free use of the facilities of the GM Proving Grounds at Milford, Mich. This included a strip of roadway with an underground refrigerator that produces a layer of genuine ice!

First test: drawbar pull. That's tractive effort—the force that can usefully be applied to drive the car. By parking one car off the ice, we had a stationary object, and we chained the other car to it. We ran tests with both rear wheels on ice, one rear wheel on ice, with and without using the parking brake. You'll find the results in a chart farther on.

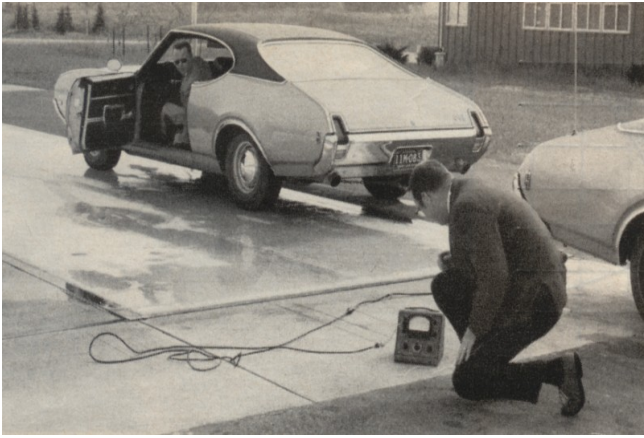


How PS measured traction on ice

Drawbar pull was measured (in pounds) with this instrument. It is adjusted to cancel out the weight of the chains, and registers only the horizontal pull produced by the vehicle. Both cars were tested with their two rear wheels on ice, then with one rear wheel on ice and one rear wheel on dry pavement.

There are some things you should keep in mind when you analyze the figures. The antislip differential sends most of the torque to the slower-moving wheel when both are on ice and both are spinning. This difference in applied torque can make all the difference between moving and being stuck. Our results prove that this is true.

With one wheel on ice and the other on dry pavement, the car with the antislip axle has enough drawbar pull to move off the line almost as if there were no ice at all. That's because the torque-bias ratio gets very high and the axle becomes almost solid. But not quite.



With one rear wheel resting on ice and the other on dry pavement, the car with the antislip axle pulls against a stationary object (the other test car, parked with all four wheels on dry road). The results are given on chart on the following page. Below, with all four wheels on ice, the car with the standard axle was hooked up to the other test car (parked off the ice) to measure drawbar pull. Without use of the brakes, it registered only 100 pounds.



We found that even with an antislip axle it was possible to sit and spin one wheel while the other (on dry road) remained still. That's because there's a limit to how high the torque-bias ratio can go. We know that 100 pounds of drawbar pull is the maximum for the spinning wheel, and even if the bias ratio should rise to 10: 1, the resultant 1,000 pounds in the gripping wheel may not be enough to prevent slippage in the multidisk clutches. So the gripping wheel remains stationary while the other spins.

For drag racing and other competitions, true locking differentials are available, but they're noisy and cause increased tire wear, and so are not recommended for street use.

We mentioned using the parking brake. We'll explain. By holding back the spinning wheel, the overall torque load is increased. That increases the separating force on the differential side gears, which adds to the pressure on the multidisk clutches, and increases drawbar pull.

If you're stuck, despite having an antislip axle, apply the parking brake and try again. Apply it lightly at first, then harder and harder until the car is moving. Don't use the foot brake; that will hold back the front wheels.

Acceleration test. We tested both cars with both their rear wheels on ice, and both cars with one rear wheel on ice. Surprisingly, the car with the standard axle was faster over a 100-foot run with both rear wheels on ice! We made a number of runs, with consistent results. Not a shadow of doubt.



Acceleration on dry road gave the edge to the car with antislip differential. With high-powered engines, standard axles suffer from tramp and partial wheelspin for a good portion of the quarter-mile. That's because of torque reaction in the axle, which tries to lift the right wheel. As wheel lifts, it loses traction, and torque reaction is canceled. The wheel regains traction, and cycle is repeated.

Then we switched tires, and made a few more runs. Now the car with the antislip axle (but new tires) was faster, by a similar margin. We concluded that on very smooth wet ice, the tire makes the difference. Even as little as 1,000 miles' wear counts!

With one rear wheel on dry pavement, the antislip-equipped car won hands down. It covered the 100 feet in 10.9 seconds. The other car needed 14.8 seconds.

As long as there is traction for one rear wheel, the car with the antislip axle has a big advantage. Our tests proved that. We also proved something else: If you have only one tire chain, that's enough to get you going if you have a limited-slip differential.



Acceleration from standstill along the 100-foot icy stretch proved that tire tread pattern plays a bigger role than the type of differential. This may be true only for very smooth surfaces, evenly iced.

We also ran acceleration tests on dry pavement. The car with antislip won. It covered the standing quarter-mile in 14.6 seconds, against 15.2 for the other. Axle tramp and wheelspin lost the race for the car with the standard axle.

