

# Some Recent Developments in Work On Skidding Problems at the Road Research Laboratory

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•WORK on skidding problems has been an interest of long standing for the British Road Research Laboratory. Early papers from the Laboratory drew attention to many questions which are still being written about and discussed today, such as the importance of surface texture, the different coefficient/speed relations on different wet surfaces and seasonal variations in slipperiness (1); calculations of braking distance from coefficient measurements, the importance of "rate of slip" and the difference between "peak" and "sliding" coefficients in braking force measurements (2); and the formulation of a specification for a reliable method of measuring and comparing the non-skid properties of road surfaces (3).

Much of this work has been written about and reviewed in more recent publications (4, 5), and the purpose of this paper is to give an account of the latest testing techniques which have been developed at the Laboratory and some of the research findings resulting from their use.

## SKIDDING RESISTANCE MEASUREMENTS ON PUBLIC ROADS

Techniques for carrying out extensive programs of measurement on public roads are under consideration in some countries at the present time. Three recent developments in the Laboratory's work in this field are presented.

As is the practice in France, Belgium and Denmark, the sideway force method of test, using an inclined wheel, is the basic method employed by the Laboratory in making most measurements of skidding resistance on public roads (6). There are some good reasons for using this method of test. For example, as the test tire rotates continuously its wear is even, and there is little risk of results being influenced by localized heating or damage. A continuous recording is obtained, and essentially there is no limit to the length of road which can be covered in a single test. A constant rate of slip of the test wheel is obtained in a simple manner and the engine power required to maintain a given speed is appreciably less than that required to tow a locked-wheel trailer. Under British conditions it is also an important advantage that use of the method is not confined to straight, or nearly straight stretches of road. The test cars are so like ordinary cars in their appearance and handling that measurements can be readily made without interrupting or inconveniencing ordinary traffic.

### Testing Resilience of Tires

To preserve continuity in the measurements, the testing conditions employed in the Laboratory's sideway force test cars are basically the same as those put forward by Bird and Scott (3). The test tires have always been specially made, and the Laboratory keeps the special mold used for this purpose. With the discovery of the importance of the hysteresis properties of tread rubber on friction on wet surfaces (7), it was suspected that steps would need to be taken to keep a check in some way on the resilience of all future test tires. Measurements showed that, in sideway force tests on wet

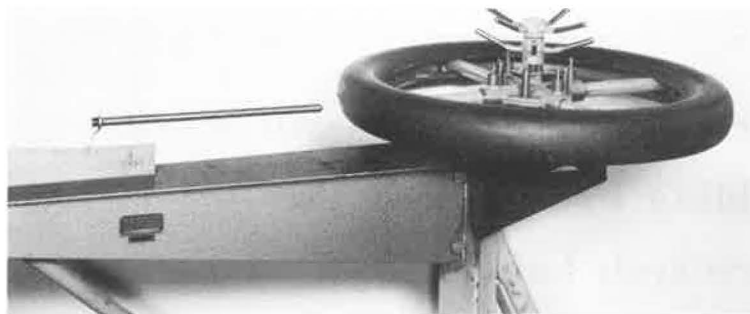


Figure 1. Lupke resiliometer modified for checking resilience of tires specially made for skidding resistance measurements.

coarse-textured surfaces, coefficient differences of the order of 0.10 at 30 mph could easily arise through differences in the resilience of the test tires.

Since 1960, measurements of resilience have therefore been carried out systematically on all the test tires used on the Laboratory's skidding machines. The apparatus used is shown in Figure 1. This consists of a Lupke resiliometer conforming to the requirements of British Standard No. 903 (8) which has been modified at the Laboratory to test tires instead of the more usual rubber discs. The resilience of the rubber is determined in terms of the percentage rebound of a hemispherically-ended steel rod supported on a long bifilar suspension which is allowed to strike the specimen under standard conditions. In the arrangement adopted, the test area of the tire is backed by a rigid metal "spoke" having a substantial head which is radiused to fit the inside profile of the tire casing so as to insure rigidity. A full range of spokes is available to suit all sizes of test tire which the Laboratory uses.

To indicate the need for this kind of testing, results of measurements on three batches of tires ( $B_1$ ,  $B_2$  +  $B_3$ ) specially made for use with the Laboratory's small braking force trailer (9) and on two batches of tires for the sideway force machines ( $S_1$  and  $S_2$ ) are summarized in Table 1.

Batches  $B_1$ ,  $B_2$  and  $S_1$  were made before the importance of resilience was recognized. In making the two subsequent batches ( $B_3$  and  $S_2$ ), close attention was paid to their resilience properties. The resulting improvement in uniformity is clearly evident, but even so there is a variation in the values of the order of  $\pm 3$  percent from the mean resilience of these batches, and there are also differences in the mean value from batch to batch.

On this evidence it would appear that, even where "standard" test tires are made in batches and conform to some closely specified rubber composition, differences in resilience between the different tire treads are to be expected. Some form of resilience test for tires is likely to be needed if good consistency in the measurements is to be maintained.

### Evaluation of Test Results

Frequently, where the sideway force test method is used to test full-scale road experiments, a single set of measurements produces a paper chart containing in graphical form the results of up to five separate test runs at some chosen test speed over 100 or more experimental sections. The full evaluation of this record can be a time-consuming

TABLE 1  
RESULTS OF RESILIENCE TESTS ON BATCHES OF  
SKIDDING TEST TIRES USING MODIFIED  
LUPKE RESILIOMETER

Batch	Range of Resilience Values in Batch (%)	Mean (%)
(a) Braking Force Test Tires		
B1	37 - 54	46
B2	46 - 59	49
B3	54 - 59	57
(b) Sideway Force Test Tires		
S1	27 - 53	44
S2	50 - 54	52

SECTION 7												
RUN	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C
1	32	0.60	32	0.62	33	0.61	33	0.62	32	0.62	32	0.62
2	31	0.65	31	0.68	31	0.65	30	0.70	30	0.68	30	0.65
3	31	0.59	31	0.63	31	0.60	31	0.62	32	0.63	32	0.60
4	31	0.63	31	0.67	31	0.65	31	0.66	31	0.63	31	0.67
5	31	0.59	31	0.63	31	0.60	31	0.61	31	0.63	31	0.59
SIDEWAY FORCE COEFFICIENT												
READINGS	MEAN SPEED		MEAN		MAX		MIN		STD DEV			
30	31		0.63		0.70		0.59		0.03			

