TP 13980E

Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces

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16. Abstract

A field test program was undertaken to obtain data to investigate the factors affecting the friction coefficients recorded by decelerometer systems commonly used for friction measurement on airport runways. Data were obtained to evaluate the effect of vehicle type (five vehicles were tested), vehicle parameters (antilock braking system on or off, weight distribution), decelerometer type (ERD Mk II, ERD Mk III, Tapley, and Bowmonk), and runway surface condition. A total of 76 tests were conducted over the January 15-18, 2002, period at North Bay Jack Garland airport.

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16. Résumé

Des essais en vraie grandeur ont été réalisés pour mieux cerner les facteurs qui influent sur les coefficients de frottement enregistrés par les décéléromètres couramment utilisés pour mesurer le frottement sur les pistes d'aéroports. Les données recueillies ont permis d'évaluer l'effet du type de véhicule (cinq véhicules ont été essayés), de certains paramètres relatifs au véhicule (freinage avec ou sans système antidérapage, répartition du poids), du type de décéléromètre (ERD Mk II, ERD Mk III, Tapley et Bowmonk) et de l'état de la surface de la piste. Un total de 76 essais ont eu lieu du 15 au 18 janvier 2002 à l'aéroport Jack Garland de North Bay.

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North Bay Airport is thanked for providing the airport runway and for preparing the winter surfaces (i.e., ice, sanded ice, packed snow, and sanded packed snow) that were used for the test program. North Bay Airport also supplied four of the vehicles used in the project and the ERD Mk II decelerometer used during the test program. Doug Wilkinson, of North Bay Airport, is thanked for operating the vehicles during the test program.

EXECUTIVE SUMMARY

A field test program was undertaken to obtain data to investigate the factors affecting the friction coefficients recorded by decelerometer systems commonly used for friction measurement at airport runways. Data were obtained to evaluate the effect of vehicle type, vehicle parameters (Antilock Braking System (ABS) on or off, weight distribution), decelerometer type, and runway surface condition. A total of 76 tests were conducted over the January 15-18, 2002, period at North Bay Jack Garland Airport.

Results

- Decelerometers: The Electronic Recording Decelerometer (ERD) Mk II and Mk III decelerometers recorded equivalent friction coefficients to all practical purposes. The Tapley decelerometer recorded friction coefficients that were consistently higher than the ERD Mk II or ERD Mk III decelerometers, by about 0.05 over the full range of surfaces tested. The Bowmonk decelerometer recorded friction coefficients that were about 0.025 higher on average over the full range of surfaces tested) than the ERD Mk II or ERD Mk III decelerometers. These variations are similar to those of previous comparative tests and may be due to the fact that the Tapley and the Bowmonk are "peak-measuring" devices whereas the ERDs are "averaging" devices. For the range of Canadian Runway Friction Indices (CRFIs) in the current Aeronautical Information Publication (AIP), the observed variations in friction coefficient with respect to decelerometer type represent a maximum variation in landing distance of about 600 ft. (182.9 m) and 250 ft. (76.2 m) for the Tapley and Bowmonk, respectively, in comparison to the two ERDs. (It should be noted that these values are for an unfactored landing distance of 3000 ft. and no reverse thrust.)

- Vehicle Type Comparison: The friction values recorded were affected by the vehicle type. The effect of vehicle type varies with the friction level and the decelerometer type. The maximum variation in the recorded friction coefficient ranged from about 0.02 to 0.08, depending on the case being considered. For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to vehicle type represent a maximum variation in landing distance of about 400 to 600 ft. (121.9 to 182.9 m) for an unfactored landing distance of 3000 ft. and no reverse thrust.

- Vehicle ABS On or Off: The decelerometer readings changed depending on whether the vehicle was operated with ABS on or ABS disabled. The observed variation depended on surface condition. Generally, it was less when the surface friction was very low, being about 0.01 for low-friction surfaces and about 0.05 when the surface friction was in the 0.3 range. For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to the vehicle's ABS being on or off represent a maximum variation in landing distance of about 400 ft. (121.9 m) for an unfactored landing distance of 3000 ft. and no reverse thrust.

- Vehicle Weight Distribution and/or Total Weight: The friction coefficient recorded with the half-ton pickup truck in a "50:50" weight balance (front:rear) was about 0.02 lower than for the "as is" weight distribution (which was about 60:40 front:rear). The observed variation in friction coefficient could be due to the difference in total weight for the "50:50" and the "as is" cases as the weight was increased for the "50:50" case. For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to the vehicle's weight distribution, or total weight, represent a maximum variation in landing distance of about 200 ft. (61 m) for an unfactored landing distance of 3000 ft. and no reverse thrust.

Recommendations

The following issues warrant further investigation:

- Effect of decelerometer type
- Decelerometer calibration techniques and procedures
- Effect of ABS systems being on or off
- Variation among the decelerometer systems (i.e., decelerometer, vehicle, and operator) in common use at airports now
- Effect of vehicle type and weight distribution/total weight
- Effect of loose contaminants
- Effect of combinations

SOMMAIRE

Des essais en vraie grandeur ont été réalisés pour mieux cerner les facteurs qui influent sur les coefficients de frottement enregistrés par les décéléromètres couramment utilisés pour mesurer le frottement sur les pistes d'aéroports. Les données recueillies ont permis d'évaluer l'effet du type de véhicule, de certains paramètres relatifs au véhicule (freinage avec ou sans système antidérapage [ABS], répartition du poids), du type de décéléromètre et de l'état de la surface de la piste. Un total de 76 essais ont eu lieu du 15 au 18 janvier 2002 à l'aéroport Jack Garland de North Bay.

Résultats

- Décéléromètres : Les décéléromètres électroniques (ERD) Mk II et Mk III ont enregistré des coefficients de frottement équivalents, à toutes fins utiles. Les coefficients de frottement mesurés par l'appareil Tapley dépassaient régulièrement de quelque 0,05 les coefficients enregistrés à l'aide de l'ERD Mk II ou Mk III, sur toute la gamme des surfaces étudiées. Quant à l'appareil Bowmonk, il a enregistré des coefficients de frottement qui étaient d'environ 0,025 supérieurs, en moyenne, à ceux mesurés par l'ERD Mk II ou l'ERD Mk III, sur toutes les surfaces étudiées. Les mêmes écarts avaient déjà été mis en lumière par des essais comparatifs antérieurs. Ceux-ci pourraient s'expliquer par le fait que les appareils Tapley et Bowmonk mesurent des «maximums», tandis que les décéléromètres électroniques mesurent plutôt des «moyennes». Pour les valeurs du coefficient canadien de frottement sur piste (CRFI) publiées dans la Publication d'information aéronautique (AIP) de Transports Canada actuellement en vigueur, les variations du coefficient de frottement attribuables au type de décéléromètre se traduisent par une variation maximale de la distance d'atterrissage d'environ 600 pi (182,9 m) et 250 pi (76,2 m), si l'on compare respectivement les appareils Tapley et Bowmonk aux deux ERD. (À noter que ces valeurs s'appliquent à une distance d'atterrissage non pondérée de 3 000 pi, sans inversion de poussée.)

- Type de véhicules : Les valeurs de frottement enregistrées étaient influencées par le type de véhicule. L'effet du type de véhicule est plus ou moins important selon le niveau de frottement et le type de décéléromètre utilisé. L'écart maximal entre les coefficients de frottement enregistrés allait, en gros, de 0,02 à 0,08, selon le cas. Pour les valeurs du CRFI publiées dans l'AIP en vigueur, les variations du coefficient de frottement attribuables au type de véhicule se traduisent par une variation maximale de la distance d'atterrissage d'environ 400 à 600 pi (121,9 à 182,9 m) dans le cas d'une distance d'atterrissage non pondérée de 3 000 pi, sans inversion de poussée.

- Freinage avec ou sans dispositif ABS : Les lectures du décéléromètre changeaient selon que le freinage se faisait avec ou sans dispositif ABS. L'écart observé dépendait de l'état de la surface. En général, l'écart variait en fonction inverse de la glissance de la chaussée. Ainsi, l'écart s'établissait à environ 0,01 sur une surface à faible coefficient de frottement et à 0,05, environ, sur une surface dont le coefficient de frottement était autour de 0,3. Pour les valeurs

du CRFI publiées dans l'AIP en vigueur, les variations du coefficient de frottement attribuables au freinage avec ou sans ABS se traduisent par une variation maximale de la distance d'atterrissage d'environ 400 pi (121,9 m), dans le cas d'une distance d'atterrissage non pondérée de 3 000 pi, sans inversion de poussée.

- Répartition du poids et/ou poids total du véhicule : Le coefficient de frottement enregistré avec la camionnette d'une demi-tonne aménagée pour que le poids soit réparti dans un rapport égal (50:50) entre l'avant et l'arrière était d'environ 0,02 inférieur à celui enregistré avec la même camionnette «en l'état» (c.-à-d. dont le poids était réparti dans un rapport de 60:40 de l'avant à l'arrière). La variation du coefficient de frottement pourrait s'expliquer par la différence de poids total entre les configurations «50:50» et «en l'état», car le poids du véhicule a été augmenté pour produire la configuration «50:50». Pour les valeurs du CRFI publiées dans l'AIP en vigueur, les variations du coefficient de frottement attribuables à la répartition du poids du véhicule, ou à son poids total, se traduisent par une variation maximale de la distance d'atterrissage d'environ 200 pi (61 m), dans le cas d'une distance d'atterrissage non pondérée de 3 000 pi, sans inversion de poussée.

Recommandations
Il y aurait lieu de pousser plus loin l'étude des questions suivantes:

- Effet du type de décéléromètre
- Techniques et procédures d'étalonnage des décéléromètres
- Effet du dispositif antidérapage
- Variation parmi les systèmes de décéléromètres (c.-à-d., décéléromètre, véhicule et opérateur) actuellement utilisés aux aéroports
- Effet du type de véhicule et de la répartition du poids/du poids total
- Effet de contaminants non fixés
- Effet de combinaisons de facteurs

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GLOSSARY

ABS	Antilock Braking System
AIP	Aeronautical Information Publication
CRFI	Canadian Runway Friction Index
ERD	Electronic Recording Decelerometer
FTL	Fleet Technology Limited
JWRFMP	Joint Winter Runway Friction Measurement Program
LD	Landing Distance
SUV	Sport Utility Vehicle

1. INTRODUCTION AND OBJECTIVES

1.1 Background

During the winter season, airports in Canada conduct runway surface inspections and forward this information to air traffic control or flight service stations for onward transmission to pilots. The friction of the runway is an essential part of the information collected. Airports take friction measurements throughout inclement winter weather periods when winter contaminants such as snow, ice, compacted snow and so forth are on the runway.

Various friction-measuring devices are used throughout the world to measure and report runway friction. In Canada, airports have used, and continue to use decelerometers for friction measurement in wintertime. These measurements are made by mounting the decelerometer in a vehicle. To make a measurement, the vehicle is put into a skid, and its deceleration is recorded by the decelerometer. In this case, the decelerometer acts as the sensor that reacts to and records the vehicle's deceleration.

It is important to recognize that the vehicle is part of this friction-measurement system, as it is in contact with the runway surface. The vehicle's deceleration and, hence, the recorded friction level, are affected by the behaviour of the vehicle as well as the contact conditions between the vehicle's tires and the runway surface. This system controls the tractive forces developed at the tire-surface interface, which the decelerometers measure and record.

Airports in Canada use a variety of vehicles as the platform for friction measurements with decelerometers. This report describes a project that was undertaken to investigate to what extent the friction levels recorded by decelerometers are affected by the use of different vehicles.

Project objectives also included a preliminary assessment of the impact of the vehicle's antilock braking system (ABS) being on or off on the friction readings. At the present time, airports are instructed (by Transport Canada) not to use vehicles with the ABS on when taking friction readings. However, airports are finding that, with vehicles currently available, it is becoming increasingly difficult to disable the ABS. Airport liability is also a concern when the ABS is disabled on these vehicles.

In Canada, several different types of decelerometers are now considered acceptable for airport use. Although these decelerometers were compared a few years ago by Transport Canada [1, 2], additional comparative data were obtained in this project to expand the information base regarding the effect of decelerometer type.

1.2 Objectives

This report describes a field test program that was undertaken to obtain data to evaluate the above issues. In summary, the specific objectives were to investigate the effect of:

(a) vehicle type

(b) vehicle parameters, including:
   i. the weight distribution of the vehicle
   ii. whether the vehicle's ABS was on or off

(c) decelerometer type

(d) runway surface condition

2. TEST LOCATION AND DATE

A total of 76 tests were conducted over the January 15-18, 2002, period at North Bay Jack Garland Airport. North Bay was selected as the test site because it had an unused runway (runway 13-31 – Figure 2.1) that was made available for test purposes and because the staff there were willing and able to provide the operational support needed to conduct such a test program. Runway 13-31 and North Bay Jack Garland Airport have been used as one of the major sites for the Joint Winter Runway Friction Measurement Program (JWRFMP), which has been ongoing since 1996.

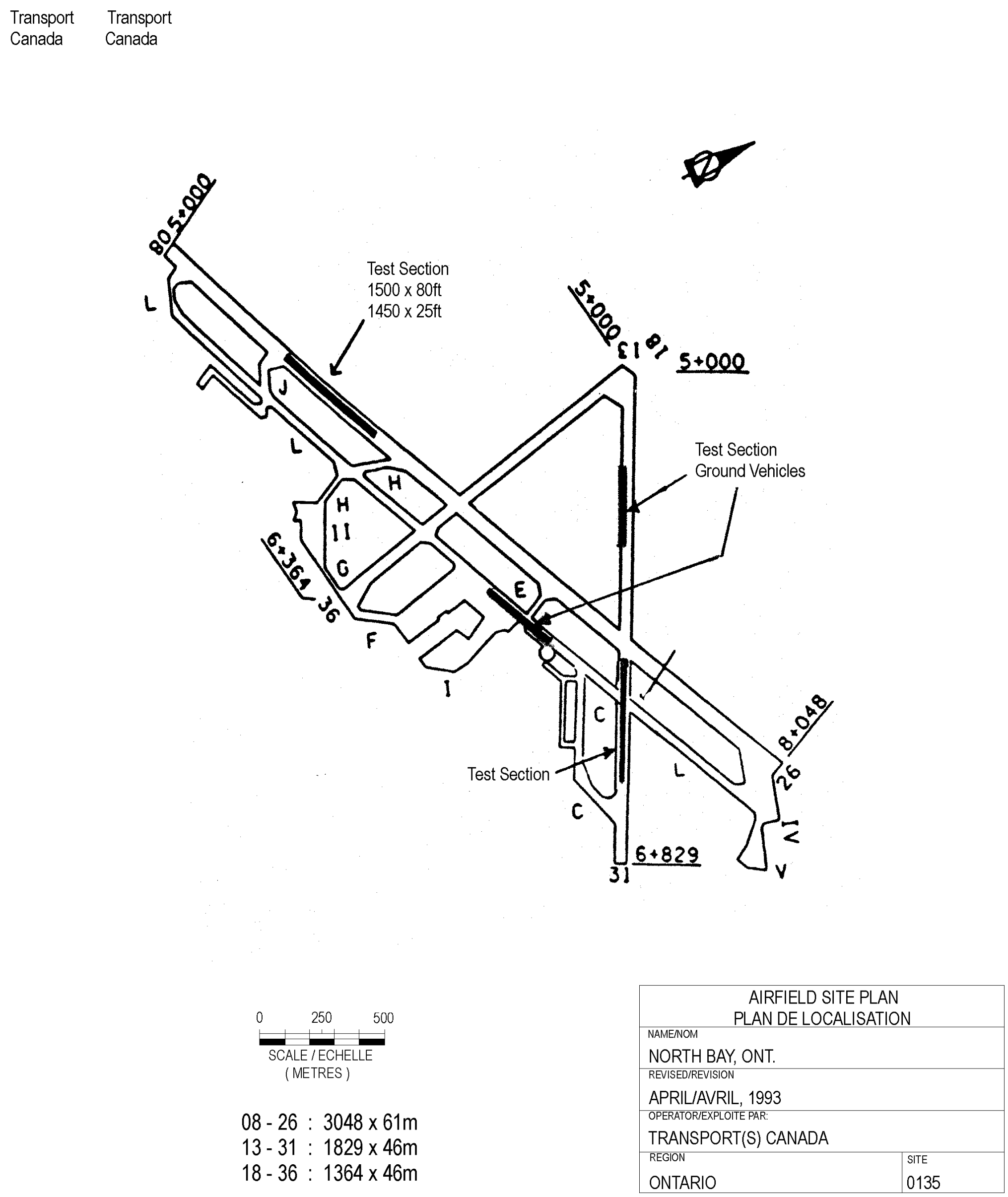


Figure 2.1: Layout Map for North Bay Jack Garland Airport

3. TEST EQUIPMENT AND TECHNIQUES

3.1 Test Vehicles

3.1.1 General Description

The following five vehicles were tested (see summary in Table 3.1):

a) the “Blazer” (Figure 3.1) - it should be noted that this is the same vehicle that has been used for most of the decelerometer friction measurements made to date as part of the JWRFMP.
b) the “half ton” pickup truck (Figure 3.2)
c) the “three-quarter ton” pickup truck (Figure 3.3)
d) the “one ton” pickup truck (Figure 3.4)
e) the “minivan” (Figure 3.5)

3.1.2 Tires on the Vehicles

Information was recorded for each tire of each vehicle. See Table 3.1 for a summary of the measured tire parameters.

3.1.3 Vehicle Weights and Weight Distribution

The weight of each vehicle was measured by placing each vehicle on four load cells (i.e., one under each tire) using a hydraulic lift at the garage at North Bay Jack Garland Airport. Each load cell had a capacity of 13.3 kN (3000 lb.). The total vehicle weights varied from 18.0 to 27.0 kN (4044 to 6069 lb., respectively).

Most of the tests were performed using the vehicles as they were supplied. These tests are referred to in this report as the “as is” weight distribution (Table 3.1).

To investigate the effect of weight distribution, tests were done with the half ton pickup truck at a 50:50 (front:rear) weight distribution. This variation in weight distribution was achieved by adding sandbags to the half ton pickup truck. It should be noted that this procedure increased the total weight of the half ton pickup truck as well (i.e., 25.7 kN vs 21.8 kN for the 50:50 and the “as-is” weight distributions, respectively).

Figure 3.1: The "Blazer"

Figure 3.2: The "Half Ton"

Figure 3.3: The "Three-Quarter Ton"

Figure 3.4: The "One Ton"

Figure 3.5: The "Minivan"

Figure 3.6: All Five Test Vehicles

Table 3.1: Vehicle Summary

Vehicle Designation	Blazer	Half ton	Half ton	3/4 ton	One ton	Minivan
Weight Dist'n Designation	As is	As is	50:50	As is	As is	As is
Vehicle Manufacturer	Chevrolet	Chevrolet	Chevrolet	Chevrolet	Ford	Dodge
Vehicle Model	Blazer	Silverado 1500	Silverado 1500	Silverado 2500	F350 Pickup	Grand Caravan
Year of Manufacture	1991	2002	2002	2000	1997	2001
Wheelbase (m)	2.72	3.9	3.9	4.04	3.38	3.07
Odometer Reading (km)	112647	6833	6833	83382	10577	8427
Vehicle Weight (kN)	18.0	21.8	25.7	27.0	25.2	18.8
Vehicle Weight (lb.)	4044	4900	5787	6069	5670	4231
Weight per Tire (kN)						
Front Passenger	4.3	5.6	5.6	7.7	6.6	5.6
Front Driver	5.3	7.3	7.3	8.3	6.5	5.0
Rear Passenger	4.0	4.5	6.5	5.7	6.2	3.9
Rear Driver	4.5	4.4	6.3	5.3	5.8	4.4
Weight Dist'n (%front:%rear)	53:47	59:41	50:50	59:41	52:48	56:44
ABS Type	4 wheel	4 wheel	4 wheel	4 wheel	no ABS	4 wheel
Tire size	P235/75 R15	LT 245/75R 16C	LT 245/75R 16C	LT 245/75 R16	LT 215/85 R16	215/65 R15
Tire Manufacturer	Michelin	Firestone	Firestone	Toyo	Firestone	Michelin
Type of Tire	LTX M/S	All season	All season	All weather radials	All weather	All season radials
Tire pressure (kPa)	240	340	340	340	448	248
Tire Footprint Area (cm^2)						
Front Passenger	164.2	121.3	146.5	139.3	156.2	141.5
Front Driver	137.5	142.2	140.0	131.8	142.6	155.9
Rear Passenger	135.4	102.6	144.4	162.7	172.4	108.0
Rear Driver	104.4	105.5	175.7	138.6	176.0	102.6
Tread Depth (mm)	9	9	9	9 to 13	8	9

3.1.4 Tire Contact Pressures

The tire footprint area was measured by raising each of the vehicles in the garage at North Bay Jack Garland Airport using a hydraulic lift. The wheels were then lowered onto a piece of paper and immediately raised by the hydraulic jacks again. This process created a tire footprint on the paper.

The footprint area of each tire for each vehicle was measured by placing a gridded acetate sheet over the tire footprint. The footprint area was measured from this overlay.

The measured tire footprint areas are summarized in Table 3.1.

The tire contact pressures were determined from the measured weights and contact areas. The overall contact pressure (defined as the total vehicle weight/the total tire contact area) varied from 332 to 462 kPa (Table 3.2).

Table 3.2: Tire Contact Pressures

Vehicle Designation	Blazer	Half ton	Half ton	3/4 ton	One ton	Minivan
Weight Dist'n Designation	As is	As is	50:50	As is	As is	As is
Contact Pressures Per Tire (kPa)						
Front Passenger	259.0	459.1	380.2	555.5	425.3	393.7
Front Driver	386.9	514.5	522.4	628.7	458.7	320.1
Rear Passenger	292.9	443.1	451.7	347.5	359.0	360.1
Rear Driver	426.5	413.8	360.8	384.0	332.1	426.2
Overall Contact Pressure[1] (kPa)	332.2	462.2	424.4	471.7	389.6	370.5

1. Overall Contact Pressure = $\frac{\text{total vehicle weight}}{\text{total tire contact area}}$

3.2 Decelerometers Used

Four different decelerometers were used in the study, as summarized in Table 3.3.

The decelerometers were tested in two groups, as listed below. For both cases, the decelerometers were mounted on a metal plate that was moved from vehicle to vehicle.

Figure 3.7: Decelerometers Installed in Vehicle

This helped to ensure that the decelerometers were all exposed to the same conditions.

Group 1 - ERD Mk II and ERD Mk III
Group 2 - ERD Mk II, ERD Mk III, Tapley, and Bowmonk

More tests were conducted with the Group 1 decelerometers than with the Group 2 ones. This resulted from the fact that a vehicle using the Bowmonk decelerometer must come to a complete stop before a friction reading is calculated. This slowed data collection in the field program when using this decelerometer. The Tapley, ERD MkII, and ERD MkIII decelerometers were all capable of measuring a friction coefficient without the vehicle having to come to a complete stop.

Table 3.3: Decelerometer Summary

Decelerometer Designation in Report	ERD Mk III	ERD Mk II	Bowmonk	Tapley
Manufacturer/Supplier	TES Limited	TES Limited	Bowmonk Limited	Tapley Instrumentation Limited
Model Number	Mk III - 21480001	Mk II	AIP2	BR 500
Serial Number	24	n/a	AF11022	97001

3.3 Test Surfaces

3.3.1 Target Surface Conditions

Target test surfaces were established to:

(a) cover a reasonable portion of the range of expected ice and packed snow surface conditions; and

(b) span a relatively wide range of friction factors, while still limiting the tests to ice and packed snow surfaces.

Figures 3.8 to 3.12 below illustrate sample test conditions.

Figure 3.8: Test Surface January 15, 2002: One Ton Truck on Compacted Snow

Figure 3.9: Test Surface January 16, 2002: Sanded Bare Ice and Sanded Compacted Snow

Figure 3.10: Test Surface January 16, 2002: Sanded Bare Ice on the Right, Sanded Compacted Snow on the Left

Figure 3.11: Test Surface January 17, 2002: Bare Ice, on the Left Sanded Compacted Snow

Figure 3.12: Test Surface January 15, 2002: Blazer Test on Bare Ice

3.3.2 Surface Preparation Methods

Tests were performed on bare ice, sanded ice, packed snow, and sanded packed snow.

Bare ice was created by having fire trucks spray the runway surface with water to build up a sufficiently deep ice surface to allow continuous vehicle testing on ice.

Packed snow was created by having North Bay Jack Garland Airport's snowplows drive over loose, natural snow that was already present on the runway.

Sanded ice and sanded packed snow were created by having the airport's sanders apply sand to the bare ice and packed snow surfaces. Friction readings were taken during these operations to assess the friction increase that was achieved by sanding. Sanding operations were stopped when a reasonable friction increase had been achieved.

3.3.3 Test Temperatures

The air temperature was recorded for most tests. The surface temperature was also recorded for a number of tests to allow the general temperature time history to be established. Table 3.4 provides a sample of the available temperature data. The full data set is included in Appendices A to E.

Table 3.4: Sample Air And Surface Temperatures

Date	Time	Air Temp. (°C)	Surface Temp. (°C)	Date	Time	Air Temp. (°C)	Surface Temp. (°C)
15-Jan/02	9:27	-6.2	-5.9	16-Jan/02	9:20	-17	-9
15-Jan/02	13:20	-5.8	-2	16-Jan/02	9:50	-17	-11
15-Jan/02	14:12	-5.1	-4.8	16-Jan/02	10:45	-14	-12.5
15-Jan/02	15:10	-8	-1	16-Jan/02	15:43	-5.2	-4.5
15-Jan/02	18:00	-6	-5.0				
17-Jan/02	13:38	-4.9	n/a	18-Jan/02	9:59	-9	n/a
17-Jan/02	13:53	-4.9	-4.8	18-Jan/02	11:01	-9	n/a
17-Jan/02	15:36	-5.2	-4.5				

3.4 Friction Coefficient Measurement Technique

3.4.1 General Approach

The tests were conducted by mounting the decelerometers in each of the test vehicles, accelerating the vehicles to the target speed, and then applying the brakes to cause the vehicle to go into a locked-wheel skid. This follows the approach normally used for friction measurements with a decelerometer in a vehicle.

It is widely recognized that this type of test affects the surface. Subsequent measurements on the same surface are likely to "see" a different test surface condition than the initial one. As a result, different results are to be expected for consecutive passes are made on the same test surface.

This potential problem was recognized at the test planning stage. It was resolved by:

(a) preparing wide test sections on runway 13-31 that extended beyond the edges of the runway well onto the shoulders, and that were divided into five test lanes (for the ice and packed snow surfaces). A separate test lane was used by each of the five test vehicles.

(b) operating the test vehicles such that skids were not made on previously-skidded surfaces.

3.4.2 Vehicle Operator

It is known that different operators could produce different friction results, depending on the way that they apply the brakes. Consequently, all data were collected by the same vehicle operator.

The use of a single operator eliminated this variable from the test results or, at least, it greatly minimized its effect. The vehicle operator used for these tests was the same individual who has collected most of the decelerometer data obtained to date during the JWRFMP. This will allow more reliable comparisons between the data collected in this project and the JWRFMP.

3.4.3 Vehicle Speed

Vehicle speed varied depending on whether all four decelerometers were used, or only the ERD Mk III and ERD Mk II decelerometers were used.

