TRANSPORTATION
RESEARCH
CENTER

Winter Vehicle Traction and Controllability Performance

by

Jian John Lu

August 1995

FINAL REPORT

Report No. INE/TRC 94.03

INSTITUTE OF
NORTHERN
ENGINEERING

UNIVERSITY OF
ALASKA FAIRBANKS

FAIRBANKS, ALASKA
99775-5900

Technical Report Documentation Page

1. Report No. 94-R02	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Winter Tire Traction Evaluations		5. Reporting Date September 29, 1994 6. Performing Organization Code
7. Author(s) Jian John Lu (UAF), David Junge (UAA), and David Esch (AKDOT&PF)		8. Performing Organization Report No. INE/TRC 94.03
9. Performing Organization Name and Address Institute of Northern Engineering University of Alaska Fairbanks Fairbanks, AK 99775-5900		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address State of Alaska Dept. of Transportation and Public Facilities Div. of Planning and Programming 2301 Peger Road, Fairbanks, Alaska 99701-6394		13. Type of Report and Period Covered. Final 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

In Alaska, studded tires have been used during the winter season to increase vehicle traction force for safety reasons. Past experience and factual data have shown that the problems of accelerated pavement wear and airborne dust have been caused by the use of studded tires. Use of studded tires has been prohibited in many countries. Recently, the Bridgestone Tire Company designed and examined a new type of studless winter tire under the "Blizzak" brand name to improve winter vehicle traction and minimize pavement wear. In order to evaluate this new type of tire, the Alaska Department of Transportation and Public Facilities conducted a preliminary field study in January of 1994 to compare the new tires with studded tires in stopping distance tests on packed snow and icy surfaces in Fairbanks and Anchorage. To verify and extend these results, more comparative tests of the Blizzaks, studded tires, and all-season tires were conducted in March and April of 1994 by the University of Alaska at locations in Fairbanks and Anchorage. The vehicles used in these tests were mid-sized front wheel drive cars, large rear wheel drive cars, and half-ton full size rear wheel drive pickup trucks. The purpose of these tests was to evaluate the differences between these tire types. Field tests included 25 mph, maximum cornering speeds on short radius curves typical of intersections, and hill climbing ability. From field tests results, the new studless tires were proven superior to all-season tires under all conditions. On icy surfaces, the Blizzaks and studded tires showed almost the same performance on cornering speed in different curves, and in hill climbing ability. However, on ice surfaces, the Blizzaks had 25 mph stopping distances, which were greater by about 8-10% (than those of studded tires) as well as longer times to reach 25 mph by about 12-15%. In summary, the Blizzaks may be used during the winter season as the best alternative to replacing the studded tires commonly used in Alaska.

17. Key Words pavement wear, Blizzak, studless tires		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page) unclassified	21. No. of Pages 54	22. Price

WINTER TIRE TRACTION EVALUATIONS

Jian John Lu
Assistant Professor
Transportation Research Center
University of Alaska Fairbanks

David Junge
Professor
School of Engineering
University of Alaska Anchorage

and

David Esch
Research Engineer
Alaska Department of Transportation and Public Facilities

A report on research sponsored by
Alaska Department of Transportation and Public Facilities

September, 1994

Report No. INE/TRC-94.03

TRANSPORTATION RESEARCH CENTER
INSTITUTE OF NORTHERN ENGINEERING
UNIVERSITY OF ALASKA FAIRBANKS
FAIRBANKS, ALASKA 99775

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Alaska Department of Transportation and Public Facilities. This report does not constitute a standard, specification or regulation.

ABSTRACT

In Alaska, studded tires have been used during the winter season to increase vehicle traction force for safety reasons. Past experience and factual data have shown that the problems of accelerated pavement wear and of airborne dust have been caused by the use of studded tires. Use of studded tires has been prohibited in many countries. Recently, the Bridgestone Tire Company designed and examined a new type of studless winter tire under the "Blizzak" brand name to improve the winter vehicle traction and minimize pavement wear. In order to evaluate this new type of tire, the Alaska Department of Transportation and Public Facilities conducted a preliminary field study in January of 1994 to compare the new tires with studded tires in stopping distance tests on packed snow and icy surfaces in Fairbanks and Anchorage. To verify and extend these results, more comparative tests of the Blizzaks, studded tires, and all-season tires were conducted in March and April of 1994 by the University of Alaska at locations in Fairbanks and Anchorage. The vehicles used in these tests were mid-size front wheel drive cars, large rear wheel drive cars, and half-ton full size rear wheel drive pickup trucks. The purpose of these tests was to evaluate the differences between these tire types. Field tests included 25 mph stopping distances, starting traction and times to reach 25 mph, maximum cornering speeds on short radius curves typical of intersections, and hill climbing ability. From field test results, the new studless tires were proven superior to all-season tires under all conditions. On packed snow surfaces, the new tires were equal to studded tires in terms of stopping distances, times to reach 25 mph, maximum cornering speeds, and hill climbing ability. On icy surfaces, the Blizzaks and studded tires showed almost the same performance on cornering speed on different curves, and in hill climbing ability. However, on ice surfaces, the Blizzaks had 25 mph stopping distances which were greater by about 8 - 10% as well as longer times to reach 25 mph by about 12 - 15%. In summary, the Blizzaks may be used during the winter season as the best alternative for to replacing the studded tires commonly used in Alaska.

SUMMARY

Stopping, starting traction, cornering, and hill climbing ability tests of studded and non-studded tires were recently completed in Fairbanks and Anchorage. A new type of non-studded ice traction tire, called the "Blizzak", and made by Bridgestone, was included in the tests. It proved superior to normal all-season tread designs under all conditions. This new tire was equal to studded tires in hill climbing, starting traction (time to reach 25 mph), and stopping distances under all conditions except on polished lake ice. On that surface, stopping distances were about 10 to 15% greater for the new tire type while all-season tire stopping distances were about 20% greater than with studs. Finally, no significant differences were found in maximum cornering speeds between any of the tire types tested. In fact, studded tires gave slightly slower cornering speeds, by 1 mph, as compared to all non-studded tire types tested.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

ACKNOWLEDGMENT

The author wishes to acknowledge the contributions of two of his colleagues who offered many thoughtful suggestions in the study and the final report: Professors Lutfi Raad and Leroy Hulsey of the University of Alaska Fairbanks.

The author would like to express his appreciation to the contact representatives of Alaska Department of Transportation and Public Facilities for their support and cooperation in this project.

The author gratefully acknowledges the field test technical support of Mr. Alex Tolmie and Mr. Shane Durand and Ms. Charlotte Barker of the Transportation Research Center at the University of Alaska Fairbanks.

The author would like to express his appreciation for the support provided by the Fairbanks International Airport. The author wishes to thank especially to Ms. Rebecca Cronkhite and Mr. Bruce Pitcher of the Fairbanks International Airport for their cooperation in field tests.

Field tests and data collection in Anchorage were conducted by the School of Engineering of the University of Alaska Anchorage.

This report was funded by the federal Highway Administration through the use of State Research Program (SRP) funding.

1. INTRODUCTION

a. Background

Studded tires are commonly used in Alaska during the winter season to increase vehicle traction forces. However, studded tires cause accelerated pavement and traffic marking wear and airborne dust. These factors have been reported by researchers from Canada, Japan, Sweden, and other countries. In Alaska, the majority of the pavement rutting on Alaska's roadways has been caused by studded tires, according to winter versus summer season wear measurements. However, vehicle owners continue to buy studded tires with expectations that the gains in traction and braking and the reductions in travel time will justify the added costs for tires and for semi-annual changeovers.

