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MEASUREMENT OF SKIDDING RESISTANCE
PART III. FACTORS AFFECTING SCRIM MEASUREMENTS

by

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MEASUREMENT OF SKIDDING RESISTANCE
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ABSTRACT

A road testing vehicle, SCRIM, has been developed by the Transport and Road Research Laboratory to provide a routine method of measuring the resistance to skidding (SFC) of wet roads.

Measurements of skidding resistance are affected by the two following classes of factors.

(1) Factors affecting the slipperiness of the road, such as the state of polish of the surface.

(2) Factors affecting the measurements themselves, such as the calibration of the test instrument.

Factors affecting SFC measurements made with SCRIM are considered in this Report and estimates are given of their magnitude. These factors, are machine variability including repeatability, reproducibility, tyre resilience and wear, calibration, recorder drift, tyre pressure and water flow; machine operation including tracking, speed and location; test conditions including water-film thickness, evenness of road surface and turning of SCRIM; and variability associated with the processing of results. There are only relatively small "errors" associated with the use of a single SCRIM to compare a number of sections during a limited period of time, and steps can be taken to allow more precise comparisons to be made over longer periods.

An Appendix gives the results of co-operative trials that were made using seven SCRIMs from several different organizations.

1. INTRODUCTION

SCRIM (Sideway-force Coefficient Routine Investigation Machine) has been developed by the Transport and Road Research Laboratory to provide a routine method of measuring the resistance to skidding of wet roads. This machine is a direct descendant of the fifth-wheel skid resistance testing machines that have been used by TRRL for research purposes since 1953 and which, in turn, were developed from the motor-cycle combination machine that was first used by the Ministry of Transport's experimental station at Harmondsworth (later to become the TRRL) in 1930.

At the time of writing there are 18 SCRIMs working all over the world and a series of reports has been written to give guidance on the operation of the machine and on the interpretation of results. It is hoped that they will be of value not only to the SCRIM user, but also to those who make use of the results. Although some sections of these reports (such as those dealing with seasonal variation) are particularly applicable to conditions in the United Kingdom, the information given should provide a basis for a modified procedure suited to other climatic conditions.

Part I[1] gives an outline of the principles and operation of SCRIM, briefly discusses the causes of variation in results (these are dealt with more fully in Parts II and III) and recommends a procedure to be adopted for routine SFC measurement.

Part II[2] gives an account of the factors affecting the slipperiness of a road surface.

Part III gives an account of the factors affecting measurements made with SCRIM.

The work reported in Parts I, II and III is limited to measurements made at lower speeds (50 km/h). It is intended that a further Part be published when current research has been completed, that will give an account of factors, such as macrotexture, which influence high-speed resistance to skidding.

2. FACTORS AFFECTING SCRIM MEASUREMENTS

There are four classes of factors affecting SCRIM measurements:

(1) Factors associated with the machine itself, some of which are influenced by the standard of maintenance and calibration.

(2) Factors associated with the operation of the machine and the difficulties of the site. These are influenced by the skill of the operator.

(3) Factors associated with test conditions, which are outside the control of the operator. These should not be regarded as a defect in the testing, but need to be taken into account when considering test results. However they do need to be reported by the operator and, to this extent, are within his control.

(4) Factors associated with the analysis and presentation of results. Although they are not directly concerned with the precision of SCRIM measurements they can influence the validity of reported results.

Each of these classes of factors is considered in turn below.

2.1 Machine variability

Machine variability in SCRIM measurements is at two levels:

(1) Small variations that occur when a single machine is used by the same operator over a relatively short test programme.

(2) Rather larger variations that occur when the same machine is used for a longer period of time. These are due to factors such as changes of the test tyre, tyre wear, calibration drift and differences in water flow.

Each of these levels of variability is considered in turn below.

2.1.1 Short term variability (repeatability) The cooperative SCRIM measurement exercise described in Appendix 1 provided data from which an estimate of short term variability can be calculated. On two separate days five test sections (with average SFCs ranging from 0.28 to 0.65) were tested by five machines (each with its own operator) using four test tyres within the resilience tolerance (see 2.1.2.1); each test run was repeated four times on the first occasion and five times on the second. Because the test sections varied in length, analysis was simplified by considering only the first ten ten-metre sub-sections; and because the variability of the sub-sections was influenced more by variations in the surfacings than by variations in testing, analysis was confined to the means of the sub-sections, (ie analysis was confined to the mean SFC of the first 100 metres of each test section). A preliminary analysis of variance showed that there was interaction between the surface characteristics of each section and the other factors. Further analyses of variance were then made for each section/tyre combination (ie 20 analyses for each of the two days), the variables being the five machines and the four test runs (five on the second occasion). The results (Table 1) suggested that the residual variation was proportional to the level of SFC being measured. Regression analysis confirmed this and showed that there was significant linear correlation between these factors; the regression equations obtained are shown in Table 2.

These results show that both the residual variation itself and the significance of the correlation between the variation and the SFC were much improved during the second trial, when tracking was better (see Appendix 1). If the results of the first trial are ignored the residual variation for a surface of SFC of 0.50 would be expected to give a standard deviation of about 0.018. But part of this residual variation can be attributed to temperature differences (Part II^2), location errors (ie small differences in starting points), tracking errors and changes in the surface being tested. Short term variability will therefore be less than this figure and is not likely to give a standard deviation of much more than 0.01.

2.1.2 Longer term variability

2.1.2.1 Resilience of the test tyre Resistance to skidding is affected by the resilience of the tyre rubber, the greater the resilience the lower the resistance to skidding. The SCRIM test tyre is therefore manufactured to have a particular resilience (46 per cent rebound at 20°C when tested by a Lüpke resiliometer^3). During this test the tyre is mounted in a jig as shown in Plate 1 with a steel anvil on the inside of the tyre at the point at which the striker falls. Manufacturing difficulties make it impracticable to produce tyres within close limits of resilience and all tyres have to be checked before distribution; a tolerance of ±3 per cent resilience has been permitted.

Three sets of data are available which may be used to study the effect of tyre resilience on SCRIM measurements; these are the two co-operative SCRIM exercises described in Appendix 1, which included tests with seven tyres of resilience ranging from 40 to 54 per cent, and a series of tests made by a single SCRIM using the same seven tyres to make 10 test runs over each of five sections of test track. The results of these three series of tests are summarized in Table 3.