Friction tests done using only the ERD Mk II and Mk III decelerometers were conducted at a speed of 40 km/h.

Friction tests done with all four decelerometers were performed at 30 km/h. This lower speed increased the number of usable friction data points for the Bowmonk decelerometer, as it reduced the tendency for the test vehicles to lose directional control, with the result that the Bowmonk decelerometer could not calculate the friction coefficient. The selection of a lower test speed also facilitated data collection with the Bowmonk as it reduced the time required for data collection (as the vehicle must come to a stop to obtain a reading with this instrument).

Both of the test speeds used (i.e., 30 and 40 km/h) were lower than Transport Canada's current standard of 50 km/h. These lower speeds were used because they increased the size of the data set that could be obtained on undisturbed surfaces. This was achieved as the lower speeds: (a) reduced the number of "cancelled" readings obtained from the decelerometers, and (b) reduced the size of the test area required for the vehicles to accelerate to the target speed. As testing done during the JWRFMP has shown that the friction coefficient on ice and packed snow is not affected significantly by speed [3], it was decided that the project objectives were better served by maximizing the size of the data set on undisturbed surfaces.

3.4.4 Sampling Frequency

Typically, about 15 to 20 individual readings were obtained for each test case. This data quantity was selected as previous analyses [3] have shown that the confidence in the friction coefficients recorded with the ERD on winter surfaces did not increase greatly with more than about 15 to 20 individual readings. Additional data were not collected as this maximized the number of measurements that could be made on undisturbed surfaces.

Each individual value is provided in this report in the appendices. The individual readings for a given test case were averaged, and the averages were used for subsequent trend investigations and analyses. This was done to obtain a representative value for the average friction coefficient in each test section.

3.5 Test Surface Variability

Measurements were made to evaluate the test surface variability with respect to two issues:

(1) Changes over the time period when the test vehicles were used for a given test case. This was investigated by having the Blazer, and in one case, the Half ton as well, make friction measurements at the start and end of a test series.

(2) Variations over the test surface itself. This was investigated by making friction measurements with the Blazer on each of the five general test lanes in the test section.

3.5.1 Friction Coefficient Variations over the Duration of a Test Series

For the most part, the friction coefficient variations were less than about 10% over the time period when the tests were conducted (Table 3.5), which shows that the test surface did not change significantly with time for most cases. Thus, the results of subsequent analyses will not be affected significantly by which test results were used (i.e., the "before" or the "after" ones). For these tests, the friction values used in subsequent analyses were the ones that minimized the overall time duration for the test period.

The results for sanded packed snow on January 17, 2002, are the only significant exception to this statement, as the variation between the "before" and "after" values is about 20 to 25% (Table 3.5). This variation was accounted for in the analyses by using the average friction coefficients for the Blazer for both test times (i.e., 13:46 and 16:28).

3.5.2 Friction Coefficient Variations over the Area of the Test Section

The measured data are summarized in Table 3.6.

Most of the results fall within a +/- 10% range (Figures 3.7 and 3.8).

Table 3.5: Test Surface Variability

Date	Vehicle	Surface	Time of Initial Measurement	Friction for ERD Mk III	Friction for ERD Mk II	Time of Final Measurement	Friction for ERD Mk III	Friction for ERD Mk II
15-Jan/02	Blazer	Bare Ice	9:27	0.14	0.14	14:20	0.15	n/a
15-Jan/02	Blazer	Packed Snow	14:36	0.23	n/a	18:41	0.24	0.25
16-Jan/02	Blazer	Sanded Ice	13:15	0.25	0.24	16:25	0.22	0.23
16-Jan/02	Half ton	Sanded Ice	14:46	0.25	0.26	17:25	0.22	0.22
16-Jan/02	Blazer	Sanded Packed Snow	13:30	0.32	0.3	16:25	0.27	0.28
16-Jan/02	Half ton	Sanded Packed Snow	14:57	0.32	0.33	17:40	0.3	0.31
17-Jan/02	Blazer, ABS off	Bare Ice	13:38	0.1	0.11	16:24	0.09	0.1
17-Jan/02	Blazer, ABS on	Bare Ice	13:53	0.09	0.1	16:26	0.08	0.08
17-Jan/02	Blazer, ABS off	Sanded Packed Snow	13:46	0.28	0.29	16:28	0.36	0.36
17-Jan/02	Blazer, ABS on	Sanded Packed Snow	13:58	0.27	0.27	16:38	0.33	0.33

Table 3.6: Variability over the Area of the Test Section

Date	Vehicle	Surface	Time of Init. Measurement	Lane No	Friction for ERD Mk III	Friction for ERD Mk II
15-Jan-02	Blazer, ABS Off	Bare Ice	14:20	1	0.15	n/a
15-Jan-02	Blazer, ABS Off	Bare Ice	14:20	2	0.11	n/a
15-Jan-02	Blazer, ABS Off	Bare Ice	14:20	3	0.15	n/a
15-Jan-02	Blazer, ABS Off	Bare Ice	14:20	4	0.15	n/a
15-Jan-02	Blazer, ABS Off	Bare Ice	14:20	5	0.15	n/a
16-Jan-02	Blazer, ABS Off	Sanded Bare Ice	16:25	1	0.22	0.23
16-Jan-02	Blazer, ABS Off	Sanded Bare Ice	16:25	2	0.22	0.23
16-Jan-02	Blazer, ABS Off	Sanded Bare Ice	16:25	3	0.2	0.21
16-Jan-02	Blazer, ABS Off	Sanded Bare Ice	16:25	4	0.25	0.26
16-Jan-02	Blazer, ABS Off	Sanded Bare Ice	16:25	5	0.27	0.28
16-Jan-02	Blazer, ABS On	Sanded Bare Ice	16:34	1	0.26	0.27
16-Jan-02	Blazer, ABS On	Sanded Bare Ice	16:34	2	0.22	0.22
16-Jan-02	Blazer, ABS On	Sanded Bare Ice	16:34	3	0.23	0.25
16-Jan-02	Blazer, ABS On	Sanded Bare Ice	16:34	4	0.24	0.25
16-Jan-02	Blazer, ABS On	Sanded Bare Ice	16:34	5	0.27	0.28
16-Jan-02	Blazer, ABS Off	Sanded Packed Snow	16:25	1	0.27	0.28
16-Jan-02	Blazer, ABS Off	Sanded Packed Snow	16:25	2	0.27	0.28
16-Jan-02	Blazer, ABS Off	Sanded Packed Snow	16:25	3	0.31	0.32
16-Jan-02	Blazer, ABS Off	Sanded Packed Snow	16:25	4	0.31	0.32
16-Jan-02	Blazer, ABS Off	Sanded Packed Snow	16:25	5	0.33	0.34
16-Jan-02	Blazer, ABS On	Sanded Packed Snow	17:06	1	0.31	0.3
16-Jan-02	Blazer, ABS On	Sanded Packed Snow	17:06	2	0.29	0.28
16-Jan-02	Blazer, ABS On	Sanded Packed Snow	17:06	3	0.32	0.32
16-Jan-02	Blazer, ABS On	Sanded Packed Snow	17:06	4	0.3	0.31
16-Jan-02	Blazer, ABS On	Sanded Packed Snow	17:06	5	0.28	0.29
17-Jan-02	Blazer, ABS on	Sanded Packed Snow	16:38	1	0.33	0.33
17-Jan-02	Blazer, ABS on	Sanded Packed Snow	16:38	2	0.34	0.33
17-Jan-02	Blazer, ABS on	Sanded Packed Snow	16:38	3	0.33	0.33
17-Jan-02	Blazer, ABS on	Sanded Packed Snow	16:38	4	0.34	0.34
17-Jan-02	Blazer, ABS on	Sanded Packed Snow	16:38	5	0.35	0.35

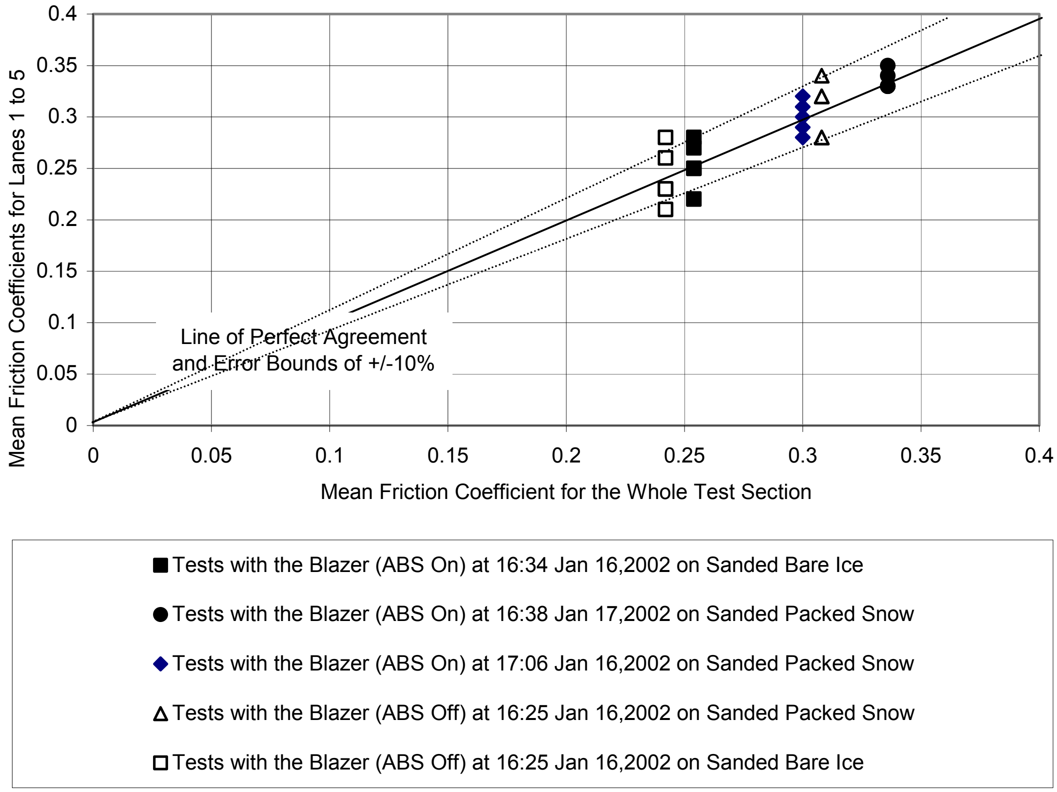


Figure 3.13: Test Section Variability: Measured Using the ERD MK III

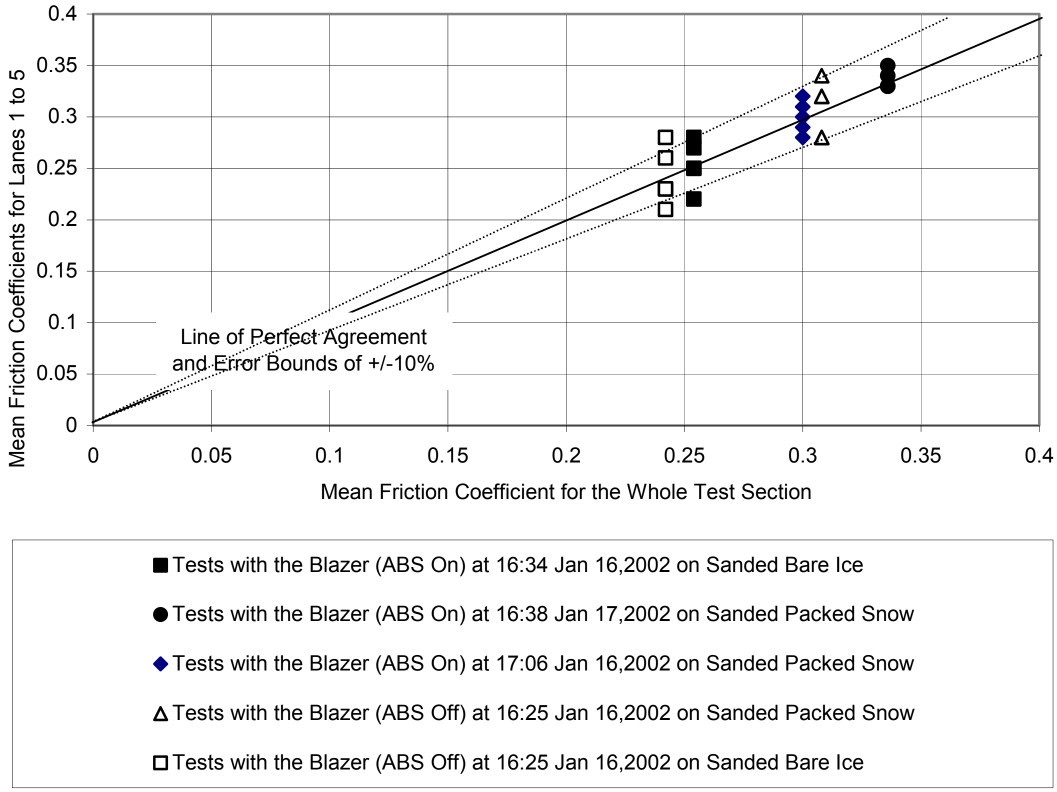


Figure 3.14: Test Section Variability: Measured Using the ERD MK II

4. FIELD TEST PROGRAM

4.1 Test Matrix

All tests were conducted on runway 13-31 at North Bay Jack Garland Airport (Figure 2.1). The tests conducted on each test day are summarized in Tables 4.1 to 4.4. A detailed description of the test conditions is provided in Appendices A to E, which also contain the test data obtained for the five vehicles tested. The following parameters were varied:

(a) Vehicle type – five vehicles were tested, as summarized in section 3.1 and listed below:
   i. a sport utility vehicle (SUV)
   ii. a half ton pickup truck
   iii. a three-quarter ton pickup truck
   iv. a one ton truck
   v. a minivan

(b) Runway surface condition – tests were done on the surfaces listed below. These surfaces are described in section 3:

   i. bare ice
   ii. sanded ice
   iii. packed snow
   iv. sanded packed snow

   Although testing on surfaces with loose contaminants was not one of the primary objectives of the test program, a few tests were also done on packed snow with 3 to 5 cm (1-2 in.) of loose snow on top of it, as an opportunity arose to acquire data on this surface. These tests are reported as well.

(c) Decelerometer – four types were tested, as listed below and summarized in section 3:

   i. Mk III Electronic Recording Decelerometer (ERD)
   ii. Mk II ERD
   iii. Electronic Tapley model BR 500 decelerometer
   iv. Electronic Bowmonk model AMF2 decelerometer

Data were acquired with respect to the key project objectives as follows:

(a) Effect of decelerometer type – the Blazer and the Half ton were used to compare all four decelerometer types. Many more tests were done with just the ERD Mk III and ERD Mk II as this combination of decelerometers was used to obtain data for meeting the other project objectives.

(b) Effect of vehicle type – data were acquired with all five vehicles for the ERD Mk III and the ERD Mk II. Tests that included the Tapley and the Bowmonk were only done with the Blazer and the Half ton.

(c) Effect of weight distribution – tests were only done with the Half ton. At the test planning stage, it had been decided to vary this parameter for the Blazer as well. However, because the "as-is" weight distribution of the Blazer was found to be close to 50:50 (Table 3.1), it was decided onsite not to alter the weight distribution for the Blazer for further tests.

(d) Effect of the vehicle's ABS being on or off – most of the test data were collected with the Blazer and the Half ton. A few data points were collected with the Minivan and the Three-quarter ton as well.

Table 4.1: Test Matrix: Jan. 15, 2002

Test Surface	Vehicle	Weight Dist'n	ABS	Test Time	Test Time	Test Time	Test Time
Bare Ice	Blazer	As is	off	9:27	14:20		18:24
Bare Ice	1/2 ton	As is	off	10:20			17:20
Bare Ice	3/4 ton	As is	off	11:00			
Bare Ice	1 ton	As is	off	13:20			
Bare Ice	Minivan	As-Is	off	11:34			
Bare Ice	Blazer	As is	on			15:10	
Bare Ice	1/2 ton	As is	on				17:43
Bare Ice	1/2 ton	50:50	off			16:35	
Packed Snow	Blazer	As is	off			14:36	18:41
Packed Snow	1/2 ton	As is	off			17:03	
Packed Snow	3/4 ton in 4WD	As is	off			16:10	
Packed Snow	1 ton	As is	off			13:40	
Packed Snow	Minivan	As is	off			15:45	
Packed Snow with 1" loose snow on top	1 ton	As is	off		13:40		
Packed Snow	Blazer	As is	on		14:50		
Packed Snow	1/2 ton	As is	on				18:00
Packed Snow	1/2 ton	50:50	off			16:49	

Notes:

1. The data are grouped in the table by test time. They were analyzed in these groupings.
2. The following tests were done to establish the degree of variability of the test surfaces with time and location:
    a. Bare Ice: Blazer @ 14:20
    b. Packed Snow: Blazer @ 18:41

Table 4.2: Test Matrix: Jan. 16, 2002

Test Surface	Vehicle	Weight Dist'n	ABS	Test Time	Test Time	Test Time	Test Time
Bare Ice	Blazer	As is	off	9:20			
Bare Ice	1/2 ton	As is	off	10:30			
Sanded Ice	Blazer	As is	off		13:15	16:25	
Sanded Ice	1/2 ton	As is	off		14:46	17:25	
Sanded Ice	3/4 ton	As is	off		13:47		
Sanded Ice	1 ton	As is	off		15:44		
Sanded Ice	Minivan	As is	off		14:18		
Sanded Ice	Blazer	As is	on				16:34
Sanded Ice	1/2 ton	As is	on				17:53
Sanded Ice	1/2 ton	50:50	off		15:12		
Packed Snow with 3-5 cm of loose snow on top of it	Blazer	As is	off	9:50			
Packed Snow with 3-5 cm of loose snow on top of it	1/2 ton	As is	off	10:45			
Sanded Packed Snow	Blazer	As is	off		13:30	16:25	
Sanded Packed Snow	1/2 ton	As is	off		14:57	17:40	
Sanded Packed Snow	3/4 ton	As is	off		14:00		
Sanded Packed Snow	1 ton	As is	off		15:54		
Sanded Packed Snow	Minivan	As is	off		14:30		
Sanded Packed Snow	Blazer	As is	on				17:06
Sanded Packed Snow	1/2 ton	As is	on		14:23		18:04
Sanded Packed Snow	1/2 ton	50:50	off			15:27	

Notes:

1. The data are grouped in the table by test time. They were analyzed in these groupings.
2. The following tests were done to establish the degree of variability of the test surfaces with time and location:
    a. Sanded Ice: Blazer @ 16:25; Half ton @ 17:25
    b. Sanded Packed Snow: Blazer @ 16:25; Half ton @ 17:40

Table 4.3: Test Matrix: Jan. 17, 2002

Test Surface	Vehicle	Weight Dist'n	ABS	Test Time	Test Time	Test Time	Test Time
Bare Ice	Blazer	As is	off		13:38	16:24	
Bare Ice	1/2 ton	As is	off		14:31		
Bare Ice	3/4 ton	As is	off		15:27		
Bare Ice	1 ton	As is	off		16:03		
Bare Ice	Minivan	As is	off		15:07		
Bare Ice	Blazer	As is	on		13:53	16:26	
Bare Ice	1/2 ton	As is	on		14:12		
Bare Ice	3/4 ton	As is	on		15:43		
Bare Ice	Minivan	As is	on		14:53		
Sanded Packed Snow	Blazer	As is	off		13:46	16:28	
Sanded Packed Snow	1/2 ton	As is	off			14:38	
Sanded Packed Snow	3/4 ton	As is	off			15:36	
Sanded Packed Snow	1 ton	As is	off			16:10	
Sanded Packed Snow	Minivan	As is	off			15:14	
Sanded Packed Snow	Blazer	As is	on		13:58	16:38	
Sanded Packed Snow	1/2 ton	As is	on		14:23		
Sanded Packed Snow	3/4 ton	As is	on		15:50		
Sanded Packed Snow	Minivan	As is	on		14:59		

Notes:

1. The data are grouped in the table by test time. They were analyzed in these groupings.
2. The following tests were done to establish the degree of variability of the test surfaces with time and location:
    a. Bare Ice with ABS off: Blazer @ 16:24
    b. Bare Ice with ABS on: Blazer @ 16:26
    c. Sanded Packed Snow with ABS off: Blazer @ 16:28
    d. Sanded Packed Snow with ABS on: Blazer @ 16:38
3. For the tests done on sanded packed snow with the Blazer, the average of the friction coefficients measured at 13:46 and 16:28 was used for subsequent analyses. This was done because there was a significant variation between these two friction coefficients (section 3.5).

Table 4.4: Test Matrix: Jan. 18, 2002

Test Surface	Vehicle	Weight Dist'n	ABS	Test Time	Test Time	Test Time	Test Time
Bare Ice	Blazer	As is	off	9:25			
Bare Ice	1/2 ton	As is	off	10:15			
Bare Ice	Blazer	As is	on	9:05			
Bare Ice	1/2 ton	As is	on	10:45			
Sanded Packed Snow	Blazer	As is	off	9:45			
Sanded Packed Snow	1/2 ton	As is	off	10:32			
Sanded Packed Snow	Blazer	As is	on	9:59			
Sanded Packed Snow	1/2 ton	As is	on	11:01			

Notes:

1. The data are grouped in the table by test time. They were analyzed in these groupings.

4.2 Raw Test Data

Data summaries were prepared for each test. Table 4.5 shows a sample data summary while Appendices A to E provide a full set of data summaries. The test results are discussed in section 5.

Table 4.5: Sample Test Data Summary

Wednesday, January 16, 2002; Surface - Bare Ice/ABS off					
Test Data – Common Parameters		**Test Data – Individual Friction Coefficients Recorded By:**			
		MK III	**MK II**	**Bowmonk**	**Tapley**
		0.13	0.13	0.18	0.20
		0.12	0.12	0.17	0.19
Vehicle	Blazer, as is, ABS off	missed	0.12	0.15	0.17
Start Time	9:20	0.12	0.13	0.21	0.14
Stop Time	9:44	0.12	0.17	0.17	0.23
Air Temp. (°C)	-17	0.17	0.12	0.18	0.19
Surface Temp. (°C)	-9	0.12	0.16	0.15	0.23
Snow Density	n/a	0.15	missed	0.17	0.19
Test Surface	Bare Ice, with some snow patches	missed	0.14	0.15	0.19
Time to Perform Test Runs (min)	24	0.13	0.14	0.17	0.20
Description of Skids	Not a straight skid	0.14	0.12	0.16	0.22
Windspeed and Direction	Calm	0.12	0.13	0.19	0.13
Vehicle Direction and Speed	30 km/h in southeast direction	0.13	0.15	0.16	0.20
		0.14	0.12	0.16	0.16
		0.10	0.11	0.17	0.23
		0.11	0.15	0.18	0.19
		0.14	0.12		0.19
		0.11	0.11		0.19
		0.10	0.12		0.19
		0.12	0.13		0.22
		0.12			
Average Friction Coefficients		**0.13**	**0.13**	**0.17**	**0.19**

Note:
1. The Blazer went at 30 km/h so that spinning was reduced. This produced more accurate results as the vehicle tended to skid in a straight line. Despite this, the Bowmonk lost a number of readings.

5. ANALYSIS

The Blazer and the ERD Mk III were mainly used as the bases of comparison as the majority of the decelerometer data collected to date during the JWRFMP has been obtained with this vehicle and type of device.

5.1 Effect of Decelerometer Type

The effect of decelerometer type is shown in Figures 5.1 to 5.5. The following trends are evident:

(a) ERD Mk III vs. ERD Mk II – these decelerometers gave the same value to all practical purposes over the full range of surfaces tested and for each of the five vehicles tested.

(b) Bowmonk vs. Tapley vs. the two ERDs – data are only available for all four decelerometers for the Blazer and the Half ton. The data indicate that:

i. the Bowmonk and the Tapley both produced higher friction coefficients than did the two ERDs (i.e., the ERD Mk III and the ERD Mk II). The Tapley friction coefficients were about 0.05 higher, on average, than those from the two ERDs over the full range of test surfaces (Figures 5.1 and 5.2). The Bowmonk values were about 0.025 higher than the two values from the two ERDs over the full range of test surfaces (Figures 5.1 and 5.2). This variation is similar to that observed during previous comprative tests [1, 2].

   This finding is applicable to both the Blazer and the Half ton.

ii. The Tapley recorded higher values than did the Bowmonk. This finding applies to both of the vehicles used for this comparison (i.e., the Blazer and the Half ton) and to the full range of surfaces tested.