Because of the problems of accelerated pavement wear and of airborne dust caused by studded tire abrasion of paved roadway surfaces, a number of States, Canadian Provinces and countries have totally banned studded tires. In Japan the use of studded tires was recently banned primarily to reduce the amount of airborne dust. New tire tread types were then developed in an attempt to improve the wintertime traction benefits of non-studded tires. One such new tire type is the "Blizzak" (brand) tire developed by Bridgestone Tire Company. To compare the traction benefits of this new tire type with currently available studded and non-studded all-season tire types, the Alaska Department of Transportation and Public Facilities (AKDOT&PF) made some stopping distance test comparisons on hard packed snow surfaces at Fairbanks and Anchorage International Airports in January of 1994. Results of these initial test runs indicated excellent performance of the new tire type in comparison to studded tires. These results provided information for State Equipment Fleet purchases of winter tires, as well as information useful to the general public in making decisions on their need for studded tires.

In March, 1994, the University of Alaska Fairbanks (UAF) and the University of Alaska Anchorage (UAA) were requested by AKDOT&PF to perform a comparative testing program of the different winter tire types, including the newly developed Blizzak tires from Bridgestone Tire Company, and studded and all-season tires purchased from Firestone, Michelin, and Goodyear. Field tests were conducted to consider tire type, vehicle type, and surface condition effects. This report summarizes the research activities and the results obtained through this study.

b. Objectives

The main objective of this study was to compare the traction performance of different types of tires. The tires tested included the newly developed Blizzak (brand) tire from Bridgestone, and two brands each of studded and non-studded all-season tires as purchased from Firestone, Michelin, and/or Goodyear. Surfaces tested included old snowpack, freshly packed snow, old surface ice deposits and newly prepared glare ice surfaces. Test vehicles included full size rear-wheel-drive sedans, full size 1/2 ton pickups, and compact front wheel drive cars. The research was conducted in March and April of 1994 by the Transportation Research Center of the University of Alaska Fairbanks (UAF) and the School of Engineering of the University of Alaska Anchorage (UAA). All tires were purchased and tested in near new condition.

2. DATA COLLECTION

During the University of Alaska's field experiments, various tests were conducted at Anchorage and Fairbanks, including stopping distance, starting traction, and cornering speed, with different surface conditions, different vehicle types, and different drivers.

a. Test Sites

Anchorage tests were done on the taxiway at the Birchwood Airport, located 20 miles northeast of Anchorage, and on Jewel Lake, a small lake on the south side of Anchorage. These airport and lake sites were selected to avoid traffic interference and traffic effects on the surfaces being tested.

Fairbanks tests were done on the taxiway end at Fairbanks International Airport. To add data on actual road surfaces additional stopping and starting traction tests were done on snowpack covered low volume sections of the Chena Lake access road and the Old Nenana Highway.

b. Tests Included

Stopping Distance Tests

The measured stopping distances of the vehicles were obtained after applying and attempting to lock the brakes from an initial speed of 25 mph. Because of the anti-lock braking systems used, full locked wheel skids did not occur but braking continued until the vehicle was stopped. The maximum braking forces were also recorded during each test with a G-Analyst force meter.

Starting Traction and Hill Climbing Ability Tests

Test vehicles were started from zero and accelerated to 25 mph as quickly as possible without excessive wheelspin. The time to reach 25 mph was recorded with a stopwatch and the maximum G-Forces were also recorded. The G-forces were then converted to maximum grades which the vehicle would be able to climb with the various surface conditions, vehicles, and tires. In fact, the value of G-force is the acceleration or deceleration of the vehicle. The mathematical relationship between the maximum G-forces and hill climbing ability will be described later in this report.

Maximum Cornering Speeds

Two curves, with radii of 25 and 50 feet, were marked with traffic cones. The curves were approached at various speeds to determine the maximum speed around the corner without skidding. Cornering speeds were observed and the maximum cornering G-forces (centrifugal accelerations) were also recorded at or near the maximum cornering speed. Because cornering speeds were difficult to observe while keeping the vehicle on course, cornering speeds were also calculated for the turn radius and recorded G-forces. This approach eliminates the errors from wheelspin and observer errors.

c. Test Vehicles:

Three different types of vehicles were used and all were selected from the State Equipment Fleet to represent 1993 or 1994 models:

Front Wheel Drive Intermediate Size Car

Chevrolet Lumina models with anti-lock brakes (ABS on all 4 wheels) were used in UAF and UAA tests.

Two-Wheel Drive 1/2 Ton Full Size Pickup Trucks

Chevrolet trucks were used and had anti lock braking on the rear axle only. This feature is typical of late model trucks and acts to prevent the rear axle brakes from locking up before the front and causing a skid. This system is inactive below 20 mph according to Chevrolet.

Rear Wheel Drive Full-Size Four-Door Cars

A Ford Crown Victoria was tested in Anchorage and a Chevrolet Caprice was used in the Fairbanks tests. Both vehicles had 4-wheel ABS systems.

d. Tires Tested

Three types of tires were included in the test program. To obtain accurate comparisons between tire types, all tires were pre-mounted on rims and tire sets were exchanged in sets of four at the test site. Different tire types were compared on the same vehicles.

Blizzak (brand) Tires by Bridgestone

This tire is a winter tire with a special soft rubber compound which incorporates micro bubbles to provide tiny gripping edges on ice.

Studded Winter Tires

Firestone studded "Town and Country" brand and Goodyear brand studded tires were tested.

All-Season Type Tires

This tire type is marketed for year round use and generally has many small gripping edges to provide good traction on snow and ice. Michelin XGT-4 and Firestone Supreme brands were tested.

e. Surface Conditions:

Packed Snow

The surface at the Birchwood airport taxiway test site was hard snowpack at the start of the tests. Snowfalls during the testing period resulted in the need for daily snow removal, resulting in a surface best described as newly packed snow over old snowpack. At Fairbanks the taxiway was covered with old and very hard snowpack, as were the local roads tested. Fairbanks had events of freezing rain earlier in the winter, which further hardened the surface snowpack.

Ice

Tests on ice at Anchorage were done on Jewel Lake. After removing the snowcover, the ice surface was found to be very rough. To prepare it for the skid tests the surface was conditioned with a "Zamboni" type machine which melts and levels the surface as for an ice-skating rink. This surface was probably smoother than any road surface the motorist will encounter. At Fairbanks the taxiway was prepared for the icy surface tests by spraying it with water and allowing overnight refreezing.

Bare Pavement

Tests on bare pavement surfaces were conducted at Birchwood Airport in Anchorage and Old

Nenana Highway in Fairbanks to compare the stopping distances and starting traction for all tires.

f. Temperatures

Most tests were conducted under near freezing temperatures. Air temperatures varied between 24° and 36°F, while surface temperatures varied from 25° to 32°F. The time required to test each vehicle with each tire type and then to change tires for the next test run resulted in some temperature effects on the comparative results. Attempts were made to randomize the tests to avoid a temperature bias.