SECTION 8												
RUN	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C	SPD	S.F.C
1	31	0.54	30	0.55	32	0.57	32	0.56	32	0.55	31	0.51
2	31	0.56	30	0.62	30	0.62	30	0.65	30	0.63	30	0.59
3	32	0.55	32	0.56	32	0.60	32	0.58	32	0.57	30	0.53
4	31	0.60	31	0.61	30	0.62	30	0.61	30	0.63	30	0.59
5	31	0.54	31	0.56	31	0.58	32	0.58	32	0.55	32	0.54
SIDEWAY FORCE COEFFICIENT												
READINGS	MEAN SPEED		MEAN		MAX		MIN		STD DEV			
30	31		0.58		0.65		0.51		0.03			

Figure 2. Example of tabulation and analysis of skidding measurements obtained using trace reader and Pegasus computer.

operation, and work is in hand to expedite this. At the present stage a chart analyzer has been developed which enables the recorded information to be transferred to punched paper tape. This can be fed into the Laboratory's "Pegasus" computer, and a program for this has been written to enable it to sort out and analyze the data automatically. An example of the way in which the results are finally arranged and printed is shown in Figure 2.

### Transverse Positioning of Test Machines

Frequently, when the slipperiness of different road materials is under study, it is necessary to carry out skidding measurements at regular intervals and over quite long periods of time. Difficulties may then arise because of inevitable variations in skidding resistance due to uneven distribution of traffic across the width of the road and the difficulty of driving the test machine along precisely the same wheel track on every occasion. To try and meet these difficulties, advantage is being taken of other work being carried out at the Laboratory on electronic techniques for vehicle guidance and control (10). Field trials will soon begin with a system developed for guiding the test driver on to the correct position on the road. This system uses an energized guidance cable installed along the edge of the test road, and a single detector coil mounted on the bumper connected to comparatively simple electronic-indicating apparatus in the vehicle.

### CROWTHORNE RESEARCH TRACK

Although full-scale experiments on busy public roads offer the most satisfactory means presently available of studying the skid-resisting properties of road materials under actual working conditions, it is becoming increasingly difficult to carry out many important researches under these conditions because of the higher speeds involved. The building of the Laboratory's Research Track at Crowthorne (11) has, therefore, provided an important opportunity for making some much-needed provisions to promote the Laboratory's work on skidding, braking and vehicle stability. The general layout of the track is shown in Figure 3, the parts specially concerned with this type of work being the Long Straight, the Terminal Area and the Central Area. On the Long Straight, six special test sections have been laid for skidding investigations, each 200 yd long by 12 ft wide, with provision for other test lengths to be laid as required. Three of the test sections represent surfaces of the rough coarse-textured kind which are commonly

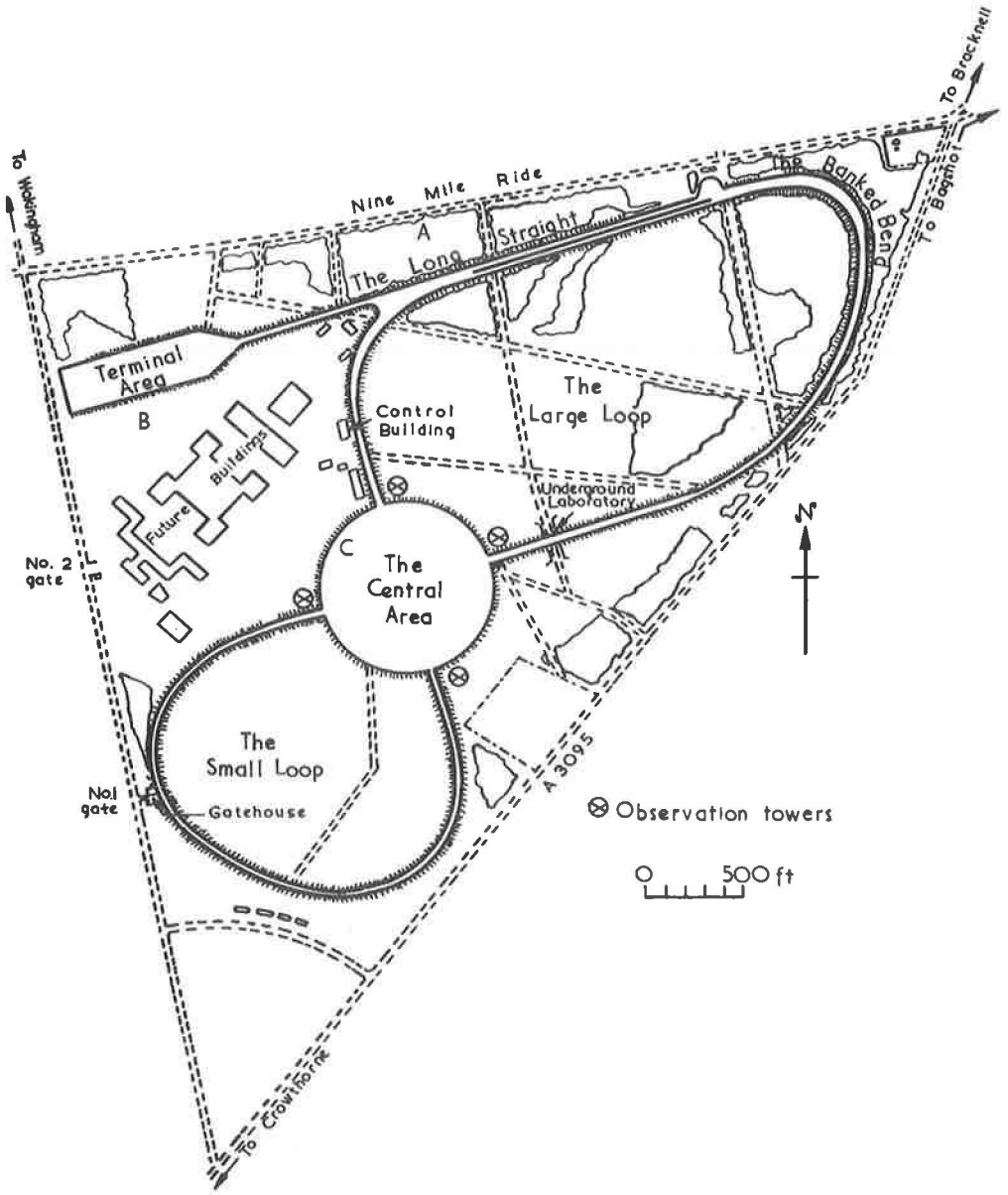


Figure 3. Crowthorne Research Track.

used on British roads, and three are surfaces of the smooth, or fine-textured type. In each section either the aggregate or the surface-finishing technique was specially chosen so that the three sections in each group cover a range of skidding-resistance properties from "non-skid" to very slippery. Skidding investigations are most frequently carried out on wetted surfaces, and the length of the Long Straight containing the six test sections has therefore been equipped with a watering system which is shown in operation at comparatively low pressure in Figure 4. The approach to the eastern end of the Long Straight is a curve of comparatively small radius (Fig. 3) and steeply banked. With suitable vehicles, approach speeds approximating 100 mph can be obtained. Stopping facilities at the other end of the Long Straight are provided by the Terminal Area which itself is 300 yd long and 83 yd wide.