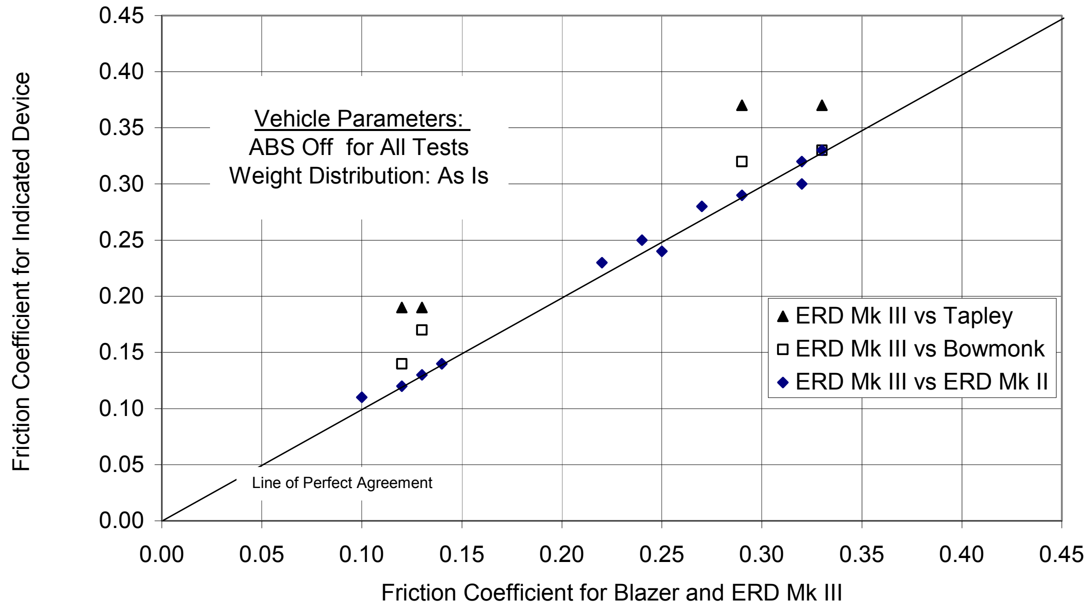


Figure 5.1: Decelerometer Comparison for the Blazer: All Test Surfaces Combined

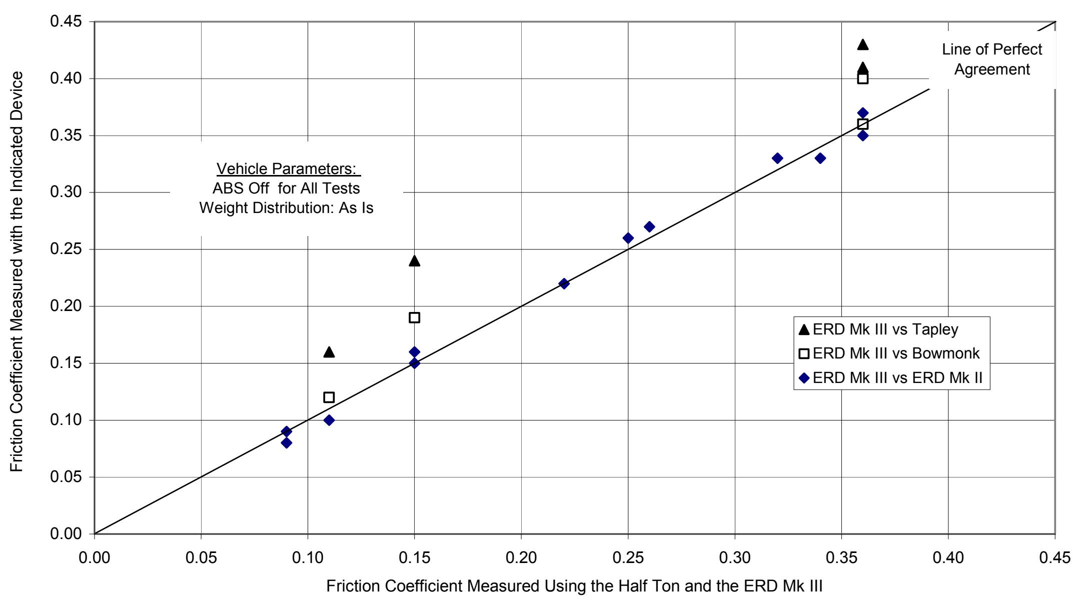


Figure 5.2: Decelerometer Comparison for the Half Ton: All Test Surfaces Combined

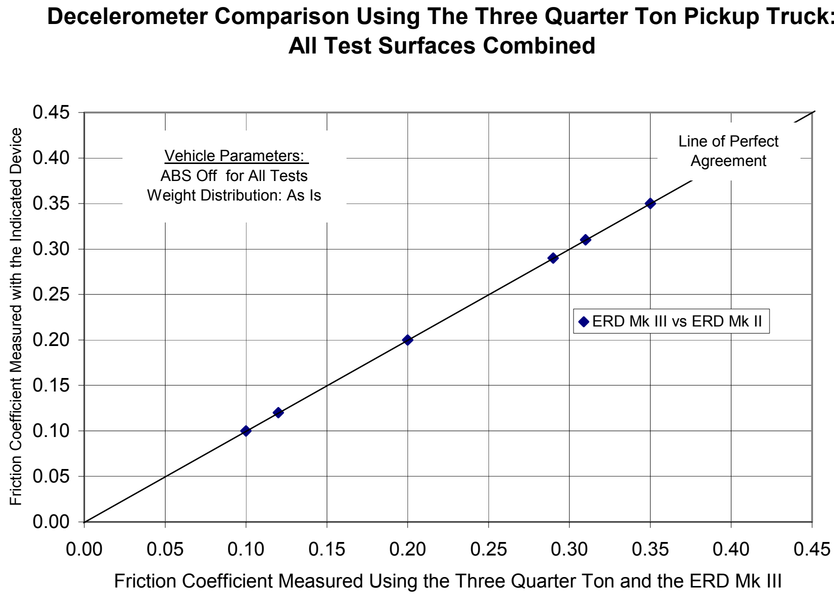


Figure 5.3: Decelerometer Comparison for the Three-Quarter Ton: All Test Surfaces

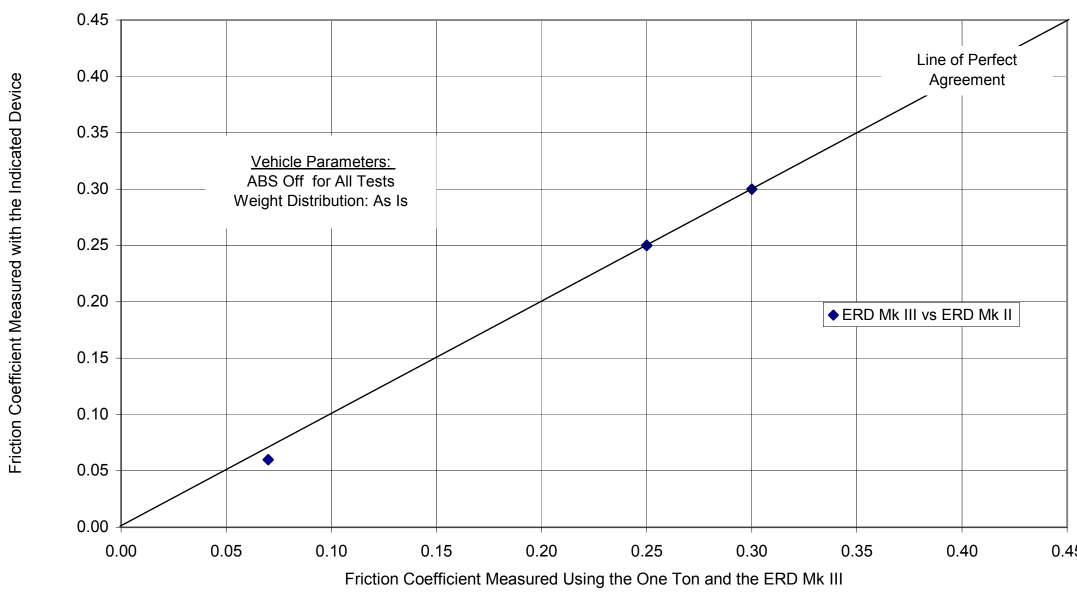


Figure 5.4: Decelerometer Comparison for the One Ton Truck: All Test Surfaces

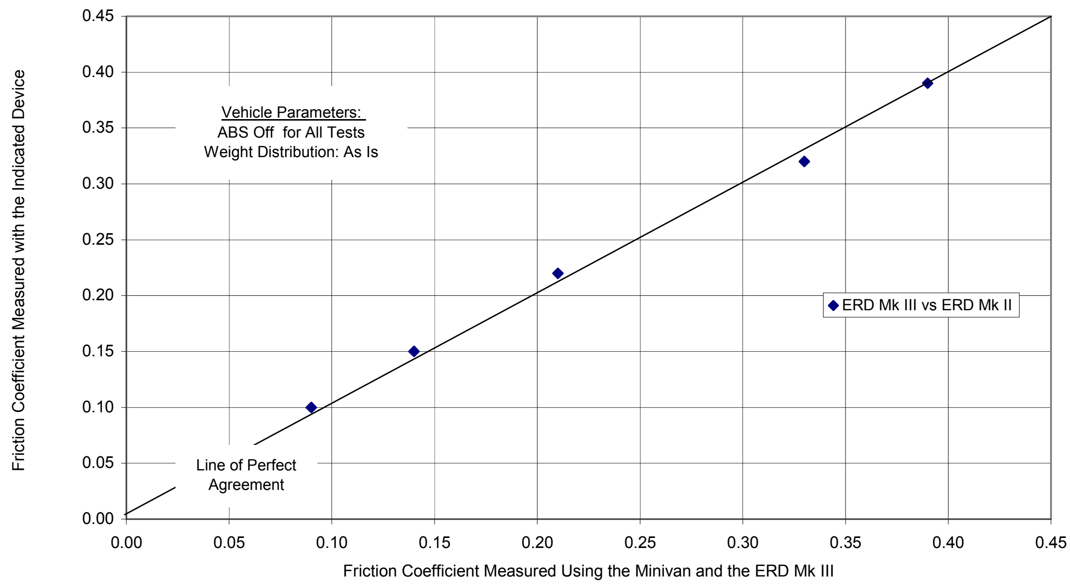


Figure 5.5: Decelerometer Comparison for the Minivan: All Test Surfaces Combined

5.2 Effect of Vehicle Type

The effect of vehicle type was found to depend on the vehicle and the friction level (Table 5.1, and Figures 5.6 to 5.9).

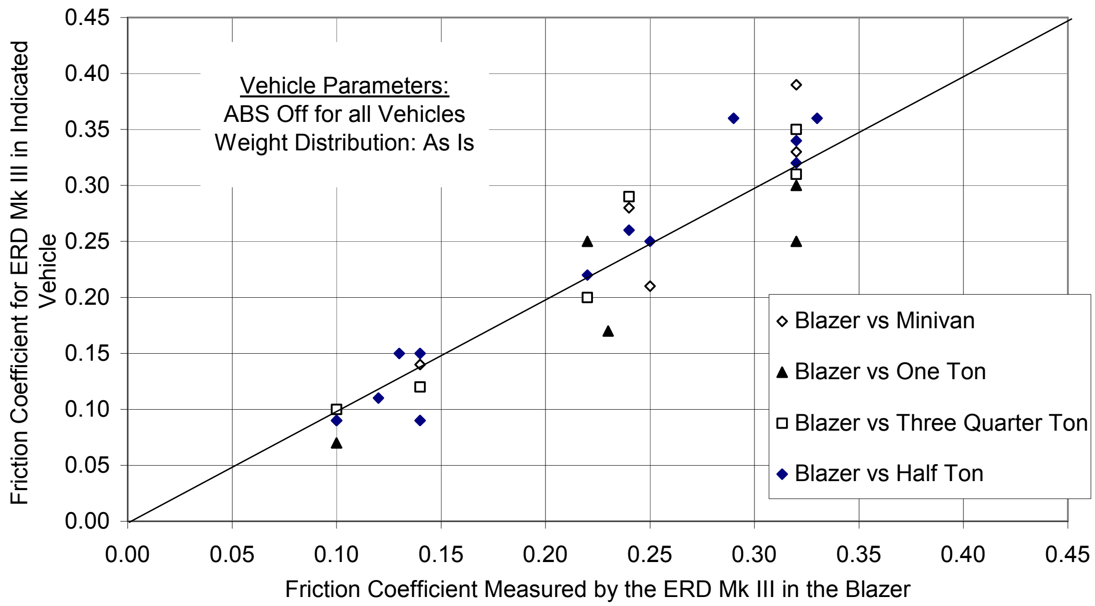


Figure 5.6: Effect of Vehicle for the ERD Mk III: All Test Surfaces Combined

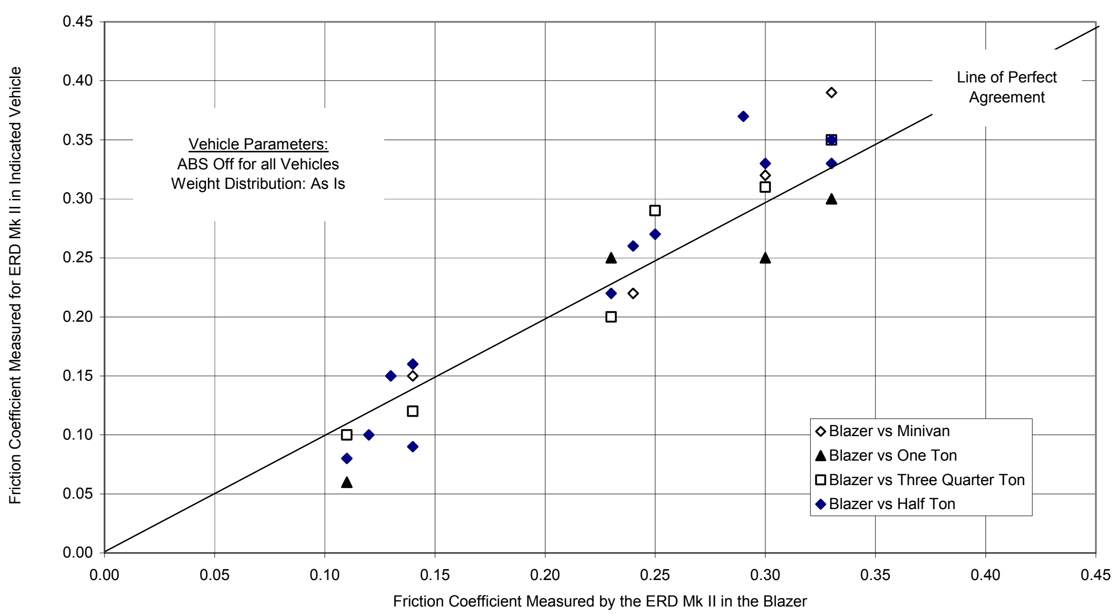


Figure 5.7: Effect of Vehicle for the ERD Mk II: All Test Surfaces Combined

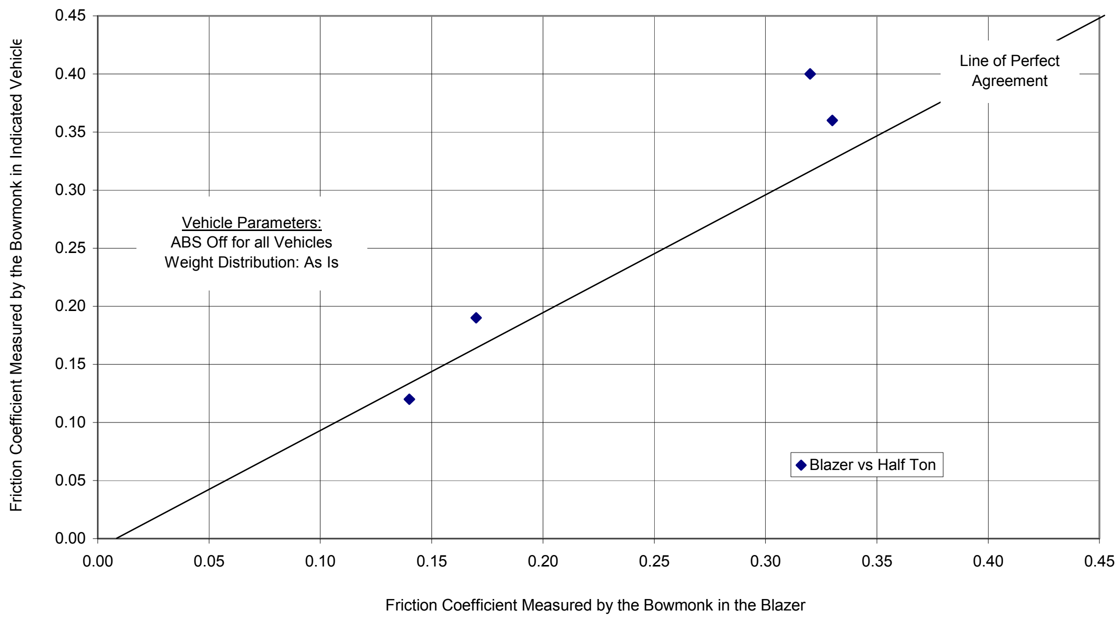


Figure 5.8: Effect of Vehicle for the Bowmonk: All Test Surfaces Combined

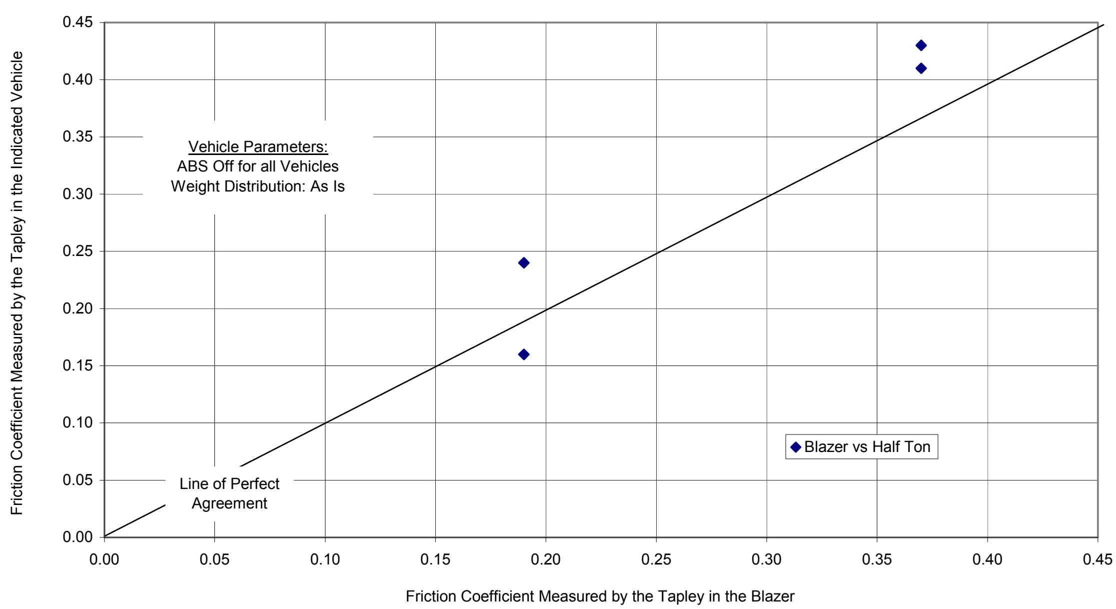


Figure 5.9: Effect of Vehicle for the Tapley: All Test Surfaces Combined

Table 5.1: Effect of Vehicle Type

	ERD Mk III	ERD Mk II	Tapley	Bowmonk
Blazer vs Half ton	Depends on friction level: a) lower values in Half ton for friction coefficients less than about 0.25. The maximum variation was about 0.05. b) higher values in Half ton at higher friction. The maximum variation was about 0.06.	Depends on friction level: (a) lower values in Half ton for friction coefficients less than about 0.25. The maximum variation was about 0.05. (b) higher values in Half ton at higher friction. The maximum variation was about 0.08.	Similar results at a friction factor of 0.15; higher friction for Half ton at 0.3-0.35 The maximum variation was about 0.08.	Similar results at a friction factor of 0.15; higher friction for Half ton at 0.3-0.35 The maximum variation was about 0.05.
Blazer vs 3/4 ton	Depends on friction level: (a) lower values in 3/4 ton for friction coefficients less than about 0.25. The maximum variation was about 0.02. (b) higher values in 3/4 ton at higher friction. The maximum variation was about 0.05.	Depends on friction level: (a) lower values in 3/4 ton for friction coefficients less than about 0.25. The maximum variation was about 0.02. (b) higher values in 3/4 ton at higher friction. The maximum variation was about 0.04.	Not tested	Not tested
Blazer vs 1 ton	Generally lower values in 1 ton. The maximum variation was about 0.07.	Generally lower values in 1 ton. The maximum variation was about 0.05.	Not tested	Not tested
Blazer vs Minivan	The correlation seems to depend on friction level but comparisons are difficult as few data are available at low friction. The data indicate: (a) similar values with little scatter for both vehicles for friction coefficients less than about 0.2. (b) similar values but more scatter at higher friction. The maximum variation was about 0.07.	The correlation seems to depend on friction level but comparisons are difficult as few data are available at low friction. The data indicate: (a) similar values with little scatter for both vehicles for friction coefficients less than about 0.2. (b) higher values in Minivan at higher friction. The maximum variation was about 0.06.	Not tested	Not tested

5.3 Effect of ABS On or Off

The effect of ABS was found to depend on the vehicle and the friction level (Table 5.2, and Figures 5.10 to 5.13).

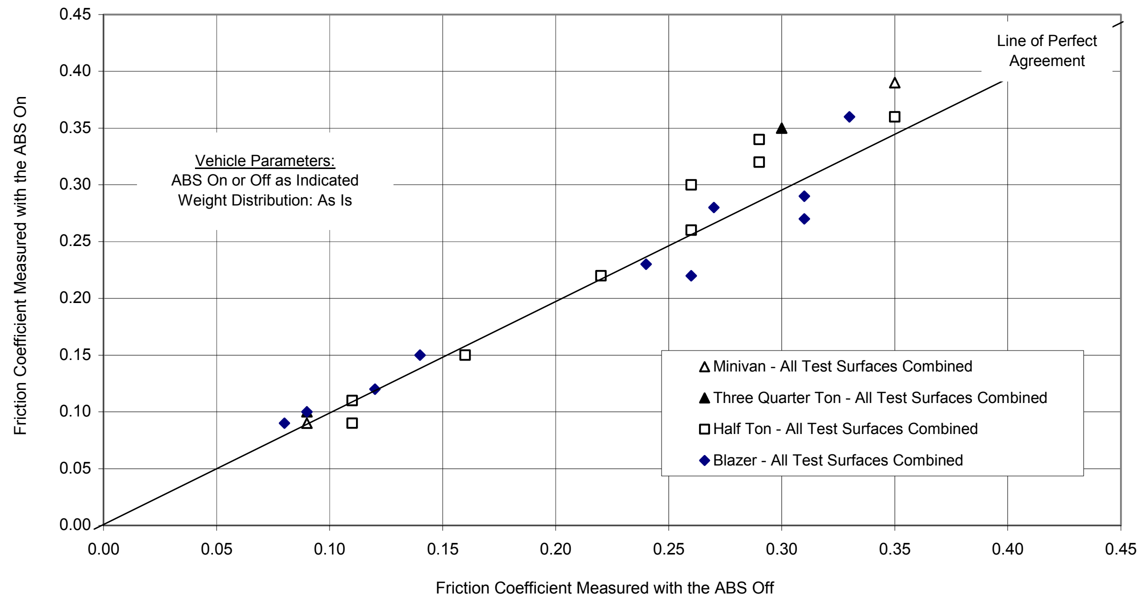


Figure 5.10: Effect of ABS On or Off for the ERD Mk III Decelerometer

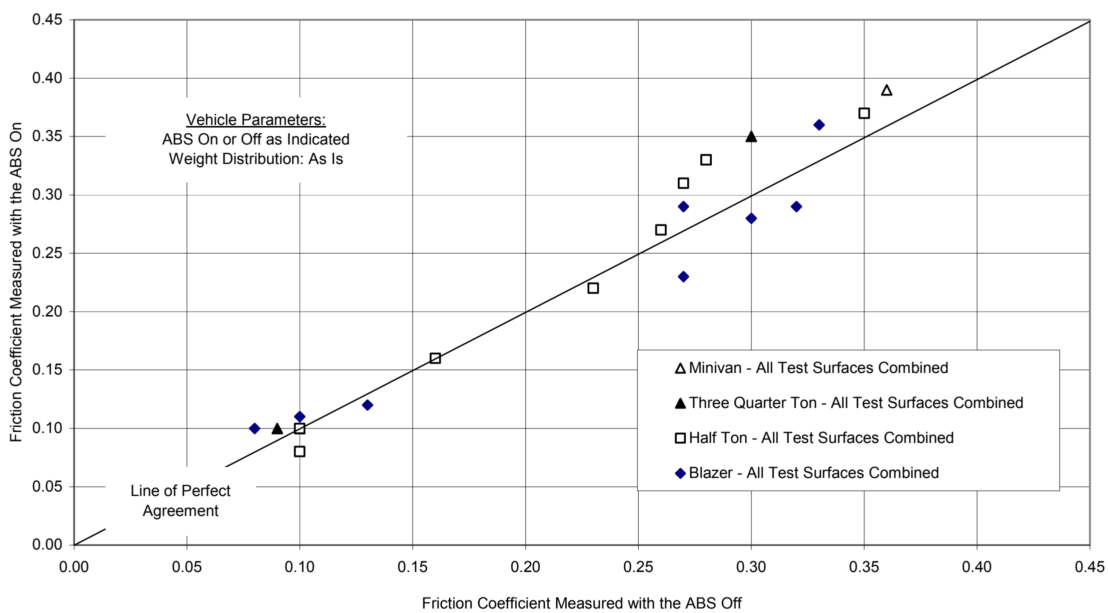


Figure 5.11: Effect of ABS On or Off for the ERD Mk II Decelerometer

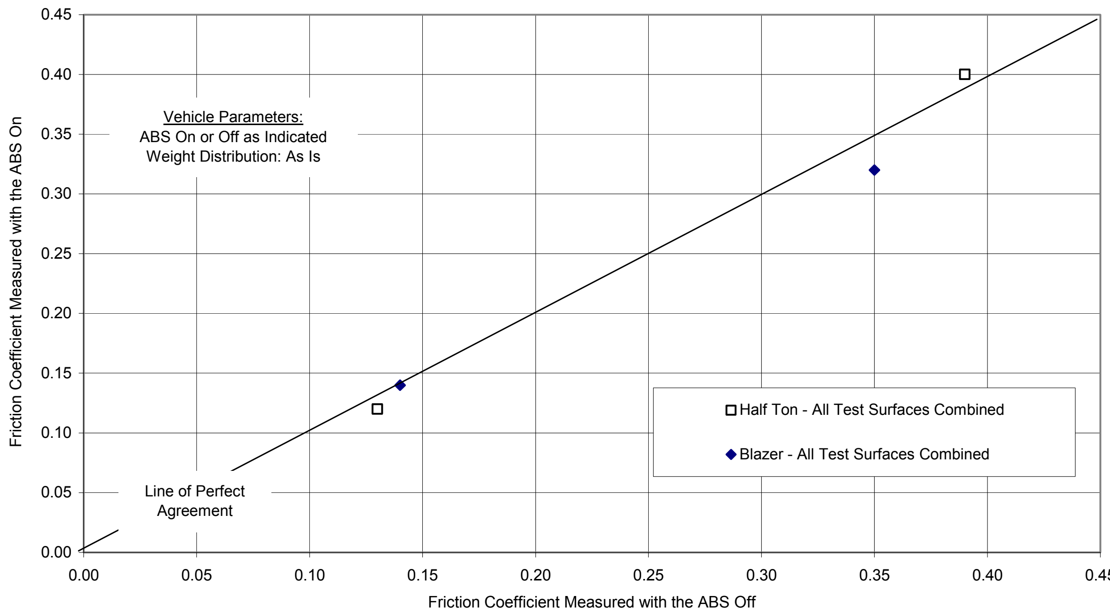


Figure 5.12: Effect of ABS On or Off for the Bowmonk Decelerometer

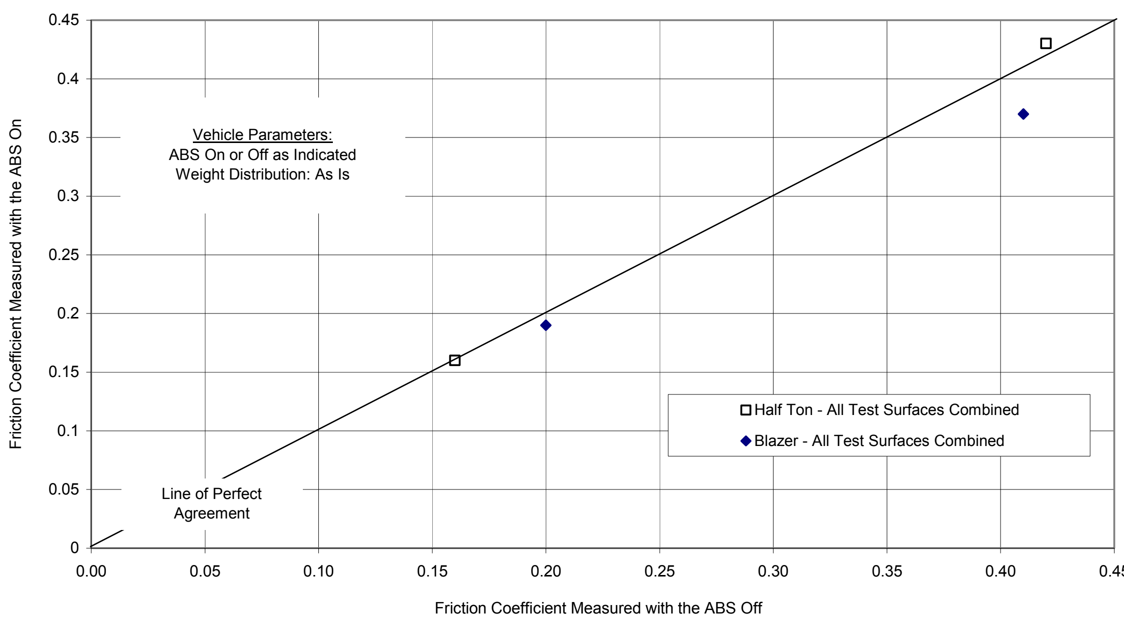


Figure 5.13: Effect of ABS On or Off for the Tapley Decelerometer

Table 5.2: Effect of ABS On or Off

	ERD Mk III	ERD Mk II	Tapley (note 1)	Bowmonk (note 1)
Blazer	Similar results for all friction levels	Similar results for all friction levels	Preliminary only - Similar results (note 1)	Preliminary only - Similar results (note 1)
Half ton	Depends on friction level: (a) similar values at friction coefficients less than about 0.25 (b) higher friction (by up to about 0.05) with ABS on for friction coefficients above about 0.25	Depends on friction level: (a) similar values at friction coefficients less than about 0.25 (b) higher friction (by up to about 0.05) with ABS on for friction coefficients above 0.25	Similar results	Similar results
3/4 ton	Only preliminary conclusions can be drawn as there are only 2 data points but it seems to depend on friction level: (a) similar results with ABS on and off at a friction factor of about 0.1 (b) higher friction with ABS on, by about 0.05, at a friction factor of about 0.30	Only preliminary conclusions can be drawn as there are only 2 data points but it seems to depend on friction level: (a) similar values at friction coefficients less than about 0.25 (b) higher friction with ABS on, by about 0.05, at a friction factor of about 0.30	Not tested	Not tested
Mini-van	Only preliminary conclusions can be drawn as there are only 2 data points but it seems to depend on friction level: (a) similar results with ABS on and off at a friction factor of about 0.1 (b) higher friction with ABS on, by about 0.04, at a friction factor of about 0.35	Only preliminary conclusions can be drawn as there are only 2 data points but it seems to depend on friction level: (a) similar results with ABS on and off at a friction factor of about 0.1 (b) higher friction with ABS on, by about 0.02, at a friction factor of about 0.35	Not tested	Not tested

Note:
1. Only a few tests were conducted with the Tapley and the Bowmonk (Figures 5.12 and 5.13); consequently, only preliminary conclusions can be drawn.

