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AN INVESTIGATION INTO MEASURING RUNWAY SURFACE TEXTURE BY THE G--ETC(U)
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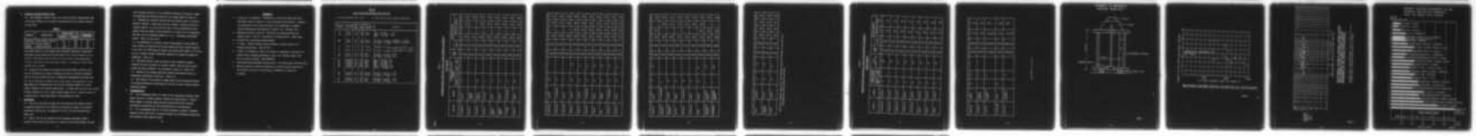

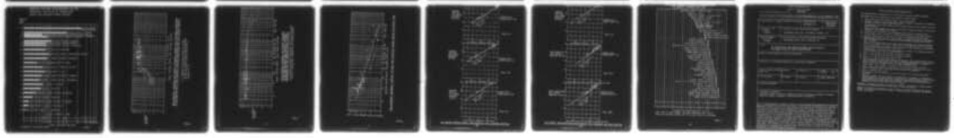

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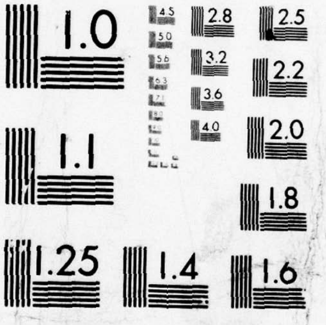

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PROCUREMENT EXECUTIVE MINISTRY OF DEFENCE

AN INVESTIGATION INTO MEASURING RUNWAY SURFACE TEXTURE BY THE GREASE PATCH AND OUTFLOW METER METHODS

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AN INVESTIGATION INTO MEASURING RUNWAY SURFACE TEXTURE BY THE GREASE PATCH AND OUTFLOW METER METHODS

(10) (11) Oct 79 (12) 35

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SUMMARY

A measurement of 'surface texture' is used by some organisations as a means of specifying runway friction for stop distance calculations and certification purposes in spite of the conclusion by the American Society for Testing and Materials that it should be discontinued. This investigation confirms the ASTM conclusions by demonstrating the poor relationship between 'surface texture' and aircraft stop distance also between it and friction measured by two ground vehicles. A method of using 'surface texture' to predict friction of ground vehicles at high speed has been studied and the conclusion is reached that within the limits found on runways it has only a very small effect on the prediction. The investigation recommends that where high speed prediction is necessary a more accurate method is to use equations based on test data. The difficulty in arriving at a single figure for 'surface texture' is demonstrated by showing the variation that can occur along a runway and the large difference in readings between operators.

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1. Introduction

1.1 A large proportion of the effort in developing skid resistant runway surfaces throughout the world has been concentrated on maintaining wet friction as wet values are lower than those obtained in the dry. Under wet conditions the objective is to obtain rapid dispersal of water in the tyre/runway contact region and the less time the tyre remains in contact with any particular point and/or the smaller the drainage channels available to carry the water away, the lower the friction. Wet surface friction is therefore speed dependent, consequently any conclusion on speed effects drawn from a friction measurement made at one speed should be treated with reservation unless some other factor is taken into consideration.

1.2 Some organisations have suggested that what is loosely called 'surface texture' can be used as this 'other factor'. For example Ref 1 claims it is possible to develop mathematical equations which use friction readings at low speed and 'surface texture' as measured by a device developed by the authors, to predict friction readings at high speed. Ref 2 claims a relationship between 'surface texture' and aircraft speed/friction curves and divides the 'surface texture' reading into five bands, each of which is associated with a specific curve. The Civil Aviation Authority wishes to use 'surface texture' as one of the factors to be used in specifying a runway surface suitable for stop distance certification purposes. Ref 3.

1.3 A Synopsium held by the Amercian Society for Testing and Materials in June 1974 on "Surface Texture versus Skidding" (Ref 4) included papers on the "Study of the Sand Patch and Outflow Meter Methods of Pavement Surface Texture Measurement" by R M Doty and "Pavement Texture Measurement and Evaluation" by J J Henry and R R Hegmon. The conclusions, which were supported by industry in the subsequent debate, regarding the usefulness of measuring 'surface texture' by these methods were unanimous and can be summarised as follows:-

(a) The Sand Patch method showed poor repeatability.

(b) Although there was a general trend towards higher friction with increased texture depths as measured by the Sand Patch and Outflow Meter methods, neither was definitive enough to be used as a means of determining the friction properties of pavement surfaces and should be promptly discontinued.

(c) Neither method will provide a usable means of predicting the slope of the speed/friction curve.

1.4 In spite of the overwhelming evidence in these papers to support the conclusions, para 1.2 shows that 'surface texture' is still being used in aircraft performance calculations and test specifications. This paper presents trials data which indicates:-

(a) The Ref 4 conclusions at para 1.3(b) and 1.3(c) are applicable to runways.

(b) There is only a poor relationship between aircraft stop distance and 'surface texture'.

(c) A change in 'surface texture' has only a small effect on friction as measured by two runway friction measuring devices.

2. 'Surface Texture' Measuring Methods

2.1 It is well known that the relationship between 'surface texture' and friction depends on two separate factors namely microtexture and macrotexture, both of which have their individual and characteristic influences. Microtexture is concerned with the sharpness of the fine grain particles and determines the friction characteristics at low speed whilst macrotexture is a measure of the drainage capability of the surface and consequently affects the high speed characteristic. However they are dependent on each other and as only macrotexture can be measured by the two methods considered by the ASTM Synopsium in this study, the conclusions are not perhaps surprising. The words 'surface texture' are therefore a misnomer and in this paper refers to macrotexture only.

2.2 Sand, or Grease Patch Method - This method uses a known volume of sand or grease which is spread evenly over a small area of runway (about one square foot) and levelled with the tips of the asperities. The area of the patch is measured and the surface texture depth obtained by dividing the volume of material by the area covered. Ref 1 states this method has poor repeatability and that since the measurement includes unconnected voids in the surface which play no part in dissipating water between tyre and runway, the authors consider there is no justification in its use as an indicator of friction at high speed. Apart from this the degree of packing of the material into the surface can introduce errors.

2.3 Outflow Meter Method - This method is aimed at simulating the ease with which water can escape from under a rolling tyre. Ref 1 states that a measure of this characteristic can be obtained by pressing a rubber ring against the surface and measuring the rate of flow of water from a superimposed reservoir through channels in the pavement surface. The Outflow Meter used for part of this trial was borrowed from the University of Birmingham. A diagram of the apparatus is of Fig 1, it consists of a cylinder with an opening at each end and an elliptical rubber plate on the bottom similar to an aircraft tyre to ground contact area. The equipment is placed on the surface to be tested and the elliptical face pressed into the texture by its weight. A hole in the bottom is closed by a bung and the cylinder filled with water, the bung is then removed and the time is taken for the water to fall between two marks on the side of the cylinder. This is known as the Water Discharge Time.

3. Relationship between aircraft stop distance and 'Surface Texture'

3.1 The NASA/USAF report at Ref 5 contains the only aircraft friction trial results where sufficient data is available of a quality and quantity that can be used to compare stop distance with 'surface texture'. The aircraft was a C141 landed on each occasion by the same pilot who applied maximum braking over the test area which had been wetted by water bowsers. Over 20 different runways were tested and stop distances determined from a 100 knot 'brakes on' speed in zero wind with the aircraft in the same configuration and weight.

3.2 Water depths were measured at 5 positions along the test strip both before and after the aircraft landed so that the average depth during the aircraft run could be established. 'Surface texture' was measured in more than one position by the same person using the grease patch method. Every effort had therefore been made to minimise scatter in the results due to operator and experimental technique and at the same time to have sufficient data to allow for a proper analysis.

3.3 The trials data is plotted in Fig 2 where it can be seen that the influence of 'surface texture' was so small that stop distances of between 1400 ft and 3000 ft were recorded at the same measured value. Although there appears to be a general trend towards higher friction with increased 'surface texture' depth, the Correlation Coefficient has been calculated as .39 which shows the relationship to be so 'poor' as to be almost non-existent.

4. Relationship between the Diagonal Braked Vehicle, Mu-Meter and 'Surface Texture'

4.1 The Diagonal Braked Vehicle and Mu-Meter are US and UK friction measuring equipments respectively developed specially for use on runways and are described in Refs 5 and 6. They have been used to measure the friction characteristics of a large number of runway surfaces. Because aircraft trials have indicated a broad relationship between stop distances and friction as measured by the two equipments, a study has also been made to decide if a change in 'surface texture' affects their friction readings. If it does not, then it reinforces the view in para 3.2 that friction and 'surface texture' are not closely related.