3. STOPPING DISTANCE TESTS

a. Tests Conducted by AKDOT&PF

In January, 1994, preliminary field tests were conducted by AKDOT&PF at the Anchorage and Fairbanks International Airports to compare the stopping distance performance between Blizzaks, studded tires, and all-season tires. For the tests conducted in Anchorage, a Ford Taurus car was used. The surface conditions were sanded snow, packed snow, and ice. Initial speed was 25 mph. Figure 3.1 shows the test results. From this figure, it is seen that on a sanded snow surface, stopping distances were almost the same for the studded tires and Blizzaks. On packed snow surfaces, compared to the studded tires the Blizzaks shortened stopping distance by 33%; on the icy surface, the Blizzaks shortened stopping distance by 5 %.

In Fairbanks tests, three types of vehicles were used. They were a sedan, wagon, and van. The surface conditions were icy, and the initial speed was 40 mph. Figure 3.2 shows the test results. This figure indicates that the Blizzaks had shortest stopping distances, followed by studded tires and then the all-season tires. Figure 3.3 presents the average stopping distances for Blizzaks, studded tires, and all-season tires by combining all vehicles tested in Fairbanks. The average 40 mph stopping distances were 121 ft. for Blizzaks, 141 ft. for studded tires, and 179 ft. for all-season tires.

b. Tests Conducted by University of Alaska Fairbanks (UAF)

For the field tests conducted in Fairbanks, three different surface conditions were used. They were packed snow, ice, and bare pavement surfaces.

Packed Snow Surface

Figure 3.4 shows stopping distance test results under the packed snow surface condition with all test site data averaged. It is seen from this figure that Blizzaks gave about 15% shorter stopping distances on the full size car, but were about 15% longer in stopping distance on the pickup, compared to either the studded or all-season tires. Figure 3.5 summarizes the same test results, but combines all testing vehicles. Based on the average of all data from the three Fairbanks sites on hard packed snow and three testing vehicles, it was shown from Figure 3.5 that all tire types gave equal stopping distances.

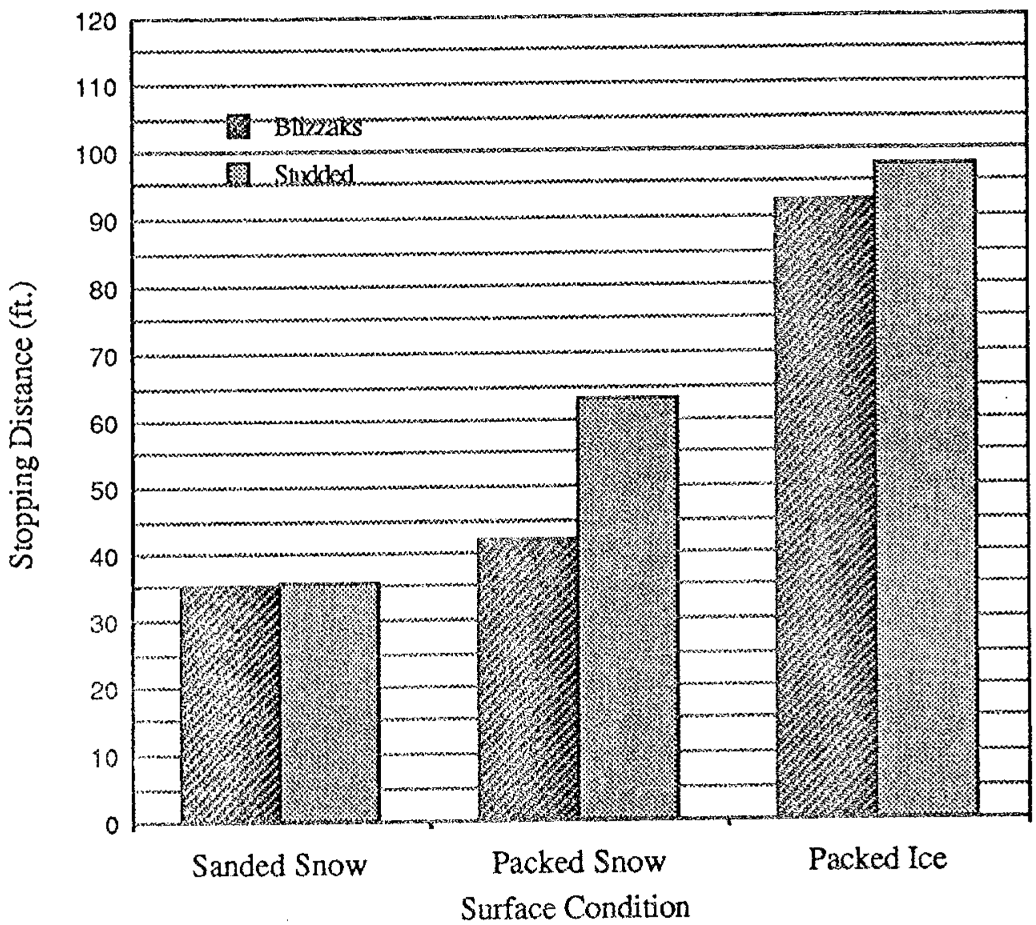

Fig. 3.1. Preliminary 25 mph Stopping Distance Tests by AKDOT&PF in Anchorage (Testing Vehicle: Taurus).

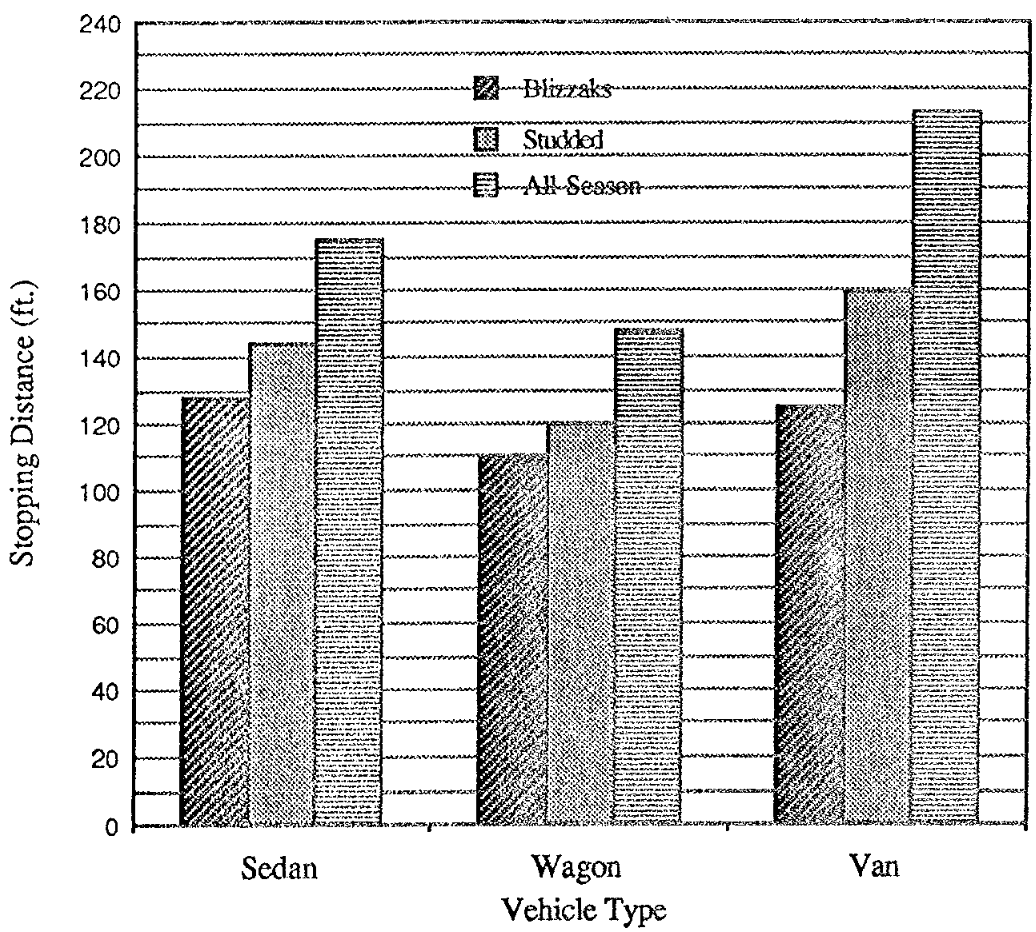

Fig. 3.2. Preliminary 40 mph Stopping Distance Tests on Icy Surface by AKDOT&PF in Fairbanks.