5.4 Effect of Weight Distribution

Data are available for all four test surfaces for the Half ton with the "as is" and the 50:50 (front:rear) weight distributions. The weight distribution for the "as is" case was 0.59:0.41 (front:rear).

The friction coefficient measured with the "as is" weight distribution was consistently about 0.02 higher than that for the "50:50" case (Figure 5.14). This finding applies to the full range of surfaces tested and to both decelerometer types tested (i.e., the ERD Mk III and the ERD Mk II).

Firm conclusions regarding the effect of the weight distribution cannot be drawn because the total weight of the vehicle changed as well between the two weight distribution cases (i.e., 25.7 kN vs. 21.8 kN for the 50:50 and the "as is" cases, respectively). This variation occurred because the weight distribution was altered by adding weight to the vehicle.

As previous tests [3] have shown that the friction factor on ice and packed snow reduces with increasing vertical load, the higher friction measured with the "as is" case may be due to the lower overall weight of the vehicle, rather the weight distribution difference. This is investigated in section 5.5.

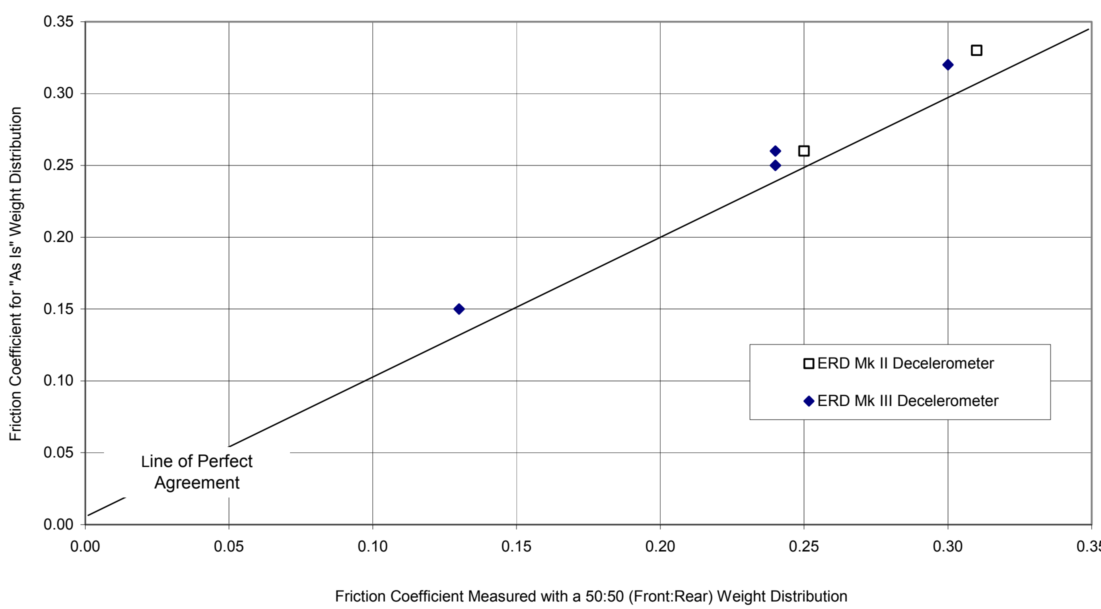


Figure 5.14: Effect of Weight Distribution for the Half Ton

5.5 Effect of Vertical Load and Contact Pressure

The relationship between vertical load and friction coefficient is shown in Figures 5.15 and 5.16 for the ERD Mk III and the ERD Mk II, respectively. The relationship between contact pressure and friction coefficient is shown in Figures 5.17 and 5.18 for the ERD Mk III and the ERD Mk II, respectively. Although the relationships for both vertical load and contact pressure are scattered, the data indicate that the friction coefficient decreases slightly with increasing vertical load and contact pressure for each test surface.

A variation in weight of 25.7 vs. 21.8 kN (which is the difference in weight for the Half ton at the “50:50” and “as is” weight distributions – section 5.4) could be responsible for a difference in friction coefficient of about 0.02, which is the observed variation in friction coefficient for these two cases (section 5.4). Hence, it is possible that weight variations (as opposed to differences in the weight distribution) were responsible for the observed differences in friction coefficient.

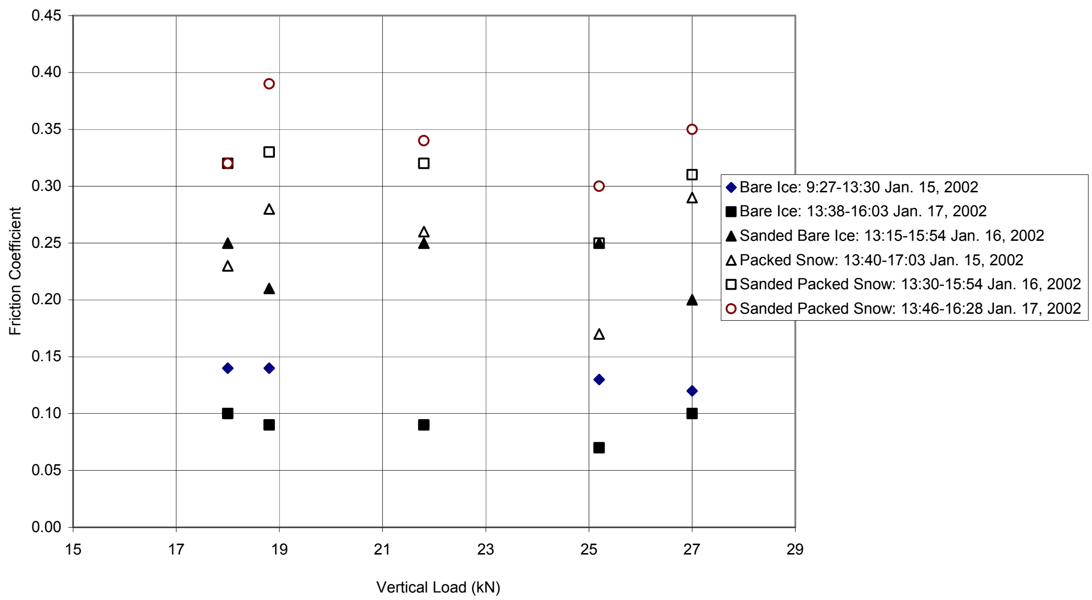


Figure 5.15: Effect of Vertical Load: ERD Mk III and All Test Surfaces

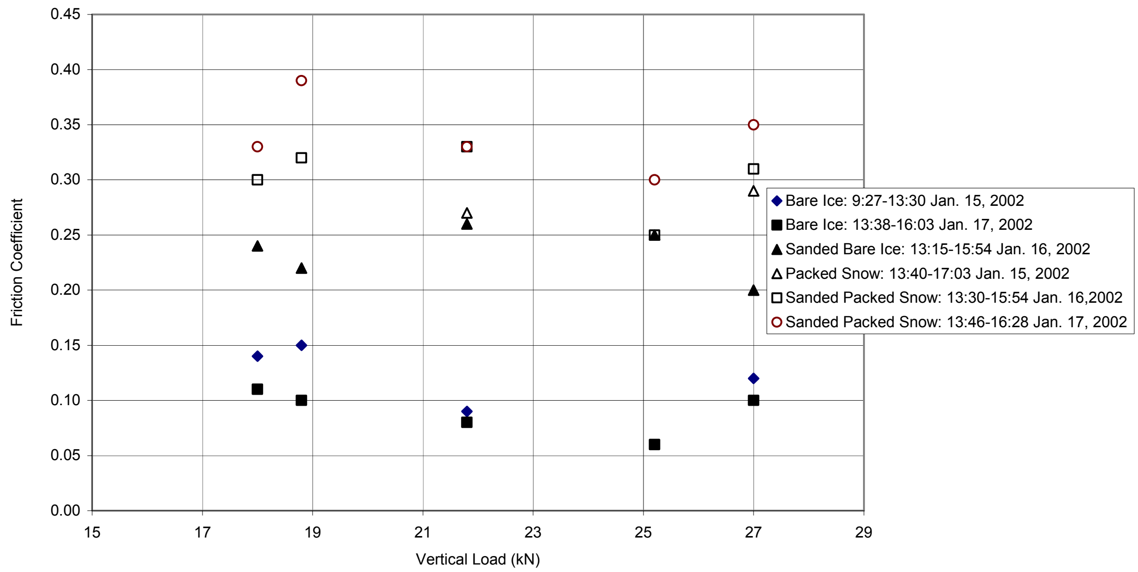


Figure 5.16: Effect of Vertical Load: ERD Mk II and All Test Surfaces

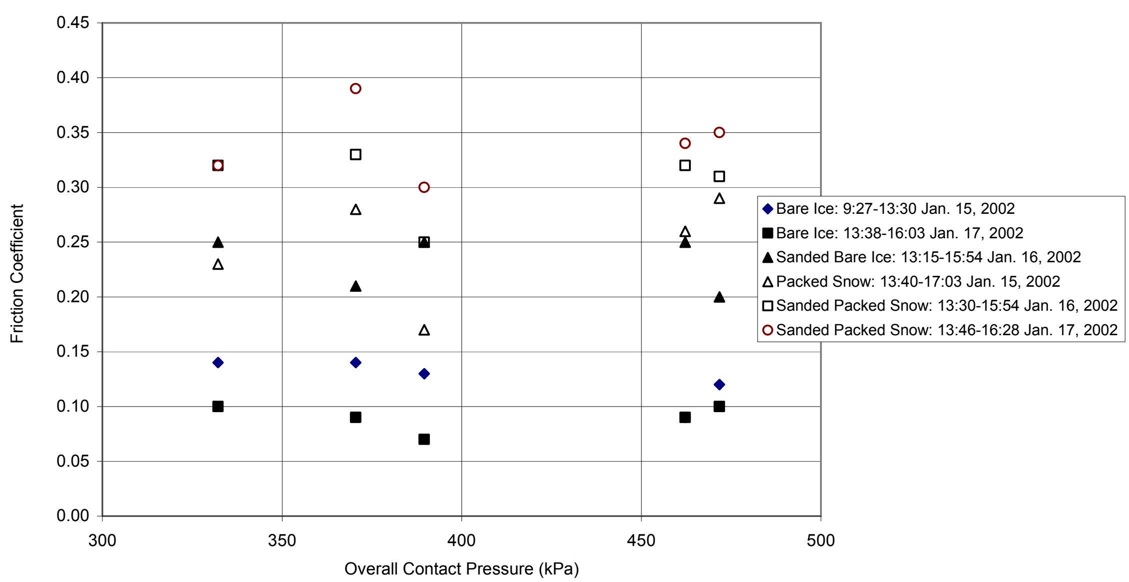


Figure 5.17: Effect of Contact Pressure: ERD Mk III and All Test Surfaces

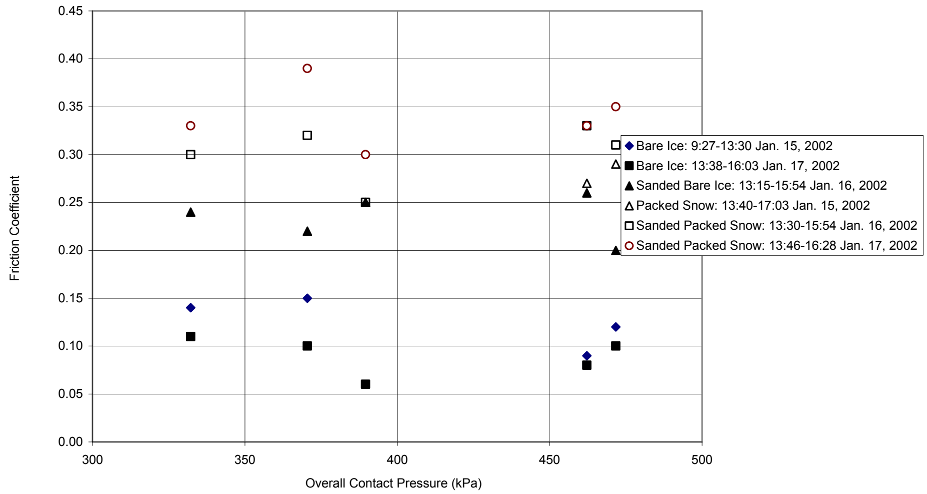


Figure 5.18: Effect of Contact Pressure: ERD Mk II and All Test Surfaces

5.6 Effect of Loose Contaminants

Although the effect of loose contaminants was not one of the primary objectives of the test program, a few data points were obtained to allow a preliminary assessment. Tests were conducted on packed snow with 3 to 5 cm (1-2 in.) of loose snow on top.

As expected, the friction coefficient was increased significantly by the presence of this material, in comparison with the most recent previous measurements of that same surface. The friction coefficients measured by the ERD Mk III and ERD Mk II were both increased by almost 50% (about 0.1 in magnitude) by the presence of the loose snow (Table 5.3).

Table 5.3: Effect of Loose Contaminants

Test Date & Time	Test Vehicle	Test Surface	Friction Factor for:			
			ERD Mk III	ERD Mk II	Bowmonk	Tapley
18:41 Jan 15, 2002	Blazer; weight “as is”; ABS off	Packed Snow with no loose contaminants on top of the packed snow	0.24	0.25	Not tested	Not tested
09:50 Jan 16, 2002	Blazer; weight “as is”; ABS off	Packed Snow with 3-5 cm of loose snow on top of the packed snow	0.33	0.33	0.33	0.37
17:03 Jan 15, 2002	Half Ton; weight “as is”; ABS off	Packed Snow with no loose contaminants on top of the packed snow	0.26	0.27	Not tested	Not tested
10:45 Jan 16, 2002	Half Ton; weight “as is”; ABS off	Packed Snow with 3-5 cm of loose snow on top of the packed snow	0.36	0.35	0.36	0.41

6. EFFECT OF FRICTION COEFFICIENT VARIATIONS ON LANDING DISTANCE

6.1 Purpose of Analyses

The previous analyses (in section 5) showed that the measured friction coefficients varied somewhat with all of the parameters investigated. These variations need to be put into perspective to assess their significance.

6.2 Analysis Approach

The Landing Distances (LDs) in the Aeronautical Information Publication (AIP) [4] were used to assess the significance of the observed variations in friction coefficient as they are related to the Canadian Runway Friction Index (CRFI). See Figure 6.1.

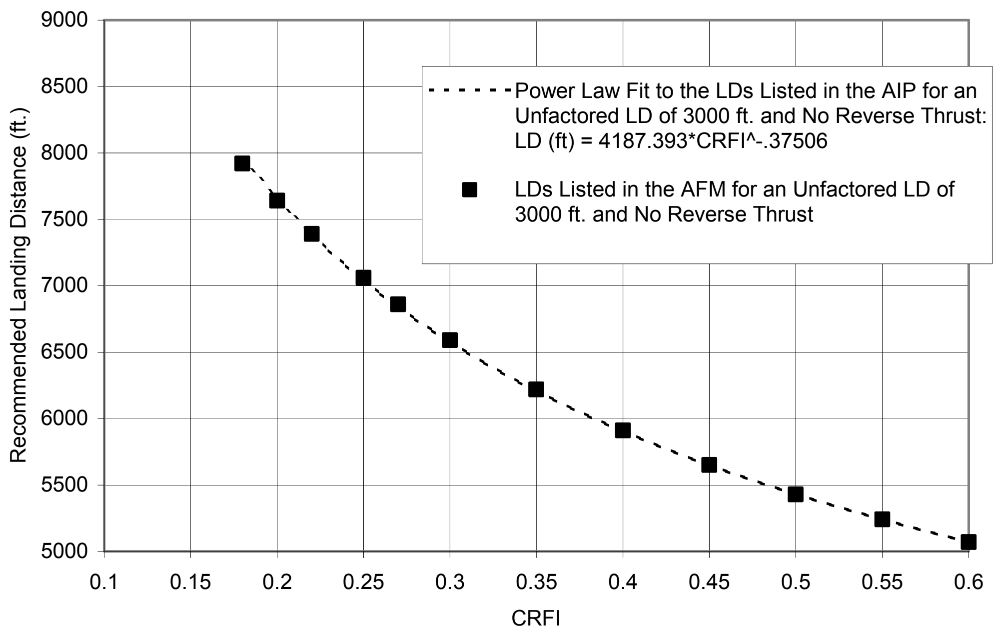


Figure 6.1: Landing Distances in the AIP [4] for No Reverse Thrust

For the purpose of this preliminary investigation, the analyses were done with respect to an unfactored AIP LD of 914.6 m (3000 ft.). While this provided an evaluation criterion for this project, it should be noted that this is an arbitrary selection, and that the results would vary for other AIP LDs. Unfortunately, further investigation could not be done here, as this was beyond the scope of this project. A more detailed investigation of this issue would be useful.

It should be further noted that the AIP [4] only provides landing distances for CRFIs ranging from 0.18 to 0.60. Consequently, the analyses could only be conducted for CRFIs in this range. Extrapolation would be necessary to infer landing distances for friction coefficients below 0.18. This was not done here because information is not available in the AIP to allow reliable extrapolation to landing distances at CRFIs lower than 0.18. Consequently, comparisons with the inferred landing distances could not be done for the whole data set. The test data obtained on lower-friction surfaces were not included in the analyses presented here, and thus the analyses presented here are only applicable to the higher-friction surfaces tested in this project.

Despite this limitation, the analyses provide a preliminary assessment of the significance of the measured variations in friction coefficient.

It should be noted that because the recommended landing distance increases significantly with deceasing CRFI values, small decreases in friction coefficient at low CRFIs cause a large increase in landing distance (Figure 6.1). Thus, greater accuracy is required for friction coefficients measured at low CRFIs to maintain the same precision with respect to inferred landing distances.

Landing distances were inferred for the measured friction coefficients (that were greater than or equal to 0.18) by fitting a power-law curve to the LDs listed in the AIP (Equation 6.1).

$$\text{Landing Distance (ft. – see note)} = 4187.393 * \text{CRFI}^{-0.37506} \qquad [6.1]$$

Note: The LDs defined by Equation 6.1 are applicable to:

a. CFRIs ranging between 0.18 and 0.6 inclusive
b. no reverse thrust
c. an unfactored LD in the AIP of 3000 ft.

Equation 6.1 was used for all subsequent analyses in this project.

The Blazer and the ERD Mk III were used as the bases of comparison, in keeping with the approach used to compare the friction coefficients measured by the various vehicles and decelerometers (section 5).

6.3 Effect of Decelerometer Type

The landing distances inferred from the test data (for friction coefficients exceeding 0.18) are shown in Figures 6.2 to 6.6.

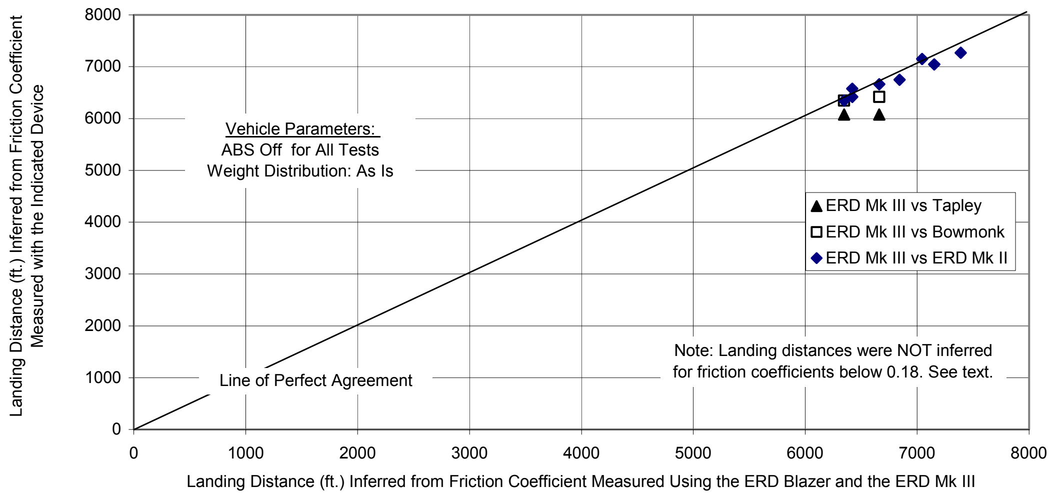


Figure 6.2: Effect on Inferred Landing Distances: Decelerometer Comparison for the Blazer for All Test Surfaces Combined

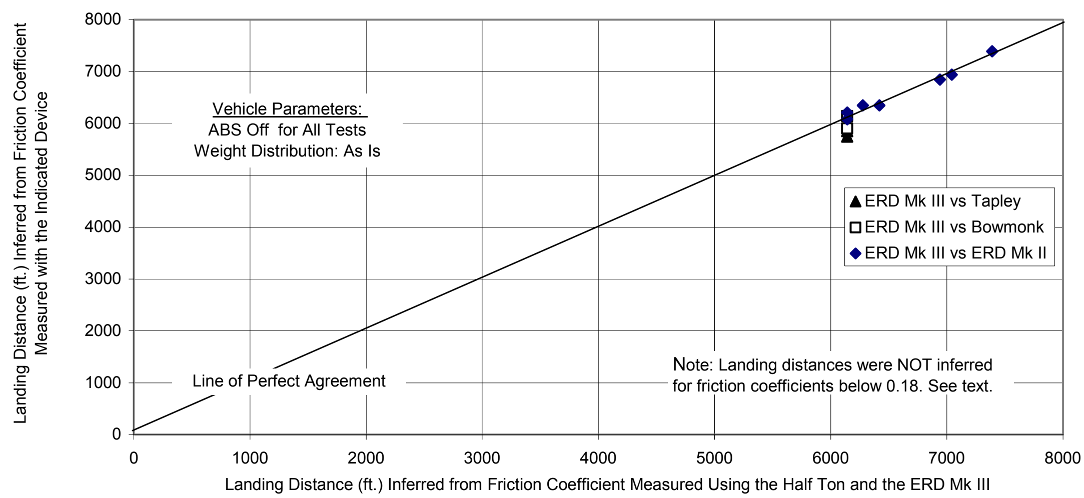


Figure 6.3: Effect on Inferred Landing Distances: Decelerometer Comparison for the Half Ton for All Test Surfaces Combined

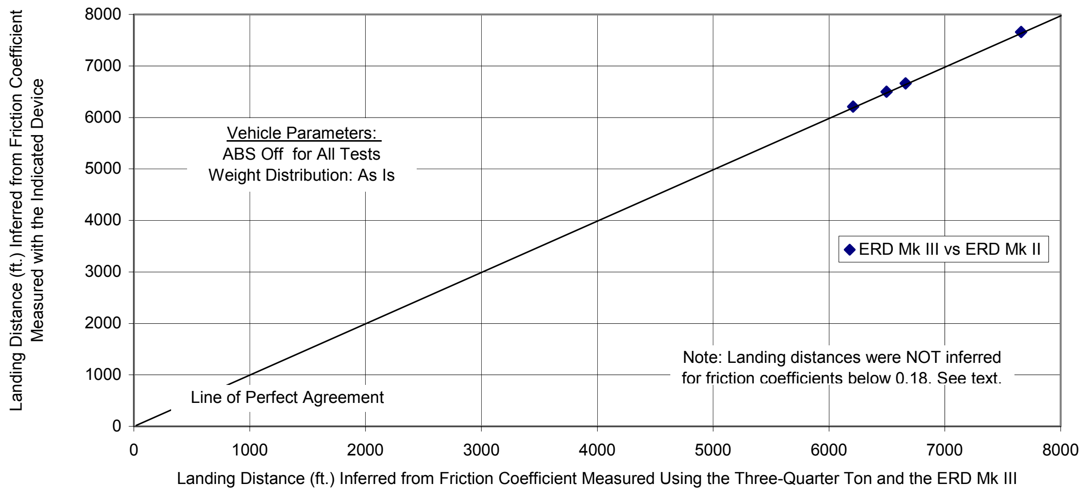


Figure 6.4: Effect on Inferred Landing Distances: Decelerometer Comparison for the Three-Quarter Ton for All Test Surfaces Combined

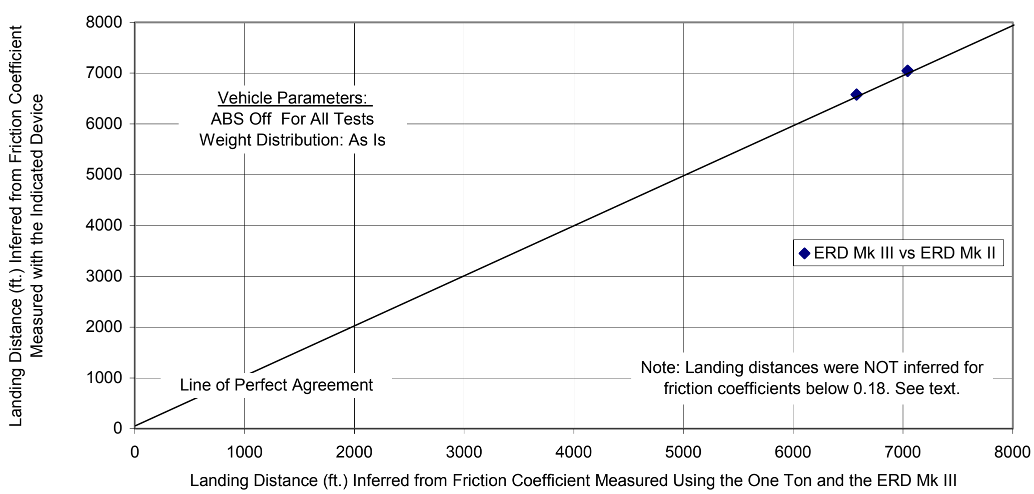


Figure 6.5: Effect on Inferred Landing Distances: Decelerometer Comparison for the One Ton for All Test Surfaces Combined

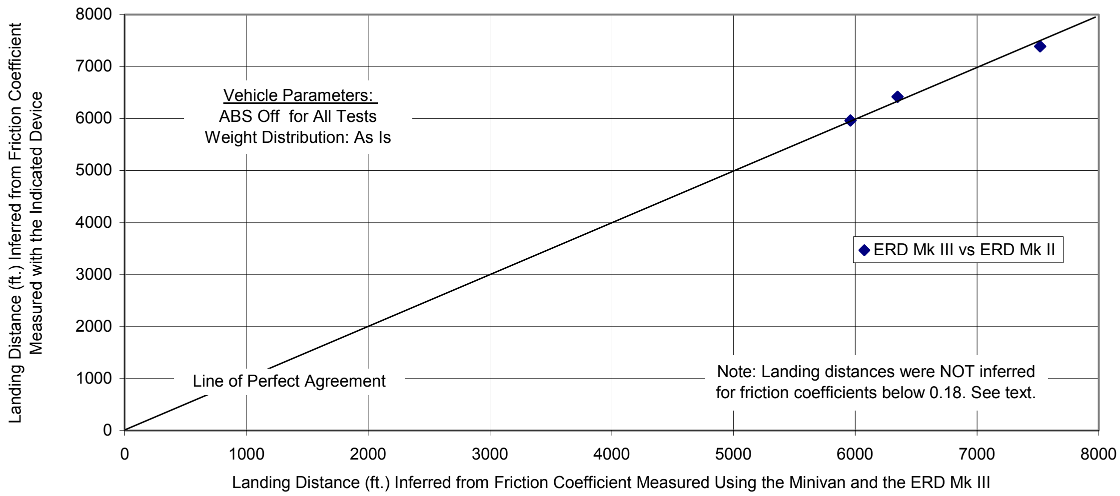


Figure 6.6: Effect on Inferred Landing Distances: Decelerometer Comparison for the Minivan for All Test Surfaces Combined

The maximum variations among the decelerometers tested are summarized in Table 6.1 and shown in Figure 6.7.