4.2 The method of using the Diagonal Braked Vehicle is to measure the distance it travels after locking diagonal front and rear wheels. When the wet stop distance is divided by the dry stop distance it becomes what is known as the 'Stop Distance Ratio' (SDR). Fig 3 plots the reciprocal of the SDR against 'surface texture' measured by the grease method during trials by the USAF and NASA. The best fit straight line has been calculated by the least squares method from which the same conclusion can be drawn as for the aircraft in para 3, ie, that although there appears to be a small trend towards higher friction with increased 'surface texture', the scatter is so large that the lack of confidence in the relationship makes it virtually unusable.

4.3 The Mu-Meter is the standard equipment used in the UK to determine the friction properties of runways. This has involved measuring friction at speeds between 20 and 80 mph whilst discharging a known volume of water immediately ahead of the two measuring wheels. This provides a standard degree of wetness against which all surfaces are compared. A number of runways have been tested by this standard method and because 'surface texture' measurements and associated friction data were difficult to reconcile with the C141 except in very generalised trends (para 3), it was decided to gather (Ref 7) 'surface texture' data during these friction trials for a later study.

4.4 'Surface texture' was measured, wherever possible, by both methods described in paras 2.2 and 2.3, the results are in figs 4 and 5. The grease patch method was not used on porous or grooved surfaces since in practise it was found difficult to fill the grooves in a consistent manner and the porous surface (because of its nature), would absorb as much grease into its pores as the operator wished to apply. Whenever the Outflow Meter was available, both methods were used 'side by side'. Where more than one measurement was made, the range is shown and in view of the claim of a relationship between 'surface texture' and five friction 'bands' in Ref 2, these 'bands' have been included in the Figures for ease of reference.

4.5 The average 'surface texture' values from Figs 4 and 5 have been plotted in Figs 6 and 7 against Mu-Meter readings of 40 and 80 mph and the best fit straight lines determined. The indications are that as with the C141 and Diagonal Braked Vehicle there is a general trend towards higher friction with increased 'surface texture' but the scatter is so large that it is not definitive enough to be used as a means of defining the friction properties of runways.

5. 'Surface texture' measurements and their influence on friction/speed relationships on wet runway surfaces

5.1 As explained in para 2.1, 'surface texture' measured by the two methods being considered affect friction characteristics of high speed only, whilst microtexture only influences the absolute level. If a method could be devised where a low speed friction measurement to define the microtexture, could be associated with 'surface texture' it might be possible to predict high speed friction readings from low speed. If this could be shown to be more accurate than mathematical prediction for the Mu-Meter based on trends established during actual trials, there would be some reason for measuring 'surface texture'.

5.2 Ref 1 describes trials by Birmingham University to develop a method of predicting the shape of the friction/speed curve using the Outflow Meter. It shows that when used in conjunction with locked wheel friction values from a vehicle at low speed, the method would predict, with 'reasonable accuracy', values at higher speeds. It is this method which is studied to decide if it will provide a more accurate method of predicting Mu-Meter friction readings at high speed from readings of 40 mph, than a mathematical method based on previous trials.

5.3 Applying the prediction equation in Ref 1 to the case of the Mu-Meter it becomes

$$\log \mu_v = \log \mu_{40} + \frac{(40-V)}{2.3026} \times C. \qquad 1.$$

where

μ_v = Mu-Meter reading at V mph

μ_{40} = Mu-Meter reading at 40 mph

C = Parameter depending on 'surface texture'.

5.4 The procedure is to determine the values of C by inserting known valves of μ_v, μ_{40} and V into equation 1. By plotting C against Outflow Meter time in seconds and determining the best fit straight line it is possible to replace C in equation 1 by Outflow Meter time. The derived equations are shown against 'prediction methods' 2A and 2B in Table 1.

5.5 Because it is more commonly used, the Ref 1 prediction method was also applied to grease patch 'surface texture' measurements, which meant deriving a relationship between it and Outflow Meter time. The data used to produce Figs 4 and 5 was supplemented by extra measurements, particularly on fine textured surfaces, to extend the range of comparison. Measurements by the two methods were made within 1 foot of each other and are plotted in Fig 8 which shows considerable scatter and that the relationship only approaches a straight line when plotted on a log log basis. Using this relationship, equations have been derived as shown against 'prediction methods' 3A and 3B in Table 1.

5.6 During a large number of runway trials, wet Mu-Meter readings have been obtained from two different methods of watering namely (a) spray bars mounted on and to the side of the test surface, or by water bowsers, and

(b) by 'self wetting' where the Mu-Meter towing vehicle carries a quantity of water which it discharges ahead of each test wheel. Because the Mu-Meter readings differ under these two conditions they have been studied separately. For the purposes of this paper the first two methods have been consolidated under the name 'Bowser wetting'.

5.7 Fig 9 shows the relationship between Mu-Meter readings at 40 mph and speeds up to 110 mph for 'bowser wetting' conditions derived from trials data. The best fit straight line equations are shown and listed under 'prediction method' 5 in Table 1.

5.8 Fig 10 shows a similar relationship under 'self wetting' conditions for speeds up to 80 mph, the best fit straight line ~~are~~ given and listed under 'prediction method' 1 in Table 1.

5.9 'Prediction method' 4 in Table 1 for 'self wetting' conditions has been introduced as a comparison with methods 2 and 3 as it is the same as the other two but omits the correction for 'surface texture'. Therefore the difference between it and the other two methods demonstrates the effect (if any) that the 'surface texture' has on the prediction.

5.10 'Prediction methods' 6 and 7 are shown to have the same equations in Table 1 since it was found that the 'surface texture' terms in the equations had a negligible effect.

5.11 The calculated results from all these prediction methods are tabulated in Tables 2 and 3 and compared with actual measured values. A comparison of 'prediction methods' 2 and 3 (Outflow and grease patch) with method 4 show that 'surface texture' has only a minimal effect on the prediction. A comparison of standard deviations between predicted and actual readings in column 6 show that the mathematical prediction based on trends established during actual trials (see Figs 7 and 8) in column 7 have the least error.

6. Spread of 'Surface Texture' data

6.1 The readings in Table 4 below are 'surface texture' measurements made on the same runways by two separate organisations(Ref 5) without reference to each other.

TABLE 4

AIRFIELD	SURFACE TYPE	TEXTURE DEPTH - MM		PERCENTAGE DIFFERENCE
		OPERATOR A	OPERATOR B	
Yeovilton	Wire brushed concrete	1.37	.305	350
Yeovilton	Scored concrete	.83	.395	110
Marham	Brushed concrete	.435	.217	100

From these results it would appear that different techniques in spreading the grease on the runway could be the cause of the large difference in the results. Consequently care was taken to ensure that all the measurements in Fig. 4 were made by the same person. Even so, a variation of over 100% occured along a runway.

6.2 Because of its method of operation the Outflow Meter resultsin Fig 5 are not influenced by operators technique and even so the Water Discharge Time on the same surface can vary by 500%,which demonstrates that there can be a large variation in texture on the same surface. The Department of the Environment has recognised this fact and use 'surface texture' as a site control technique for concrete runways only. It would seem therefore that neither of these methods will give a usable single figure for the 'surface texture' of a runway unless a very large number of measurements are made.

7. Conclusions

7.1 The poor correlation between C141 stop distances and surface texture as measured during the trial indicates the fallacy of using it in aircraft performance calculations as suggested in Ref 2, and test specifications (Para 3.2).

7.2 Trials with the two runway friction measuring equipments confirm aircraft results that whilst there is a general trend towards higher friction with increased texture it is not definitive enough to be used as a means of determining the friction qualities of a runway (Paras 4.2 and 4.5)

7.3 Mathematical equations derived from the method in Ref 1 to predict Mu-Meter readings at high speed and which contain a function related to 'surface texture' to correct for the slope of the speed/friction curve, indicate that the effect of this function is so small as to be negligible. The most accurate prediction method is to use previously established trends. (Para 5.11 and 5.12).

7.4 As differences in 'surface texture' measurements of over 300% can occur between two operators on the same runway and with a single operator it can vary over 100% along the runway, the grease patch method is of little use as a 'surface texture' measuring technique for runways and should be prohibited. (Para 6.1).

7.5 The Outflow Meter, which was found to give repeatable results, confirmed the wide variation in 'surface texture' that can occur along a runway and merely reinforce the conclusion in para 7.4. (Para 6.2).

7.6 Neither of the methods used would measure microtexture which is a fundamental constituent of friction. (Para 2.1).

7.7 The results of this study on runways agree with the American Society for Testing and Materials conclusions on the use of these 'surface texture' measuring methods.

8. Recommendations

8.1 It is recommended that as a result of the conclusions reached in this paper, any use of 'surface texture' measured by grease patch or Outflow Meter methods to specify runway friction characteristics for aircraft performance calculations and test specifications, be discontinued.

8.2 It is recommended that if it becomes necessary to predict a Mu-Meter reading at high speed from a low speed reading, the relationship established from previous trials should be used.