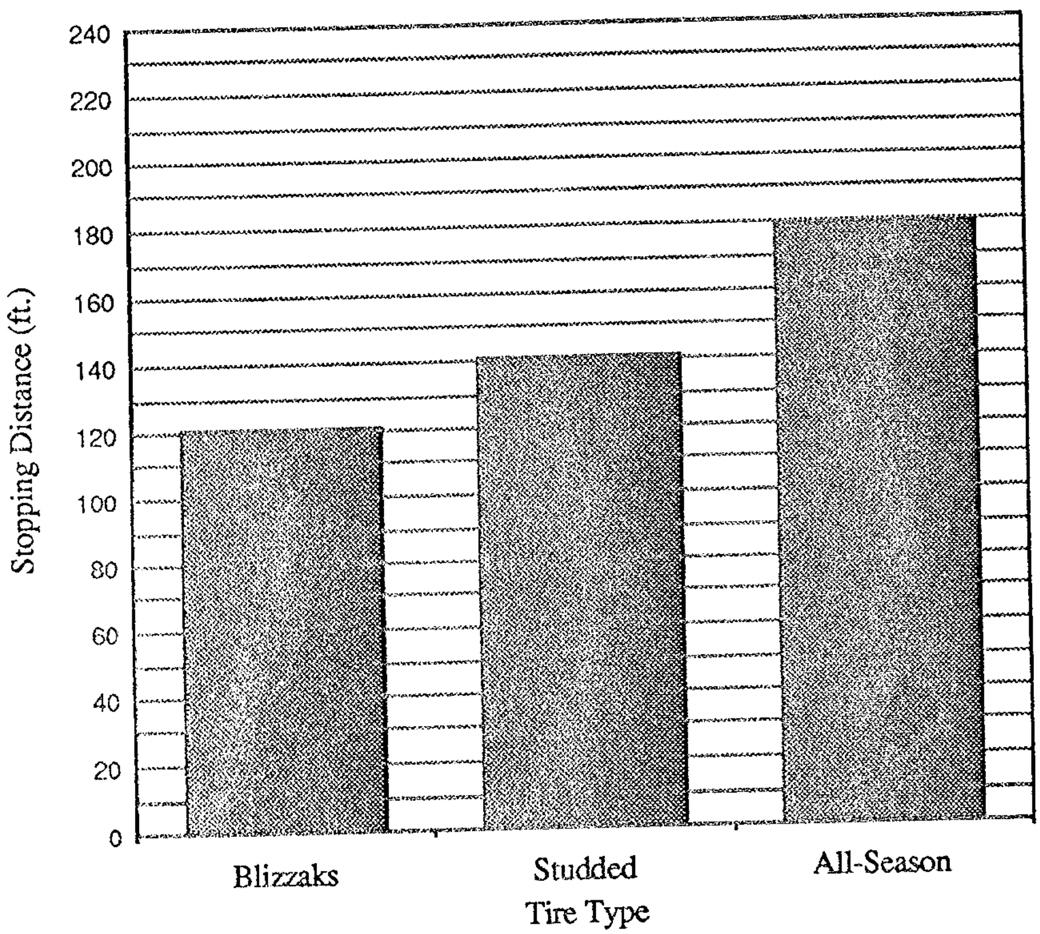

Fig. 3.3. Average 40 mph Stopping Distances on Icy Surface by AKDOT&PF in Fairbanks (All Vehicles Combined).

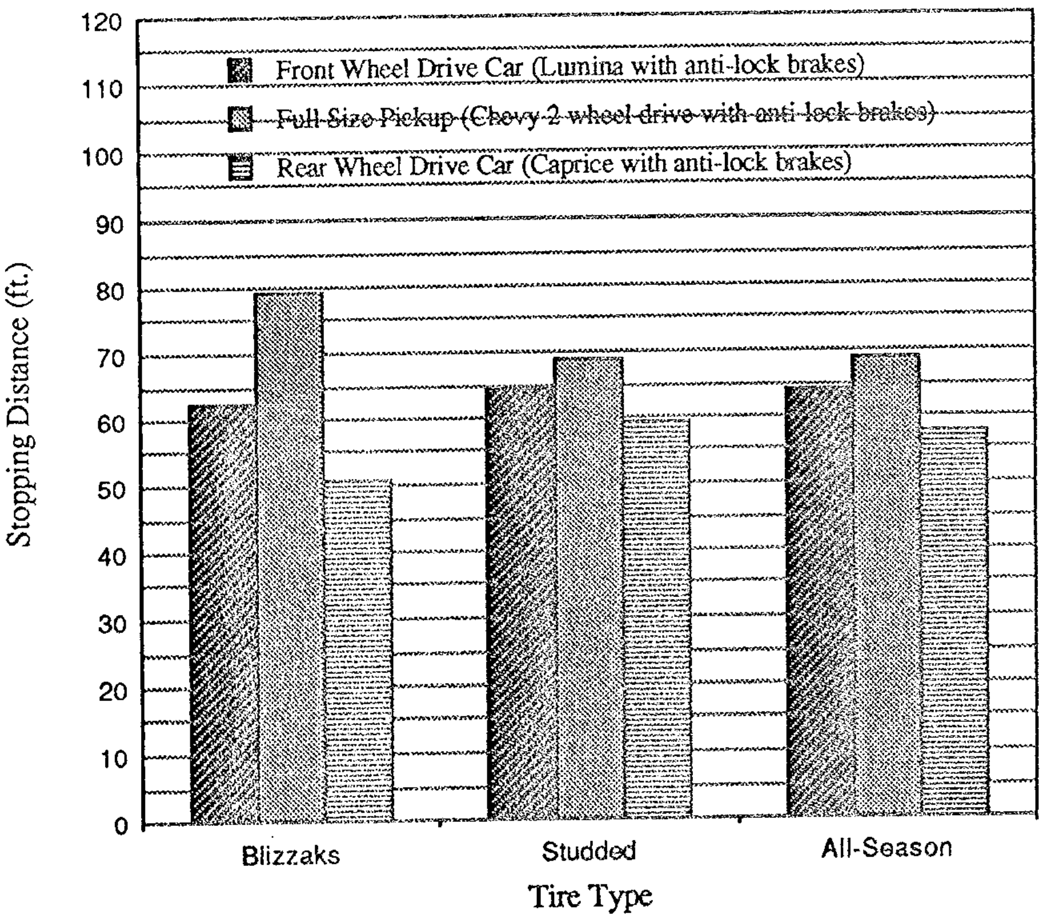

Fig. 3.4. 25 mph Stopping Distances on Packed Snow Surface in Fairbanks (All Test Sites Combined).