Figure 4. Crowthorne Research Track spraying system in operation under comparatively low pressure.



Figure 5. Test trailer used for measurement of braking force coefficient.

#### MEASUREMENTS AT HIGH SPEED WITH SMALL BRAKING FORCE TRAILER

The Laboratory has been making measurements on aerodrome runways and roads with a small braking force trailer (9) (Fig. 5). Some typical results showing the different kinds of coefficient/speed relations which are found are shown in Figure 6. Smooth or fine-textured surfaces are represented by the steeper coefficient/speed curves shown in Figure 6, and coarse-textured surfaces by the flatter curves. For the test conditions used on the trailer the "tire-hydroplaning speed" using Horne's simple approximate formula (12) is only of the order of 47 mph.

With the completion of the Crowthorne track the coefficient/speed relationship for locked wheels on wet coarse-textured surfaces could be studied at higher speeds than

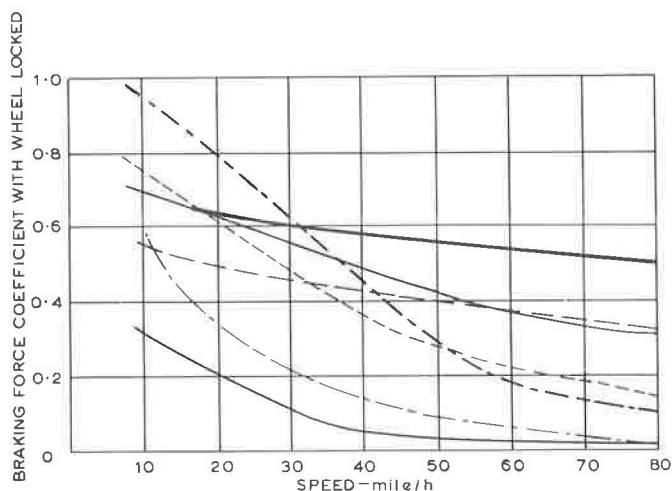


Figure 6. Results of braking force measurements on different wet surfaces made with small braking force trailer.

had previously proved possible. Results were rather unexpected as illustrated by the example shown in Figure 7a. This compares results obtained on the most "non-skid" of the smooth looking surfaces on the track (Fig. 7b) with results on the most slippery of the rough coarse-textured ones (Fig. 7c). On the latter surface at speeds above 80 mph the locked-wheel coefficients show a sharp increase in value. Similar increases in the coefficients above this speed have been obtained on the other rough coarse-textured surfaces on the track.

There are a number of clues to the reasons for this behavior. First, although the surfaces were maintained in a thoroughly wet condition, there was a smell of hot rubber each time the wheel was locked in the tests above 80 mph, and the tire showed evidence of a very deep "scalding" over the area actually in contact with the surface. This scalding appears to be due to heating and softening of the rubber just below the surface of the tread, by the energy dissipated there through hysteresis losses due to the repeated deformation and recovery of the rubber as the projections in the road surface are dragged through it. The speed of sliding appears to be an important factor because in tests made on similar surfaces using  $\frac{3}{16}$ - in place of  $\frac{3}{8}$ -in. stones, it was

again necessary to exceed 80 mph before the rising coefficient effects could be observed. There may possibly be some connection between this and the rate at which deformations recover in natural rubber treads. For example, the sliding speeds are approaching the speeds at which "standing wave" effects in tires are observed (13), and there is also other evidence of retraction speeds of this order (14). Grosch (15) has discussed the effect of rate of recovery on rubber friction. Finally, when similar tests were made with a low resilience tire of butyl rubber, higher coefficients were obtained at all speeds, and similar tire damage occurred at very much lower speeds of test.

TABLE 2  
EFFECT OF WATER DEPTH AND  
SPEED ON COEFFICIENTS OBTAINED  
WITH SMALL TRAILER APPARATUS  
ON WET SURFACES

Test Speed (mph)	Braking Force Coefficient <sup>1</sup>	
	Water Depth	
	0.007 in.	0.030 in.
26	0.70	0.69
60	0.20	0.11

<sup>1</sup>Small trailer apparatus, locked wheel.