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5. T Yager, W P Phillips, W Horne, H C Sparks "A comparison of Aircraft and ground vehicle stopping performance on dry, wet, flooded, slush, snow and ice covered runways" - NASA TND-6068.
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TABLE 1

LIST OF EQUATIONS DERIVED FROM TEST DATA

x = Water discharge time - secs   y = mean texture depth (grease method)-mm

Prediction Method	Wetting Method	Prediction from MPH	To MPH	Texture Measurement Method	Equation
1A	Self	40	60	None	$\mu_{60} = 1.27\ \mu_{40} - .22$
1B	Self	40	80	None	$\mu_{80} = 1.28\ \mu_{40} - .28$
2A	Self	40	60	Water	$\log \mu_{60} = \log \mu_{40} - (.000139\ x + .0217)$
2B	Self	40	80	Water	$\log \mu_{80} = \log \mu_{40} - (.000278\ x + .0434)$
3A	Self	40	60	Grease	$\log \mu_{60} = \log \mu_{40} - (.0000\ 49y^{-3.45} + .0217)$
3B	Self	40	80	Grease	$\log \mu_{80} = \log \mu_{40} - (.0000\ 98y^{-3.45} + .0434)$
4A	Self	40	60	None	$\log \mu_{60} = \log \mu_{40} - .0217$
4B	Self	40	80	None	$\log \mu_{80} = \log \mu_{40} - .0434$
5A	Bowser	40	50	None	$\mu_{50} = 1.28\ \mu_{40} - .23$
5B	Bowser	40	60	None	$\mu_{60} = 1.43\ \mu_{40} - .36$
5C	Bowser	40	80	None	$\mu_{80} = 1.56\ \mu_{40} - .5$
5D	Bowser	40	100	None	$\mu_{100} = 1.41\ \mu_{40} - .46$
5E	Bowser	40	110	None	$\mu_{110} = 1.42\ \mu_{40} - .49$
6A	Bowser	40	60	Grease	$\log \mu_{60} = \log \mu_{40} - .156$
6B	Bowser	40	80	Grease	$\log \mu_{80} = \log \mu_{40} - .313$
7A	Bowser	40	60	None	$\log \mu_{60} = \log \mu_{40} - .156$
7B	Bowser	40	80	None	$\log \mu_{80} = \log \mu_{40} - .313$

TABLE 2

MU-METER READING PREDICTIONS USING SURFACE TEXTURE MEASUREMENTS

SELF WETTING

LOCATION	SURFACE	AVERAGE TEXTURE DEPTH METHODS		SPEED MPH	MU-METER READING				
		GREASE - MM	WATER - SECS		ACTUAL	PREDICTION METHODS			
						1	2	3	4
1	2	3	4	5	6	7	8	9	10
Bentwaters	Slurry	.6	-	40	.76	-	-		
				60	.71	.75	-	.72	.72
				80	.61	.69	-	.69	.69
Binbrook	Grooved Asphalt	-	-	40	.73	-	-	-	
				60	.70	.71	-	-	.69
				80	.65	.65	-	-	.66
Coningsby	Scored Concrete	.38	-	40	.66	-	-		
				60	.63	.62	-	.63	.63
				80	.59	.56	-	.60	.60
Heathrow	Concrete	.5	-	40	.58	-	-		
				60	.53	.52	-	.55	.55
				80	.50	.46	-	.53	.53
Lyneham 07/25	Slurry	.15	-	40	.68	-	-		
				60	.61	.65	-	.65	.65
				80	.45	.59	-	.62	.62
Lyneham 18/36	Asphalt	.16	-	40	.57	-	-		
				60	.48	.51	-	.54	.54
				80	.36	.45	-	.52	.52
St Mawgan	$\frac{1}{8}$ Chippings	.41	-	40	.74	-	-		
				60	.74	.72	-	.70	.70
				80	.70	.67	-	.67	.67
Stansted	Asphalt	.62	-	40	.61	-	-		
				60	.56	.56	-	.58	.58
				80	.54	.50	-	.55	.55

1	2	3	4	5	6	7	8	9	10
Waddington	Asphalt	.18	-	40	.43	-	-	-	-
				60	.39	.33	-	.41	.41
				80	.37	.27	-	.39	.39
Waddington	$\frac{1}{8}$ Chippings	.52	-	40	.77	-	-	-	-
				60	.74	.76	-	.73	.73
				80	.69	.70	-	.70	.70
Woodbridge	Slurry	.41	-	40	.75	-	-	-	-
				60	.73	.73	-	.71	.71
				80	.65	.68	-	.68	.68
Edinburgh	Concrete	.66	3.25	40	.61	-	-	-	-
				60	.56	.56	.58	.58	.58
				80	.55	.50	.55	.55	.55
Laarbruch	Concrete	.44	6.1	40	.64	-	-	-	-
				60	.62	.59	.61	.60	.61
				80	.61	.54	.58	.59	.58
Gutersloh	$\frac{1}{8}$ Chippings	.43	10.3	40	.74	-	-	-	-
				60	.68	.72	.70	.70	.70
				80	.61	.67	.67	.67	.67
Bruggen	Slurry	.45	8.8	40	.74	-	-	-	-
				60	.74	.72	.70	.70	.70
				80	.68	.67	.67	.67	.67
Luqa	Asphalt	.54	6.6	40	.57	-	-	-	-
				60	.51	.51	.54	.54	.54
				80	.48	.45	.51	.52	.52
Cranfield	$\frac{1}{8}$ Chippings	.72	4.6	40	.77	-	-	-	-
				60	.70	.76	.73	.73	.73
				80	.68	.71	.70	.70	.70
Cranfield	Slurry	.26	32	40	.55	-	-	-	-
				60	.49	.48	.52	.52	.52
				80	.46	.42	.49	.49	.50

1	2	3	4	5	6	7	8	9	10
Cranfield	**Porous**	-	5.7	40	.70	-	-	-	
				60	.66	.67	.67	-	.67
				80	.64	.63	.63	-	.63
Contractors Airfield	**$\frac{1}{2}$" Chippings**	1.2	-	40	.72	-	-	-	-
				60	.72	.69	-	.69	.68
				80	.68	.64	-	.65	.65
Contractors Airfield	**Schlamme**	.86	-	40	.67	-	-	-	-
				60	.62	.63	-	.64	.64
				80	.56	.58	-	.61	.61
Aberdeen	**Asphalt**	.18	-	40	.62	-	-		-
				60	.48?	.57	-	.57	.59
				80	.48	.51	-	.52	.56
Edinburgh	**$\frac{1}{8}$ Chippings**	.59	-	40	.74	-	-	-	-
				60	.72	.72	-	.70	.70
				80	.61	.67	-	.67	.67
Chateauroux	**Asphalt**	.62	-	40	.72	-	-	-	-
				60	.68	.69	-	.69	.69
				80	.64	.64	-	.65	.65
Kemble	**Asphalt**	.28	50	40	.70	-	-	-	-
				60	.67	.67	.66	.66	.67
				80	.65	.62	.61	.62	.63
Contractors Airfield	**$\frac{1}{8}$" Grooved Asphalt**	-	8.2	40	.66	-	-	-	-
				60	.60	.62	.63	-	.63
				80	.58	.57	.60	-	.60
Birmingham	**$\frac{1}{8}$" Goooved Asphalt**	-	9.45	40	.71	-	-	-	-
				60	.68	.68	.67	-	.68
				80	.60	.63	.64	-	.64

1	2	3	4	5	6	7	8	9	10
Hurn	Asphalt	.42	7.15	40	.735	-	-		-
				60	.73	.71	.70	.70	.70
				80	.68	.66	.66	.66	.67
Tarrant Rushton	Slurry	.43	6.8	40	.77	-	-	-	-
				60	.75	.76	.73	.73	.73
				80	.73	.71	.69	.70	.70
Kemble	Asphalt	.28	50	40	.70	-	-	-	-
				60	.67	.67	.66	.67	.67
				80	.65	.62	.61	.63	.63

Note. For a complete list of all 'self wetting' results at 80 mph to date and their relationship to NATO standards, see Fig. 11

TABLE 3

MU-METER READING PREDICTIONS USING SURFACE TEXTURE MEASUREMENTS

BOWSER WETTING

LOCATION	SURFACE	AVERAGE TEXTURE DEPTH METHODS		WATER DEPTH - INS	SPEED MPH	MU-METER READING		
		GREASE-MM	WATER-SECS			ACTUAL	PREDICTION METHOD 5	PREDICTION METHOD 6/7
1	2	3	4	5	6	7	8	9
Chateauroux	Concrete	.43	-	.056	40	.44	-	
					60	.24	.27	.31
					80	.17	.19	.21
Chateauroux	Concrete	.43	-	.022	40	.48	-	
					60	.29	.33	.34
					80	.17	.25	.23
Chateauroux	Concrete	.43	-	.013	40	.50	-	
					60	.35	.36	.35
					80	.28	.28	.24
Chateauroux	Asphalt	.65	-	.037	40	.48	-	
					60	.30	.33	.34
					80	.18	.25	.23
Chateauroux	Asphalt	.65	-	.033	40	.59	-	
					60	.40	.49	.41
					80	.29	.42	.29
Roissy	Concrete	.40	-	.043	40	.48	-	
					60	.37	.33	.34
					80	.30	.25	.23
Roissy	Concrete	.40	-	.031	40	.58	-	
					60	.40	.47	.41
					80	.30	.41	.28
Roissy	Concrete	.40	-	.020	40	.54	-	
					60	.43	.41	.38
					80	.36	.34	.26