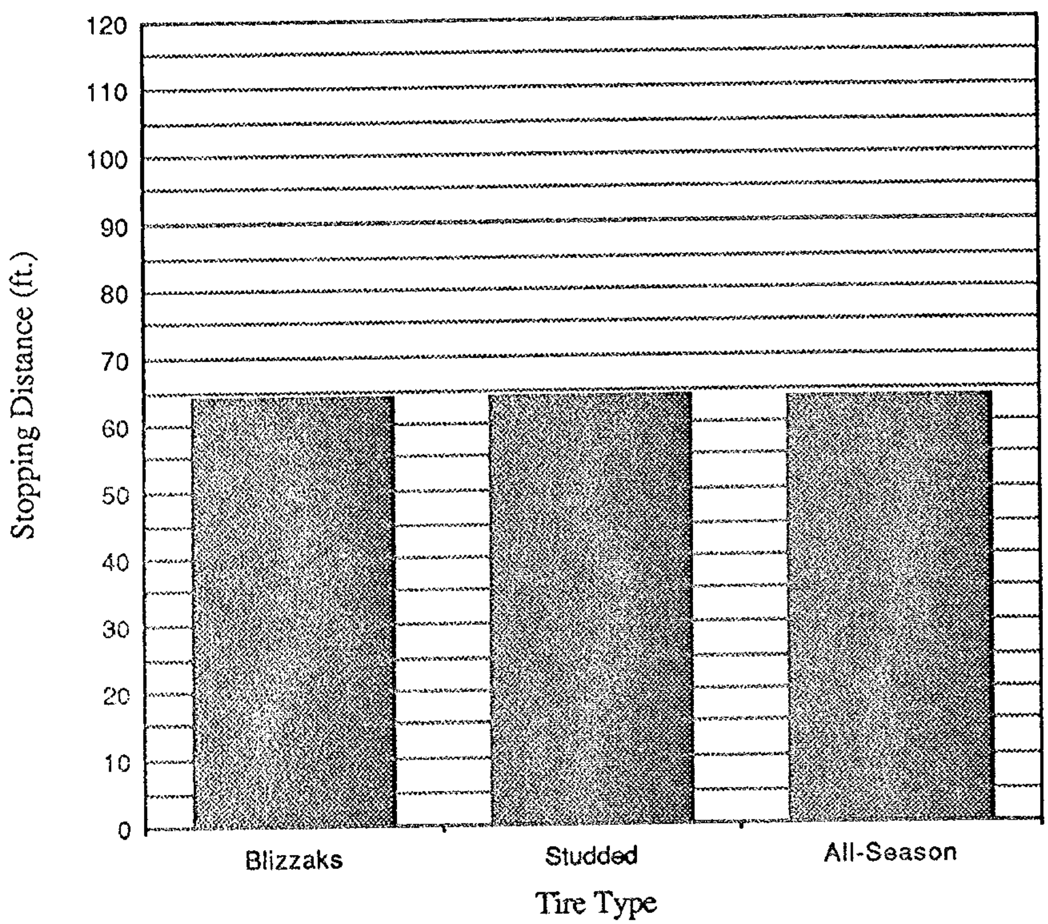

Fig. 3.5. 25 mph Stopping Distances on Packed Snow Surface in Fairbanks (All Test Sites and Vehicles Combined).

Icy Surface

The stopping distances on ice were typically two to three times longer than distances on packed snow. Figure 3.6 shows the results obtained at Fairbanks International Airport test site. Figure 3.7 shows the averaged stopping distances for Blizzaks, studded tires, and all-season tires. As shown in Figure 3.7, stopping distances were shortest for the studded tires, followed by the Blizzaks and then the all-season tire types. The average 25 mph stopping distances were 106 ft. for the studs, 118 ft. for the Blizzaks and 128 ft. for the All-Season tires. In comparison to the Blizzaks, studs shortened stopping distances by 15%, while all-season distances were greater by 8%.

Bare Pavement Surface

Stopping distance tests were conducted on the Old Nenana Highway test site. Only a pickup truck was tested at this site. Two drivers were asked to drive the testing vehicle. One was a male driver, and the other was a female driver. To statistically see the differences between tires, both driver results were combined and the final results are shown in Figure 3.8. From this figure, it can be concluded that on bare pavement surface, no significant differences were found between tires, in terms of stopping distance. In fact, the Blizzaks and all-season tires showed 5% and 2% shorter stopping distances, respectively, than studded tires.

c. Tests Conducted by University of Alaska Anchorage (UAA)

Three different surface conditions were tested in the Anchorage area by the UAA. They were packed snow, ice, and bare pavement.

Packed Snow Surface

Figure 3.9 shows the stopping distance test results from the site on the taxiway at the Birchwood Airport. Figure 3.10 shows the stopping distances by combining vehicle type. The averaged data from three vehicles indicates that the Blizzaks were slightly (1') superior to studded tires and better (by 11') in 25 mph stopping distances when compared to the all-season tires.

Icy Surface

Stopping distance tests on icy surface were conducted on Jewel Lake, and covered only the Blizzaks versus studded tires. Figure 3.11 shows the test results with vehicle type combined. Studded tires again reduced stopping distances by 11% over the Blizzaks.

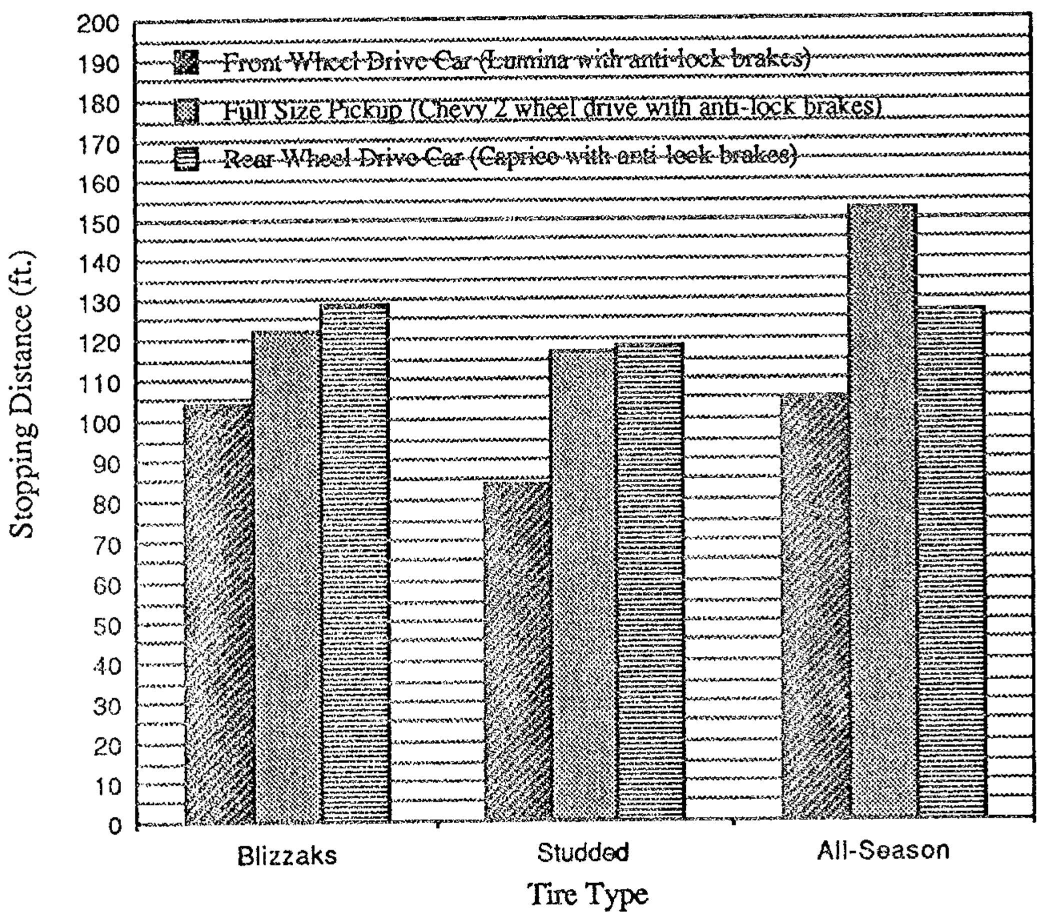

Fig. 3.6. 25 mph Stopping Distances on Icy Surface in Fairbanks.