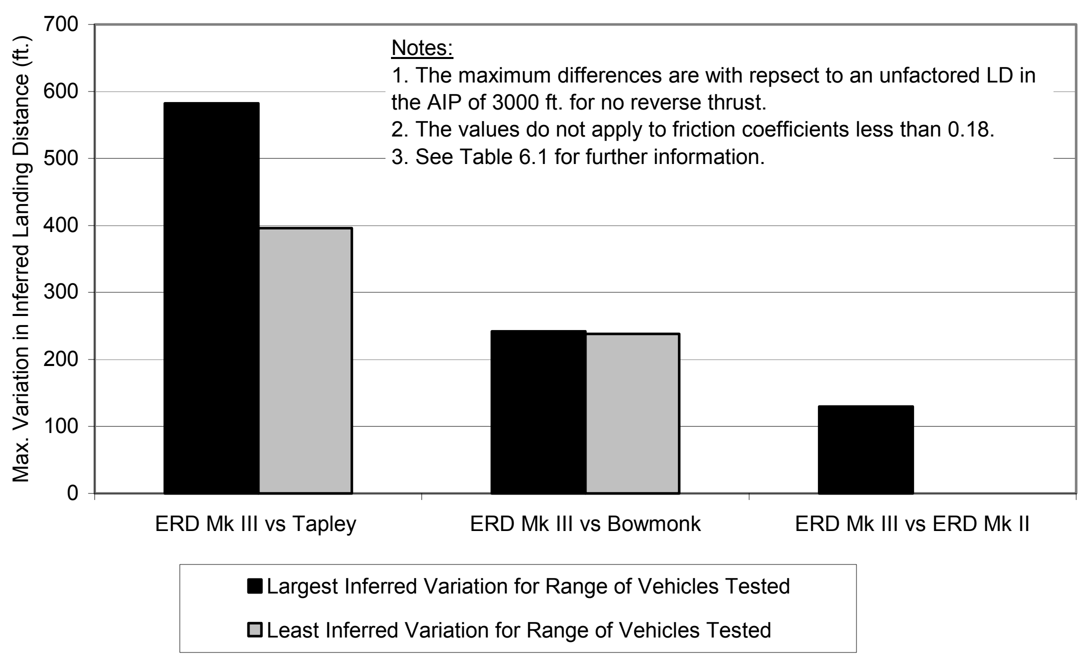


Figure 6.7: Effect of Decelerometer Type on Inferred Landing Distances

Table 6.1: Effect of Decelerometer Type:
Maximum Differences in Inferred Landing Distances

	Maximum Variation (ft.) in Inferred Landing Distances (notes 1 & 2) for:		
	ERD Mk III vs ERD Mk II	ERD Mk III vs Tapley	ERD Mk III vs Bowmonk
Blazer	109	582	242
Half ton	97	396	238
Three-quarter ton	0	not tested	not tested
One ton	0	not tested	not tested
Minivan	130	not tested	not tested

Notes:
1. The maximum differences are with respect to an unfactored LD in the AIP of 3000 ft. for no reverse thrust.
2. The above values do not apply to friction coefficients less than 0.18.

The landing distances inferred from the Tapley were consistently less than those from the two ERDs, as the Tapley consistently recorded higher friction coefficients (section 5.1). The landing distances inferred from the Bowmonk data were intermediate to those for the two ERDs and the Tapley.

6.4 Effect of Vehicle Type

The landing distances inferred from the test data (for friction coefficients exceeding 0.18) are shown in Figures 6.8 to 6.11.

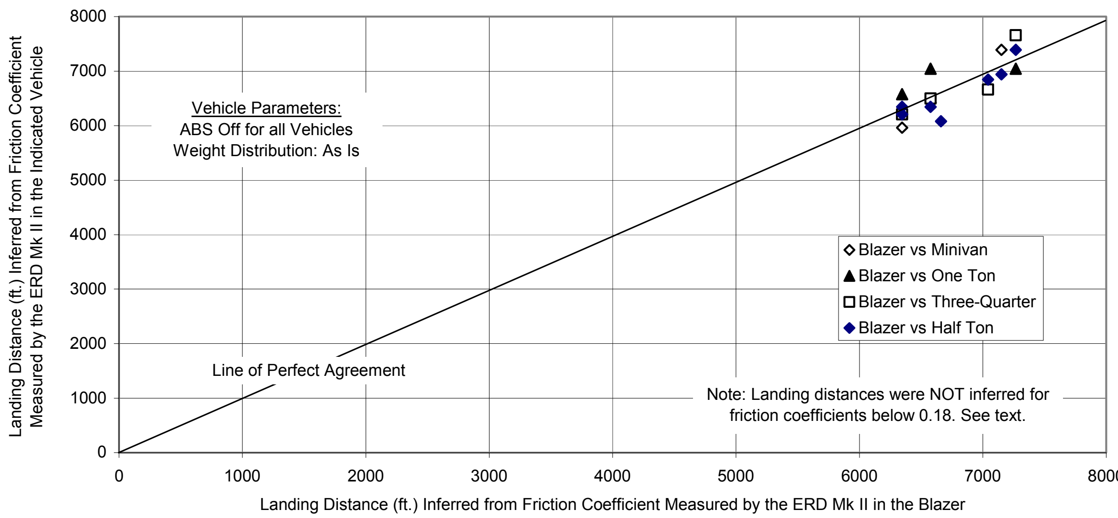


Figure 6.8: Effect on Inferred Landing Distances: Vehicle Comparison for the ERD Mk III for All Test Surfaces Combined

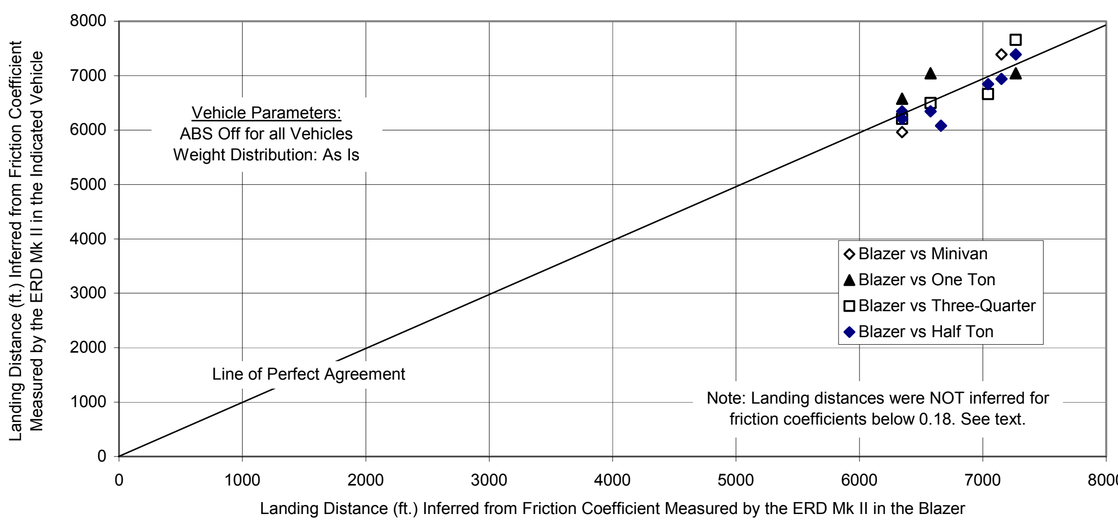


Figure 6.9: Effect on Inferred Landing Distances: Vehicle Comparison for the ERD Mk II for All Test Surfaces Combined

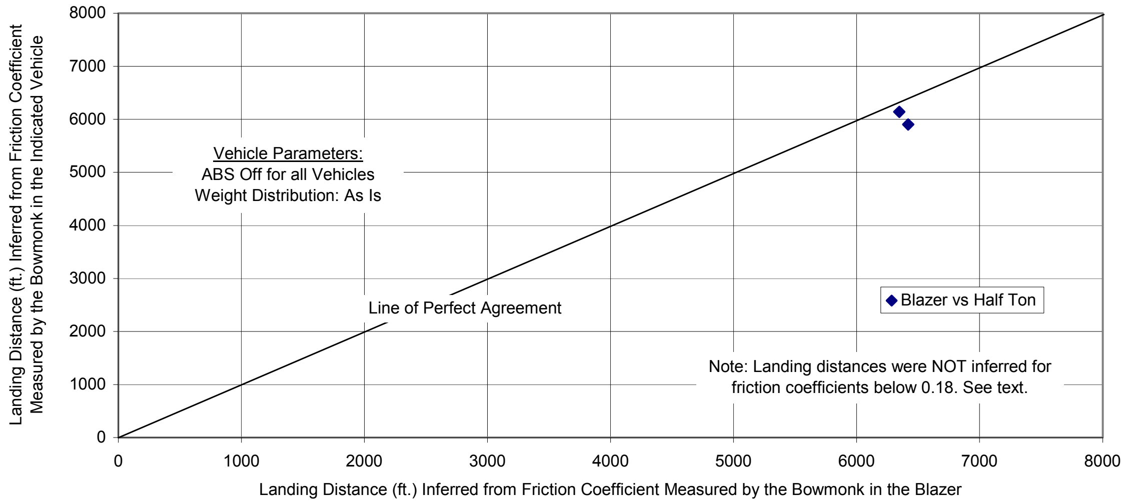


Figure 6.10: Effect on Inferred Landing Distances: Vehicle Comparison for the Bowmonk for All Test Surfaces Combined

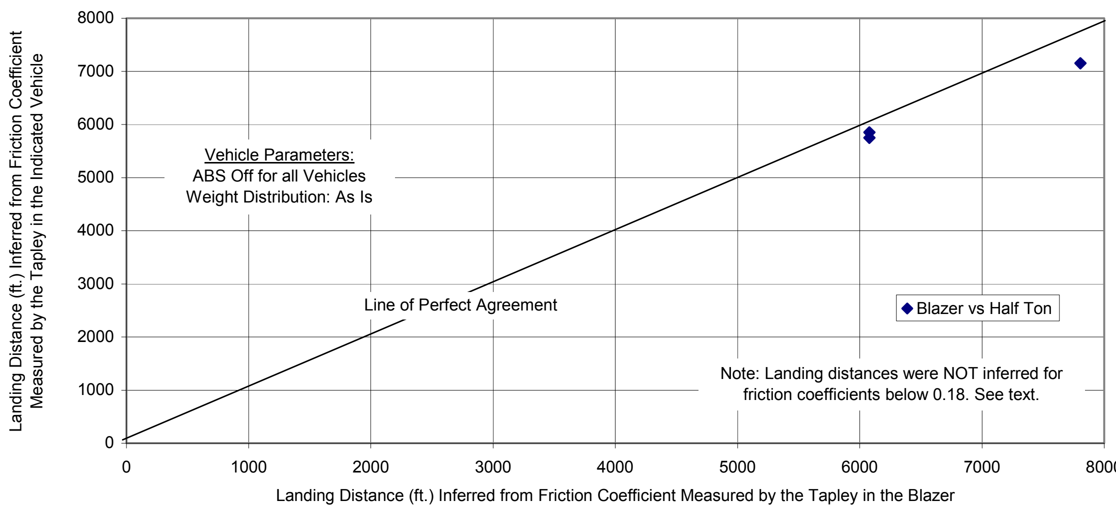
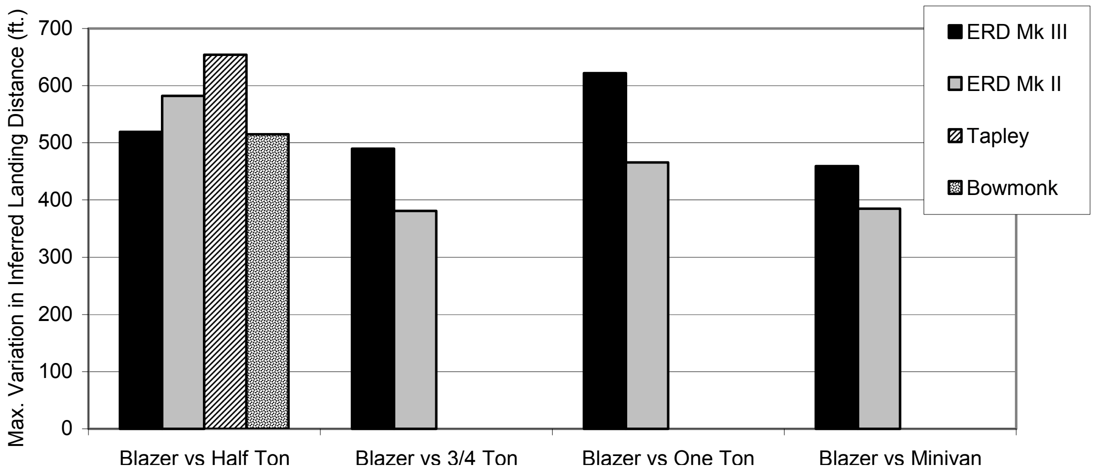


Figure 6.11: Effect on Inferred Landing Distances: Vehicle Comparison for the Tapley for All Test Surfaces Combined

The maximum variations are summarized in Table 6.2, and shown in Figure 6.12. The maximum variations in inferred landing distances are similar for each vehicle and decelerometer.



Notes:
1. The maximum differences are with repsect to an unfactored LD in the AIP of 3000 ft. for no reverse thrust.
2. The values do not apply to friction coefficients less than 0.18.
3. Refer to Table 6.2 for further information.

Figure 6.12: Effect of Vehicle Type on Inferred Landing Distances

Table 6.2: Effect of Vehicle Type:

Maximum Differences in Inferred Landing Distances	Max. Variation (ft.) in Inferred Landing Distances (notes 1 & 2) for:			
	Blazer vs half ton	Blazer vs 3/4 ton	Blazer vs one ton	Blazer vs minivan
ERD Mk III	519	490	622	459
ERD Mk II	582	381	466	385
Tapley	654	not tested	not tested	not tested
Bowmonk	515	not tested	not tested	not tested

Notes:
1. The maximum differences are with respect to an unfactored LD in the AIP of 3000 ft. for no reverse thrust.
2. The above values do not apply to friction coefficients less than 0.18.

6.5 Effect of ABS On or Off

The landing distances inferred from the test data (for friction coefficients exceeding 0.18) are shown in Figures 6.13 to 6.16.

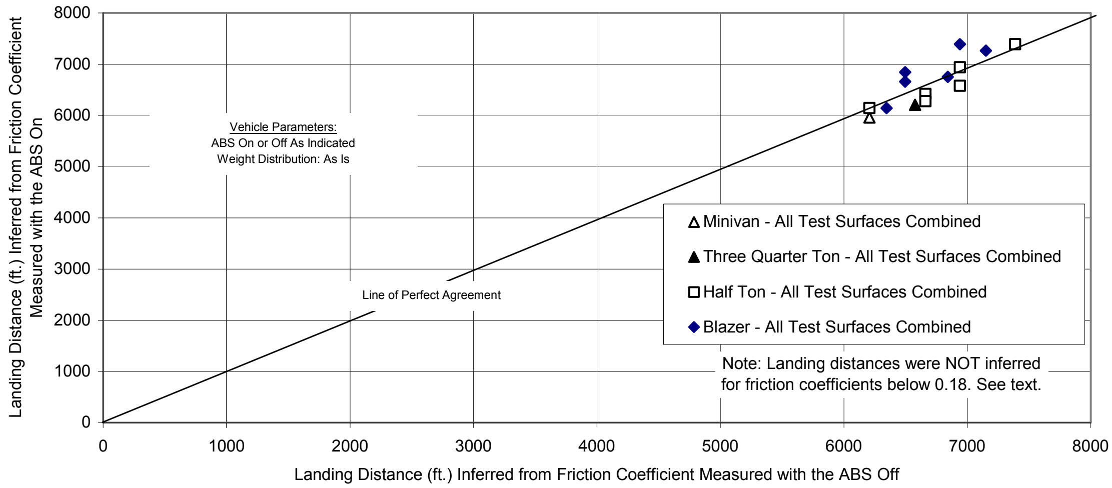


Figure 6.13: Effect on Inferred Landing Distances: ABS On or Off for the ERD Mk III for All Test Surfaces Combined

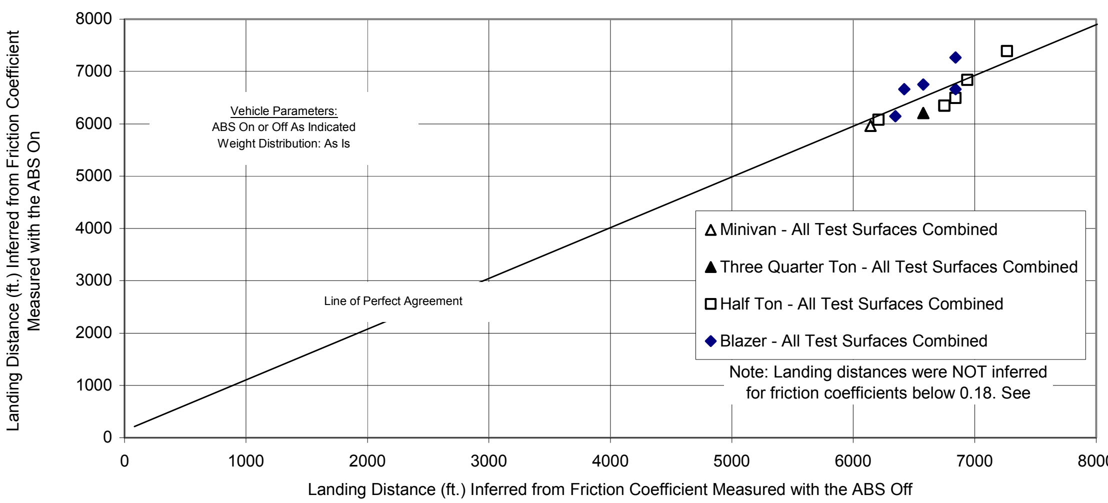


Figure 6.14: Effect on Inferred Landing Distances: ABS On or Off for the ERD Mk II for All Test Surfaces Combined

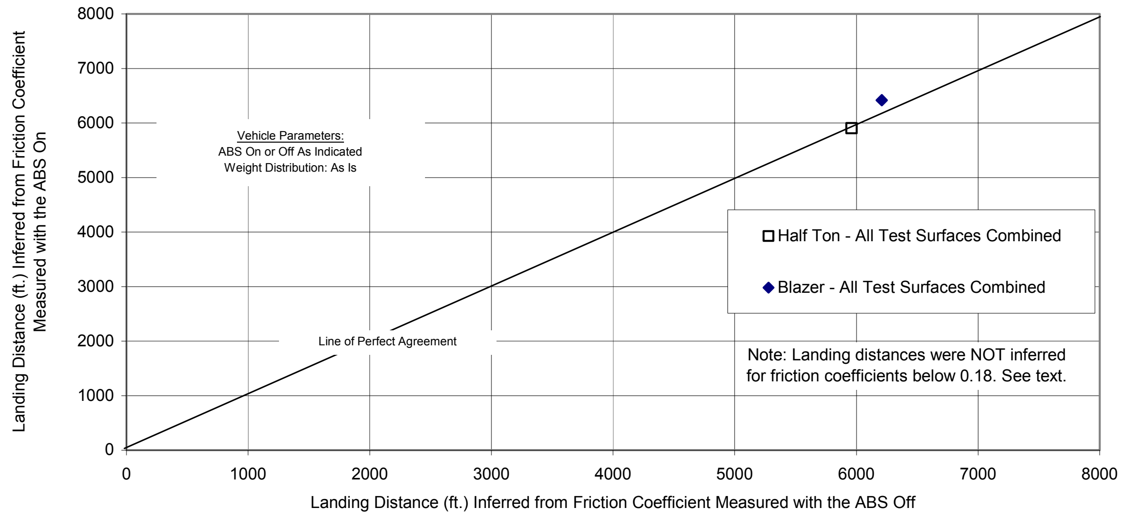


Figure 6.15: Effect on Inferred Landing Distances: ABS On or Off for the Bowmonk for All Test Surfaces Combined

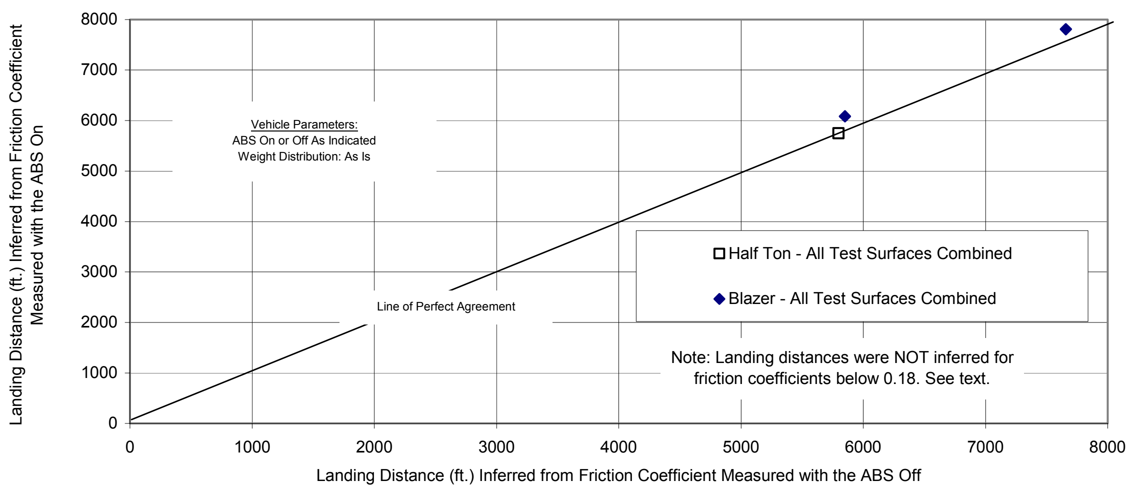
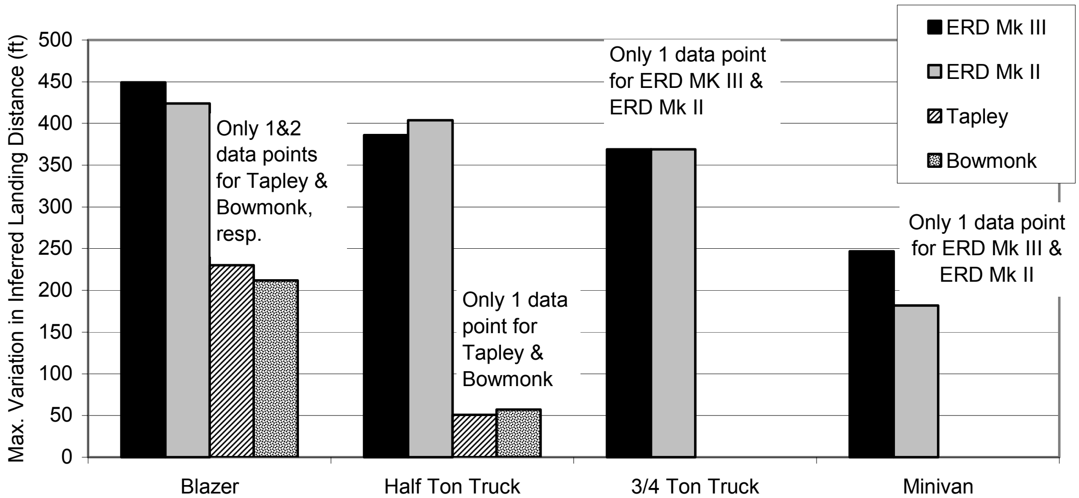


Figure 6.16: Effect on Inferred Landing Distances: ABS On or Off for the Tapley for All Test Surfaces Combined

The maximum variations are summarized in Table 6.3 and shown in Figure 6.17. The maximum variations in inferred landing distances are similar for the Blazer and Half ton, and for the ERD Mk III and ERD Mk II. Very few data points are available for the Tapley and the Bowmonk, and for the Three-quarter ton and Minivan. This limits the conclusions that can be drawn for these cases.



Notes:
1. The maximum differences are with repsect to an unfactored LD in the AIP of 3000 ft. for no reverse thrust.
2. The values do not apply to friction coefficients less than 0.18.
3. Refer to Table 6.3 for further information.