1	2	3	4	5	6	7	8	9
Cranfield	**Asphalt**	.61	5.2	-	40	.52	-	-
					60	.40	.39	.36
					80	.34	.31	.25
Cranfield	**Brushed Concrete**	-	1.0	-	40	.47	-	-
					60	.36	.31	.34
					80	.30	.23	.23
Cranfield	**$\frac{1}{8}$" Grooved Asphalt**	-	1.7	-	40	.65	-	-
					60	.58	.57	.45
					80	.52	.51	.32
					100	.49	.46	-
					110	.48	.44	-
Farnborough	**Slurry**	.26	-	-	40	.56	-	-
					60	.42	.44	.39
					80	.38	.37	.27
Cranfield	**$\frac{1}{8}$" Grooved Concrete**	-	3.9	-	40	.58	-	-
					60	.48	.47	.40
					80	.40	.41	.28
					100	.35	.36	-
					110	.32	.32	-

(For TABLE 4 see page 9)

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OUTFLOW METER (MK. I)

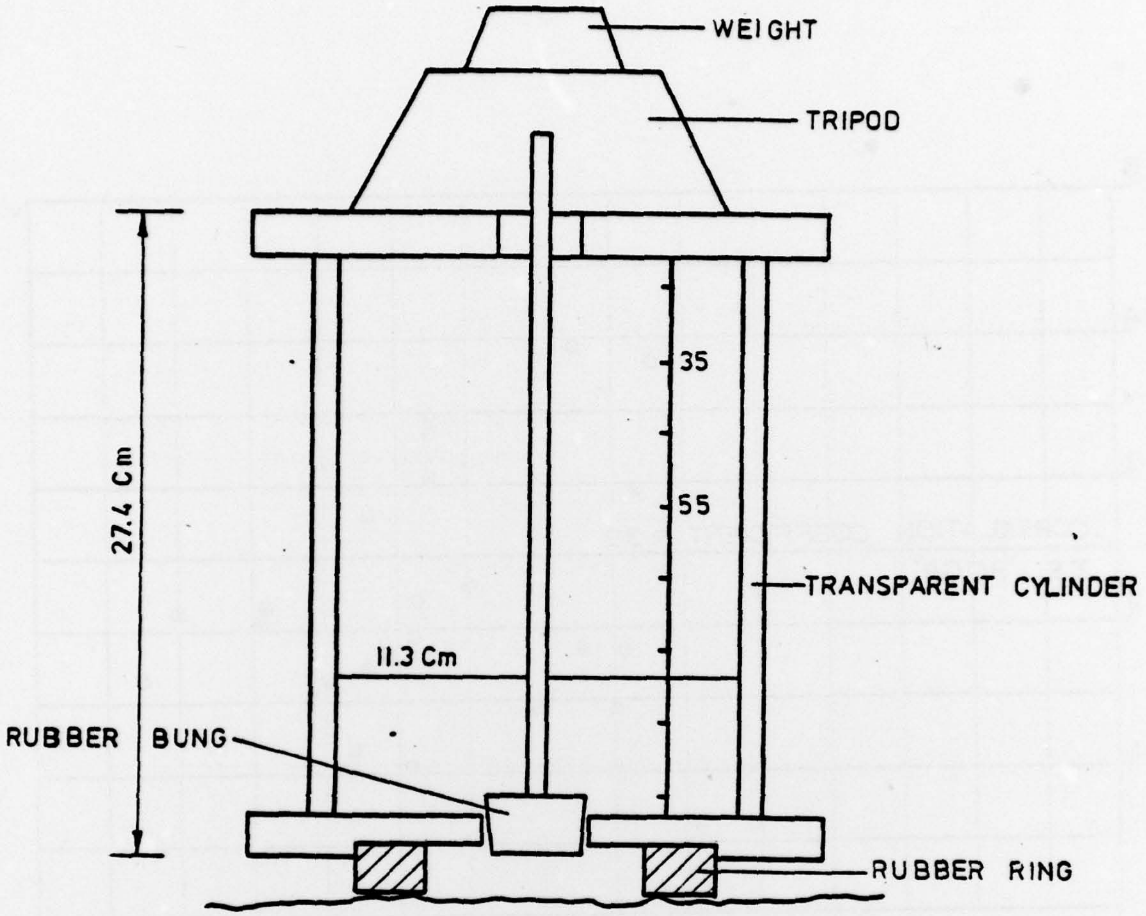
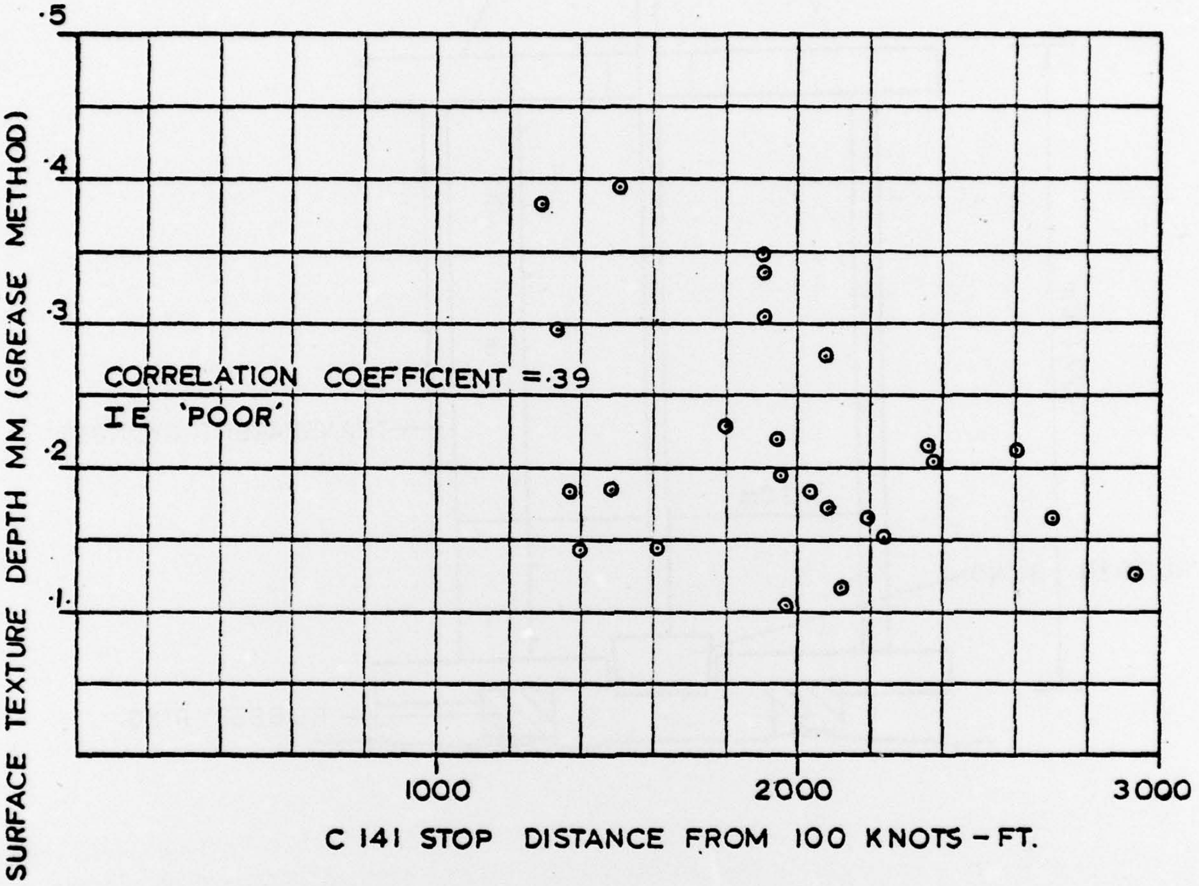
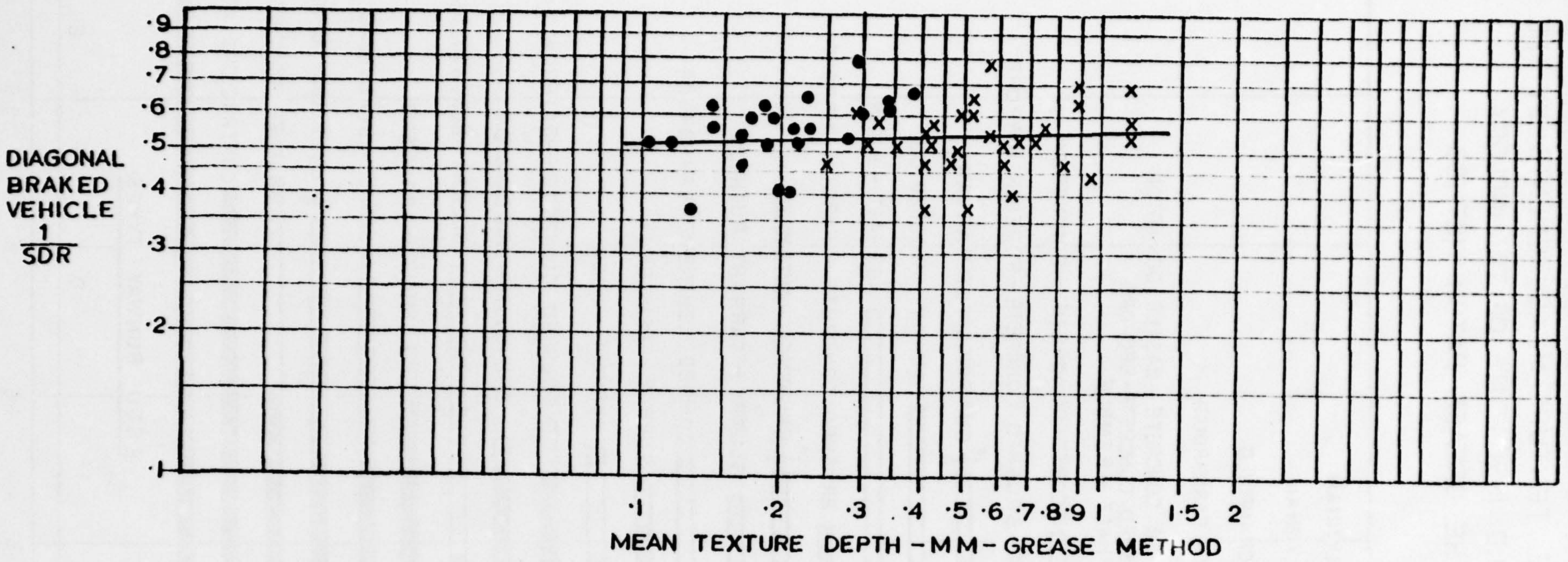