DRAWBAR PULL-TEST RESULTS

DIFFERENTIAL	WHEELS ON ICE	PARKING BRAKE	DRAWBAR PULL (pounds)
Standard	All four	Not used	100
Anti-spin	All four	Not used	180
Standard	All four	In use	150
Anti-spin	All four	In use	325
Standard	Left F&R	Not used	125
Anti-spin	Left F&R	Not used	400
Standard	Left F&R	In use	200

Comparison of cars, pull-tested with one or both driving wheels on ice, with and without use of parking brake, is shown at right. Holding back the spinning wheel with parking brake increases the load on the multiplate clutches in antislip differential and makes possible a considerably higher drawbar pull.

Antislip drawbacks. Limited-slip differentials are accused of being noisy, of wearing out, and of causing fishtailing.

The noise complainers refer to chatter that may occur when sharp turns are made on dry pavement. Oldsmobile says this problem is not completely licked, though our test car could not be made to chatter on any surface, or on any combination of surfaces.

Olds axle engineer Ed Rosatti says chatter won't show up until after 50,000 miles. Our car was practically new. As for wearing out, all manufacturers count on at least 100,000 miles for the clutch disks.

A lot of progress has been made in lubricants in the past couple of years. Mobil came up with a better formula to prevent chatter and plate wear. It contains special friction modifiers that play up the dynamic friction in the clutches and play down the static friction.

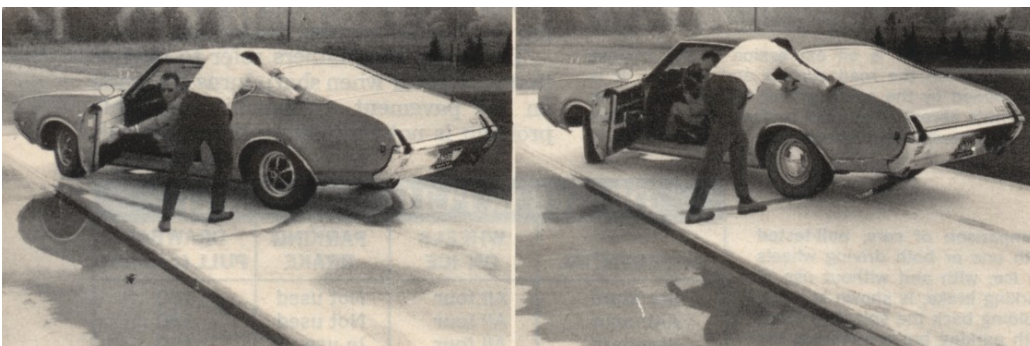
Oldsmobile (which makes its own axles and differentials) has developed clutch disks with improved configuration and hardness. They're treated (Tufftrided) to prevent warpage in extreme heat, and have a special pattern for better lubricant retention during periods of extreme centrifugal force.

Our test car had a certain vibration, although without noise, when accelerating hard from standstill on a sharp right-hand turn.

This occurs because of torque reactions in the axle itself. The axle tries to turn around the pinion shaft, in a direction opposite to that of pinion rotation. Thus the right wheel is subject to a lifting force while the left one is pressed harder to the ground. Without antiskid, this results in wheel hop and intermittent wheelspin. The antislip unit overcomes the torque reactions, but their intermittent nature gives rise to slight vibration in the whole rear suspension.

The lateral weight transfer to the left due to centrifugal force set up by making a right-hand turn aggravates the situation. On left-hand turns, there is no vibration, mainly because the motion of the car causes a weight transfer to the right rear wheel.

What about stability? Does the antispin axle produce lateral instability on slippery roads? Our tests (see photos) proved that the standard axle offers higher stability at or near standstill. But some instability at a walking pace or even less speed would seem far preferable to not moving at all!



With only one rear wheel spinning on the standard axle car, the Olds engineer couldn't push it sideways. With both wheels spinning, he did-but then the car also crept forward. The standard-axle car we tested carried brand-new tires; the car with antislip had tires bearing 1,000-mile wear.

With rear wheels spinning together, car equipped with antislip was easily pushed sideways on ice by Olds engineer. Its lateral stability at very low speed proved inferior to that of car with standard axle. Whether more directional stability under these conditions has value is, of course, questionable.

At higher speeds, we found the same lack of stability on both types of axles. Any lateral drift in the tail of the car seemed to come from extraneous causes such as road camber, front-wheel steering angles, or road-surface unevenness-which had the same effect regardless of whether the car had an antislip axle or not.

Conclusion. After these tests, we know that limited-slip differentials produce no miracles. You can be so badly stuck that they can't get you going. But do we recommend limited-slip differentials? We sure do. As a factory-installed option, they're a real bargain, ranging from \$45 to \$60, depending on make and model.

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