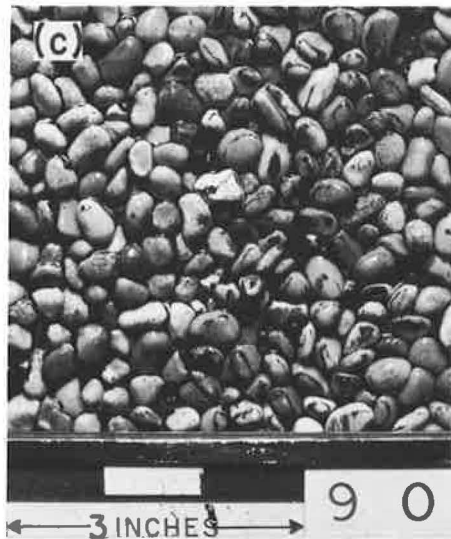
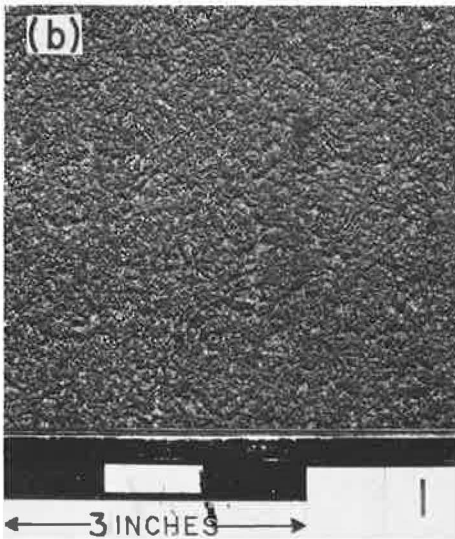
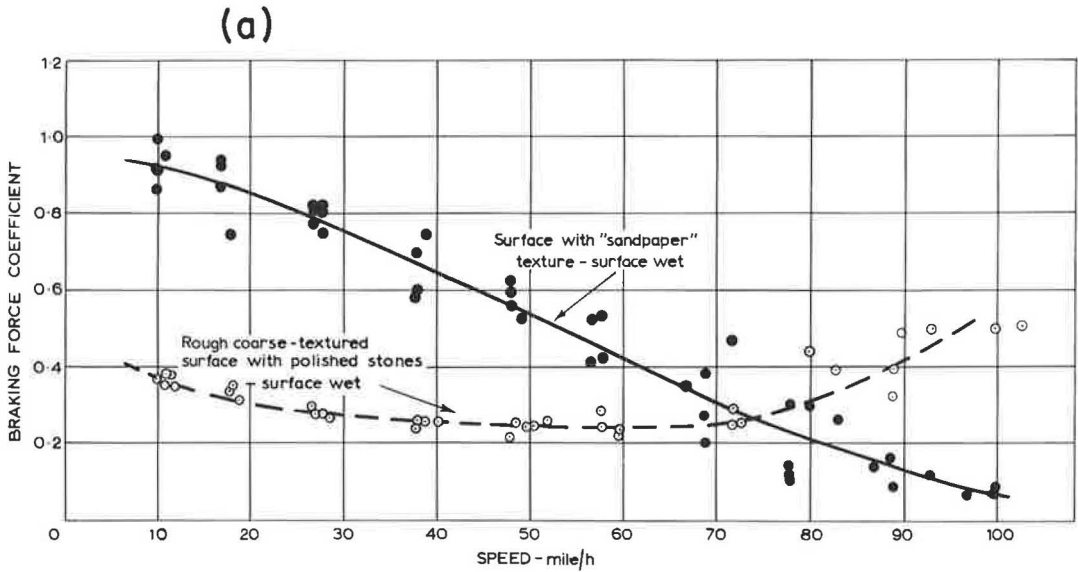


Figure 7. (a) Measurements of braking force coefficient obtained with locked wheels and patterned tires on two surfaces; (b) fine-textured asphalt test surface representing a "smooth-looking" surface with a good sandpaper texture; and (c) rough coarse-textured test surface made with highly polished stones to give a relatively low resistance to skidding when wet.

#### WATER DEPTH AND SKIDDING RESISTANCE

One factor relevant to skidding resistance which has been shown in the research work carried out in this field by the N.A.S.A. (12, 16, 17) is the importance of the inertia of the water when the tire is required to displace it at high speeds. Test results with the small trailer machine illustrating the effect of some comparatively small differences in water depth on a smooth surface and the importance of the speed are given in Table 2.



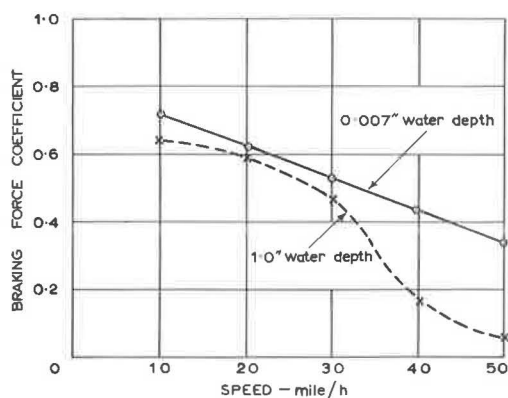


Figure 8. Effect of water depth on results of locked-wheel braking tests on a smooth surface with a patterned tire.

Table 2 shows that (a) in testing the slipperiness of roads there may be some disadvantages, as far as the consistency of the results is concerned, in attempting to carry out measurements at too high a speed unless very precise control over the depth of water in front of the test tire can be maintained, and (b) where front and rear wheels follow in the same tracks, rear wheels have the advantage of running over parts of the surface from which a great deal of water will have been cleared, or splashed away, by the front wheels. At the higher speeds this could clearly make some substantial increases in the adhesion available at the rear wheels, and it may be an important factor to consider when attempting to deduce behavior of four-wheeled vehicles at high speeds from coefficients measured with single- or twin-wheeled testing machines.

Of course, if the water is at all deep, vehicles running into it will experience a great deal of drag. Decelerations of the order of 0.5 g have been observed in a vehicle running into 2½ in. of water at 45 mph (19). Under such conditions tire/road friction coefficients fall to low values. Test results illustrating this are shown in Figure 8.

#### HEAVY WHEEL LOAD SKIDDING MACHINE

Although the small trailer machine has been used quite extensively for various investigations, it has always been recognized that its wheel load (320 lb), tire size (4.00 × 8) and inflation pressure (20 psi) are such that it is difficult to infer from the results



Figure 9. Heavy wheel load skidding machine showing test wheel mounted on calibration rig.