FIG. I.



RELATIONSHIP BETWEEN 'SURFACE TEXTURE' AND C141 STOP DISTANCE

FIG. 2.



RELATIONSHIP BETWEEN DIAGONAL BRAKED VEHICLE STOP DISTANCE RATIO AND SURFACE TEXTURE DETERMINED BY THE GREASE PATCH METHOD.

X FROM USAF SKID RESISTANCE TESTS AFCEC - TR - 75-3
● FROM NASA TECHNICAL NOTE NASA TN D-6098

FIG. 3

'SURFACE TEXTURE' MEASUREMENTS BY THE CRANFIELD INSITITUTE OF TECHNOLOGY USING THE GREASE PATCH METHOD

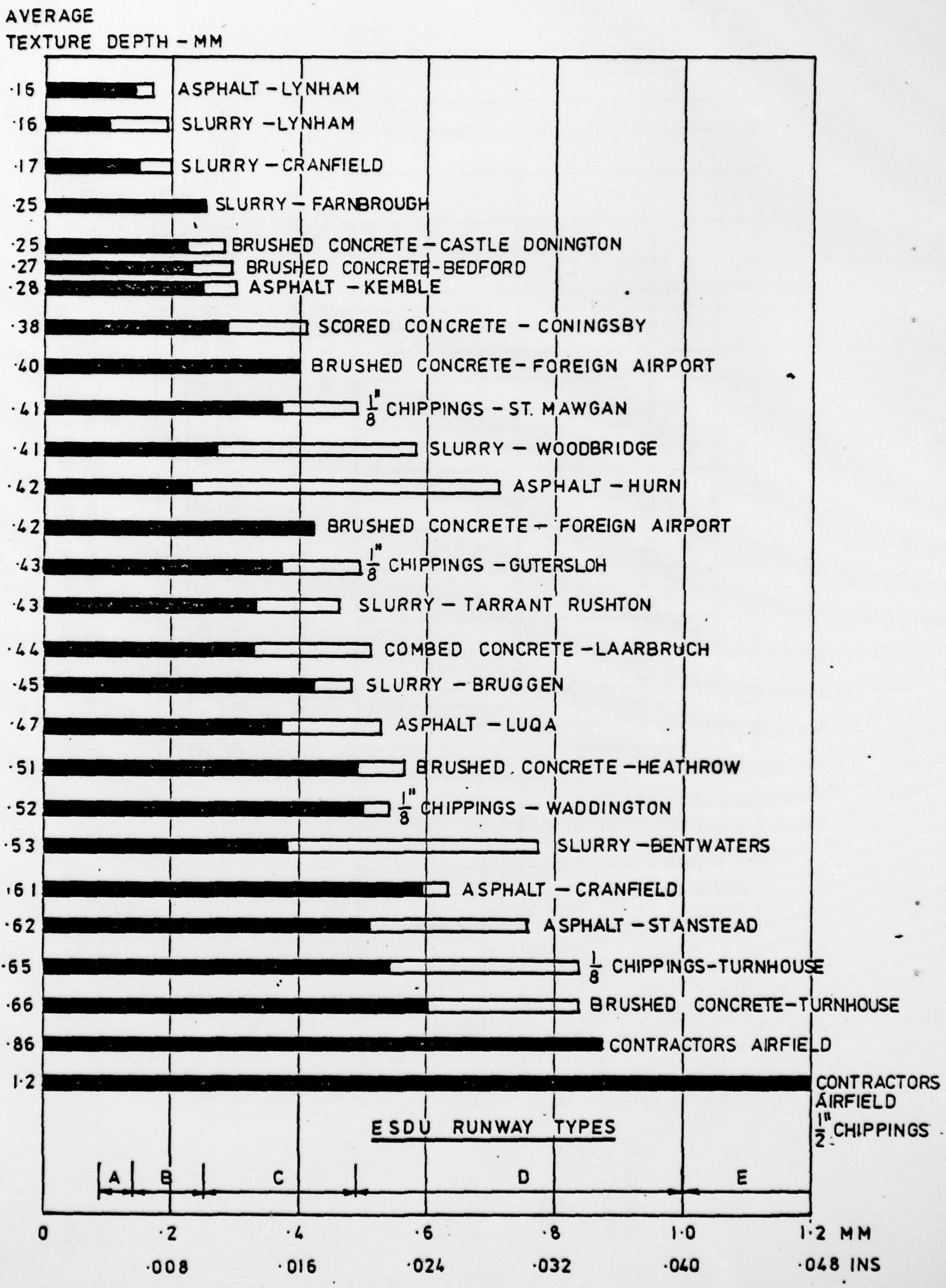
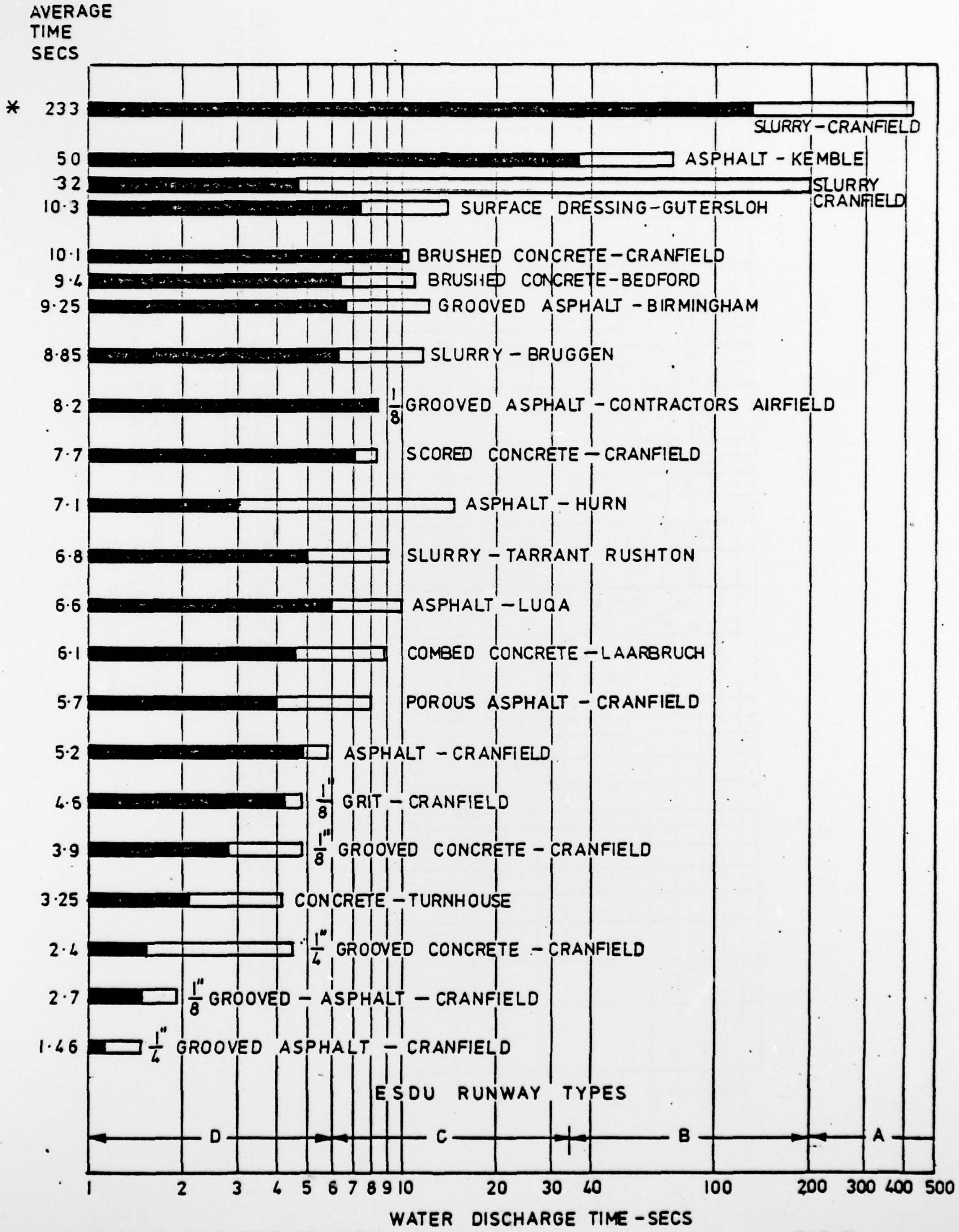