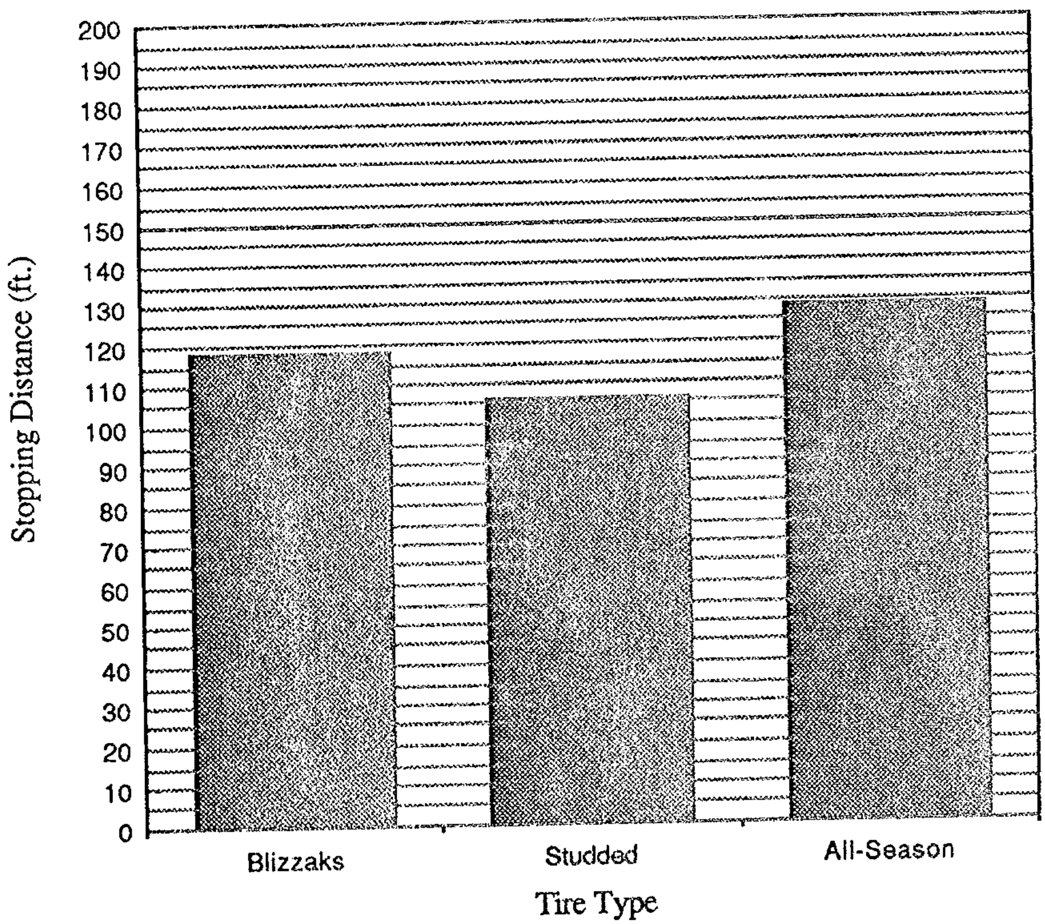

Fig. 3.7. 25 mph Stopping Distances on Icy Surface in Fairbanks (All Vehicles Combined).

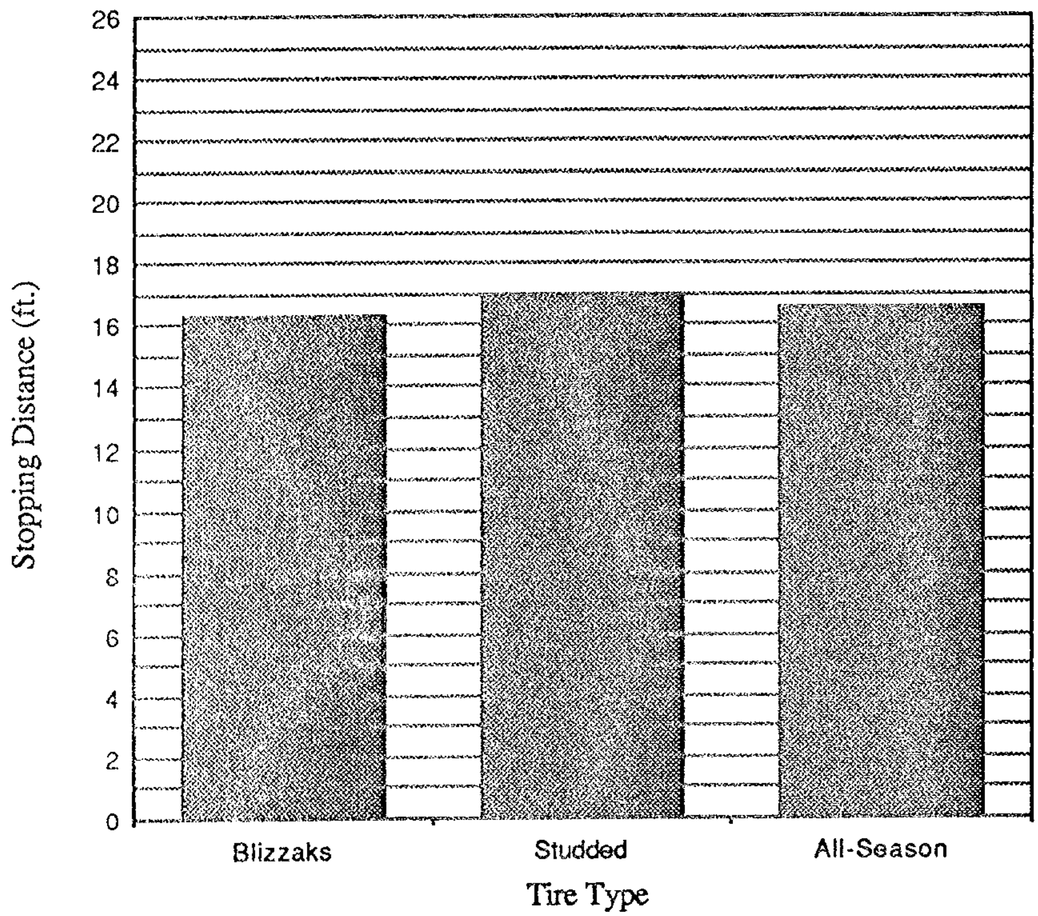

Fig. 3.8. 25 mph Stopping Distances on Bare Pavement Surface at Old Nenana Highway Test Site in Fairbanks (Pick-Up only and All Drivers Combined).