Figure 6.17: Effect of ABS On or Off on Inferred Landing Distances

Table 6.3: Effect of ABS On or Off:
Maximum Differences in Inferred Landing Distances

	Max. Variation (ft.) in Inferred Landing Distances (notes 1 & 2) for:			
	Blazer: ABS on vs ABS off	Half ton: ABS on vs ABS off	Three-quarter ton: ABS on vs. ABS off	Minivan: ABS on vs. ABS off
ERD Mk III	449	386	369 (only 1 data pt in range of analyses)	247 (only 1 data pt in range of analyses)
ERD Mk II	424	404	369 (only 1 data pt in range of analyses)	182 (only 1 data pt in range of analyses)
Tapley	230 (only 2 data pts in range of analyses)	51 (only 1 data pt in range of analyses)	not tested	not tested
Bowmonk	212 (only 1 data pt in range of analyses)	57 (only 1 data pt in range of analyses)	not tested	not tested

Notes:
1. The maximum differences are with respect to an unfactored LD in the AIP of 3000 ft. for no reverse thrust.
2. The above values do not apply to friction coefficients less than 0.18.

6.6 Effect of Weight Distribution or Total Weight

As noted in section 5.4, higher friction coefficients were recorded for the Half ton when it had a 50:50 (front:rear) weight distribution than for the "as is" weight distribution. Variations in vehicle weight may have contributed to this difference as the Half ton was heavier in the 50:50 configuration, compared to the "as is" case (section 5.5).

The inferred landing distances (for a 3000 ft. unfactored LD with no reverse thrust) for these test data are shown in Figure 6.18.

The higher friction coefficients recorded for the "50:50" case would cause decreases in landing distance of 212 ft. (64.6 m) and 151 ft. (46 m) for the ERD Mk III and the ERD Mk II decelerometers, respectively.

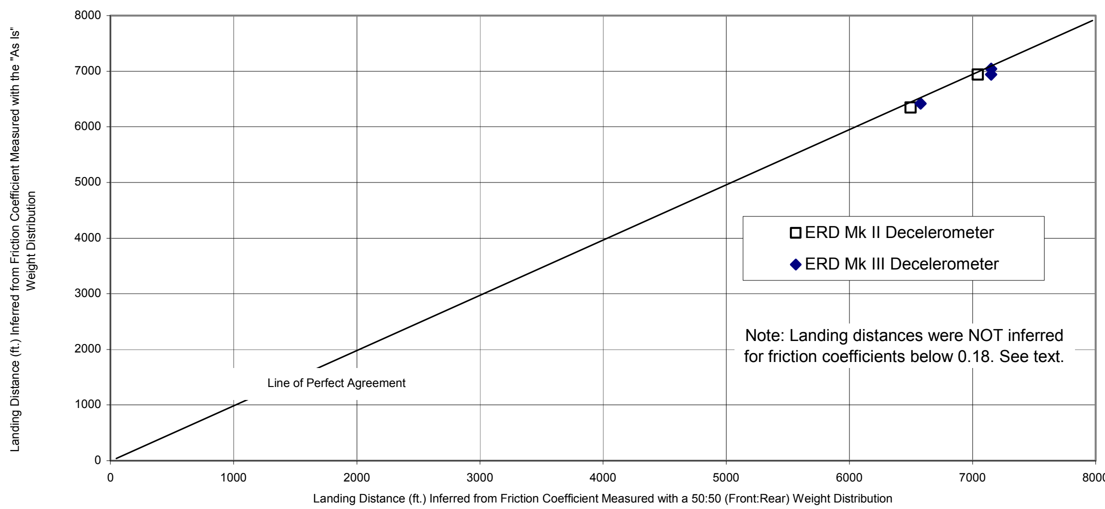


Figure 6.18: Effect on Inferred Landing Distances: Effect of Weight Distribution for the Half Ton

6.7 Commentary: Effect of Combinations of Parameters

The maximum variations in inferred landing distance attributable to each main parameter (i.e., decelerometer type, vehicle type, ABS on or off, and weight distribution/total weight) have been presented in the previous sections. This analysis serves to highlight the relative significance of each parameter. However, it is highly unlikely that the landing distance variations expected for a combination of parameters will be equal to the sum of the individual maximums for each sub-case. This is due to the fact that the individual maximums are quite unlikely to all occur at once.

This is illustrated in Figure 6.19 for a two-parameter case.

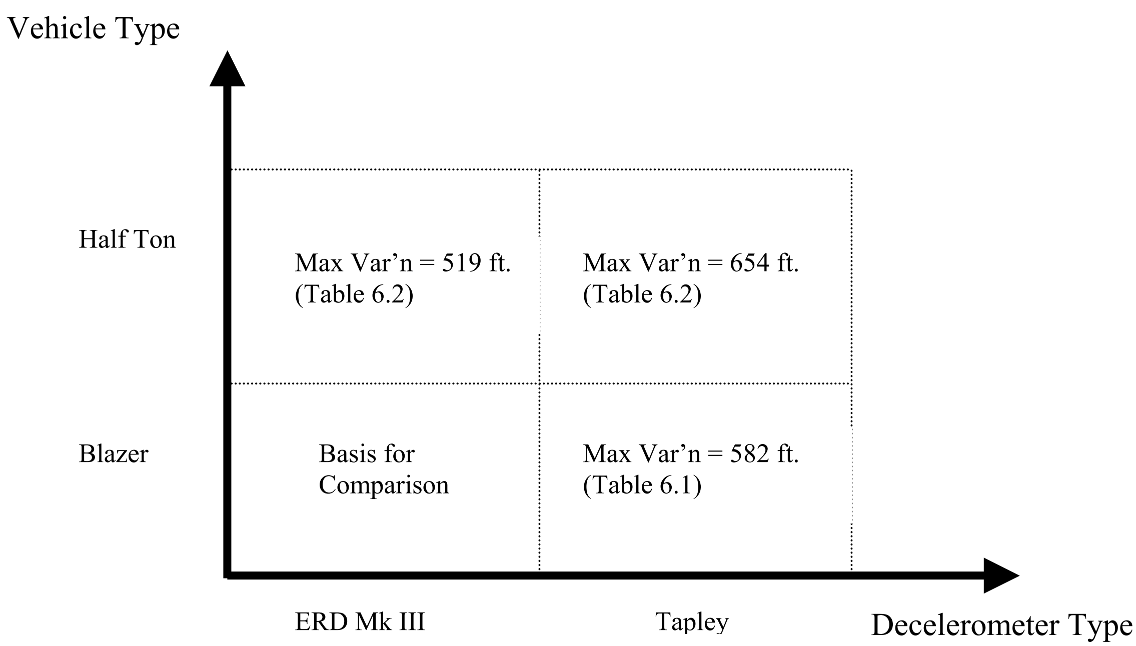


Figure 6.19: Schematic: Effect of Parameter Combinations

The observed maximum landing distance variation for the combination of the two parameters (i.e., Blazer vs. Half-ton and Tapley vs. ERD MkIII) is significantly less than the sum of the two individual maximums.

Figure 6.19 serves to highlight the trends expected. Unfortunately, this could not be investigated further in this project as more analyses and data are required to fully address this issue.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

7.1.1 Decelerometers

(a) The ERD Mk II and ERD Mk III decelerometers recorded equivalent friction coefficients to all practical purposes.

(b) The Tapley decelerometer recorded friction coefficients that were consistently higher than the ERD Mk II or ERD Mk III decelerometers, by about 0.05 over the full range of surfaces tested. This variation is similar to that observed during previous comprative tests [1, 2]. This may reflect the fact that the Tapley is set up to record the peak friction whereas the ERDs incorporate some averaging of the results.

(c) The Bowmonk decelerometer recorded friction coefficients that were higher than the ERD Mk II or ERD Mk III decelerometers by about 0.025 on average over the full range of surfaces tested. This variation is similar to that observed during previous comprative tests [1, 2]. This may reflect the fact that the Bowmonk is set up to record the peak friction whereas the ERDs incorporate some averaging of the results.

(d) For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to decelerometer type represent a maximum variation in landing distance of about 600 ft. (182.9 m) and 250 ft. (76.2 m) for the Tapley and Bowmonk, respectively, in comparison to the two ERDs. (It should be noted that these values are applicable to an unfactored landing distance of 3000 ft. and no reverse thrust.)

7.1.2 Vehicle Type Comparison

(a) The friction values recorded were affected by the vehicle type.

(b) The effect of vehicle type varied with the friction level and the decelerometer type. The maximum variation in the recorded friction coefficient ranged from about 0.02 to 0.08, depending on the case being considered.

(c) For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to vehicle type represent a maximum variation in landing distance of about 400 to 600 ft. (121.9 – 182.9 m) for an unfactored landing distance of 3000 ft. and no reverse thrust.

7.1.3 Vehicle ABS On or Off

(a) The decelerometer readings changed depending on whether the vehicle was operated with its ABS on or its ABS disabled.

(b) The observed difference varied with the surface condition. It was generally less when the surface friction was very low, being about 0.01 on low-friction surfaces, and about 0.05 for surfaces with friction coefficients in the 0.3 range.

(c) For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to the vehicle's ABS being on or off represent a maximum variation in landing distance of about 400 ft. (121.9 m) for an unfactored landing distance of 3000 ft. and no reverse thrust.

7.1.4 Vehicle Weight Distribution and/or Total Weight

(a) The friction coefficient recorded with the Half ton in a "50:50" weight balance (front:rear) was about 0.02 lower than for the "as is" weight distribution (which was about 60:40 front:rear).

(b) The observed variation in friction coefficient could be due to the difference in total weight for the "50:50" and the "as is" cases as the weight was increased for the "50:50" case.

(c) For the range of CRFIs in the current AIP, the observed variations in friction coefficient with respect to the vehicle's weight distribution, or total weight, represent a maximum variation in landing distance of about 200 ft. (61 m) for an unfactored landing distance of 3000 ft. and no reverse thrust.

7.2 Recommendations

The test program has provided data that allows some conclusions to be drawn regarding several of the key issues (as described in section 7.1). However, several issues warrant further attention, as follows:

(a) Effect of Decelerometer Type – the Tapley, and to a lesser extent the Bowmonk as well, recorded higher friction values than did the two ERDs (i.e., the Mk III and the Mk II). This may be due to the fact that the Tapley and the Bowmonk are "peak-measuring" devices whereas the ERDs are "averaging" devices.

Nevertheless, this raises questions regarding whether all decelerometers can be presumed to produce equivalent values. Further investigation should be conducted to determine whether this variation represents a systematic difference with respect to Tapleys vs. Bowmonks vs. ERDs, or whether it is due to unique characteristics of the instruments tested.

(b) Decelerometer Calibration Techniques and Procedures – because it has been shown that the various manufactured decelerometers do give different results, test and calibration procedures should be developed by Transport Canada to determine the acceptability of decelerometers. Once these are developed, airports could use these procedures to check their friction device.

(c) Effect of ABS On or Off – further ABS tests should be carried out for a number of reasons. It is expected that ABS systems on vehicles will become increasingly difficult to disable for airports due to vehicle design, airport liability, etc. As it appears that the use of vehicles with ABS on may be possible, it would be useful to understand this issue well. Furthermore, the data quantity obtained in this project (to evaluate the effect of ABS) was relatively sparse, especially for the Tapley and Bowmonk decelerometers. More data are needed to draw definitive conclusions.

(d) Variation in Results for Different Decelerometer Systems (i.e., sensor, vehicle and operator) – no data are available to assess the variation among the various decelerometer measurement systems (i.e., the decelerometer, the vehicle, and the operator) currently in common use at airports. A calibration test program should be conducted by bringing a number of them together at one airport.

(e) Effect of Vehicle Type and Parameters – further investigation is recommended regarding the following:

   i. The mix of vehicles currently being used at airports in Canada should be investigated. If there are vehicles that are significantly different from those used for this test, a repeat of the tests using those vehicles should be conducted.

ii. Further testing should be conducted to investigate the requirement for balancing the weight to give a 50:50 weight distribution. A study should also be undertaken to try to determine whether airports are currently balancing the vehicles to give a 50:50 load ratio.

(f) Effect of Loose Contaminants – it is well known that the friction data measured by decelerometers are affected by the presence of loose contaminants (e.g., snow, slush, etc.), which is supported by the preliminary results obtained in this project. In response, various organizations have specified limiting depths for various types of loose contaminants above which decelerometer readings are considered to be unreliable. Further tests quantifying the effect of loose contaminants in relation to their type and depth would be useful.

(g) Effect of Combinations – the combined effects of the various main parameters investigated (i.e., decelerometer type, vehicle type, ABS on or off, and weight distribution/total weight) should be considered in more detail.

REFERENCES

[1] Thomas, R., and Green, C., 1997, Correlation Testing of Decelerometers, contractor report by TES Limited to Transport Canada.

[2] Green, C., 1998, Correlation Testing of Decelerometers, contractor report by TES Limited to Transport Canada.

[3] Comfort, G., and Gong, Y., 1998, Analysis of the Friction Factors Measured by the Ground Vehicles at the 1998 North Bay Trials, TP 13366E Transportation Development Centre, Transport Canada.

[4] AIP, 2002, Aeronautical Information Publication, TP 2300.

APPENDIX A

RAW TEST DATA: BLAZER

Tuesday, January 15, 2002

Surface - Bare Ice/ABS off

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.17	0.19		
Vehicle	Blazer, abs off, as-is	missed	0.17		
Start Time	9:27	0.18	0.14		
Stop Time	9:40	0.14	0.12		
Air Temp (celsius)	-6.2	0.12	0.16		
Ground Temp (celsius)	-5.9	0.15	missed		
Snow Density	N/A	0.17	0.16		
Test Surface	bare ice with some snow patches	0.16	0.16		
Time to perform test runs (min)	13	0.15	0.14		
Number of runs conducted	19	0.13	0.11		
Description of skids	loss of directional control	0.12	0.10		
Windspeed and direction	North, 5 knots	0.10	0.11		
Vehicle Direction and speed	40 km/hr in southeast direction	0.12	0.14		
Notes:		0.14	0.12		
		0.13	0.15		
		0.14	0.11		
		0.11	0.10		
		0.11	0.13		
		0.13	0.13		
		0.14			
	Average	**0.14**	**0.14**		

Test Run Data		**MK III**	**Location**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.15	**lane 1**		
Vehicle	Blazer, as-is, abs off	0.15	lane 1		
Start Time	14:20	0.15	lane 1		
Stop Time	14:30	0.09	**lane 2**		
Air Temp (celsius)	-8	0.13	lane 2		
Ground Temp (celsius)		0.11	lane 2		
Snow Density	N/A	0.14	**lane 3**		
Test Surface	bare ice with some snow patches	0.16	lane 3		
Time to perform test runs (min)	10	0.15	lane 3		
Number of runs conducted	15	0.13	**lane 4**		
Description of skids	loss of directional control	0.17	lane 4		
Windspeed and direction	North 6 knots	0.16	lane 4		
Vehicle Direction and speed	40 km/hr in southeast direction	0.16	**lane 5**		
Notes:	Taken to see if morning conditions	0.18	lane 5		
	changed, readings taken in all 5	0.12	lane 5		
	vehicle test tracks, MKII was out of commission				
	Average	**0.14**			

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.12	0.12		
Vehicle	Blazer, as-is, abs off	0.10	0.10		
Start Time	18:24	0.09	0.09		
Stop Time	18:36	0.14	missed		
Air Temp (celsius)	-9.3	0.13	0.18		
Ground Temp (celsius)		0.12	0.13		
Snow Density	N/A	0.15	0.17		
Test Surface	bare ice with some snow patches	0.15	0.16		
Time to perform test runs (min)	12	0.10	0.16		
Number of runs conducted	15-18	0.17	0.13		
Description of skids	loss of directional control	0.11	0.11		
Windspeed and direction	northwest 7 knots, or 300 degrees	0.12	0.12		
Vehicle Direction and speed	40 km/hr in southeast direction	0.16	0.18		
Notes:	some snow	0.16	0.14		
	(270 degrees is west, and	0.13	missed		
	360 degrees is north)	0.17	0.20		
	180 degrees is south	0.16	missed		
		0.17	0.17		
	Average	**0.14**	**0.14**		

Tuesday, January 15, 2002

Surface - Bare Ice/ABS on

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.16			
Vehicle	Blazer, as-is, abs on	0.17			
Start Time	15:10	0.11			
Stop Time	15:20	0.14			
Air Temp (celsius)	-8	0.12			
Ground Temp (celsius)	-1	0.10			
Snow Density	N/A	0.15			
Test Surface	bare ice with some snow patches	0.12			
Time to perform test runs (min)	10	0.11			
Number of runs conducted	15	0.16			
Description of skids	loss of directional control	missed			
Windspeed and direction	North 6 knots	0.14			
Vehicle Direction and speed	40 km/hr in southeast direction	0.11			
Notes:		0.17			
		0.15			
		0.12			
	Average	**0.14**			

Wednesday, January 16, 2002

Surface - Bare Ice/ABS off

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Wednesday, January 16, 2002	0.13	0.13	0.18	0.20
Vehicle	blazer, as-is, abs off	0.12	0.12	0.17	0.19
Start Time	9:20	missed	0.12	0.15	0.17
Stop Time	9:44	0.12	0.13	0.21	0.14
Air Temp (celsius)	-17	0.12	0.17	0.17	0.23
Ground Temp (celsius)	-9	0.17	0.12	0.18	0.19
Snow Density	N/A	0.12	0.16	0.15	0.23
Test Surface	Bare Ice, with some snow patches	0.15	missed	0.17	0.19
Time to perform test runs (min)	24	missed	0.14	0.15	0.19
Number of runs conducted		0.13	0.14	0.17	0.20
Description of skids	not a straight skid	0.14	0.12	0.16	0.22
Windspeed and direction	calm	0.12	0.13	0.19	0.13
Vehicle Direction and speed	30 km/hr in southeast direction	0.13	0.15	0.16	0.20
Notes	Went at 30km/hr so spinning was reduced and	0.14	0.12	0.16	0.16
	get more accurate results so that car skidded	0.10	0.11	0.17	0.23
	in a straight line	0.11	0.15	0.18	0.19
	had to lock up wheel to get results from the	0.14	0.12		0.19
	bowmark, maintain directional control	0.11	0.11		0.19
	Bowmark lost a number of readings	0.10	0.12		0.19
		0.12	0.13		0.22
		0.12			
	Average	**0.13**	**0.13**	**0.17**	**0.19**

Thursday, January 17, 2002

Surface - Bare Ice/ABS off

Test Run Data		**MKIII**	**MKII**
Vehicle	Blazer, as is, abs off	0.11	0.11
Date	Thursday, January 17, 2002	0.10	0.10
Start	13:38	0.10	0.10
Stop	13:45	0.11	0.12
Location	13-31	0.10	0.11
Type of Surface	Bare Ice	0.10	0.11
Depth of Snow	N/A	0.09	0.10
Snow Density	N/A	0.10	0.10
Air Temp (celsius)	-4.9	0.10	0.11
Surf Temp (celsius)		0.11	0.12
Speed (km/hr)	40	0.10	0.10
		0.08	0.08
		0.10	0.10
		0.11	missed
		0.11	0.12
	Average	**0.10**	**0.11**

Test Run Data		**MKIII**	**MKII**
Vehicle	Blazer, as is, abs off	0.08	0.09
Date	Thursday, January 17, 2002	0.09	0.10
Start	16:24	0.09	0.10
Stop	16:26	0.10	0.10
Location	13-31	0.10	0.09
Type of Surface	Bare Ice		
Depth of Snow	N/A		
Snow Density	N/A		
Air Temp (celsius)	-6		
Surf Temp (celsius)			
Speed (km/hr)	40		

Thursday, January 17, 2002

Surface - Bare Ice/ABS on

Test Run Data			MKIII	MKII
Vehicle	Blazer, as is, abs on		0.08	0.11
Date		Thursday, January 17, 2002	0.07	0.10
Start		13:53	0.09	0.10
Stop		13:58	0.09	0.09
Location	13-31		0.12	0.13
Type of Surface	Bare Ice		0.09	0.10
Depth of Snow	N/A		0.09	0.09
Snow Density	N/A		0.09	0.10
Air Temp (celsius)		-4.9	0.11	0.11
Surf Temp (celsius)		-4.8	0.09	0.10
Speed (km/hr)		40	0.09	0.11
			0.08	0.09
			0.10	0.10
			0.09	0.10
			0.09	0.10
	Average		**0.09**	**0.10**

Test Run Data			MKIII	MKII
Vehicle	Blazer, as is, abs on		0.08	0.07
Date		Thursday, January 17, 2002	0.07	0.07
Start		16:26	0.09	0.08
Stop		16:28	0.10	0.09
Location	13-31		0.08	0.08
Type of Surface	Bare Ice			
Depth of Snow	N/A			
Snow Density	N/A			
Air Temp (celsius)		-6		
Surf Temp (celsius)				
Speed (km/hr)		40		
	Average		**0.08**	**0.08**

Friday, January 18, 2002

Surface - Bare Ice/ABS off

Test Run Data			MKIII	MKII	Bowmonk	Tapley
Vehicle	Blazer, as is, abs off		0.13	0.14	0.15	0.19
Date		Friday, January 18, 2002	0.12	0.12	0.12	0.20
Start		9:25	0.12	0.12	0.15	0.17
Stop		9:41	0.12	0.12	0.18	0.22
Location	13-31		0.10	0.11	0.17	0.17
Type of Surface	Bare Ice		0.12	0.12	0.14	0.22
Depth of Snow	N/A		0.13	0.14	0.16	0.22
Snow Density	N/A		0.11	0.11	0.12	0.17
Air Temp (celsius)		-9	0.13	0.14	0.12	0.19
Surf Temp (celsius)			0.11	0.11	0.11	0.17
Speed (km/hr)		30	0.13	0.13	0.12	0.20
			0.09	0.10		0.14
			0.10	0.10		0.16
			0.09	0.10		0.14
			0.13	missed		0.28
	Average		**0.12**	**0.12**	**0.14**	**0.19**

Friday, January 18, 2002

Surface - Bare Ice/ABS on

Test Run Data			MKIII	MKII	Bowmonk	Tapley
Vehicle	Blazer, as is, abs on		0.15	0.15	0.16	0.23
Date		Friday, January 18, 2002	0.11	0.10	0.12	0.20
Start		9:05	0.11	missed	0.15	missed
Stop		9:25	0.12	0.12	0.14	0.09
Location	13-31		0.12	0.11	0.15	0.25
Type of Surface	Bare Ice		0.13	0.13	0.15	0.22
Depth of Snow	N/A		0.11	0.12	0.13	0.22
Snow Density	N/A		0.12	0.13	0.14	0.20
Air Temp (celsius)		-9	0.10	0.12	0.14	0.19
Surf Temp (celsius)			0.11	0.13		0.22
Speed (km/hr)			missed	0.15		0.22
		30	0.14	missed		0.20
			0.12	0.11		0.20
			0.12	0.14		0.20
			0.14	0.15		0.22
			0.13	0.13		0.19
			0.12	0.14		0.20
			0.11			
	Average		**0.12**	**0.13**	**0.14**	**0.20**

Tuesday, January 15, 2002

Surface - Compact Snow/ABS off

Test Run Data			**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date		Tuesday, January 15, 2002	0.24	0.25		
Vehicle	blazer, as-is, abs off		0.23	0.24		
Start Time		18:41	0.21	0.22		
Stop Time			0.23	0.20		
Air Temp (celsius)		-9.3	0.25	0.25		
Ground Temp (celsius)			0.22	0.22		
Snow Density	N/A		0.21	0.25		
Test Surface	compact snow		0.29	0.28		
Time to perform test runs (min)			0.25	0.23		
Number of runs conducted		18	0.30	0.31		
Description of skids	better direction control than on ice		0.27	0.29		
Windspeed and direction	300, 7 knots northwest		0.29	0.30		
Vehicle Direction and speed	40 km/hr in southeast direction		0.26	0.28		
Notes	some light snowfall		0.19	0.20		
			0.24	0.25		
			0.23	0.23		
			0.19	0.20		
			0.22	0.22		
	Average		**0.24**	**0.25**		

Test Run Data			**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date		Tuesday, January 15, 2002	0.20			
Vehicle	Blazer, as-is, abs off		0.25			
Start Time		14:36	0.19			
Stop Time		14:46	0.20			
Air Temp (celsius)		-8	0.23			
Ground Temp (celsius)			0.23			
Snow Density	N/A		0.23			
Test Surface	compacted snow		0.22			
Time to perform test runs (min)		10	0.26			
Number of runs conducted		21	0.25			
Description of skids	loss of directional control		0.25			
Windspeed and direction			0.24			
Vehicle Direction and speed	40 km/hr in southeast direction		0.26			
Notes:	MK II out of commision, mistake		0.25			
	wiring		0.22			
			0.21			
			0.22			
			0.24			
			0.24			
			0.25			
			0.22			
	Average		**0.23**			

Tuesday, January 15, 2002

Surface - Compact Snow/ABS on

Test Run Data			**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date		Tuesday, January 15, 2002	0.24			
Vehicle	Blazer, as-is, abs on		0.24			
Start Time		14:50	0.19			
Stop Time		15:00	0.24			
Air Temp (celsius)			0.24			
Ground Temp (celsius)			0.26			
Snow Density	N/A		0.22			
Test Surface	compacted snow		0.19			
Time to perform test runs (min)		10	0.22			
Number of runs conducted		21	0.26			
Description of skids	loss of directional control		0.24			
Windspeed and direction			0.21			
Vehicle Direction and speed	40 km/hr in southeast direction		0.29			
Notes:	MK II out of commision, mistake		0.22			
	wiring		0.20			
			0.27			
			0.26			
			0.22			
			0.23			
			0.27			
			0.27			
	Average		**0.24**			

Wednesday, January 16, 2002					
	Surface - Compact Snow/ABS off				
Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Wednesday, January 16, 2002	0.32	0.33	0.32	0.38
Vehicle	blazer, as-is, abs off	0.31	0.32	0.32	0.36
Start Time	9:50	0.33	0.33	0.33	missed
Stop Time	10:06	0.33	0.34	0.35	0.36
Air Temp (celsius)	-17	0.33	0.33	0.32	0.39
Ground Temp (celsius)	-11	0.33	0.34	0.34	0.36
Snow Density	N/A	0.31	0.32	0.31	0.36
Test Surface	compact snow with 1"-2" loose snow on top	0.33	0.33	0.33	0.35
Time to perform test runs (min)	24	missed	0.34	0.34	0.38
Number of runs conducted	18	0.34	0.34	0.34	0.38
Description of skids	straight skid	0.33	0.34	0.35	0.38
Windspeed and direction	calm	0.34	0.34	0.34	0.38
Vehicle Direction and speed	30 km/hr in southeast direction	0.33	0.33	0.32	0.36
Notes	Travelled 30km/hr	0.32	0.36	0.37	0.38
		0.36	0.31	0.31	0.42
		0.32	0.32	0.32	0.35
		0.31	0.32	0.33	0.36
		0.31			0.38
	Average	**0.33**	**0.33**	**0.33**	**0.37**

Wednesday, January 16, 2002

Surface - Sanded Bare Ice/ABS off

Test Run Data			**MKIII**	**MKII**
Vehicle	Blazer, as is, ABS off		0.22	0.23
Date		Wednesday, January 16, 2002	0.29	0.28
Start		13:15	0.22	0.20
Stop		13:26	0.20	0.18
Location	13-31		0.24	0.23
Type of Surface	Sanded Bare Ice		0.22	0.23
Depth of Snow	n/a		0.26	0.24
Snow Density	n/a		0.25	0.23
Air Temp (celsius)			0.25	missed
Wind	calm		0.20	0.15
Skid description	skid in straight line		0.22	0.21
Vehicle Speed	40 Km/hr southeast		0.26	0.23
			0.31	0.30
			0.31	0.29
			0.30	0.24
			0.26	0.25
			0.26	0.29
			0.27	0.25
			0.25	0.26
			0.28	0.22
			0.24	
	Average		**0.25**	**0.24**