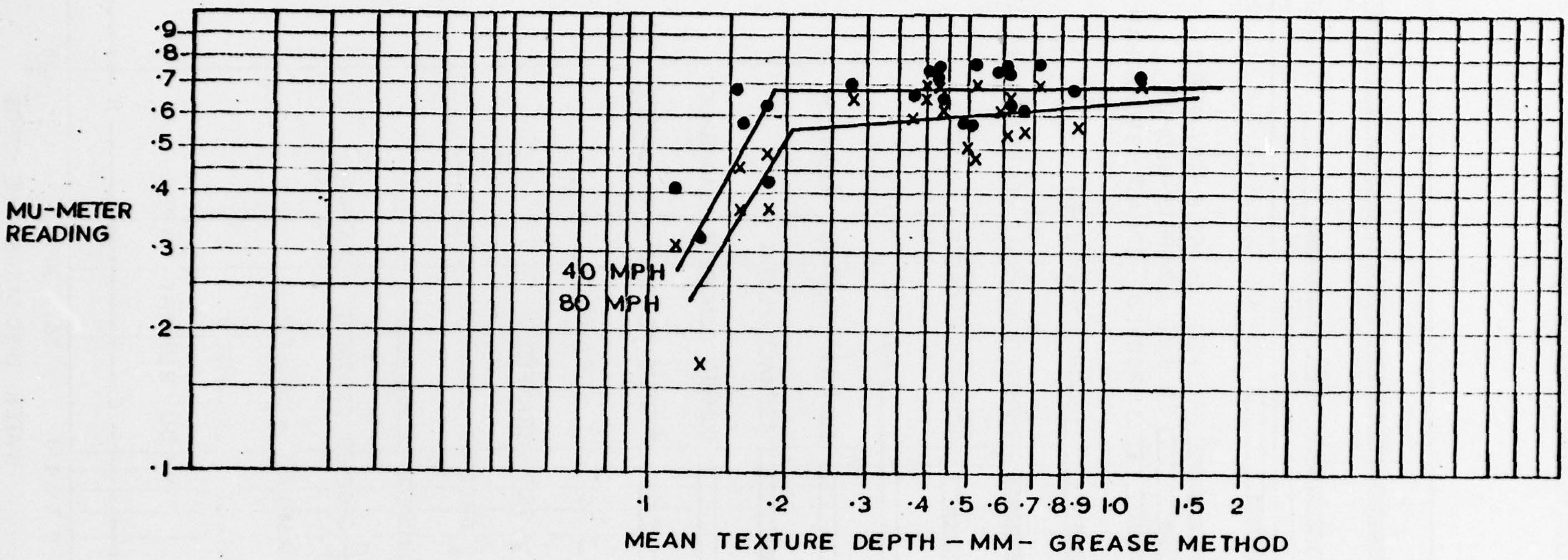
FIG. 4

'SURFACE TEXTURE' MEASUREMENTS BY THE CRANFIELD INSTITUTE OF TECHNOLOGY USING THE OUTFLOW METER METHOD



* SELECTED FINE TEXTURE AREAS

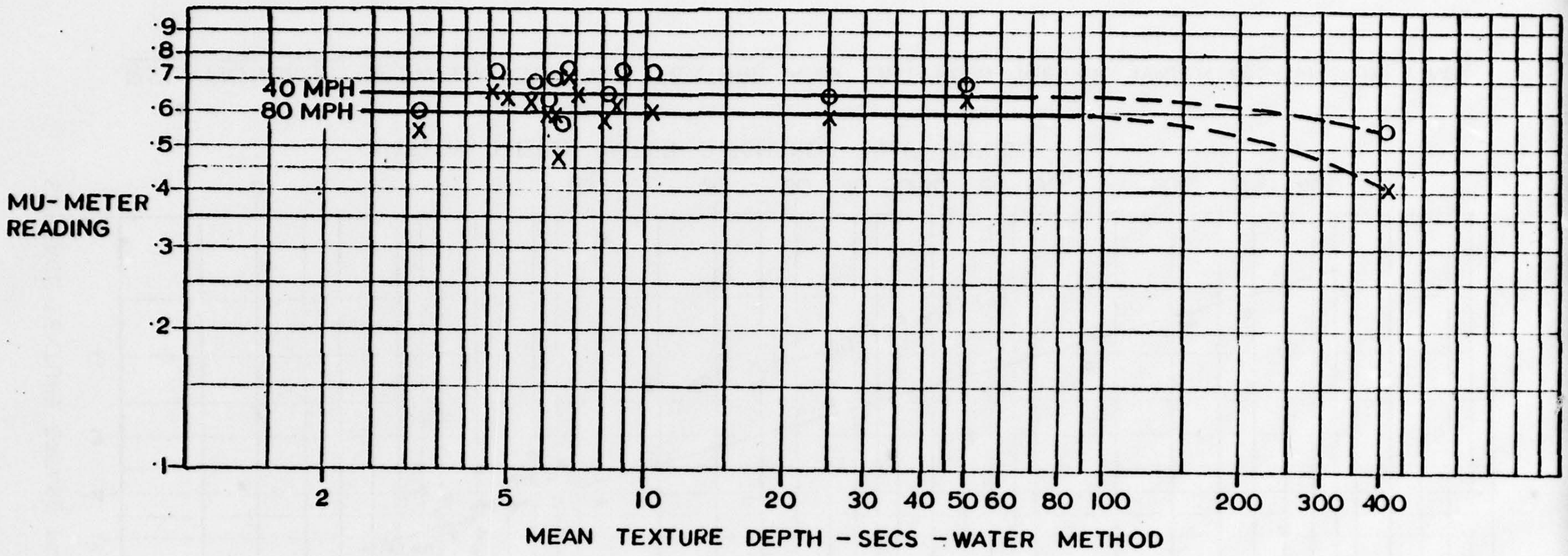
FIG.5



RELATIONSHIP BETWEEN MU-METER READINGS UNDER SELF WETTING CONDITIONS AT 40 AND 80 MPH AND 'SURFACE TEXTURE' DETERMINED BY THE GREASE METHOD

ie A CHANGE IN TEXTURE DEPTH OF ·7 MM
CAUSES A CHANGE IN MU-METER READING
AT 40 MPH OF ·01 AND AT 80 MPH A
CHANGE OF ·07

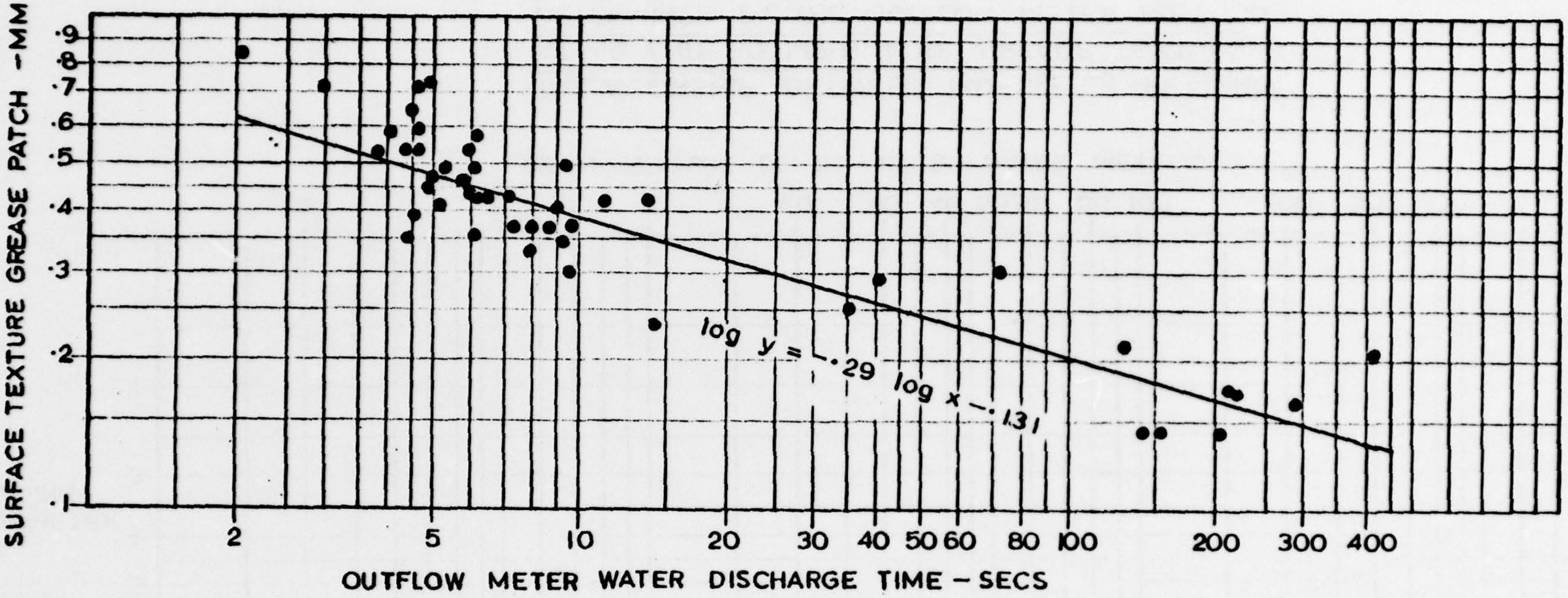
FIG. 6



<u>RELATIONSHIP BETWEEN MU-METER READING AT 40 AND 80 MPH AND SURFACE TEXTURE DETERMINED BY THE OUTFLOW METER METHOD.</u>