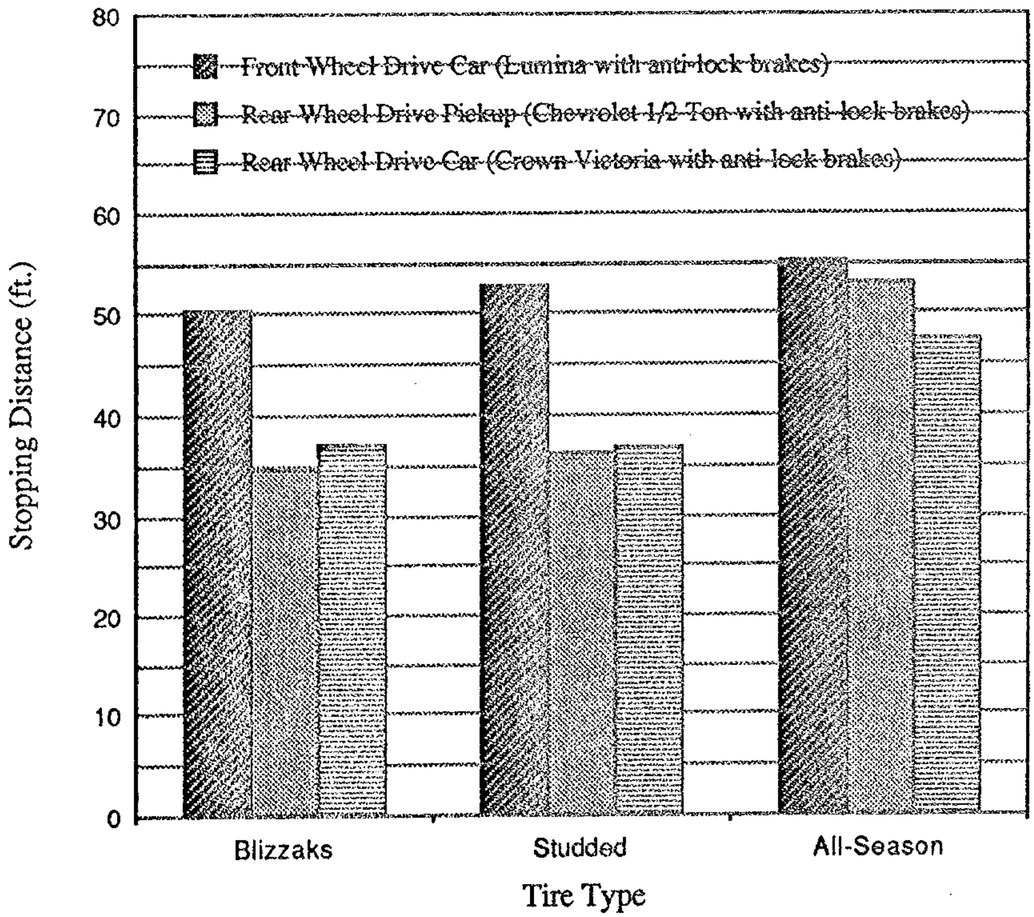

Fig. 3.9. 25 mph Stopping Distances on Packed Snow in Anchorage.

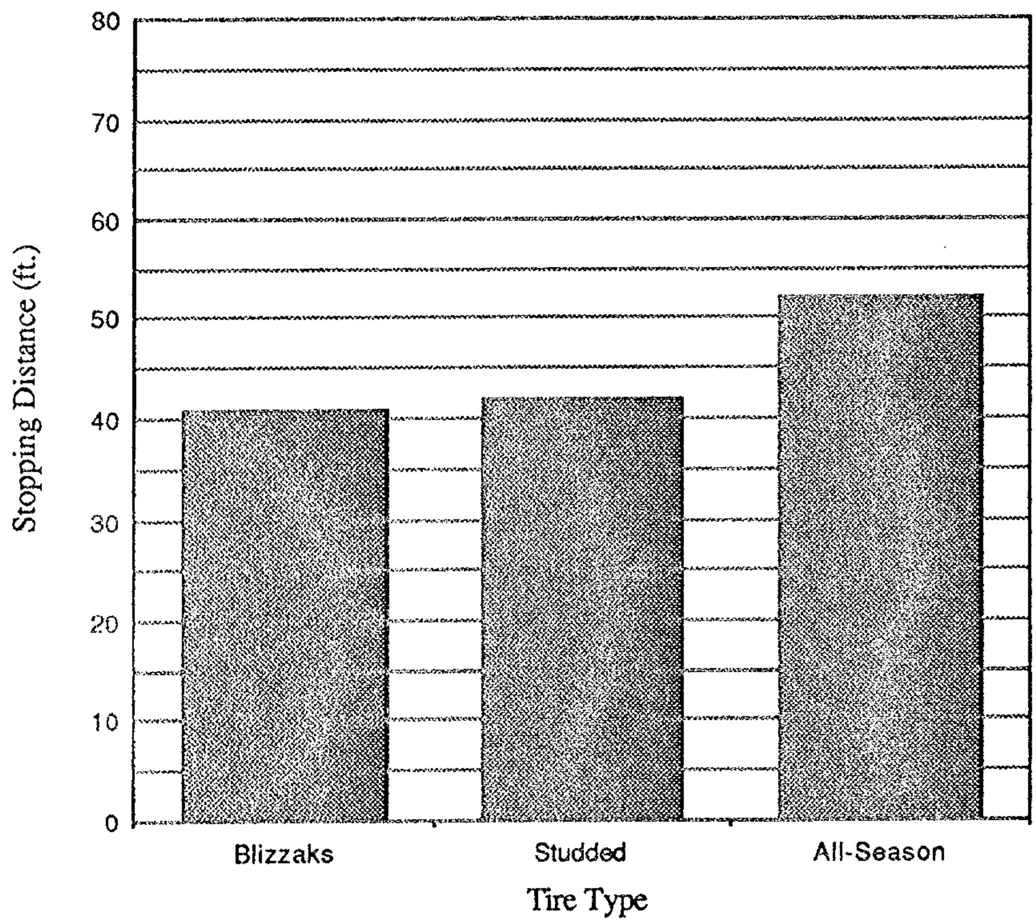

Fig. 3.10. 25 mph Stopping Distances on Packed Snow Surface in Anchorage (All Vehicles Combined).