Regression analyses for each of the three sets of five sections showed significant linear correlation between resilience and SFC, but as in the tyre temperature study (Part II^2) the correlation varied with the level of SFC being measured. The same method of analysis was therefore employed: first the SFCs for the target resilience level (46 per cent) were calculated from the regression equations, then the ratio $SFC_R:SFC_{46}$ was calculated (where SFC_R and SFC_{46} are respectively the SFC at resiliences of R per cent and 46 per cent) and, finally,

TABLE 1

Summary of standard deviations of SFC in
the co-operative SCRIM trials

Surface No (SFC)	Tyre No	TRIAL					
		1			2		
		STANDARD DEVIATION					
		Machine	Residual	Overall	Machine	Residual	Overall
3 (0.29,0.28)	2	0.0503	0.0093	0.0511	0.0281	0.0065	0.0288
	3	0.0504	0.0082	0.0510	0.0378	0.0038	0.0388
	4	0.0355	0.0117	0.0373	0.0423	0.0096	0.0434
	5	0.0126	0.0128	0.0179	0.0337	0.0093	0.0349
2 (0.52,0.50)	2	0.0923	0.0162	0.0937	0.0420	0.0167	0.0451
	3	0.0949	0.0187	0.0967	0.0526	0.0115	0.0538
	4	0.0692	0.0123	0.0703	0.0782	0.0223	0.0813
	5	0.0576	0.0203	0.0611	0.0741	0.0236	0.0778
7 (0.59,0.59)	2	0.1523	0.0143	0.1530	0.0380	0.0253	0.0457
	3	0.1151	0.0331	0.1198	0.0551	0.0138	0.0568
	4	0.0974	0.0268	0.1010	0.0779	0.0205	0.0806
	5	0.0761	0.0236	0.0831	0.0722	0.0128	0.0734
8 (0.29,0.29)	2	0.0981	0.0113	0.0988	0.0335	0.0140	0.0363
	3	0.0671	0.0123	0.0682	0.0409	0.0090	0.0419
	4	0.1385	0.0232	0.1404	0.0445	0.0122	0.0461
	5	0.0538	0.0180	0.0567	0.0350	0.0149	0.0380
9 (0.65,0.64)	2	0.1909	0.0364	0.1943	0.0685	0.0304	0.0749
	3	0.1010	0.0433	0.1099	0.0816	0.0205	0.0841
	4	0.1370	0.0572	0.1484	0.1159	0.0268	0.1189
	5	0.0679	0.0377	0.0777	0.0931	0.0214	0.0956

TABLE 2

Correlation found between standard deviation and level of SFC

Factor	1st TRIAL			2nd TRIAL		
	m*	c*	r*	m	c	r
Machine	0.154	0.016	0.55	0.121	0.001	0.78
Residual	0.062	–0.007	0.73	0.036	0.000	0.77
Overall	0.167	0.013	0.59	0.128	0.001	0.80

*r is the correlation coefficient and m and c are constants in the equation:
standard deviation = m(SFC) + c

TABLE 3

Summary of resilience and SFC results for the co-operative SCRIM trials

Surface	Tyre	Resilience (%)	TRIAL 1		TRIAL 2		TRIAL 3	
			Mean SFC*	SFC$_{46}$**	Mean SFC†	SFC$_{46}$**	Mean SFC††	SFC$_{46}$**
1	1	40	0.2983	0.282	0.2938	0.288	0.2761	0.249
	2	42	0.2818		0.2945		0.2442	
	3	42	0.2860		0.2895		0.2387	
	4	46	0.2978		0.2958		0.2590	
	5	46	0.2965		0.2972		0.2591	
	6	54	0.2633		0.2745		0.2250	
	7	54	0.2477		0.2680		0.2398	
2	1	40	0.5384	0.508	0.5205	0.503	0.4784	0.441
	2	42	0.4981		0.5032		0.4277	
	3	42	0.5236		0.5078		0.4417	
	4	46	0.5225		0.5146		0.4601	
	5	46	0.5373		0.5270		0.4539	
	6	54	0.4868		0.4672		0.3998	
	7	54	0.4413		0.4720		0.4149	
3	1	40	0.6113	0.586	0.6051	0.589	0.5463	0.517
	2	42	0.5837		0.6012		0.4988	
	3	42	0.6177		0.6115		0.5260	
	4	46	0.6138		0.5983		0.5387	
	5	46	0.6006		0.6026		0.5338	
	6	54	0.5515		0.5396		0.4669	
	7	54	0.5140		0.5532		0.5048	
4	1	40	0.3175	0.303	0.3040	0.291	0.2723	0.243
	2	42	0.2929		0.2910		0.2357	
	3	42	0.2908		0.2828		0.2314	
	4	46	0.3286		0.3019		0.2625	
	5	46	0.3250		0.3033		0.2434	
	6	54	0.2945		0.2836		0.2169	
	7	54	0.2673		0.2692		0.2376	
5	1	40	0.6660	0.642	0.6652	0.643	0.5978	0.560
	2	42	0.6307		0.6561		0.5524	
	3	42	0.6408		0.6560		0.5754	
	4	46	0.6835		0.6507		0.5738	
	5	46	0.6606		0.6532		0.5731	
	6	54	0.6294		0.6105		0.5070	
	7	54	0.5721		0.6041		0.5351	

* From Table 8

** Estimated SFC at resilience of 46 per cent (obtained from regression lines)

† From Table 9, with estimated values for Machine 4:Tyre 6 and Machine 5:Tyre 7:Run 1 (based on results for tyres 1 to 5)

†† Mean of 10 test runs with Machine 5

TABLE 4

Summary of tyre resiliences and SFC ratios for the co-operative SCRIM trials

Surface	Tyre	Resilience (%)	Ratio of mean measured SFC to estimated SFC at resilience of 46%			
			TRIAL 1	TRIAL 2	TRIAL 3	
1	1	40	1.058	1.020	1.109	
	2	42	0.999	1.023	0.981	
	3	42	1.014	1.005	0.959	
	4	46	1.056	1.027	1.040	
	5	46	1.051	1.032	1.041	
	6	54	0.934	0.953	0.904	
	7	54	0.878	0.931	0.963	
2	1	40	1.060	1.035	1.085	
	2	42	0.981	1.000	0.970	
	3	42	1.031	1.010	1.002	
	4	46	1.029	1.023	1.043	
	5	46	1.058	1.048	1.029	
	6	54	0.958	0.929	0.907	
	7	54	0.869	0.938	0.941	
3	1	40	1.043	1.027	1.057	
	2	42	0.996	1.021	0.965	
	3	42	1.054	1.038	1.017	
	4	46	1.047	1.016	1.042	
	5	46	1.025	1.023	1.032	
	6	54	0.941	0.916	0.903	
	7	54	0.877	0.939	0.976	
4	1	40	1.048	1.045	1.121	
	2	42	0.967	1.000	0.970	
	3	42	0.960	0.972	0.952	
	4	46	1.084	1.037	1.080	
	5	46	1.073	1.042	1.002	
	6	54	0.972	0.975	0.893	
	7	54	0.882	0.925	0.978	
5	1	40	1.037	1.035	1.068	
	2	42	0.982	1.020	0.986	
	3	42	0.998	1.020	1.028	
	4	46	1.065	1.012	1.025	
	5	46	1.029	1.016	1.023	
	6	54	0.980	0.949	0.905	
	7	54	0.891	0.940	0.956	Overall
Regression equations where: Ratio = m x Resilience + C		m	–0.00811	–0.00638	–0.00751	–0.00733
		c	1.373	1.294	1.346	1.338
		Correlation coefficient	–0.69	–0.83	–0.67	–0.71

regression analysis was carried out between the ratio and the resilience for each of the 105 observations (see Table 4). Highly significant linear correlation was found (correlation coefficient –0.71) taking the form:

$$\text{Ratio } \frac{SFC_R}{SFC_{46}} = 1.338 - 0.00733R$$

Substitution of R values of 46 ± 3 per cent for an SFC_{46} of 0.50 yielded SFCs of 0.50 ± 0.011, ie a range of 0.02 in SFC over the permissible resilience range.