Test Run Data			**MKIII**	**MKII**	**Location**
Vehicle	Blazer,as is, abs off		0.22	0.23	Lane 1
Date		Wednesday, January 16, 2002	0.25	0.25	Lane 1
Start		16:25	0.20	0.21	Lane 1
Stop		16:33	0.23	0.24	Lane 2
Location	13-31		0.20	0.21	Lane 2
Type of Surface	Sanded Bare Ice		0.23	0.24	Lane 2
Depth of Snow	n/a		0.17	0.18	Lane 3
Snow Density	n/a		0.20	0.21	Lane 3
Air Temp (celsius)			0.22	0.23	Lane 3
Wind			0.26	0.27	Lane 4
Skid description			0.25	0.27	Lane 4
Vehicle Speed	40 km/hr southeast		0.23	0.24	Lane 4
Notes	Test to see if surface conditions		0.26	0.28	Lane 5
	have changed, 3 readings per		0.26	0.27	Lane 5
	vehicle track		0.28	0.30	Lane 5
	Average		**0.23**	**0.24**	

Wednesday, January 16, 2002

Surface - Sanded Bare Ice/ABS on

Test Run Data			**MKIII**	**MKII**	**Location**
Vehicle	Blazer,as is, abs on		0.25	0.25	Lane 1
Date		Wednesday, January 16, 2002	0.28	0.30	Lane 1
Start		16:34	0.25	0.26	Lane 1
Stop		16:47	0.25	0.26	Lane 2
Location	13-31		0.23	0.23	Lane 2
Type of Surface	Sanded Bare Ice		0.17	0.18	Lane 2
Depth of Snow	n/a		0.23	0.25	Lane 3
Snow Density	n/a		0.23	0.26	Lane 3
Air Temp (celsius)			0.23	0.24	Lane 3
Wind			0.23	0.24	Lane 4
Skid description			0.27	0.28	Lane 4
Vehicle Speed	40 km/hr southeast		0.23	0.24	Lane 4
Notes	Test to see if surface conditions		0.28	0.30	Lane 5
	have changed, 3 readings per vehicle track		0.28	0.29	Lane 5
			0.25	0.26	Lane 5
	Average		**0.24**	**0.26**	

Wednesday, January 16, 2002				
	Surface - Sanded Compact Snow/ABS off			
Test Run Data		**MKIII**	**MKII**	**Location**
Vehicle	Blazer, abs off, as is	0.30	0.31	Lane 1
Date	Wednesday, January 16, 2002	0.27	0.29	Lane 1
Start	16:25	0.23	0.25	Lane 1
Stop	16:33	0.28	0.30	Lane 2
Location	13-31	0.30	0.29	Lane 2
Type of Surface	Sanded compact snow	0.23	0.24	Lane 2
Depth of Snow	n/a	0.30	0.32	Lane 3
Snow Density	n/a	0.36	0.37	Lane 3
Air Temp (celsius)		0.26	0.28	Lane 3
Wind		0.31	0.32	Lane 4
Skid description		0.34	0.36	Lane 4
Vehicle Speed	40 Km/hr southeast	0.28	0.29	Lane 4
Notes	Used as a reference to	0.37	0.39	Lane 5
	see if surface changed 3 tests in 5 test lanes	0.31	0.31	Lane 5
		0.30	0.31	Lane 5
	Average	**0.30**	**0.31**	

Wednesday, January 16, 2002				
	Surface - Sanded Compact Snow/ABS on			
Test Run Data		**MKIII**	**MKII**	**Location**
Vehicle	Blazer, abs on, as is	0.33	0.32	Lane 1
Date	Wednesday, January 16, 2002	0.36	0.33	Lane 1
Start	17:06	0.24	0.25	Lane 1
Stop	17:16	0.35	0.29	Lane 2
Location	13-31	0.27	0.28	Lane 2
Type of Surface	Sanded compact snow	0.25	0.26	Lane 2
Depth of Snow	n/a	0.34	0.34	Lane 3
Snow Density	n/a	0.33	0.33	Lane 3
Air Temp (celsius)		0.28	0.28	Lane 3
Wind		0.31	0.32	Lane 4
Skid description		0.29	missed	Lane 4
Vehicle Speed	40 Km/hr southeast	0.31	0.31	Lane 4
Notes	Used as a reference to	0.29	0.30	Lane 5
	see if surface changed 3 tests in 5 test lanes	0.29	0.29	Lane 5
		0.25	0.27	Lane 5
	Average	**0.30**	**0.30**	

Test Run Data		**MKIII**	**MKII**
Vehicle	Blazer, as is, ABS off	0.33	0.32
Date	Wednesday, January 16, 2002	0.35	0.31
Start	13:30	0.31	0.29
Stop	13:38	0.34	0.32
Location	13-31	0.32	0.30
Type of Surface	Sanded compact snow	0.34	0.32
Depth of Snow	n/a	0.33	0.31
Snow Density	n/a	0.34	0.32
Air Temp (celsius)	-12	0.30	0.27
Wind	calm	0.30	0.28
Skid description	skid in straight line	0.30	0.28
Vehicle Speed	40 Km/hr southeast	0.32	0.30
		0.29	0.27
		0.28	0.25
		0.30	0.28
		0.31	0.32
		0.32	0.31
		0.31	0.30
		0.33	0.31
		0.32	0.31
	Average	**0.32**	**0.30**

Thursday, January 17, 2002

Surface - Sanded Compact Snow/ABS off

Test Run Data			**MKIII**	**MKII**
Vehicle	Blazer, as is, abs off		0.25	missed
Date		Thursday, January 17, 2002	0.30	missed
Start		13:46	0.32	0.32
Stop		13:52	0.29	0.30
Location	13-31		0.29	0.31
Type of Surface	Sanded Compact Snow		0.29	0.29
Depth of Snow	N/A		0.24	0.24
Snow Density	N/A		0.30	0.30
Air Temp (celsius)			0.29	0.30
Surf Temp (celsius)			0.31	0.33
Speed (km/hr)		40	0.25	0.26
Notes			0.27	0.28
			0.26	0.27
			0.29	0.29
			0.27	0.27
	Average		**0.28**	**0.29**

Test Run Data			**MKIII**	**MKII**
Vehicle	Blazer, as is, abs off		0.33	missed
Date		Thursday, January 17, 2002	0.40	0.40
Start		16:28	0.40	0.39
Stop		16:38	0.33	0.33
Location	13-31		0.36	0.38
Type of Surface	Sanded Compact Snow		0.40	0.39
Depth of Snow	N/A		0.33	0.34
Snow Density	N/A		0.40	0.41
Air Temp (celsius)		-4.9	0.28	0.29
Surf Temp (celsius)			0.37	0.39
Speed (km/hr)		40	0.37	0.36
			0.34	0.33
			0.34	0.34
			0.33	0.33
			0.36	0.36
	Average		**0.36**	**0.36**

Thursday, January 17, 2002

Surface - Sanded Compact Snow/ABS on

Test Run Data			MKIII	MKII
Vehicle	Blazer, as is, abs on		missed	0.28
Date		Thursday, January 17, 2002	0.29	0.30
Start		13:58	0.26	0.24
Stop		14:07	0.23	missed
Location	13-31		0.24	0.25
Type of Surface	Sanded Compact Snow		0.32	0.28
Depth of Snow	N/A		0.20	0.22
Snow Density	N/A		0.24	0.25
Air Temp (celsius)		-4.9	0.32	0.32
Surf Temp (celsius)			0.31	0.31
Speed (km/hr)		40	0.28	0.29
			0.28	0.26
			0.27	0.27
			0.31	0.29
			0.28	0.27
	Average		**0.27**	**0.27**

Test Run Data			MKIII	MKII	Location
Vehicle	Blazer, as is, abs on		0.35	0.35	Lane 1
Date		Thursday, January 17, 2002	0.30	0.30	Lane 1
Start		16:38	0.35	0.34	Lane 1
Stop		16:48	0.31	0.30	Lane 2
Location	13-31		0.35	0.35	Lane 2
Type of Surface	Sanded Compact Snow		0.35	0.34	Lane 2
Depth of Snow	N/A		0.34	0.34	Lane 3
Snow Density	N/A		0.38	0.39	Lane 3
Air Temp (celsius)		-6	0.28	0.27	Lane 3
Surf Temp (celsius)			0.31	0.31	Lane 4
Speed (km/hr)		40	0.35	0.35	Lane 4
Notes	3 readings per vehicle		0.36	0.37	Lane 4
	track, 15 readings total		0.35	0.36	Lane 5
			0.35	0.36	Lane 5
			0.34	0.32	Lane 5
	Average		**0.34**	**0.34**	

Friday, January 18, 2002

Surface - Sanded Compact Snow/ABS off

Test Run Data			MKIII	MKII	Bowmonk	Tapley
Vehicle	Blazer, as is, abs off		0.31	0.31	0.34	0.42
Date		Friday, January 18, 2002	0.31	0.31	0.33	0.39
Start		9:45	0.30	0.30	0.34	0.41
Stop		9:56	0.30	0.30	0.32	0.36
Location	13-31		0.23	0.23	0.29	0.35
Type of Surface	Sanded Compact Snow		0.28	0.28	0.31	0.36
Depth of Snow	N/A		0.34	0.34	0.35	0.41
Snow Density	N/A		0.33	0.34	0.35	0.41
Air Temp (celsius)		-9	0.30	0.30	0.32	0.39
Surf Temp (celsius)			0.27	0.27	0.29	0.33
Speed (km/hr)		30	0.30	0.30	0.32	0.38
			0.27	0.28	0.29	0.33
			0.30	0.31	0.35	0.39
			0.31	0.31	0.33	0.38
			0.30	0.31	0.32	0.39
			0.30	0.30	0.26	0.36
			0.25	0.24	0.29	0.30
			0.24	0.23		0.33
	Average		**0.29**	**0.29**	**0.32**	**0.37**

Friday, January 18, 2002

Surface - Sanded Compact Snow/ABS on

Test Run Data			MKIII	MKII	Bowmonk	Tapley
Vehicle	Blazer, as is, abs on		0.33	0.33	0.33	0.39
Date		Friday, January 18, 2002	0.32	0.33	0.35	0.41
Start		9:59	0.33	0.31	0.36	0.42
Stop		10:10	0.32	0.33	0.36	0.41
Location	13-31		0.29	0.30	0.32	0.36
Type of Surface	Sanded Compact Snow		0.30	0.30	0.33	0.38
Depth of Snow	N/A		0.35	0.35	0.37	0.43
Snow Density	N/A		0.32	0.34	0.37	0.42
Air Temp (celsius)		-9	0.33	0.34	0.37	0.43
Surf Temp (celsius)			0.29	0.29	0.34	0.41
Speed (km/hr)		30	missed	0.31	0.37	0.42
			0.32	0.30	0.34	0.39
			0.30	0.32	0.38	0.45
			0.33	0.32	0.36	0.42
			0.32	0.31	0.34	0.38
			0.30	0.33	0.37	0.41
			0.32	0.28	0.33	0.36
			0.28			
	Average		**0.31**	**0.32**	**0.35**	**0.41**

APPENDIX B

RAW TEST DATA:
HALF TON PICKUP TRUCK

Tuesday, January 15, 2002

Surface - Bare Ice/ABS off

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.11	0.09		
Vehicle	1/2 Ton, as-is, abs off	0.11	0.11		
Start Time	10:20	0.10	0.10		
Stop Time	10:35	0.09	0.08		
Air Temp (celsius)	-6.2	0.11	0.10		
Ground Temp (celsius)	-5.9	0.11	0.10		
Snow Density	N/A	0.12	0.13		
Test Surface	bare ice with some snow patches	0.12	0.12		
Time to perform test runs (min)	15	0.09	missed		
Number of runs conducted	16-21	0.07	0.06		
Description of skids	fish tailing	0.09	missed		
Windspeed and direction	North, 5 knots	0.08	missed		
Vehicle Direction and speed	40 km/hr in southeast direction	0.07	0.08		
Notes:	had to maintain direction stability	0.08	missed		
	to get readings from MKII, if	0.08	0.08		
	vehicle spun out than no lost	0.07	0.06		
	reading, also tried to prevent	0.10	0.11		
	loss of directional control	0.07	0.06		
	which would cause us to end up in	0.06	0.05		
	a snow bank and reduce travel in wheel tracks	0.10	missed		
		0.09	0.08		
	Average	**0.09**	**0.09**		

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.14	0.14		
Vehicle	1/2 ton, as-is, abs off	0.14	0.16		
Start Time	17:20	0.11	0.12		
Stop Time	17:34	0.12	0.13		
Air Temp (celsius)	-6.5	0.16	0.16		
Ground Temp (celsius)	-5	0.09	0.10		
Snow Density	N/A	0.14	0.15		
Test Surface	bare ice with some snow patches	0.17	0.19		
Time to perform test runs (min)	11	0.15	0.17		
Number of runs conducted	17-18	0.15	0.16		
Description of skids	fish tailing	0.21	0.22		
Windspeed and direction		0.13	0.14		
Vehicle Direction and speed	40 km/hr in southeast direction	0.19	0.19		
Notes:	Sky is dark and some light snow	0.18	0.19		
		0.17	0.20		
		0.13	0.14		
		0.16	0.17		
		0.16	0.17		
	Average	**0.15**	**0.16**		

Tuesday, January 15, 2002

Surface - Bare Ice / ABS off / 50:50 Weight Distribution

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.11			
Vehicle	1/2 ton Pickup, abs off, weight 50:50	0.11			
Start Time	16:35	0.10			
Stop Time	16:45	0.19			
Air Temp (celsius)		0.14			
Ground Temp (celsius)	-5	0.07			
Snow Density	N/A	0.12			
Test Surface	bare ice with some snow patches	0.13			
Time to perform test runs (min)	10	0.14			
Number of runs conducted	13	0.10			
Description of skids	some fishtailing	missed			
Windspeed and direction		0.17			
Vehicle Direction and speed	40 km/hr in southeast direction	0.13			
Notes		missed			
		0.17			
	Average	**0.13**			

Tuesday, January 15, 2002

Surface - Bare Ice / ABS on		MK III	MK II	Bowmonk	Tapley
Test Run Data					
Date	Tuesday, January 15, 2002	0.14	0.15		
Vehicle	1/2 ton, as-is, abs on	0.14	0.14		
Start Time	17:43	0.14	0.15		
Stop Time	17:54	0.17	0.17		
Air Temp (celsius)	-6	0.16	0.16		
Ground Temp (celsius)	-5	0.11	0.12		
Snow Density	N/A	0.17	0.17		
Test Surface	bare ice with some snow patches	0.14	0.15		
Time to perform test runs (min)	11	0.17	0.18		
Number of runs conducted	17-18	0.14	0.14		
Description of skids	straight skids	0.16	0.16		
Windspeed and direction		0.17	0.17		
Vehicle Direction and speed	40 km/hr in southeast direction	0.16	missed		
Notes:	Sky is dark and some light snow	0.18	0.18		
		0.17	0.17		
		0.16	0.16		
		0.18	0.18		
		0.14	0.13		
	Average	**0.16**	**0.16**		

Wednesday, January 16, 2002

Surface - Bare Ice / ABS off		MK III	MK II	Bowmonk	Tapley
Test Run Data					
Date	Wednesday, January 16, 2002	0.13	0.14	0.24	0.25
Vehicle	1/2 ton, as-is, abs off	0.19	0.19	0.17	0.30
Start Time	10:30 AM	0.16	0.16	0.20	0.20
Stop Time	10:42 AM	0.14	0.14	0.22	0.23
Air Temp (celsius)	-17	0.17	0.17	0.18	0.23
Ground Temp (celsius)	-7.5	0.15	0.15	0.16	0.28
Snow Density	N/A	0.15	0.15	0.16	0.22
Test Surface	Bare Ice, with some snow patches	0.13	0.13	0.16	0.20
Time to perform test runs (min)	12	0.13	0.14	0.14	0.19
Number of runs conducted		0.13	0.14	0.22	0.23
Description of skids	not a straight skid, almost spun out once	0.12	0.13	0.22	0.22
Windspeed and direction	calm	0.13	0.14	0.23	0.23
Vehicle Direction and speed	30 km/hr in southeast direction	0.13	0.13		0.19
Notes	Went at 30km/hr, bowmark lost some	0.17	0.14		0.28
	readings	0.17	0.17		0.28
		0.18	0.17		0.28
		0.13	0.13		0.22
		0.20	0.19		0.28
	Average	**0.15**	**0.15**	**0.19**	**0.24**

Thursday, January 17, 2002

Surface - Bare Ice / ABS on		MKIII	MKII
Test Run Data			
Vehicle	1/2 ton , as is, abs on	0.10	0.08
Date	Thursday, January 17, 2002	0.12	0.12
Start	14:12	0.10	0.09
Stop	14:22	0.12	0.10
Location	13-31	0.14	0.13
Type of Surface	Bare Ice	0.09	0.08
Depth of Snow	N/A	0.10	0.09
Snow Density	N/A	0.09	0.08
Air Temp (celsius)	-5.1	0.11	0.10
Surf Temp (celsius)	-4.8	0.14	missed
Speed (km/hr)	40	0.10	0.08
		0.10	0.09
		0.10	0.10
		0.11	0.07
		0.13	0.12
	Average	**0.11**	**0.10**

Thursday, January 17, 2002				
	Surface - Bare Ice / ABS off			
Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton , as is, abs off		0.09	0.09
Date		Thursday, January 17, 2002	0.09	0.08
Start		14:31	0.09	0.08
Stop		14:37	0.09	0.09
Location	13-31		0.11	0.10
Type of Surface	Bare Ice		0.09	0.09
Depth of Snow	N/A		0.09	0.08
Snow Density	N/A		0.09	0.08
Air Temp (celsius)		-5.1	0.10	0.09
Surf Temp (celsius)		-4.8	0.11	0.10
Speed (km/hr)		40	0.08	0.07
			0.08	0.07
			0.09	0.08
			0.09	0.09
			0.09	0.08
	Average		**0.09**	**0.08**

Friday, January 18, 2002						
	Surface - Bare Ice / ABS on					
Test Run Data			**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1/2 ton, as-is, abs on		0.08	0.08	0.11	0.14
Date		Friday, January 18, 2002	0.09	0.08	0.11	0.16
Start		10:45	0.10	0.08	0.11	0.16
Stop		11:00	0.14	0.14	0.16	0.17
Location	13-31		0.11	0.11	0.13	0.17
Type of Surface	Bare Ice		0.10	0.10	0.11	0.13
Depth of Snow	N/A		0.11	0.10	0.12	0.19
Snow Density	N/A		0.11	0.11	0.16	0.16
Air Temp (celsius)		-9	0.13	0.13	0.14	0.14
Surf Temp (celsius)			0.11	0.11		0.16
Speed (km/hr)		30	0.08	0.07		0.17
			0.12	0.12		0.16
			0.13	0.12		0.14
			0.11	0.11		0.16
			missed	missed		0.17
			0.09	0.07		
			0.14	0.13		
	Average		**0.11**	**0.10**	**0.13**	**0.16**

Friday, January 18, 2002						
	Surface - Bare Ice / ABS off					
Test Run Data			**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1/2 ton, as-is, abs off		0.10	0.10	0.11	0.14
Date		Friday, January 18, 2002	0.11	0.11	0.11	0.16
Start		10:15	0.11	0.11	0.12	0.17
Stop		10:32	0.11	0.11	0.11	0.16
Location	13-31		0.11	0.11	0.16	0.14
Type of Surface	Bare Ice		0.11	0.10		0.20
Depth of Snow	N/A		0.11	0.11		0.16
Snow Density	N/A		0.11	0.10		0.14
Air Temp (celsius)		-9	0.11	0.10		0.16
Surf Temp (celsius)			0.10	0.10		0.16
Speed (km/hr)		30	0.10	0.09		0.16
			0.10	0.10		0.17
			0.10	0.10		0.16
			0.12	0.12		0.17
			0.11	0.10		0.17
	Average		**0.11**	**0.10**	**0.12**	**0.16**

Tuesday, January 15, 2002

Surface - Compact Snow / ABS off / 50:50 Weight Distribution

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.20	0.24		
Vehicle	1/2 ton pickup, weighted 50:50, abs off	0.20	0.23		
Start Time	16:49	0.22	0.10		
Stop Time	17:01	0.23	0.32		
Air Temp (celsius)		0.25	0.26		
Ground Temp (celsius)	-5	0.21	0.31		
Snow Density	N/A	0.29	0.24		
Test Surface	compact snow, 1.5 " thick	0.29			
Time to perform test runs (min)	12	0.23			
Number of runs conducted	18	0.27			
Description of skids	incomplete directional control	0.27			
Windspeed and direction		0.26			
Vehicle Direction and speed	40 km/hr in southeast direction	0.22			
Notes	some light snowfall	0.30			
	The friction values for the MKIII and MK II did not	0.25			
	match up the MKII lost a number of reading	0.25			
	most likely due to fishtailing	0.30			
		0.22			
	Average	**0.25**	**0.24**		

Tuesday, January 15, 2002

Surface - Compact Snow / ABS off

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.27	0.29		
Vehicle	1/2 ton pickup, as-is, abs off	missed	0.33		
Start Time	17:03	0.24	0.25		
Stop Time	17:17	0.21	0.23		
Air Temp (celsius)	-6	0.30	0.31		
Ground Temp (celsius)	-4.5	0.25	0.26		
Snow Density	N/A	0.25	0.26		
Test Surface	compact snow, 1.5 " thick	0.30	0.30		
Time to perform test runs (min)	12	0.28	0.29		
Number of runs conducted	17-18	0.18	missed		
Description of skids	fish tailing	0.25	0.27		
Windspeed and direction		0.29	0.29		
Vehicle Direction and speed	40 km/hr in southeast direction	0.28	0.28		
Notes		0.30	0.32		
		0.30	0.30		
		0.21	0.22		
		0.26	0.25		
		0.20	0.20		
	Average	**0.26**	**0.27**		

Tuesday, January 15, 2002

Surface - Compact Snow / ABS on

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.31	0.31		
Vehicle	1/2 ton pickup, as-is, abs on	0.31	0.30		
Start Time	18:00	0.23	0.23		
Stop Time	18:12	0.23	missed		
Air Temp (celsius)	-6	0.24	0.25		
Ground Temp (celsius)	-5	0.25	0.25		
Snow Density	N/A	0.27	0.27		
Test Surface	compact snow, 1.5 " thick	0.23	0.24		
Time to perform test runs (min)	12	0.26	0.26		
Number of runs conducted	17-18	0.26	0.26		
Description of skids	complete directional control	0.26	0.25		
Windspeed and direction		0.27	0.27		
Vehicle Direction and speed	40 km/hr in southeast direction	0.25	0.26		
Notes	some light snowfall	0.26	0.25		
		0.24	0.24		
		0.24	0.24		
		0.25	0.24		
		0.23	0.23		
	Average	**0.26**	**0.26**		

Wednesday, January 16, 2002

Surface - Compact Snow / ABS off

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Wednesday, January 16, 2002	0.37	0.36	0.39	0.43
Vehicle	1/2 ton, as-is, abs off	0.37	0.35	0.37	0.42
Start Time	10:45	0.35	0.35	0.36	0.42
Stop Time	11:00	0.33	0.32	0.36	0.39
Air Temp (celsius)	-14	0.34	0.33	0.33	0.39
Ground Temp (celsius)	-12.5	0.37	0.36	0.37	0.41
Snow Density	0.15 g/ml	0.32	0.32	0.33	0.38
Test Surface	compact snow with 1"-2" loose snow on top	0.37	0.37	0.37	0.43
Time to perform test runs (min)	15	0.37	0.36	0.37	0.42
Number of runs conducted	18	0.37	0.37	0.36	0.41
Description of skids	straight skid	0.36	0.36	0.34	0.41
Windspeed and direction	140 degrees, 2 knots (southeast)	0.35	0.35	0.36	0.41
Vehicle Direction and speed	30 km/hr in southeast direction	0.34	0.33	0.32	0.38
Notes	Travelled 30km/hr	0.37	0.37	0.36	0.41
		0.37	0.38	0.37	0.42
		0.38	0.37	0.39	0.46
		0.38	0.38	0.38	0.42
		0.35	0.35	0.37	0.42
	Average	**0.36**	**0.35**	**0.36**	**0.41**

Wednesday, January 16, 2002

Surface - Sanded Bare Ice/ABS off

Test Run Data		**MKIII**	**MKII**
Vehicle	1/2 ton pickup, abs off, as is	0.30	0.30
Date	Wednesday, January 16, 2002	0.23	0.23
Start	14:46	0.26	0.27
Stop	14:55	0.31	0.31
Location	13-31	0.29	0.29
Type of Surface	Sanded Bare Ice	0.22	0.23
Depth of Snow	n/a	0.27	0.28
Snow Density	n/a	0.30	0.32
Air Temp (celsius)	-11	0.28	0.28
Wind	calm	0.24	0.27
Skid description	skid in straight line	0.23	0.24
Vehicle Speed	40 km/hr southeast	0.21	0.20
		0.22	0.23
		0.26	0.26
		0.24	0.24
		0.25	0.25
		0.25	0.26
		0.23	0.23
		0.23	0.24
		0.26	0.26
	Average	**0.25**	**0.26**

Test Run Data		**MKIII**	**MKII**
Vehicle	1/2 ton, abs off, as is	0.20	0.20
Date	Wednesday, January 16, 2002	0.20	0.20
Start	17:25	0.18	0.18
Stop	17:37	0.29	0.29
Location	13-31	0.24	0.24
Type of Surface	Sanded Bare Ice	0.17	0.19
Depth of Snow	n/a	0.22	missed
Snow Density	n/a	0.18	0.20
Air Temp (celsius)		0.16	0.18
Wind		0.20	0.21
Skid description		0.24	0.23
Vehicle Speed	40 km/hr southeast	0.20	0.21
Notes		0.26	0.25
		0.25	0.25
		0.27	0.27
	Average	**0.22**	**0.22**

Wednesday, January 16, 2002

Surface - Sanded Bare Ice/ABS on

Test Run Data		**MKIII**	**MKII**
Vehicle	1/2 ton, abs on, as is	0.26	0.26
Date	Wednesday, January 16, 2002	0.25	0.25
Start	17:53	0.24	0.25
Stop	18:01	0.23	0.22
Location	13-31	0.22	0.23
Type of Surface	Sanded Bare Ice	0.18	0.19
Depth of Snow	n/a	0.22	0.23
Snow Density	n/a	0.18	0.18
Air Temp (celsius)		0.17	0.18
Wind		0.21	0.22
Skid description		0.22	0.24
Vehicle Speed	40 km/hr southeast	0.24	0.25
Notes		0.21	0.21
		0.24	0.25
		0.23	0.25
	Average	**0.22**	**0.23**