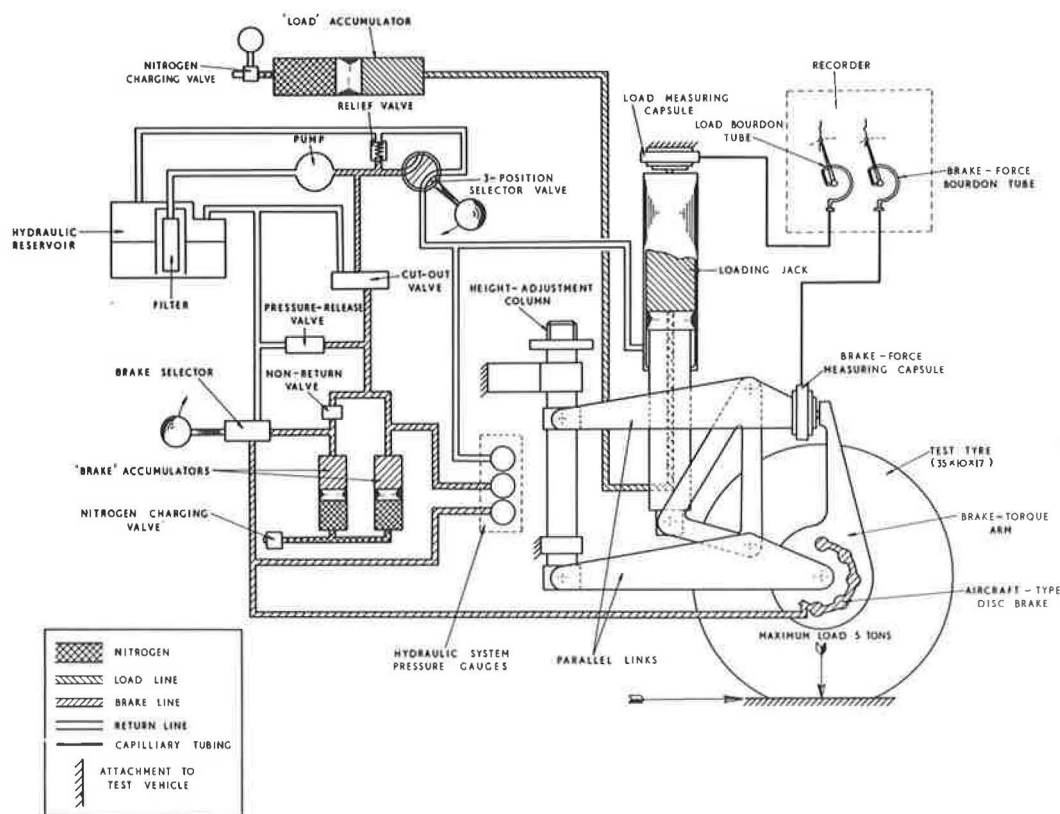


Figure 10. Heavy wheel load skidding test vehicle—diagrammatic arrangement of hydraulic systems and test wheel apparatus.

what values of coefficient are likely to apply under the same conditions for the wheels of cars and even more difficult for the wheels of aircraft.

In cooperation with the Ministry of Aviation, the Laboratory has, therefore, begun a new investigation into the effects of heavy wheel loads and high tire pressures on friction on wet surfaces. To carry out the tests a new testing machine was required and after considering various alternatives, a prototype of a fire-crash tender capable of speeds of 60 mph was specially modified for the work by the British Fighting Vehicle Research and Development Establishment. Some details of this vehicle showing the test wheel on its specially developed calibration rig are shown in Figure 9. The vehicle, which weighs 11 tons, has four-wheel drive and independent suspension on all wheels and is powered by a rear-mounted 240 B.H.P. engine. The vehicle can accelerate from rest to a test speed of 60 mph in 4,000 ft.

Details of the arrangement of test wheel and hydraulic recording system are shown in Figure 10. An aircraft test wheel and brake mounted in a parallel link suspension are used, and for considerations of stability when testing, the wheel is set within the wheelbase on the centerline of the vehicle and just behind the front wheels. By adjusting the nitrogen pressure in the loading accumulator the load on the test wheel (which is taken off the other wheels) can be set to any desired value up to a maximum of 5 tons. With this range of loadings, inflation pressures are over the range from 25 to 320 psi can be used.

On test the vehicle is first accelerated up to the desired speed and then, when it is running straight towards the test section, the test wheel is lowered. Enough load remains on the front wheels to provide sufficient traction, and to make small corrections to the steering the test wheel is arranged to pivot through a small angle about its

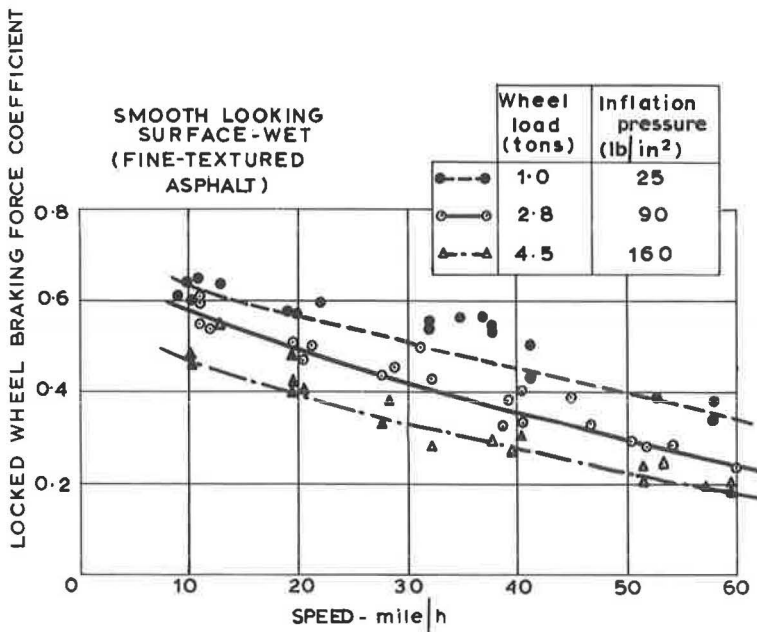


Figure 11. Relation between locked-wheel braking force coefficient and speed for various wheel loads and inflation pressure.

mounting column. On reaching the test section the wheel is braked, and immediately the ram is operated to raise the test wheel so that the vehicle can be braked to a standstill in the normal way.

Test results obtained with the machine are shown in Figures 11 and 12. In these experiments wheel loads and inflation pressures were adjusted to values shown to maintain an overall contact area of 72 sq in. for the tire in contact with a smooth surface. The results in Figure 11 show that there is a fall in the values of the locked-wheel coefficient when the higher values of the wheel load and inflation pressure are used. Thus it is very clear that under these conditions factors other than the pressure available to displace the water from the contact area are having an important influence on the coefficients obtained. Figure 12 shows that on slippery rough-coarse-textured surface results were rather different, and for speeds greater than 30 mph there appears to be little, if any, effect of load or inflation pressure on the coefficients obtained.

The results indicate that there are some fundamental differences in the mechanism of tire/road friction on these two main types of surface. This was further emphasized by the kinds of tire wear produced by locking the wheel on the different surfaces. As the load and tire pressure were increased there tended to be increasing amounts of tire wear when the wheel was locked, in spite of the fact that the tests were being made on wet surfaces. This increased wear may be a pointer to the mechanisms responsible for the decreased coefficients which were found. On the smooth or fine-textured surfaces fine particles of rubber were abraded from the surface of the tire while on the coarse-textured surfaces. The scalding type of wear associated with heating below the surface of the tire was produced.