2.1.2.2 Tyre wear It has been the practice at TRRL to discard test tyres when they have lost 6 mm in diameter (3 mm tread wear) and experience suggests that the change in SFC during this period is small. Confirmation was obtained in March 1976 when a study was made of the effect of tyre wear on SFC.

Six new tyres of the same resilience (46 per cent) were selected and used to make three runs over two reference lengths of road each 1 km long with mean SFCs of 0.76 and 0.64 respectively. Two tyres (1 and 2) were then used to repeatedly test a 32 km circuit of local roads, tests on the reference sections being made at intervals during this period using tyres 1, 2, 3 and 4. When tyres 1 and 2 had lost 6 mm in diameter (after 682 km and 518 km respectively), tests were again made with each of the six tyres on the two reference sections.

A summary of the results obtained at the beginning and at the end of these tests is given in Table 5.

TABLE 5

The effect of tyre wear on SFC

	Reference section	Tyre number						Average
		1	2	3	4	5	6	
SFC at the beginning of testing (mean of three runs)	1	0.760	0.783	0.730	0.763	0.767	0.770	0.762
	2	0.633	0.663	0.613	0.640	0.650	0.663	0.644
	Average	0.697	0.723	0.672	0.702	0.709	0.717	0.703
SFC at the end of testing (mean of three runs)	1	0.807	0.833	0.790	0.797	0.797	0.797	0.804
	2	0.653	0.680	0.647	0.660	0.677	0.667	0.664
	Average	0.730	0.757	0.719	0.729	0.737	0.732	0.734
Total distance tested (km)		682	518	30	30	13	13	
Average gain in SFC during the period of test		0.033	0.034	0.047	0.027	0.028	0.015	0.031
Average gain in SFC for worn and unworn tyres		worn 0.033		unworn 0.030				

These results show a small (about 0.03 units) increase in SFC during the period, probably because of differences in temperature and climate (see Part II[2]), and that there was no significant difference in the increase for the worn and the unworn tyres. They also show that the life of a tyre is about 500 km on surfaces of fairly high SFC.

A similar conclusion was drawn in the course of a study* of the life of the rubber sliders used in the portable skid-resistance tester[4]. This study showed that considerable wear could take place without significantly affecting test results.

2.1.2.3 Calibration Because of the difficulties involved in the provision of standard test surfaces for calibration, other methods have to be employed. Two methods, rolling table and electronic, are used; both are described in Part I[1]. Of these the rolling table method is preferred because it tests the whole system including the hub rather than only the pressure transducer and recorder and because it is more basic, using weights to load the system. However the electronic method can give a quick check that the transducer and recorder are behaving linearly. The repeatability of the rolling table calibration in the middle of the range (SFC = 0.50) is ± 0.001 in either the upward or downward direction of loading. There is a hysteresis effect and the SFC is usually about 0.02 higher when the load is being removed than when the load is being increased.

2.1.2.4 Recorder drift With the earlier type of recorder used in prototype equipment, Lander† found that drift during a series of measurements was no more than 0.01 units of SFC provided the recorder was given a 10 to 15 minutes warm up period. Production models of SCRIM use solid-state equipment in which the warm-up period is insignificant and drift is likely to be less than with the earlier recorder. Although no specific study has been made of drift with solid-state equipment observations suggest that weekly calibration checks are desirable if drift is to be kept below 0.01 units of SFC.

2.1.2.5 Tyre pressure Test tyre pressure should be maintained at 3.5 kg/cm^2 (50 psi) in order to reduce any variation due to this cause. However tests suggest that changes of up to ± 0.2 kg/cm^2 do not have an important effect on SFC results.

2.1.2.6 Water flow See 2.3.1 – Water film thickness.

2.2 Variability associated with machine operation

2.2.1 Tracking The resistance to skidding of a road surface varies transversely across its width; this is because of variation in the degree of trafficking and lowest values are normally obtained in clearly defined wheel-tracks. The nearside wheel-track has become the standard place for SFC measurements, because it is readily identifiable and is more easily tested (particularly with the portable skid-resistance tester[4] and the earlier motor cycle combination SFC apparatus). Minimum SFC does not necessarily occur in the nearside track. Greater London Council have found that the offside wheel-track frequently yields the lower resistance to skidding and TRRL have made similar observations in the nearside of motorways (see Fig 1). Because of this, Greater London Council are using a SCRIM with two test wheels, the second being mounted in the offside wheel-track of the vehicle, so that minimum SFC can be more readily measured. However it should be noted that measurements in the nearside wheel-track have been used as a basis for present-day standards of SFC and for the study of SFC in relation to accident frequency and surfacing materials used.

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* Unpublished report by Hosking and Palmer

† Unpublished report

The width of the more highly polished track can be quite narrow particularly when traffic is canalized. This means that small tracking errors can lead to considerable differences in the values of SFC recorded. At sites with less canalized traffic, for example motorways, the tracks are wider and there is more latitude for testing. Fortunately the nature of SCRIM is such that tracking errors are normally kept to a minimum because it tends to be driven in the correct path.

The SCRIM operator must be aware of the need to test in the correct track and to draw attention to any measurements that are made when the track has been left so that erroneously high values are not reported. Measurements made at TRRL (see Table 6) show that differences averaging 0.05 units of SFC can occur when testing 30 to 45 cm on either side of the track under canalized traffic conditions. Errors as large as 0.20 units of SFC have been reported which have been attributed to misjudgement of the track position.

Tracking error is potentially the greatest single source of error in all forms of skid-resistance measurement and its influence is greatest when testing large mileages of road under routine monitoring conditions. The test results recorded are correct for the road under the test wheel, but if incorrect tracking occurs they are not truly representative of the road under test and will be higher than the correct values.

TABLE 6

Effect on SFC measurements of departure from the wheel-track on sections of the TRRL test track

Section	Average sideway-force coefficient		
	Normal track	30 to 45 cm from track	Difference
1	0.63	0.69	0.06
2	0.79	0.84	0.05
3	0.56	0.61	0.05
4	0.48	0.53	0.05
5	0.40	0.47	0.07
Average	0.57	0.63	0.06

2.2.2 Speed It is not always possible when working in traffic to maintain a uniform speed of 50 km/h, the standard speed of test, and there are some situations where it is impossible to test at this speed. Roundabouts are such a case. It is not possible to travel round them at speed and there is no certainty of unimpeded access. Some information on the relationship between SFC and speed is therefore necessary.

Observations were made on the motorway M40 which had been closed for other measurements. The bituminous surfacings tested were laid with aggregates of PSV between 60 and 75 and had a range of texture depths between 0.5 and 2.5 mm. Eighteen sections were tested to cover the full range of texture depths and PSVs. These sections were tested five times in each direction at each of five speeds, nominally 16, 32, 48, 64 and 80 km/h. All the work was done in one day and twelve or thirteen readings were obtained for each section on each run at the lower speeds, but only 6 readings were possible at 80 km/h.