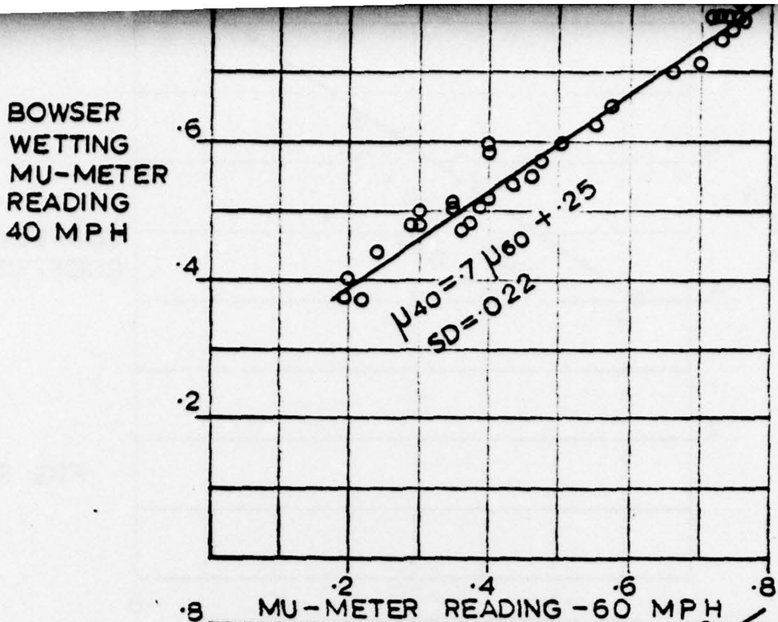
ie. A CHANGE IN WATER DISCHARGE TIME OF 50 SECONDS CAUSES A NEGLEGIBLE CHANGE IN MU-METER READING