These results were obtained in locked-wheel tests, but an aircraft type of "anti-skid" braking control system has now been installed on the vehicle. This has proved extremely effective in reducing tire wear and tests are continuing.

#### CONTROLLED SLIP SKIDDING MACHINE

Besides reducing tire wear under high/wheel loads anti-locking braking systems have the advantage of enabling a vehicle to use the better adhesion which can be obtained on

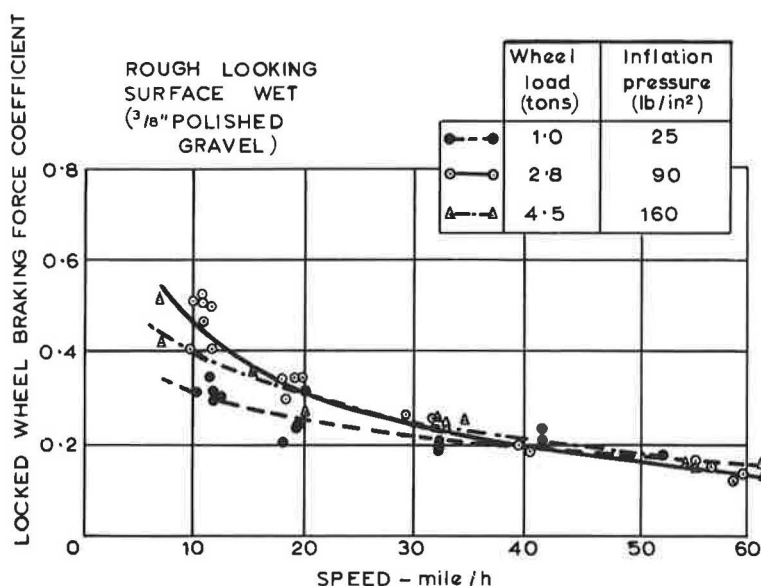


Figure 12. Relation between locked-wheel braking force coefficient and speed for various wheel loads and inflation pressures.

wet surfaces before the wheel is locked. To enable the braking force/slip relation to be studied more closely and also the effect of combined braking and cornering forces, a new machine has been built at the Laboratory (Fig. 13). The test wheel is installed within the wheelbase of a medium-sized truck, so that it runs just clear of the track of the nearside wheels. In developing the apparatus, use was made of a variable-ratio hydraulic transmission system. This comprises a variable displacement hydraulic motor coupled to a power take-off on the transmission of the towing vehicle, and this motor is connected to a similar but fixed displacement hydraulic pump driven through a suitable shaft and gearbox from the test wheel. This arrangement gives a "regenerative" braking system, and by controlling the displacement of the motor the test wheel can be made to turn with any desired rate of slip between free rotation and complete locking.

To facilitate testing, a direct-reading digital slip-meter has been developed. This consists essentially of two transistor counting units and some associated "gating" circuits. The first unit is used to count pulses from a photoelectric pulse generator coupled to one of the undriven wheels of the vehicle, and this unit controls the gating of the second unit. The second unit counts similar pulses from the test wheel. When both wheels are running freely they both generate pulses at the same rate. The gating of the second unit, however, is arranged to open or close at each successive count of 100 on the free-running wheel. If the rate of slip of the test wheel is now  $S$  percent, this second unit will only count  $100-S$  pulses while the gate is open, and it is this count which is displayed to the operator on the digital indicator while the next count is being made. For all practical purposes a continuous indication of wheel slip is obtained, and it becomes a simple matter for the operator to set the slip control lever to give whatever rate of slip may be required.

To measure the wheel load, and forces in the plane of the wheel, and at right angles to it, a compact cruciform wire strain-gage unit has been fitted between the socket of the upper kingpin ball joint, and the casing of the hub unit. Signals from this strain-gage unit are recorded on photographic film using a multi-channel galvanometer recorder which is sufficiently sensitive to record the signals direct, without amplification. Building the strain-gage unit into the hub casing in this way has an important advantage in that when the plane of the wheel is turned, the gages turn as well, and the forces both

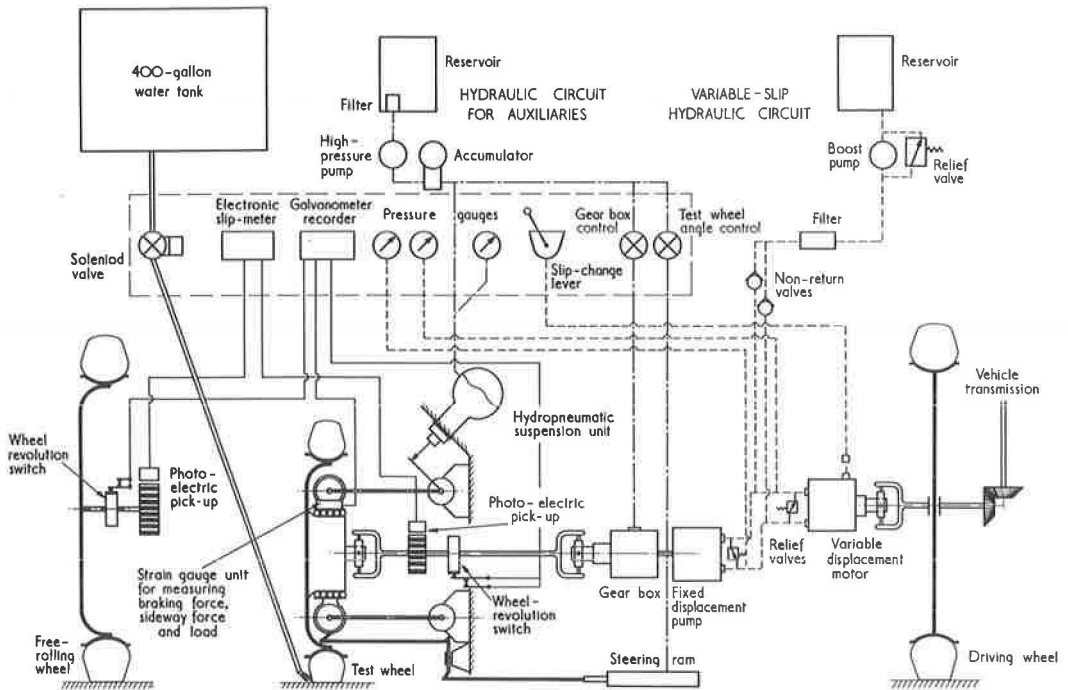


Figure 13. Apparatus for investigating skid-resisting properties under conditions of combined braking and cornering.

in, and at right angles to the plane of the wheel continue to be measured by the same arms of the strain-gage unit.