Multiple regression analysis of the mean values of SFC for each run/section gave the following relationships:

In the direction of trafficking:

$$\text{SFC} = 0.015\ \text{PSV} + 0.028\ \text{TD} - 0.0027\ \text{K} - 0.286$$

(Correlation coefficient 0.92)

In the opposite direction to trafficking:

$$\text{SFC} = 0.014\ \text{PSV} + 0.026\ \text{TD} - 0.0025\ \text{K} - 0.200$$

(Correlation coefficient 0.86)

where PSV = polished-stone value of aggregate

TD = texture depth in mm of the surfacing (measured by the sand patch method)

K = speed in kilometres per hour

The SFC values for the tests in opposition to the traffic were higher than those in the direction of the traffic. This result agrees with work carried out with the portable skid-resistance tester which showed that tests carried out in the opposite direction to trafficking averaged about 4 units of skid-resistance value (equivalent to approximately 0.04 units of SFC) higher than in the direction of trafficking.

The effect of speed was similar for each direction of travel (0.0027 and 0.0025 units respectively for each km/h) and agreed closely with figures obtained by Greater London Council as a result of their experience when testing at lower speeds. The speed of SCRIM can be maintained within ± 2 km/h under most conditions, which results in a negligible error (± 0.005 units of SFC), but under some conditions, particularly in urban areas, testing at lower speeds is unavoidable. Under these conditions a correction may be applied to obtain an estimate of the SFC at 50 km/h. For practical purposes this involves reducing the measured SFC by 0.01 units for each 4 km/h the speed falls below the target 50 km/h. However the estimate becomes less accurate as the actual speed becomes increasingly different from the target and correction is not advisable for speeds of less than 30 km/h. Automatic correction during computer processing of results is feasible provided it is applied to a prescribed limited range of speed.

2.2.3 Location Job identity and section identity markers facilitate the relation of SCRIM results to the road site and part of the road being tested. Correct identification is essential or results could be meaningless or even misleading. It is desirable for the SCRIM operator to be familiar with the road to be tested and advisable that he should have checked marks and markers (which can become obliterated or overgrown) in advance.

2.3 Variability associated with test conditions

2.3.1 Water film thickness There is a rapid fall in the value of SFC from a dry surface to one which is just wet. After the thickness of the water film has reached about 0.1 mm, further increases in its thickness do not cause further great decreases in SFC. As most roads are not smooth a greater thickness than this is needed, however, to ensure that all the asperities have the minimum film of water, and a film 1.0 mm thick has been generally accepted as meeting this requirement.

SCRIM users in France have reported variations in SFC of up to 2 per cent for good road surfaces and up to 6 per cent for smooth surfaces which are attributable to variations in the water supply of SCRIM. They have consequently fitted a simple constant head tank to the water supply to minimize variations due to this cause.

Rainfall can also affect the SFC recorded by increasing the water film thickness and cross-winds have been reported to reduce water film thickness in the test track. If testing under conditions of heavy rainfall or strong cross-winds is unavoidable, the conditions should be recorded. Blockages in water supply (stones etc) have on occasions affected water film thickness.

2.3.2 Evenness of road surface On a bumpy road surface, shocks will be superimposed on the loading of the test wheel resulting in variable SFC results being recorded. This means that SFC measurements on such roads will be less uniform than those made under better conditions.

2.3.3 Testing while SCRIM is turning Apart from the lower level of resistance to skidding that is found on curves (such as bends and roundabouts) as a consequence of the more severe trafficking action[5] differences in recorded SFC can result from the following factors:

(1) *Change in effective angle of the test wheel.* The effect of increasing the test wheel angle from zero is to increase the level of SFC recorded until a critical angle is reached beyond which there is no further change in SFC, ie it reaches a maximum value. This critical angle varies with the maximum SFC of the surface being measured, being small for surfaces of low SFC and increasing to about 20° for surfaces giving an SFC of about 1.00[6, 7] (see Fig 2). This means that the increase in effective test angle (the standard angle for SCRIM is 20°) when turning to the left has no effect on the SFC measured, but that some reduction can be expected at higher SFC levels when turning to the right. For a turn of 40 m radius (which is as small a radius at which measurements should be attempted) the change in effective angle is about 3°. Reference to Fig 2 indicates that this can be expected to lead to a loss in measured SFC of about 0.04 units for a surface of SFC 1.00, but that there would be no difference for surfaces with an SFC of less than about 0.85.

(2) *Reduction in test speed.* The standard test speed of 50 km/h cannot always be maintained whilst SCRIM is turning. Any decrease in speed will have the effect of increasing the SFC recorded by 0.01 units for each 4 km/h reduction in speed (see 2.2.2).

(3) *Incorrect tracking.* Testing may require a faster speed with SCRIM than is normal at a bend. This can lead to incorrect tracking which would result in a higher SFC being recorded than in the correct track (see 2.2.1).

(4) *Changes in test wheel loading.* The tilting of SCRIM while it is turning can affect the loading on the test wheel. This is because the 'dead-load' force is damped in order to smooth out the shocks from irregular road surfaces, and hence tilting of the vehicle can cause the damping mechanism to influence the actual loading. The effect is to increase the loading and hence the SFC recorded as the vehicle turns to the right, and to reduce the loading and SFC recorded as it turns to the left. Trials on a newly surfaced area of the TRRL test track (with an SFC of 0.78) showed that when SCRIM is driven in a circle of radius of 45 m, the SFC recorded was lowered

by about 0.08 units for a turn to the right and increased by about 0.18 for a turn to the left. At a radius of 150 m there was virtually no difference between the measurements.

2.4 Variability associated with processing results

SCRIM SFC recordings for a length of road are essentially a series of mean values for sub-lengths of 5, 10 or 20 metres. For each particular sub-length (10 metres being normal) variability of a reported mean result will be affected by the number of sub-lengths from which it has been calculated. Other factors being equal the improvement in variability will be proportional to the square root of the number of sub-lengths averaged. This means that there will be a progressively diminishing benefit as the number increases; thus taking a mean of four will halve the variability but a further 12 are required to halve it again. Increasing the number of sub-lengths will also increase the section length and will tend to reduce the value of the result in pin-pointing maintenance needs. Desirable section length will also be dependent on the nature of the site and maintenance practice; it will be relatively long for simple straightforward sites such as rural roads and motorways and relatively short for difficult urban roads involving complications such as road junctions and pedestrian crossings.

Sections of 100 metres in length (ten 10-metre sub-sections or five 20-metre sub-sections) have been found to be useful on rural roads and motorways, but under other conditions a shorter section may be desirable. The actual length will be dictated to some extent by the site conditions, but 50 metres is suggested as a target. Under urban conditions it may be worth while to consider individual readings.