FIG. 7



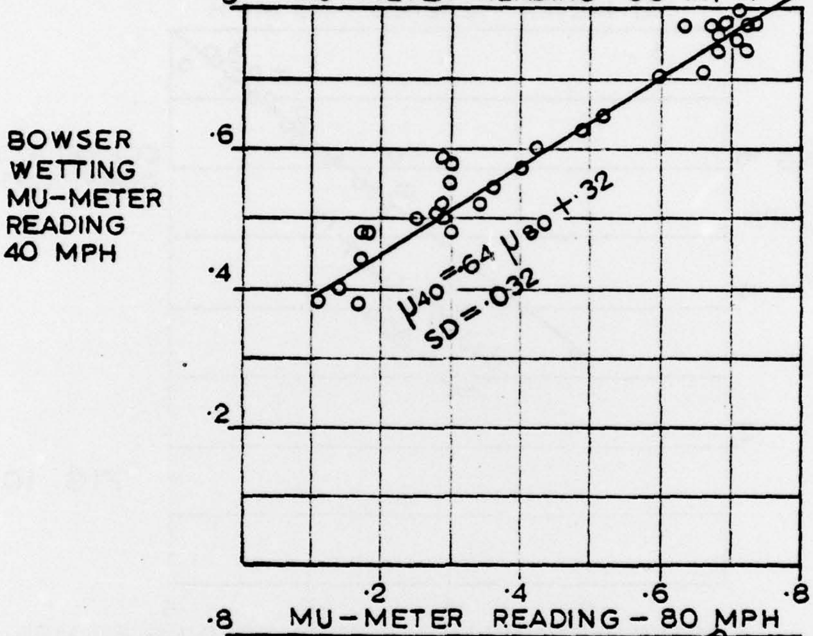
RELATIONSHIP BETWEEN SURFACE TEXTURE AND OUTFLOW METER WATER DISCHARGE TIME

FIG.8



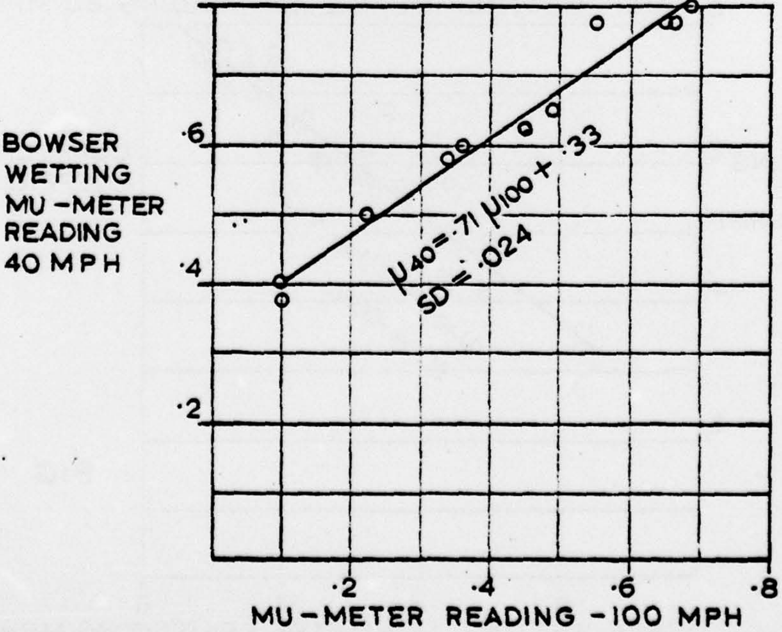
CORRELATION COEFFICIENT = ·98

FIG. 9 A



CORRELATION COEFFICIENT = ·97

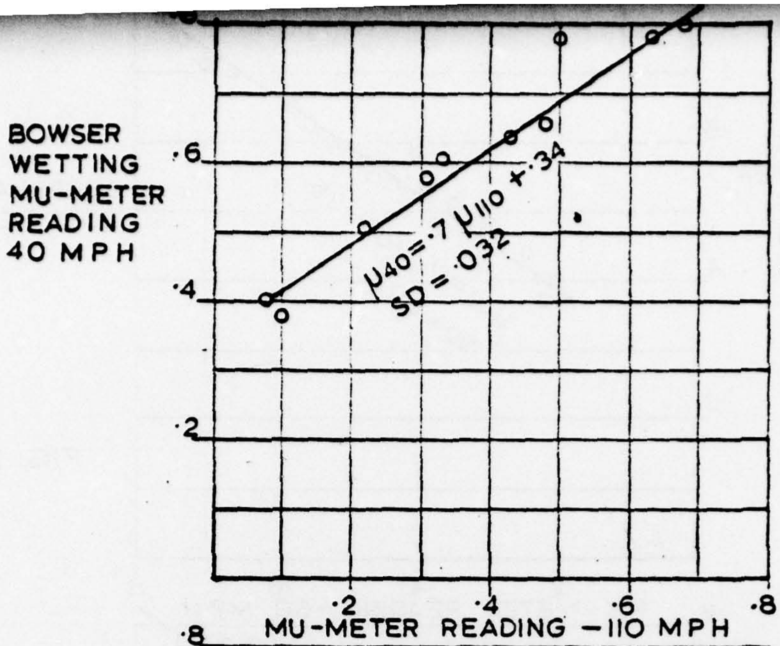
FIG. 9 B



CORRELATION COEFFICIENT = ·98

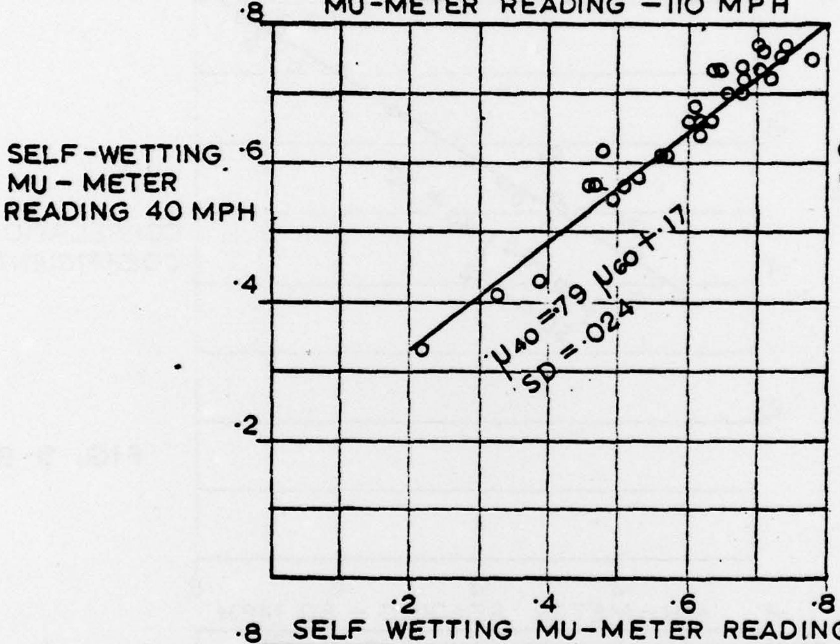
FIG. 9 C

MU-METER READING/SPEED RELATIONSHIP WITH BOWSER WETTING



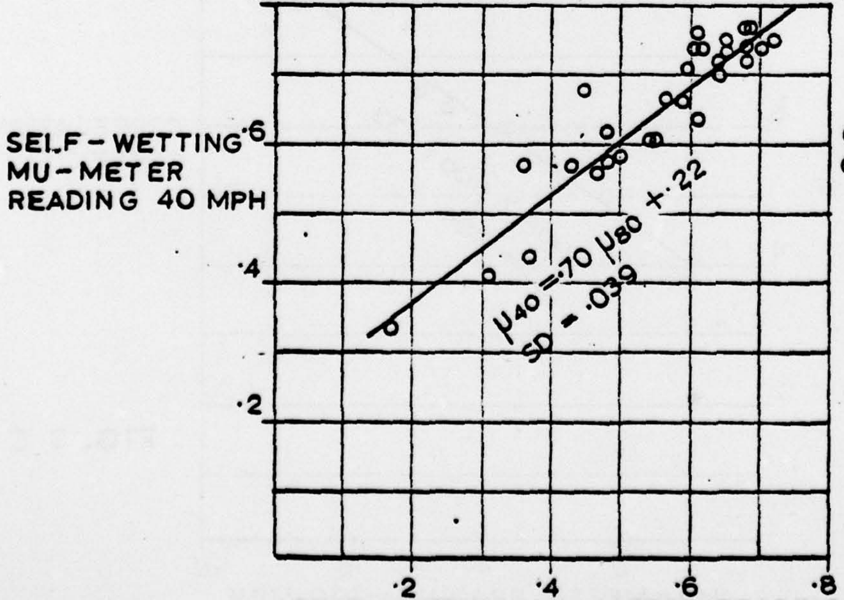
CORRELATION COEFFICIENT = ·98

FIG 9 D



CORRELATION COEFFICIENT = ·97

FIG. 10 A

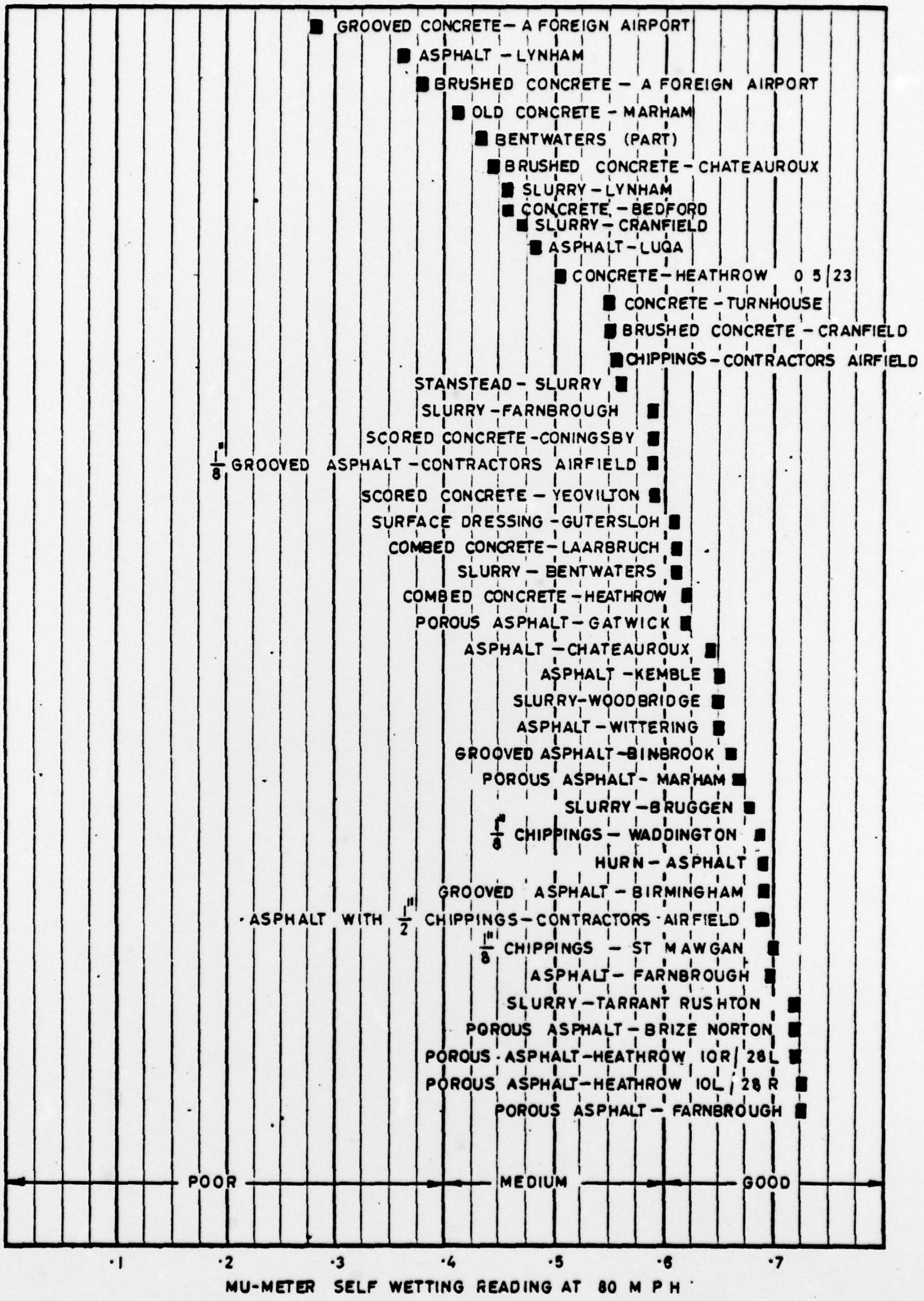


CORRELATION COEFFICIENT = ·90

FIG. 10 B

MU-METER READING/SPEED RELATIONSHIP WITH BOWSER AND SELF WETTING

TO DRAFT STANAG 3811 FS



NOTE 1 – SOME OF THESE RUNWAYS HAVE BEEN RESURFACED SINCE TESTING.

NOTE 2 – THE READINGS RECORDED ARE FOR THE MAIN PORTION OF THE RUNWAY

FIG. 11

REPORT DOCUMENTATION PAGE

(Notes on completion overleaf)

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(As far as possible this sheet should contain only unclassified information. If is is necessary to enter classified information, the box concerned must be marked to indicate the classification eg (R),(C) or (S)).

1. DRIC Reference (if known)	2. Originator's Reference	3. Agency Reference S&T-MEMO-2-79	4. Report Security Classification UNLIMITED

5. Originator's Code (if known) 7210000X	6. Originator (Corporate Author) Name and Location Procurement Exec.,Min. of Defence, DA Mech., UK
5a. Sponsoring Agency's Code (if known) 7273000C	6a. Sponsoring Agency (Contract Authority) Name and Location Procurement Exec., Min. of Defence, UK

7. Title

AN INVESTIGATION INTO MEASURING RUNWAY SURFACE TEXTURE BY THE GREASE PATCH AND OUTFLOW METER METHODS.

7a. Title in Foreign Language (in the case of translations)

7b. Presented at (for conference papers). Title, place and date of conference

8. Author 1, Surname, initials Sugg, R.W.	9a Author 2	9b Authors 3, 4...	10. Date 10.1979	pp 34	ref 7
11. Contract Number	12. Period	13. Project	14. Other References		

15. Distribution statement

Descriptors (or keywords)

*Aircraft landing, *Friction, *Runways, *Texture, Distance, Flowmeters, Greases, Moisture content, Stopping, Surface properties, Wettability.

Abstract A measurement of 'surface texture' is used by some organisations as a means of specifying runway friction for stop distance calculations and certification purposes in spite of the conclusion by the American Society for Testing and Materials that it should be discontinued. This investigation confirms the ASTM conclusions by demonstrating the poor relationship between 'surface texture' and aircraft stop distance also between it and friction measured by two ground vehicles. A method of using 'surface texture' to predict friction of ground vehicles at high speed has been studied and the conclusion is reached that within the limits found on runways it has only a very small effect on the prediction. The investigation recommends that where high speed prediction is necessary a more accurate method is to use equations based on test data. The difficulty in arriving at a single figure for 'surface texture' is demonstrated by showing the variation that can occur along a runway and the large difference in readings between operators.

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