At present, tests with the machine have been chiefly concerned with following the coefficient/slip relationship in braking (with the wheel traveling straight ahead). Figure 14 shows preliminary results obtained under these conditions using a smooth tire, and a patterned tire, on two smooth or fine-textured surfaces, and on two coarse-textured surfaces. In most instances the coefficients obtained at 10-20 percent slip are higher than the locked-wheel values. However, the optimum slip, and more particularly, the precise form of the coefficient/slip relationship shows some marked differences. This can be seen, for example, in comparing the results given by the smooth tire, and the patterned tire, on the mastic asphalt surface. In the curves, in some instances, there was sharp drop in the coefficient values between 90 and 100 percent slip. It appears that on wet surfaces an anti-locking system could often be beneficial in improving braking even if it was not possible to modulate the brake pressure so as to keep the slip very close to the optimum value.

#### FRONT WHEEL BRAKING TESTS

Additional evidence of the importance of the difference between "peak" and "sliding" values of braking force coefficient especially at the higher speeds has been obtained in another type of skidding investigation carried out on the Laboratory's Research Track. In this investigation use was made of the front wheel braking technique first described by Lister and Kemp (20). Experiments were made to explore the possibility of studying the effects of tread pattern, tread composition, and surface texture at moderately high speeds by direct measurements of braking effects using an ordinary vehicle with the minimum of modification.

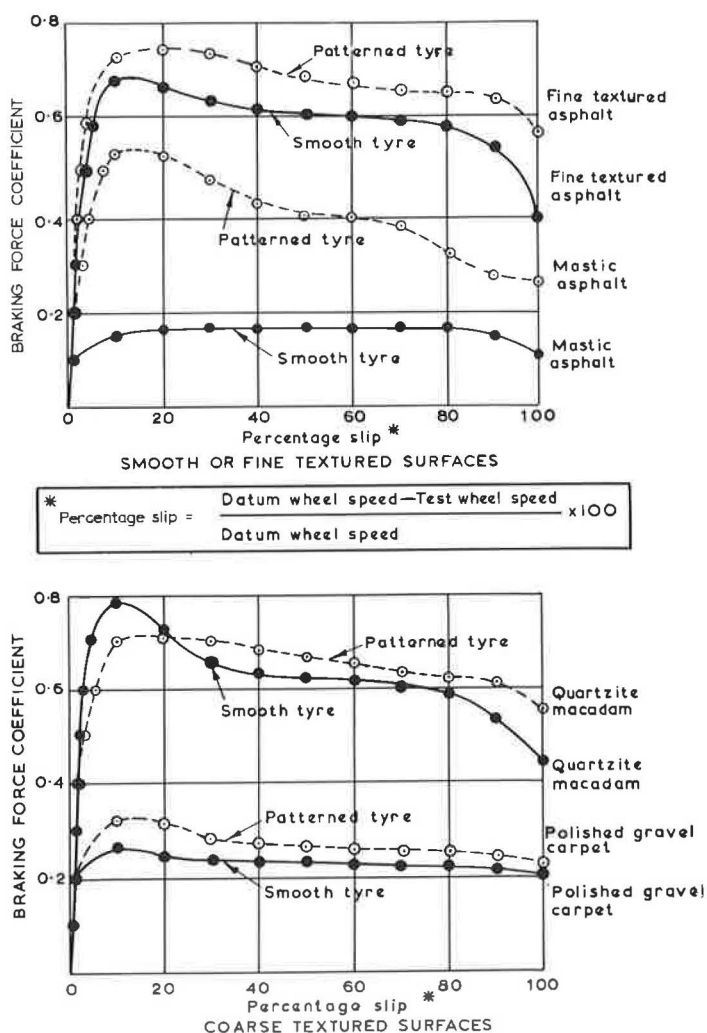


Figure 14. Braking force coefficient/slip relationships obtained at 30 mph with 500 X 16-in. tires on various wet surfaces.

In the past this has frequently been done by making measurements of the skidding distances of a vehicle with all its wheels locked from various speeds. Experience has shown that with this method difficulties can arise through the failure of the vehicle to stay on a reasonably straight course when the initial speed is of the order of 40 mph or more. The front wheel braking technique offers an effective way of overcoming these difficulties because a vehicle with only the front wheels braked tends to be directionally stable, and to continue on a straight path even after the front wheels have locked. An additional advantage (20) is that when the front brakes are applied slowly, the deceleration of the vehicle generally passes through a clearly defined maximum as the rate of slip of the wheels attains the value which gives the peak coefficient of friction between tire and road, before the wheels lock and slide. Each test, therefore, gives two values of braking force coefficient; the peak or maximum value corresponding with a comparatively low rate of sliding of the tire over the road and the sliding value obtained when the wheels are completely locked.

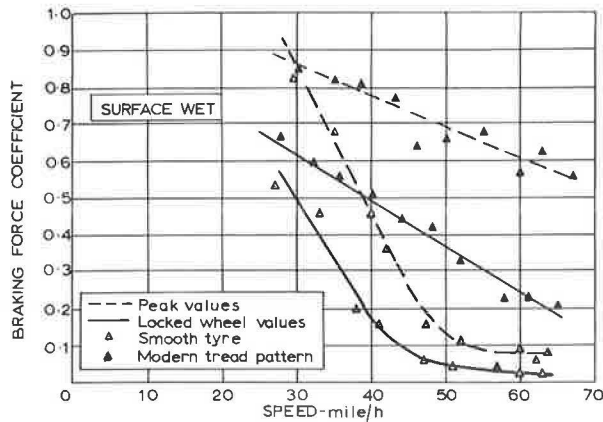


Figure 15. Results obtained in front wheel braking tests on a fine-textured surface (fine-textured asphalt).

To achieve this result the hydraulic braking system of the test car was modified by the addition of electrically operated valves so that, by operating a switch the rear wheel brakes could be disconnected and a needle control valve included in the front brake line. In this way the rate of application of the front brakes when full pressure was applied to them could be adjusted according to the skidding resistance of the surface. To measure the deceleration of the vehicle a potentiometer type of accelerometer was used, the output being recorded on one channel of a multi-channel recording galvanometer. Signals were also recorded from photoelectric pulse generators indicating the rotation of each of the wheels and from a wire strain-gage pressure transducer used to measure the hydraulic pressure being applied to the front brakes.