The co-operative SCRIM measurements described in Appendix 1 provided data relating to the variation between 10-metre sub-sections for a range of surfacings. Analysis showed that the variation was virtually the same for each of the SCRIMs used (their average standard deviation over each run for each surface ranged from 0.030 to 0.036). However differences were observed between the different surfacings (their average standard deviation over each run for each of the machines ranging from 0.016 to 0.052), variation tending to be least for those with lower SFCs and in better condition, and greatest for those with higher SFCs and in poorer condition. On average the standard deviation of the 10-metre sub-sections within each section was about 0.03.

These results indicate that this variation is caused by real differences in the surfaces being tested and not by differences in measurement. Likely causes of differences are variations in the surfacing material (aggregate, binder and mix proportions), variation in the laying and compacting processes and variations in subsequent trafficking.

2.5 Variability between machines

The co-operative SCRIM measurement exercise referred to in 2.1.1 above and described in Appendix 1 provided data from which an estimate of the variation occurring between different SCRIMs could be calculated. The results are summarized in Tables 1 and 2 which show that the between machine variation was proportional to the SFC of the surface being tested. If the results of the first trial are ignored for reasons given in 2.1.1 the relationship took the form:

$$\text{Standard deviation (between machines)} = 0.121\ \text{SFC} + 0.001$$

Thus for a surface with a mean SFC of 0.50 the standard deviation of between-machine variation was found to be about 0.06.

In consequence of these findings improvements have been incorporated into SCRIM design, such as improved vertical shaft bearings. These combined with the regular use of rolling table calibration and attention to the various factors affecting results (particularly tracking error) should reduce the error to a figure well below that given above. Experience at TRRL, where four SCRIMs are based, shows that this is the case even when they are used by several different operators and drivers.

3. DISCUSSION

The SFC measurements obtained by using SCRIM are dependent both on the actual slipperiness of the road and a number of factors affecting the measurement itself.

Table 7 gives a summary of the factors that are known to affect SCRIM measurements and gives estimates of the maximum likely error differences that can result from each in the case of a single measurement of a 100-metre section of the road. These estimates show that there are only relatively small 'errors' associated with the use of a single SCRIM to compare a number of sections during a limited period of time. Furthermore steps can be taken to allow more precise comparisons to be made over longer periods of time; these steps include 'correction' for tyre resilience and speed, frequent rolling-table calibration and the use of means of two or more runs.

These estimates also highlight the need for care both in testing and in interpreting results when working under difficult conditions, such as on irregular surfaces (eg setts and pot-holed surfacings), at low speeds, on very short sections and on bends.

4. ACKNOWLEDGEMENTS

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Grateful acknowledgement is made for the help given by the following organizations:-

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Greater London Council, County Hall, London,
Ministry of Development, Northern Ireland,
Surrey County Council (Highways and Bridges Department), South Ewell,

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TABLE 7

Factors affecting SCRIM measurements

Reference Number	Factor	Standard deviation of SFC (where applicable)	Maximum likely difference in SFC	Remarks
1	Short-term machine variability	0.01*	±0.02*†	'Repeatability'.
2	Difference between machines	–	–	No figures available for present day equipment.
3	Tyre resilience	–	±0.01*	Over permitted 46±3 per cent resilience range.
4	Tyre wear	–	negligible	Over the full life of the test tyre.
5	Calibration	–	±0.01	Can be reduced for any particular part of the range being measured.
6	Recorder drift and warm up	–	<0.01	
7	Tyre pressure	–	negligible	If maintained within ±0.2 kg/cm^2.
8	Tracking	–	0 to +0.05	Can be much larger if badly out of track.
9	Speed	–	±0.005**	When regulated to ±2 km/h.
10	Water film thickness	–	±0.005	For normal surfaces. Can be eliminated by use of constant head tank.
11	Unevenness of road	–	not known	Detrimental to precise measurement.
12	Bends in road	–	negligible at radius 150 m	At radius 45 m, +0.18 for turns to the right and –0.08 for turns to the left.

* Proportional to SFC level, estimated for an SFC of 0.50

† 95 per cent confidence limits

** About 0.03 when correction is applied down to 30 km/h

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6. APPENDIX 1

CO-OPERATIVE SCRIM TRIALS

The number of SCRIM machines that has been made is small and they are distributed over a wide area, which means that comparisons are infrequent. However in the spring of 1973 seven SCRIMs were assembled at TRRL, Crowthorne and two sets of comparative measurements made on sections of the test track. Three SCRIMs belonged to TRRL, two to WDM Ltd., the manufacturers of the machine, one to Greater London Council and one to the Ministry of Development, Northern Ireland. Each set of measurements took the form of a factorial experiment involving the measurement of five types of road surfacing (with SFCs ranging from 0.28 to 0.65), using seven tyres chosen to give a wide resilience range (40 to 54 per cent Lüpke). As many runs as possible were made on the day devoted to each trial.

Machine 7 did not arrive in time for the first trial and Machine 1 was needed elsewhere at the time of the second trial. Machine 2 developed a fault and the results had to be rejected, leaving sets of results for five machines on each occasion.

At least four complete runs were made by each machine on the first occasion and five on the second and therefore, to facilitate analysis, results for additional runs by some of the machines were ignored. Similarly, analysis was confined to the first ten 10-metre sub-sections of each surfacing. Means and standard deviations were then calculated for each surfacing: the means are summarized in Tables 8 and 9.

Correct tracking was found to be rather difficult because of the absence of a clearly marked edge to the sections and the difficulty of ensuring that all vehicles followed the same track. Operators noticed rather large differences between the tracks made by the different SCRIMs during the first set of measurements. However experience gained during this trial led to better tracking on the second occasion.