Wednesday, January 16, 2002				
	Surface - Sanded Bare Ice / ABS off / Weight Distribution 50:50			
Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton pickup, abs off, 50:50		0.26	0.27
Date		16-Jan-02	0.26	missed
Start		15:12	0.23	0.23
Stop		15:22	0.23	0.24
Location	13-31		0.30	0.30
Type of Surface	Sanded Bare Ice		0.25	0.25
Depth of Snow	n/a		0.21	0.21
Snow Density	n/a		0.26	0.26
Air Temp (celsius)		-12	0.19	0.20
Wind			0.20	0.21
Skid description			0.26	0.27
Vehicle Speed	40 km/hr southeast		0.27	0.28
			0.22	0.22
			0.21	0.22
			0.21	missed
			0.31	0.32
			0.31	0.32
			0.25	0.26
			0.23	0.25
			0.21	0.22
	Average		**0.24**	**0.25**

Wednesday, January 16, 2002

Surface - Sanded Compact Snow/ABS off

Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton, abs off, as is		0.34	0.34
Date		Wednesday, January 16, 2002	0.37	0.37
Start		14:57	0.31	0.31
Stop		15:06	0.33	0.34
Location	13-31		0.31	0.34
Type of Surface	Sanded compact snow		0.35	0.35
Depth of Snow	n/a		0.32	0.32
Snow Density	n/a		0.33	0.33
Air Temp (celsius)			0.30	0.31
Wind			0.28	0.28
Skid description			0.30	0.30
Vehicle Speed	40 Km/hr southeast		0.33	0.33
Notes	Light Snow fall		0.34	0.34
			0.33	0.33
			0.27	0.28
			0.30	0.30
			0.38	0.38
			0.32	0.33
			0.31	0.32
			0.30	0.30
	Average		**0.32**	**0.33**

Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton , abs off, as is		0.30	0.29
Date		Wednesday, January 16, 2002	0.31	0.34
Start		17:40	0.31	0.33
Stop		17:49	0.32	0.25
Location	13-31		0.33	0.34
Type of Surface	Sanded compact snow		0.25	0.27
Depth of Snow	n/a		0.28	0.28
Snow Density	n/a		0.32	0.32
Air Temp (celsius)			0.28	0.28
Wind			missed	missed
Skid description			0.32	0.34
Vehicle Speed	40 Km/hr southeast		0.31	0.32
Notes			0.32	0.31
			0.30	0.30
			0.30	0.31
	Average		**0.30**	**0.31**

Wednesday, January 16, 2002

Surface - Sanded Compact Snow / ABS off / Weight Distribution 50:50

Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton, abs off, 50:50		0.31	0.32
Date		Wednesday, January 16, 2002	0.30	0.31
Start		15:27	0.29	0.30
Stop		15:34	0.31	0.32
Location	13-31		0.31	0.33
Type of Surface	Sanded compact snow		0.29	0.29
Depth of Snow	n/a		0.32	0.32
Snow Density	n/a		0.28	0.28
Air Temp (celsius)			0.30	0.32
Wind			0.27	0.27
Skid description			0.33	0.33
Vehicle Speed	40 Km/hr southeast		0.31	0.32
Notes	Light Snow fall		0.33	0.33
			0.30	0.31
			0.29	0.30
			0.30	0.30
			0.31	0.32
			0.30	0.30
			0.28	0.29
			0.31	0.32
	Average		**0.30**	**0.31**

Wednesday, January 16, 2002				
	Surface - Sanded Compact Snow / ABS on			
Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton, abs on, as is		0.24	0.26
Date		Wednesday, January 16, 2002	0.29	0.29
Start		18:04	0.23	0.24
Stop		18:12	0.25	0.26
Location	13-31		0.27	0.27
Type of Surface	Sanded compact snow		0.26	0.27
Depth of Snow	n/a		0.25	0.27
Snow Density	n/a		0.25	0.27
Air Temp (celsius)			0.29	0.29
Wind			0.26	0.28
Skid description			0.25	0.26
Vehicle Speed	40 Km/hr southeast		0.27	0.29
Notes	Light Snow fall		0.27	0.28
			0.27	0.28
			0.26	0.27
	Average		**0.26**	**0.27**

Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton, as is, abs on		0.28	0.27
Date		Thursday, January 17, 2002	0.28	0.27
Start		14:23	0.28	0.27
Stop		14:30	0.28	0.26
Location	13-31		0.30	0.29
Type of Surface	Sanded Compact Snow		0.27	0.26
Depth of Snow	N/A		0.28	0.28
Snow Density	N/A		0.32	0.29
Air Temp (celsius)		-5.1	0.29	0.28
Surf Temp (celsius)			0.29	0.27
Speed (km/hr)		40	0.29	0.28
			0.29	0.27
			0.29	0.27
			0.29	0.28
			0.32	0.29
	Average		**0.29**	**0.28**

Thursday, January 17, 2002				
	Surface - Sanded Compact Snow / ABS off			
Test Run Data			**MKIII**	**MKII**
Vehicle	1/2 ton, as is, abs off		0.34	0.36
Date		Thursday, January 17, 2002	0.34	0.31
Start		14:38	missed	0.35
Stop		14:44	0.35	0.34
Location	13-31		0.33	0.31
Type of Surface	Sanded Compact Snow		0.30	0.29
Depth of Snow	N/A		0.37	0.36
Snow Density	N/A		0.30	0.29
Air Temp (celsius)		-5.1	0.35	missed
Surf Temp (celsius)			0.35	0.36
Speed (km/hr)		40	0.39	missed
Notes			0.35	0.33
			missed	0.35
			0.35	0.27
			0.33	missed
	Average		**0.34**	**0.33**

Friday, January 18, 2002						
	Surface - Sanded Compact Snow / ABS off					
Test Run Data			**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1/2 ton, as is, abs off		0.30	0.32	0.41	0.46
Date		Friday, January 18, 2002	0.40	0.39	0.40	0.43
Start		10:32	0.37	0.37	0.40	0.43
Stop		10:43	0.39	0.40	0.41	0.43
Location	13-31		0.38	0.38	0.40	0.43
Type of Surface	Sanded Compact Snow		0.33	0.32	0.41	0.45
Depth of Snow	N/A		0.39	0.39	0.41	0.43
Snow Density	N/A		0.38	0.39	0.39	0.42
Air Temp (celsius)			0.32	0.32	0.37	0.41
Surf Temp (celsius)			0.38	0.38	0.39	0.42
Speed (km/hr)		30	0.40	0.40	0.40	0.42
			0.33	0.33	0.38	0.42
			0.33	0.32	0.40	0.42
			0.36	0.37	0.39	0.43

Friday, January 18, 2002						
	Surface - Sanded Compact Snow / ABS on					
Test Run Data			**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1/2 ton, as is, abs on		0.35	0.34	0.37	0.43
Date		Friday, January 18, 2002	0.38	0.37	0.38	0.46
Start		11:01	0.36	0.35	0.41	0.42
Stop		11:14	0.38	0.38	0.40	0.42
Location	13-31		0.36	0.35	0.40	0.42
Type of Surface	Sanded Compact Snow		0.35	0.34	0.38	0.39
Depth of Snow	N/A		0.37	0.37	0.45	0.46
Snow Density	N/A		0.33	0.32	0.34	0.39
Air Temp (celsius)		-9	0.35	0.36	0.41	0.43
Surf Temp (celsius)			0.34	0.33	0.36	0.39
Speed (km/hr)		30	0.32	0.31	0.41	0.45
			0.32	0.32	0.34	0.39
			0.33	0.32	0.35	0.38
			0.39	0.38	0.41	0.43
			0.35	0.35	0.37	0.41
	Average		**0.35**	**0.35**	**0.39**	**0.42**

APPENDIX C

RAW TEST DATA:
THREE-QUARTER TON PICKUP TRUCK

Tuesday, January 15, 2002

Surface - Bare Ice/ABS off

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.10	0.10		
Vehicle	3/4 ton, abs off, as-is	0.09	0.09		
Start Time	11:00 AM	0.09	0.09		
Stop Time	11:14 AM	0.13	0.13		
Air Temp (celsius)	-6.2	0.15	0.16		
Ground Temp (celsius)	-5.9	0.12	0.12		
Snow Density	N/A	0.12	0.12		
Test Surface	bare ice with some snow patches	0.16	0.15		
Time to perform test runs (min)	14	0.11	0.11		
Number of runs conducted	16-17	0.12	0.12		
Description of skids	fish tailing	0.12	0.11		
Windspeed and direction	North, 5 knots	0.12	0.13		
Vehicle Direction and speed	40 km/hr in southeast direction	0.11	0.12		
Notes:	Better directional control than the	0.13	0.13		
	lighter vehicles	0.14	0.14		
		0.12	0.11		
		0.11	0.10		
		0.16	0.17		
	Average	**0.12**	**0.12**		

Wednesday, January 16, 2002

Surface - Bare Ice/ABS on

Test Run Data		**MKIII**	**MKII**
Vehicle	3/4 ton pickup, as is, abs on	0.08	0.12
Date	Wednesday, January 16, 2002	0.07	0.11
Start	15:43	0.08	missed
Stop	15:49	0.08	0.09
Location	13-31	0.09	0.09
Type of Surface	Bare Ice	0.10	0.10
Depth of Snow	N/A	0.08	0.06
Snow Density	N/A	missed	missed
Air Temp (celsius)	-5.2	0.10	missed
Surf Temp (celsius)	-4.5	0.10	0.09
		0.09	0.12
		0.08	0.07
		0.07	0.08
		0.10	0.09
		0.12	0.10
	Average	**0.09**	**0.09**

Thursday, January 17, 2002

Surface - Bare Ice/ABS off

Test Run Data		**MKIII**	**MKII**
Vehicle	3/4 ton pickup truck, as is, abs off	0.11	0.11
Date	Thursday, January 17, 2002	0.10	0.10
Start	15:27	0.09	0.09
Stop	15:36	0.09	0.09
Location	13-31	0.12	0.12
Type of Surface	Bare Ice	0.10	0.09
Depth of Snow	N/A	0.09	0.08
Snow Density	N/A	0.09	0.10
Air Temp (celsius)	-5.2	0.09	0.09
Surf Temp (celsius)	-4.5	0.12	0.13
Speed (km/hr)	40	0.09	0.10
		0.08	0.07
		0.08	0.08
		0.09	0.09
		0.10	0.10
	Average	**0.10**	**0.10**

Tuesday, January 15, 2002					
	Surface - Compact Snow / ABS off				
Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.27	0.28		
Vehicle	3/4 ton, ABS off, as-is, 4 wheel drive	0.24	0.20		
Start Time	16:10	0.28	0.29		
Stop Time	16:25	0.26	0.29		
Air Temp (celsius)		0.32	0.41		
Ground Temp (celsius)	-6	0.31	0.31		
Snow Density	N/A	0.27	0.26		
Test Surface	compact snow, 1.5 " thick	missed	0.26		
Time to perform test runs (min)	15	0.36	Not in Order		
Number of runs conducted	18	0.27	MKII		
Description of skids	incomplete directional control	0.38	malfunctioned		
Windspeed and direction	North 6 knots	0.31			
Vehicle Direction and speed	40 km/hr in southeast direction	0.30			
Notes	some light snowfall	0.30			
		0.27			
		0.28			
		0.26			
		0.29			
		0.27			
	Average	**0.29**	**0.29**		

Wednesday, January 16, 2002			
	Surface - Sanded Bare Ice / ABS off		
Test Run Data		**MKIII**	**MKII**
Vehicle	3/4 ton, as is, abs off	0.22	0.22
Date	Wednesday, January 16, 2002	0.20	0.20
Start	13:47	0.19	0.21
Stop	13:54	0.21	0.20
Location	13-31	0.17	0.18
Type of Surface	Sanded Bare Ice	0.25	0.26
Depth of Snow	n/a	0.22	0.22
Snow Density	n/a	0.15	0.16
Air Temp (celsius)	-12	0.17	0.17
Wind	calm	0.18	0.20
Skid description	skid in straight line	0.23	0.25
Vehicle Speed	40 km/hr southeast	0.21	0.21
		0.16	0.17
		0.15	0.15
		0.19	0.19
		0.27	0.27
		0.23	0.23
		0.16	0.15
		0.16	0.16
		0.21	0.21
	Average	**0.20**	**0.20**

Wednesday, January 16, 2002			
	Surface - Sanded Compact Snow / ABS off		
Test Run Data		**MKIII**	**MKII**
Vehicle	3/4 ton,abs off, as is	0.31	0.31
Date	Wednesday, January 16, 2002	0.36	0.34
Start	14:00	0.35	0.35
Stop	14:11	0.34	0.33
Location	13-31	0.30	0.31
Type of Surface	Sanded compact snow	0.30	0.28
Depth of Snow	n/a	0.31	0.32
Snow Density	n/a	0.31	0.32
Air Temp (celsius)	-12	0.34	0.35
Wind	calm	0.27	0.28
Skid description	skid in straight line	0.30	0.31
Vehicle Speed	40 Km/hr southeast	0.34	0.34
		0.27	0.27
		0.32	0.33
		0.24	0.25
		0.32	0.34
		0.31	0.30
		0.30	0.28
		0.32	0.32
		0.26	0.26
	Average	**0.31**	**0.31**

Thursday, January 17, 2002			
	Surface - Sanded Compact Snow / ABS off		
Test Run Data		**MKIII**	**MKII**
Vehicle	3/4 ton, as is, abs off	0.34	0.34
Date	Thursday, January 17, 2002	0.35	0.35
Start	15:36	0.29	0.28
Stop	15:41	0.36	0.36
Location	13-31	0.28	0.26
Type of Surface	Sanded Compact Snow	0.35	0.36
Depth of Snow	N/A	0.34	0.33
Snow Density	N/A	0.38	0.37
Air Temp (celsius)	-5.2	0.36	0.36
Surf Temp (celsius)	-4.5	0.29	0.34
Speed (km/hr)	40	0.40	0.41
Notes		0.39	0.41
		0.39	0.38
		0.36	0.38
		0.33	0.33
	Average	**0.35**	**0.35**

Thursday, January 17, 2002			
	Surface - Sanded Compact Snow / ABS on		
Test Run Data		**MKIII**	**MKII**
Vehicle	3/4 ton, as is, abs on	0.30	0.28
Date	Thursday, January 17, 2002	0.30	0.30
Start	15:50	0.32	0.33
Stop	15:55	0.30	0.32
Location	13-31	0.29	0.28
Type of Surface	Sanded Compact Snow	0.27	0.28
Depth of Snow	N/A	0.29	0.29
Snow Density	N/A	0.30	0.34
Air Temp (celsius)	-5.2	0.29	0.28
Surf Temp (celsius)	-4.5	0.29	0.28
Speed (km/hr)	40	missed	0.32
Notes		0.29	0.29
		0.32	0.30
		0.32	0.33
		0.27	0.27
	Average	**0.30**	**0.30**

APPENDIX D

RAW TEST DATA:
ONE TON PICKUP TRUCK

Tuesday, January 15, 2002

Surface - Bare Ice/ABS off					
Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.11			
Vehicle	1 ton pickup, abs off, as-is	0.16			
Start Time	13:20	0.14			
Stop Time	13:36	0.14			
Air Temp (celsius)	-5.8	0.12			
Ground Temp (celsius)	-2	0.12			
Snow Density	N/A	0.12			
Test Surface	bare ice with some snow patches	0.13			
Time to perform test runs (min)	16	0.16			
Number of runs conducted	21	0.15			
Description of skids	no fishtailing	0.15			
Windspeed and direction		0.13			
Vehicle Direction and speed	40 km/hr in southeast direction	0.15			
Notes:		0.13			
		0.12			
		0.14			
		0.13			
		0.11			
		0.12			
		0.11			
		0.10			
	Average	**0.13**			

Thursday, January 17, 2002

Surface - Bare Ice/ABS off					
Test Run Data		**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1 ton pickup truck, as is, abs off	0.08	0.07		
Date	Thursday, January 17, 2002	0.07	0.07		
Start	16:03	0.07	0.07		
Stop	16:10	0.06	0.06		
Location	13-31	0.08	0.07		
Type of Surface	Bare Ice	0.07	0.06		
Depth of Snow	N/A	0.08	0.07		
Snow Density	N/A	0.06	0.07		
Air Temp (celsius)		0.06	0.05		
Surf Temp (celsius)		0.08	0.07		
Speed (km/hr)	40	missed	0.06		
		0.06	missed		
		0.06	0.06		
		0.05	0.05		
		0.08	0.07		
	Average	**0.07**	**0.06**		

Wednesday, January 16, 2002					
	Surface - Sanded Bare Ice/ABS off				
Test Run Data		**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1 ton, as is, abs off	0.24	0.24		
Date	Wednesday, January 16, 2002	0.31	0.27		
Start	15:44	0.23	0.22		
Stop	15:52	0.24	0.25		
Location	13-31	0.28	0.28		
Type of Surface	Sanded Bare Ice	0.25	0.26		
Depth of Snow	n/a	0.23	0.25		
Snow Density	n/a	0.24	0.25		
Air Temp (celsius)	-12	0.25	0.24		
Wind		0.27	0.27		
Skid description		missed	0.24		
Vehicle Speed	40 km/hr southeast	0.23	0.23		
		0.22	0.21		
		0.25	0.25		
		0.23	0.22		
		0.24	0.24		
		0.26	0.26		
		0.25	0.25		
		0.26	0.26		
		0.27	0.25		
	Average	**0.25**	**0.25**		

Tuesday, January 15, 2002					
	Surface - Compact Snow/ABS off				
Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.15			
Vehicle	1 ton pickup truck,as is, no abs	0.16			
Start Time	13:40	0.19			
Stop Time	13:56	0.16			
Air Temp (celsius)		0.16			
Ground Temp (celsius)	-5.7	0.16			
Snow Density	N/A	0.17			
Test Surface	compact snow, 1.5 " thick	0.16			
Time to perform test runs (min)	20	0.16			
Number of runs conducted	17-18	0.16			
Description of skids	complete directional control	0.18			
Windspeed and direction		0.17			
Vehicle Direction and speed	40 km/hr in southeast direction	0.17			
Notes	some light snowfall	0.15			
		0.19			
		0.17			
		0.16			
		0.18			
		0.18			
		0.16			
	Average	**0.17**			

Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.20			
Vehicle	1 ton pickup, abs off, as is	0.24			
Start Time	done in early afternoon	0.23			
Stop Time					
Air Temp (celsius)					
Ground Temp (celsius)					
Snow Density	none taken				
Test Surface	compacted snow, with 1" of loose material				
Time to perform test runs (min)					
Number of runs conducted	3				
Description of skids	stable straight skids				
Vehicle Direction and speed	40 km/hr in southeast direction				
Notes:	Just took some readings to see the level of friction on surface				
	Average	**0.22**			

Wednesday, January 16, 2002					
	Surface - Sanded Compact Snow / ABS off				
Test Run Data		**MKIII**	**MKII**	**Bowmonk**	**Tapley**
Vehicle	1 ton, abs off, as is	0.28	0.27		
Date	Wednesday, January 16, 2002	0.26	0.26		
Start	15:54	0.26	0.26		
Stop	16:00	0.27	0.27		
Location	13-31	0.26	0.25		
Type of Surface	Sanded compact snow	0.27	0.28		
Depth of Snow	n/a	0.24	0.26		
Snow Density	n/a	0.26	0.25		
Air Temp (celsius)		0.23	0.23		
Wind		0.25	0.26		
Skid description		0.26	0.26		
Vehicle Speed	40 Km/hr southeast	0.25	0.24		
Notes		0.24	0.24		
		0.23	0.24		
		0.21	0.21		
		0.25	0.25		
		0.24	0.22		
		0.24	0.25		
		missed	0.24		
		0.25	0.24		
	Average	**0.25**	**0.25**		

Thursday, January 17, 2002			
	Surface - Sanded Compact Snow / ABS off		
Test Run Data		**MKIII**	**MKII**
Vehicle	1 ton, as is, abs off	missed	0.35
Date	Thursday, January 17, 2002	0.30	0.30
Start	16:10	0.29	0.29
Stop	16:15	0.28	0.28
Location	13-31	0.33	0.34
Type of Surface	Sanded Compact Snow	0.33	0.34
Depth of Snow	N/A	0.31	0.29
Snow Density	N/A	missed	0.31
Air Temp (celsius)		0.32	0.31
Surf Temp (celsius)		0.25	0.23
Speed (km/hr)	40	0.31	0.31
		0.33	0.32
		0.27	0.28
		0.26	0.26
		0.29	0.29
	Average	**0.30**	**0.30**

APPENDIX E

RAW TEST DATA:
MINIVAN

Tuesday, January 15, 2002					
	Surface - Bare Ice/ABS off				
Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.13	0.13		
Vehicle	Minivan, ABS off, as-is	0.09	0.10		
Start Time	11:34	0.15	0.15		
Stop Time	11:47	0.12	0.12		
Air Temp (celsius)	-6.2	0.18	0.21		
Ground Temp (celsius)	-5.9	0.17	0.18		
Snow Density	N/A	0.17	0.17		
Test Surface	bare ice with some snow patches	0.16	missed		
Time to perform test runs (min)	13	0.14	0.15		
Number of runs conducted	16-17	0.12	0.13		
Description of skids	fish tailing	0.11	0.12		
Windspeed and direction	North, 5 knots	0.12	missed		
Vehicle Direction and speed	40 km/hr in southeast direction	0.13	0.13		
Notes:		0.18	0.18		
		0.13	0.15		
		0.10	0.10		
		missed	0.17		
		0.10	0.13		
	Average	**0.14**	**0.15**		

Thursday, January 17, 2002					
	Surface - Bare Ice/ABS on				
Test Run Data		**MKIII**	**MKII**		
Vehicle	Minivan, abs on, as is	0.09	0.09		
Date	Thursday, January 17, 2002	0.08	0.09		
Start	14:53	0.09	0.10		
Stop	14:59	0.11	0.11		
Location	13-31	0.09	0.10		
Type of Surface	Bare Ice	0.09	0.08		
Depth of Snow	N/A	0.08	0.08		
Snow Density	N/A	0.08	0.10		
Air Temp (celsius)	-4.8	0.10	0.10		
Surf Temp (celsius)		0.10	0.11		
Speed (km/hr)	40	0.09	0.08		
		0.10	0.09		
		0.10	0.11		
		0.11	0.11		
		0.10	0.12		
	Average	**0.09**	**0.10**		

Thursday, January 17, 2002					
	Surface - Bare Ice/ABS off				
Test Run Data		**MKIII**	**MKII**		
Vehicle	Minivan, as is, abs off	0.08	0.10		
Date	Thursday, January 17, 2002	0.09	0.11		
Start	15:07	0.09	0.11		
Stop	15:12	0.10	missed		
Location	13-31	0.09	0.09		
Type of Surface	Bare Ice	0.09	missed		
Depth of Snow	N/A	0.08	0.07		
Snow Density	N/A	0.08	0.10		
Air Temp (celsius)	-6	0.08	0.10		
Surf Temp (celsius)	-4.5	0.11	0.11		
Speed (km/hr)	40	0.09	0.11		
		0.08	0.10		
		0.09	0.10		
		0.08	0.10		
		0.09	0.11		
	Average	**0.09**	**0.10**		

Tuesday, January 15, 2002					
	Surface - Compact Snow/ABS off				
Test Run Data		**MK III**	**MK II**	**Bowmonk**	**Tapley**
Date	Tuesday, January 15, 2002	0.27			
Vehicle	Minivan, As-is, no abs	0.24			
Start Time	15:45	0.27			
Stop Time	16:00	0.24			
Air Temp (celsius)		0.27			
Ground Temp (celsius)	-6	0.28			
Snow Density	N/A	0.28			
Test Surface	compact snow, 1.5 " thick	0.26			
Time to perform test runs (min)	20	0.28			
Number of runs conducted	20	0.23			
Description of skids	no fish tailing	0.27			
Windspeed and direction	North 6 knots	0.23			
Vehicle Direction and speed	40 km/hr in southeast direction	0.28			
Notes		0.30			
		0.29			
		0.25			
		0.29			
		missed			
		0.27			
		0.36			
		0.36			
	Average	**0.28**			

Wednesday, January 16, 2002					
	Surface - Sanded Bare Ice/ABS off				
Test Run Data		**MKIII**	**MKII**		
Vehicle	Minivan,as is, ABS off	0.17	0.18		
Date	Wednesday, January 16, 2002	0.19	0.19		
Start	14:18	0.18	0.19		
Stop	14:26	0.23	0.21		
Location	13-31	0.19	0.18		
Type of Surface	Sanded Bare Ice	0.25	0.26		
Depth of Snow	n/a	0.22	0.23		
Snow Density	n/a	0.17	0.19		
Air Temp (celsius)	-12	0.22	0.22		
Wind	calm	0.23	0.23		
Skid description	some loss of directional control	0.26	0.25		
Vehicle Speed	40 km/hr southeast	0.19	0.21		
		0.21	0.24		
		0.25	0.25		
		0.21	0.19		
		0.24	0.25		
		0.20	0.23		
		0.21	0.23		
		0.19	0.22		
		0.19	0.21		
	Average	**0.21**	**0.22**		

Wednesday, January 16, 2002					
	Surface - Sanded Compact Snow / ABS off				
Test Run Data		**MKIII**	**MKII**		
Vehicle	Minivan, abs off, as is	0.35	0.35		
Date	Wednesday, January 16, 2002	0.34	0.33		
Start	14:30	0.34	0.35		
Stop	14:36	0.31	0.30		
Location	13-31	0.30	0.28		
Type of Surface	Sanded compact snow	0.35	0.34		
Depth of Snow	n/a	0.33	0.34		
Snow Density	n/a	0.36	0.34		
Air Temp (celsius)		0.35	0.35		
Wind		0.30	0.30		
Skid description		0.35	0.34		
Vehicle Speed	40 Km/hr southeast	0.29	0.31		
		0.36	0.34		
		0.29	0.30		
		0.30	0.31		
		0.30	0.29		
		0.33	0.31		
		0.32	0.33		
		0.35	0.32		
		0.34	0.34		
	Average	**0.33**	**0.32**		

Thursday, January 17, 2002					
	Surface - Sanded Compact Snow / ABS off				
Test Run Data		**MKIII**	**MKII**		
Vehicle	Minivan, as is, abs off	0.40	0.39		
Date	Thursday, January 17, 2002	0.39	0.39		
Start	15:14	0.30	0.31		
Stop	15:21	0.46	0.45		
Location	13-31	0.37	0.37		
Type of Surface	Sanded Compact Snow	0.39	0.39		
Depth of Snow	N/A	0.39	0.40		
Snow Density	N/A	0.39	0.40		
Air Temp (celsius)		0.43	0.42		
Surf Temp (celsius)		0.39	0.38		
Speed (km/hr)	40	0.38	0.37		
		0.41	0.40		
		0.43	0.42		
		0.38	0.39		
		0.37	0.38		
	Average	**0.39**	**0.39**		

Thursday, January 17, 2002					
	Surface - Sanded Compact Snow / ABS on				
Test Run Data		**MKIII**	**MKII**		
Vehicle	Minivan, as is, abs on	0.35	0.35		
Date	Thursday, January 17, 2002	0.34	0.36		
Start	14:59	0.34	0.32		
Stop	15:05	0.35	0.35		
Location	13-31	0.30	0.31		
Type of Surface	Sanded Compact Snow	0.37	0.37		
Depth of Snow	N/A	0.34	0.34		
Snow Density	N/A	0.34	0.36		
Air Temp (celsius)	-4.8	0.37	0.38		
Surf Temp (celsius)		0.33	0.32		
Speed (km/hr)	40	0.38	0.40		
		0.36	0.38		
		missed	0.40		
		0.37	0.37		
		0.34	0.41		
	Average	**0.35**	**0.36**		