With these arrangements deceleration measurements were made on a number of test surfaces on the Laboratory's Research Track at speeds between 30 and 65 mph, when the surfaces were flooded with water to a depth of the order of 0.1 in. Knowing such factors as the weight distribution and height of the center of gravity, the deceleration values were then converted into the equivalent peak or locked-wheel braking force coefficients at the front wheels.

The set of curves in Figure 15 compares the results of tests on a smooth-looking surface with a good sandpaper texture and two sets of tires, both of the same rubber composition, but one set being quite smooth and the other having a typical modern tread pattern. It is evident that on a surface such as this, where speed affects the value of the coefficient, the tread pattern makes an important contribution to safety.

It is also evident from Figure 15 that the rate of slip is a most important factor particularly with the patterned tire, the peak coefficient at 60 mph being more than twice the value with locked wheels. With the smooth tires the braking force coefficients at this speed are very low, and even the peak coefficient is only of the order of 0.10. Thus on this one surface at a single speed, depending on the conditions, a wide range of coefficients is likely to be obtained.

Results obtained using the same two sets of tires on a rough coarse-textured surface are shown in Figure 16. By comparison with Figure 15 these results clearly show the superiority of rough coarse-textured surfaces in giving higher coefficients at the higher speeds. They also show the smaller influence of speed and the reduced importance of tread pattern effects on surfaces of this type. Also, on this surface it will be seen that the peak coefficients obtained are roughly twice as large as the sliding values with locked wheels. On surfaces covered by the tests it was found that peak braking force coefficients of the order of 0.5-0.8 were attainable under wet conditions at 60 mph where the corresponding locked-wheel values using some of the most modern tires available only lay between 0.20 and 0.25.

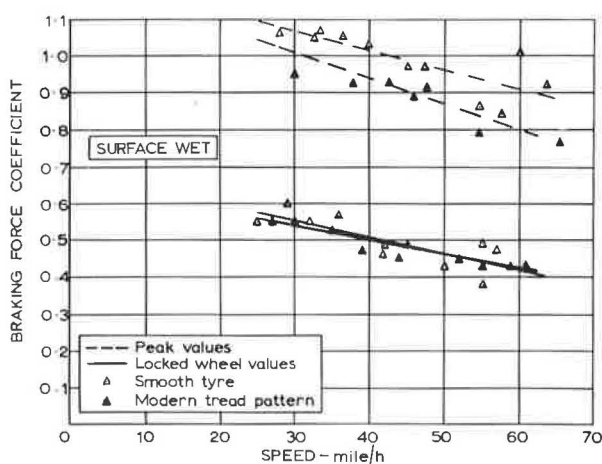


Figure 16. Results obtained in front wheel braking tests on a rough coarse-textured surface.

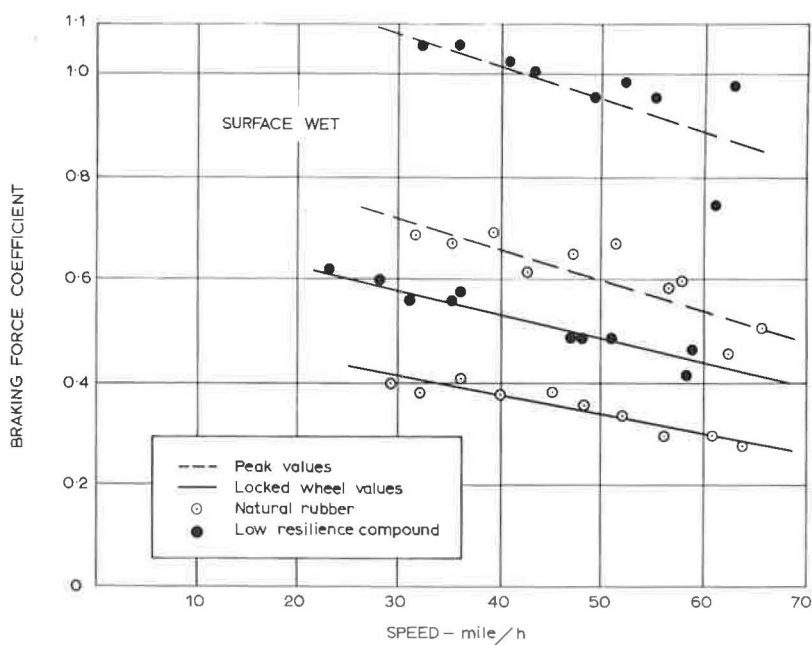


Figure 17. Effect of tread rubber resilience on a coarse-textured surface with smooth tires.

Other tests made during the experiments confirmed the gains obtained by using low resilience rubbers for the treads of tires. One such comparison is shown in Figure 17, where results are compared for two sets of smooth tires on the type of surface where tread patterns have little effect.

These results show that the front wheel braking technique, in conjunction with the facilities of the Crowthorne Research Track, promises to make an extremely direct and valuable means of studying tire/road friction problems over a range of speeds and test conditions which are less readily obtainable with conventional testing machines.



## CONCLUSION

From the recent developments in testing techniques and facilities for work on skidding problems at the British Road Research Laboratory, the following conclusions are given:

1. Rough coarse-textured surfaces are likely to give better values of skidding resistance at high speeds under wet conditions than are surfaces of the smooth or fine-textured type. In certain conditions coefficients on the rough coarse-textured surfaces have even been observed to increase in value again as the speed is raised.
2. At higher speeds, effects due to the inertia of the water on a wet road becomes increasingly important and this point is likely to assume increasing importance in skid-testing when higher testing speeds are attempted.
3. Results obtained with the heavy wheel load machine show that on a number of surfaces increases in wheel load and inflation pressure lead to reductions in the values of coefficient obtained.
4. Previous findings on the importance of tire tread pattern, the resilience properties of the tread rubbers and the importance of their interaction with the texture of the road surface are confirmed over a wide range of conditions.
5. When wheels are braked on a wet surface the rate of slip has a very important influence on the value of coefficient which is obtained. The precise form of the coefficient/slip relation is influenced by the texture of the surface and the tire's pattern and resilience properties. It is clear that there may be quite large differences between the "peak" and "sliding" coefficients, particularly at the higher speeds.

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