TABLE 8

Results of first co-operative SCRIM trial

Machine		1				3				4				5				6			
RUN		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Surface	Tyre†	SIDEWAY FORCE COEFFICIENT (X1000)*																			
1	1	357	302	316	318	298	293	282	283	283	259	269	279	287	286	284	259	328	339	320	323
	2	300	297	300	301	272	279	269	285	259	256	256	283	265	265	238	250	320	316	306	318
	3	307	308	301	287	311	315	305	314	269	275	269	283	250	253	241	248	306	284	286	307
	4	291	309	291	298	317	312	304	319	303	309	299	302	265	260	265	281	336	299	310	285
	5	299	284	278	292	310	309	296	303	297	295	293	285	291	323	297	287	314	313	272	291
	6	244	245	256	238	261	270	253	250	270	259	269	264	253	264	275	262	272	286	292	282
	7	239	243	237	239	226	210	219	214	240	247	239	240	252	253	253	256	287	287	291	282
2	1	581	571	564	566	549	527	544	512	463	441	463	476	517	520	515	497	627	587	632	616
	2	502	536	543	553	527	510	512	507	478	463	445	464	446	429	442	432	575	535	537	526
	3	570	532	567	536	587	606	576	581	492	465	487	464	511	490	459	456	531	499	533	530
	4	518	534	517	517	561	559	567	547	541	524	537	526	463	478	451	470	528	564	516	532
	5	565	530	478	514	572	555	566	554	505	532	537	556	563	558	571	589	502	492	508	499
	6	482	433	444	410	549	527	544	512	463	441	463	476	517	520	515	497	495	517	484	501
	7	405	408	403	407	389	381	408	397	430	453	451	438	460	461	441	450	531	514	508	490
3	1	633	762	695	740	564	561	564	556	477	523	533	532	565	573	583	554	653	776	638	744
	2	716	685	724	687	549	551	548	542	531	513	528	522	530	539	539	507	607	597	638	620
	3	734	716	692	677	660	659	635	635	568	636	567	553	574	549	593	550	558	586	547	664
	4	712	708	659	708	603	616	601	593	596	579	618	583	554	531	605	584	619	653	591	563
	5	692	653	627	603	607	601	585	567	598	586	599	604	628	620	598	663	567	535	535	543
	6	585	607	620	603	524	501	490	493	571	533	527	503	540	540	534	529	643	575	558	554
	7	581	554	574	537	391	421	421	442	498	521	483	516	507	540	516	505	600	540	553	580
4	1	335	405	341	513	291	292	302	292	245	271	287	301	267	268	282	290	327	327	333	381
	2	382	368	386	350	277	275	274	271	269	258	262	285	231	241	265	241	306	301	305	311
	3	353	353	313	335	314	308	311	301	269	269	276	268	246	242	262	261	273	307	275	279
	4	475	457	375	454	314	313	306	303	301	300	315	322	245	247	248	266	314	358	315	343
	5	356	359	334	345	306	307	298	291	300	305	301	306	315	385	343	392	329	310	308	310
	6	342	341	338	327	260	250	247	244	291	272	274	281	269	278	264	267	358	371	311	305
	7	327	303	321	261	184	212	219	221	259	245	268	277	283	251	248	277	291	302	293	304
5	1	726	745	705	783	642	651	662	667	462	520	534	578	637	634	622	613	771	823	723	822
	2	722	790	691	757	610	611	617	636	552	561	558	563	434	515	543	593	705	712	736	708
	3	815	664	633	652	693	690	705	696	600	596	591	596	566	583	618	597	572	635	676	637
	4	884	819	630	816	661	673	660	660	626	651	618	613	610	585	629	676	673	756	761	669
	5	689	567	619	641	677	670	658	649	631	626	631	626	651	755	746	688	657	620	687	724
	6	671	668	688	635	580	572	599	576	558	562	584	568	669	625	572	636	757	693	622	753
	7	665	527	628	564	400	486	487	503	521	539	544	550	585	610	587	540	617	700	707	682

* Mean of ten sub-sections

† Tyres 1, 6 and 7 were outside resilience limits for normal testing

TABLE 9

Results of second co-operative SCRIM trial

Machine		3					4					5					6					7				
RUN		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Surface	Tyre†	SIDEWAY FORCE COEFFICIENT (X1000)*																								
1	1	321	306	296	296	297	269	253	257	252	251	303	282	286	305	276	305	305	311	313	308	318	304	312	316	304
	2	274	270	274	278	279	299	295	306	295	298	301	278	287	297	284	308	293	303	315	303	311	304	306	298	306
	3	281	274	272	273	275	268	259	277	267	274	292	302	275	305	296	319	303	300	306	315	319	289	300	300	296
	4	286	279	292	294	286	276	294	273	264	272	304	272	285	280	283	325	331	316	321	311	315	312	295	307	323
	5	310	292	292	306	315	282	284	282	287	278	307	285	290	285	274	279	306	300	289	284	321	313	328	316	325
	6	287	270	271	271	266	–	–	–	–	–	273	256	267	263	248	304	277	281	286	272	342	286	287	280	280
	7	274	281	276	272	271	258	267	268	272	259	–	253	260	261	250	280	267	272	273	275	261	256	278	266	276
2	1	576	533	551	587	538	448	448	436	448	448	477	504	495	502	506	547	542	582	552	595	551	533	528	530	555
	2	512	485	517	507	495	545	499	537	481	498	466	470	480	477	466	521	527	530	521	507	523	498	532	494	492
	3	525	526	524	512	511	489	493	487	459	491	475	474	485	497	480	512	540	550	524	548	526	510	512	518	526
	4	523	515	523	552	517	463	475	485	484	478	485	468	490	469	482	522	621	532	566	531	534	533	543	565	508
	5	535	544	543	568	618	454	492	505	501	531	503	503	493	473	473	499	527	543	564	530	554	554	559	544	565
	6	465	498	490	505	506	–	–	–	–	–	428	435	432	431	438	478	482	479	469	479	503	492	481	496	489
	7	506	484	490	497	475	448	449	456	438	552	–	453	437	432	464	467	477	500	479	476	475	464	465	481	451
3	1	654	661	633	663	635	572	592	574	572	571	585	604	595	596	602	641	617	597	621	626	564	582	580	586	605
	2	624	630	610	563	591	660	654	603	621	583	595	573	607	597	571	591	592	654	605	601	566	586	614	579	560
	3	607	621	626	629	609	583	560	582	579	548	607	626	609	605	607	614	641	631	630	660	616	608	624	617	649
	4	629	617	624	623	616	601	541	554	532	542	598	565	558	555	562	653	665	607	619	608	610	641	630	608	599
	5	638	662	652	651	657	564	599	617	605	575	553	584	560	569	555	606	584	590	592	597	615	616	604	605	615
	6	621	564	610	609	563	–	–	–	–	–	510	507	513	530	519	532	544	541	566	530	587	508	529	525	536
	7	586	587	563	574	599	594	582	565	573	540	–	549	549	552	562	519	543	537	557	540	562	489	504	509	529
4	1	391	344	329	357	340	254	268	261	276	256	283	297	293	284	276	299	302	323	317	362	311	292	296	298	291
	2	310	307	295	318	284	295	287	315	288	283	269	274	273	261	265	287	306	337	302	294	276	275	312	281	280
	3	282	297	322	311	305	278	266	264	282	277	254	256	259	256	265	293	295	293	302	303	276	280	273	295	285
	4	358	327	321	316	330	270	280	284	293	304	281	285	284	279	283	316	313	296	326	314	305	290	284	290	318
	5	315	360	318	338	312	275	321	304	296	276	305	279	280	295	282	310	296	311	308	308	293	297	295	320	289
	6	278	293	256	344	319	–	–	–	–	–	263	253	253	254	236	283	290	286	292	285	298	298	348	292	330
	7	292	291	273	272	308	281	264	277	254	256	–	246	259	260	253	272	278	275	279	273	255	256	263	258	258
5	1	804	707	686	722	746	567	573	582	602	572	641	652	662	651	628	691	798	676	708	691	692	640	664	635	641
	2	693	652	691	675	681	652	641	638	644	634	608	614	629	602	608	669	646	739	663	666	628	607	694	689	740
	3	640	642	684	707	653	620	598	597	622	594	617	628	642	634	657	652	688	671	675	667	717	708	675	677	734
	4	719	657	642	664	654	594	579	582	609	583	642	603	587	581	600	667	720	671	720	678	700	695	681	676	764
	5	717	694	682	713	694	603	651	654	601	592	601	598	611	611	592	647	639	671	654	673	722	707	647	668	687
	6	660	629	639	714	635	–	–	–	–	–	560	560	557	559	569	580	596	590	596	589	630	698	621	712	688
	7	665	645	645	663	689	572	591	582	585	571	–	581	573	620	584	580	591	685	580	603	574	570	575	583	577

* Mean of ten sub-sections

† tyres 1, 6 and 7 were outside resilience range for normal testing

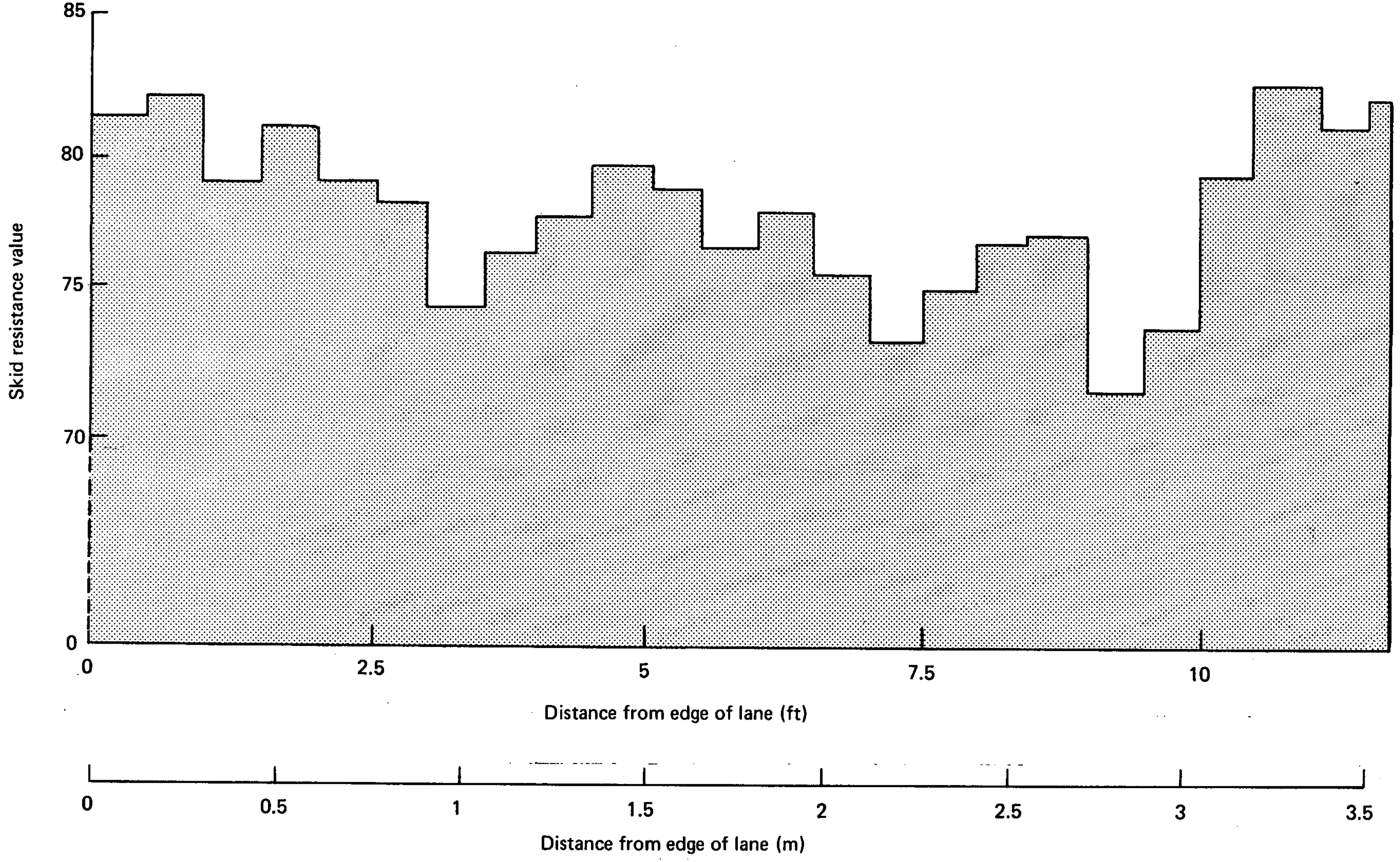

Fig. 1 TRANSVERSE DISTRIBUTION OF SKID–RESISTANCE ACROSS A SECTION OF THE NEAR–SIDE LANE OF MOTORWAY M40

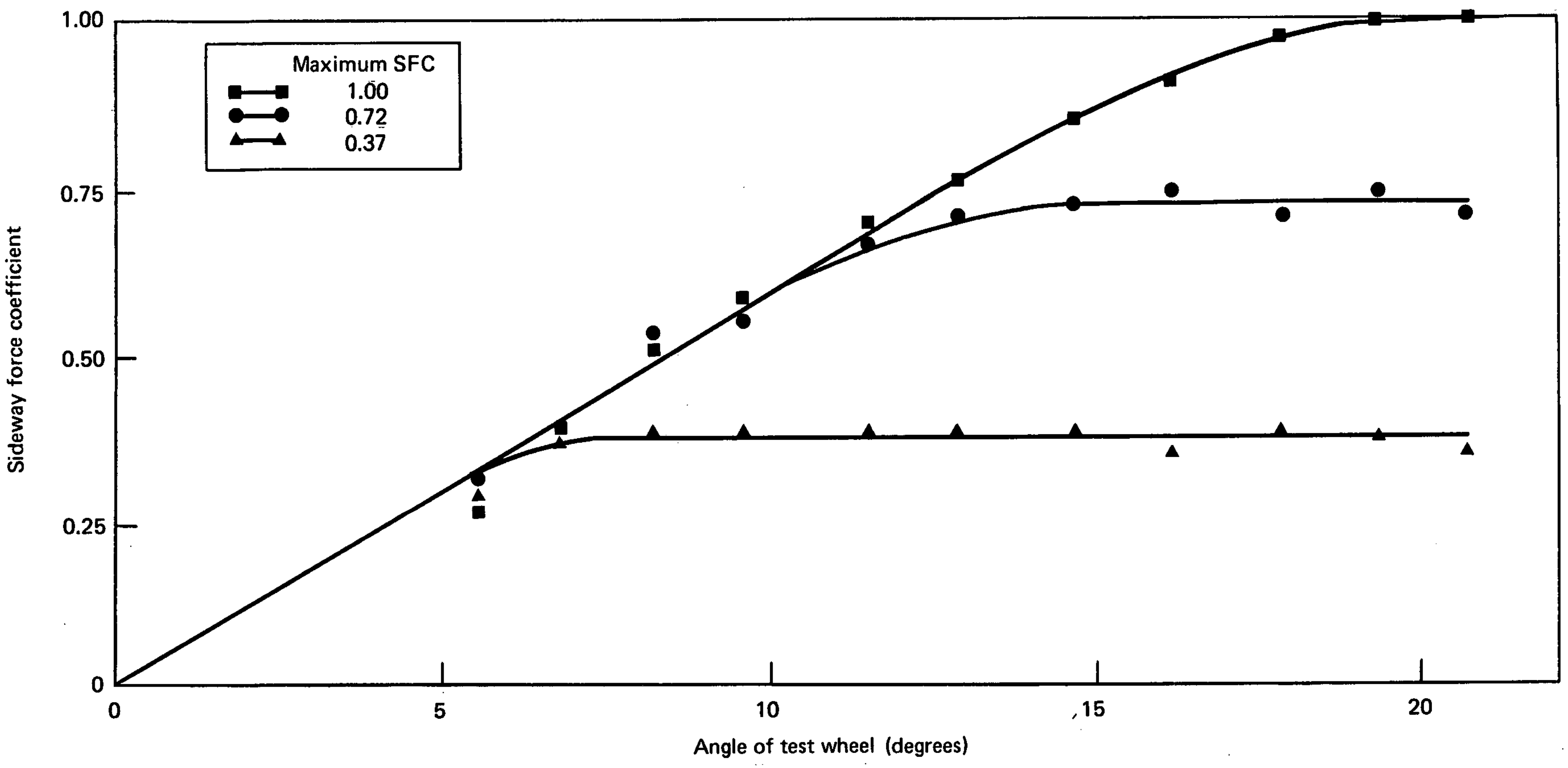

Fig. 2 RELATION BETWEEN SFC AND THE ANGLE OF THE TEST WHEEL

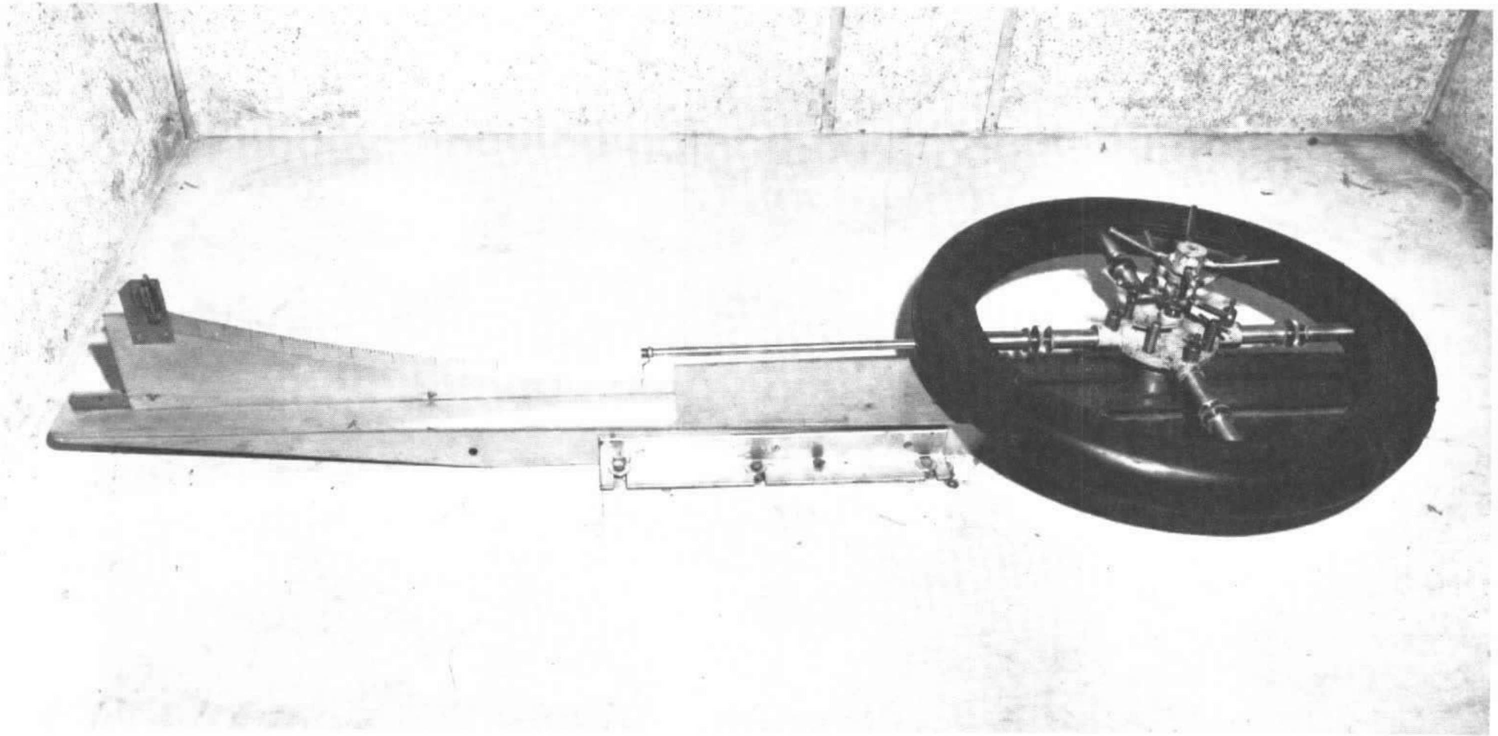

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PLATE 1. The apparatus for measuring the Lüpke resilience of test tyres with a tyre in place

(1666) Dd209447 2M 11/76 HPLtd So'ton G1915
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ABSTRACT

Measurement of skidding resistance Part III. Factors affecting SCRIM measurements: J R HOSKING MSc ACSM and G C WOODFORD: Department of the Environment, TRRL Laboratory Report 739: Crowthorne, 1976 (Transport and Road Research Laboratory). A road testing vehicle, SCRIM, has been developed by the Transport and Road Research Laboratory to provide a routine method of measuring the resistance to skidding (SFC) of wet roads.

Measurements of skidding resistance are affected by the two following classes of factors:–

(1) Factors affecting the slipperiness of the road, such as the state of polish of the surface.

(2) Factors affecting the measurements themselves, such as the calibration of the test instrument.

Factors affecting SFC measurements made with SCRIM are considered in this report and estimates are given of their magnitude. These factors are machine variability including repeatability, reproducibility, tyre resilience and wear, calibration, recorder drift, tyre pressure and water flow; machine operation including tracking, speed and location; test conditions including water-film thickness, evenness of road surface and turning of SCRIM; and variability associated with the processing of results. There are only relatively small "errors" associated with the use of a single SCRIM to compare a number of sections during a limited period of time, and steps can be taken to allow more precise comparisons to be made over longer periods.

An Appendix gives the results of co-operative trials that were made using seven SCRIMS from several different organizations.

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(1) Factors affecting the slipperiness of the road, such as the state of polish of the surface.

(2) Factors affecting the measurements themselves, such as the calibration of the test instrument.

Factors affecting SFC measurements made with SCRIM are considered in this report and estimates are given of their magnitude. These factors are machine variability including repeatability, reproducibility, tyre resilience and wear, calibration, recorder drift, tyre pressure and water flow; machine operation including tracking, speed and location; test conditions including water-film thickness, evenness of road surface and turning of SCRIM; and variability associated with the processing of results. There are only relatively small "errors" associated with the use of a single SCRIM to compare a number of sections during a limited period of time, and steps can be taken to allow more precise comparisons to be made over longer periods.

An Appendix gives the results of co-operative trials that were made using seven SCRIMS from several different organizations.

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