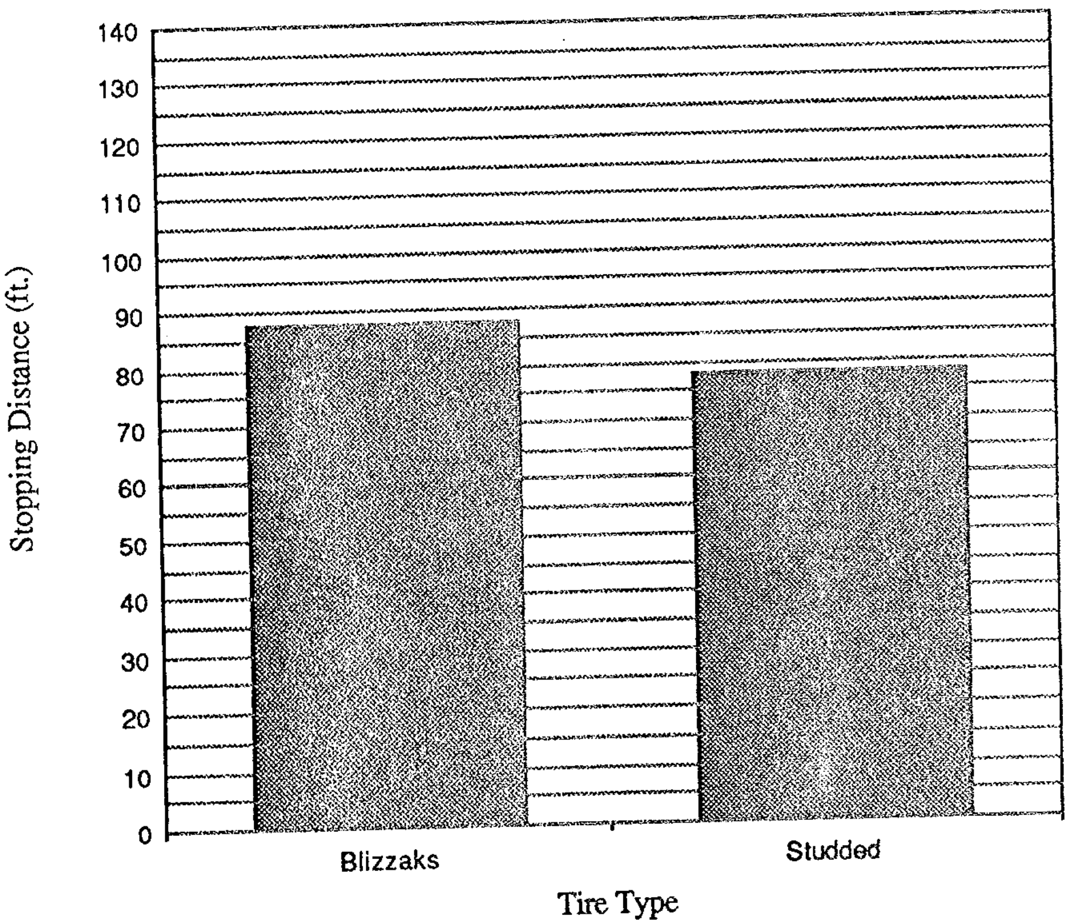

Fig. 3.11. 25 mph Stopping Distances on Ice Surface in Anchorage (All Vehicles Combined).

Bare Pavement Surface

Tests were limited to the full size Ford Crown Victoria Sedan. As shown in Figure 3.12, tests on bare pavement indicated increased stopping distances with the studded tires as compared to any of the non-studded tire types. The studded tires had about 40% and 42% longer stopping distances than that with the Blizzaks and all-season tires, respectively.

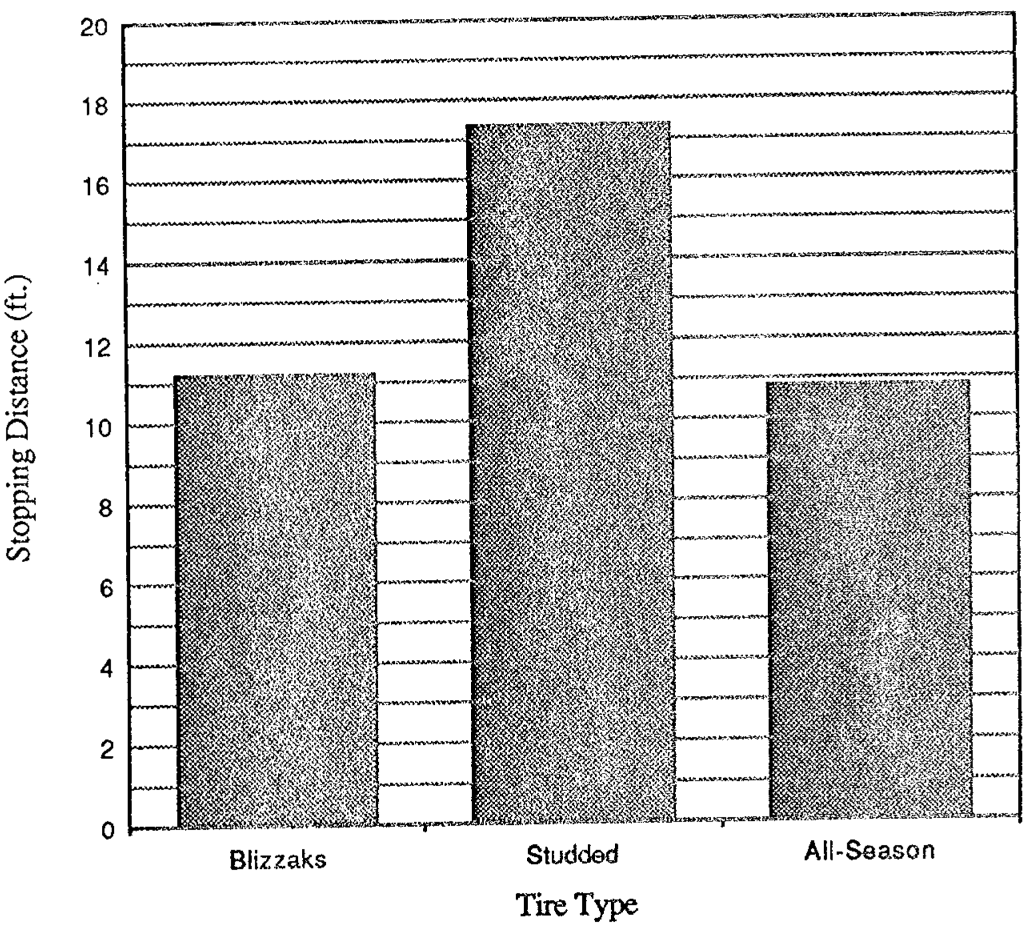

Fig. 3.12. 25 mph Stopping Distances on Bare Pavement Surface in Anchorage (Crown Victoria only).

4. STARTING TRACTION TESTS

The main purpose of conducting starting traction tests was to compare the times required for a vehicle to start from zero and accelerate to 25 mph with different types of tires, including the Blizzaks, studded tires, and all-season tires. Tests were conducted in Fairbanks by UAF and Anchorage by UAA on packed snow and icy surfaces.

a. Tests Conducted by University of Alaska Fairbanks (UAF)

Packed Snow Surface

Field tests were made at the Fairbanks International Airport, Chena Lake access road, and Old Nenana Highway test sites. Figure 4.1 shows the field test results. Except for the studded tires, the front wheel drive car had the best traction, followed by the full size pickup, and then rear wheel drive car. For the studded tires, the full size pickup showed the shortest time to reach 25 mph from zero, and the rear wheel drive car, again, had the longest starting time. To eliminate the effect of vehicle type, starting traction data from different vehicles were averaged and shown in Figure 4.2. The average starting time to reach 25 mph for the studded tires and Blizzaks were about 9.2 sec. and 9.6 sec., respectively. The all-season tires took about 10.5 sec. to reach 25 mph. Basically, there was no significant difference between the Blizzaks and studded tires.

Icy Surface

In this experiment, only the Fairbanks International Airport test site was used because of the weather condition limitation. Figure 4.3 shows field test results obtained from icy surface. As might be expected, starting traction tests on ice were very operator and vehicle dependent, as well as tire dependent. Front wheel drive cars were superior to rear wheel drives. Blizzaks and studded tires were about equal on the pickup, and were superior in starting time to all-season tires by about 40% on that vehicle. For the average of all vehicles shown in Figure 4.4, Blizzak starting times to reach 25 mph were about 18% longer than for studded tires, but were about 13% less than times for the all-season tires.

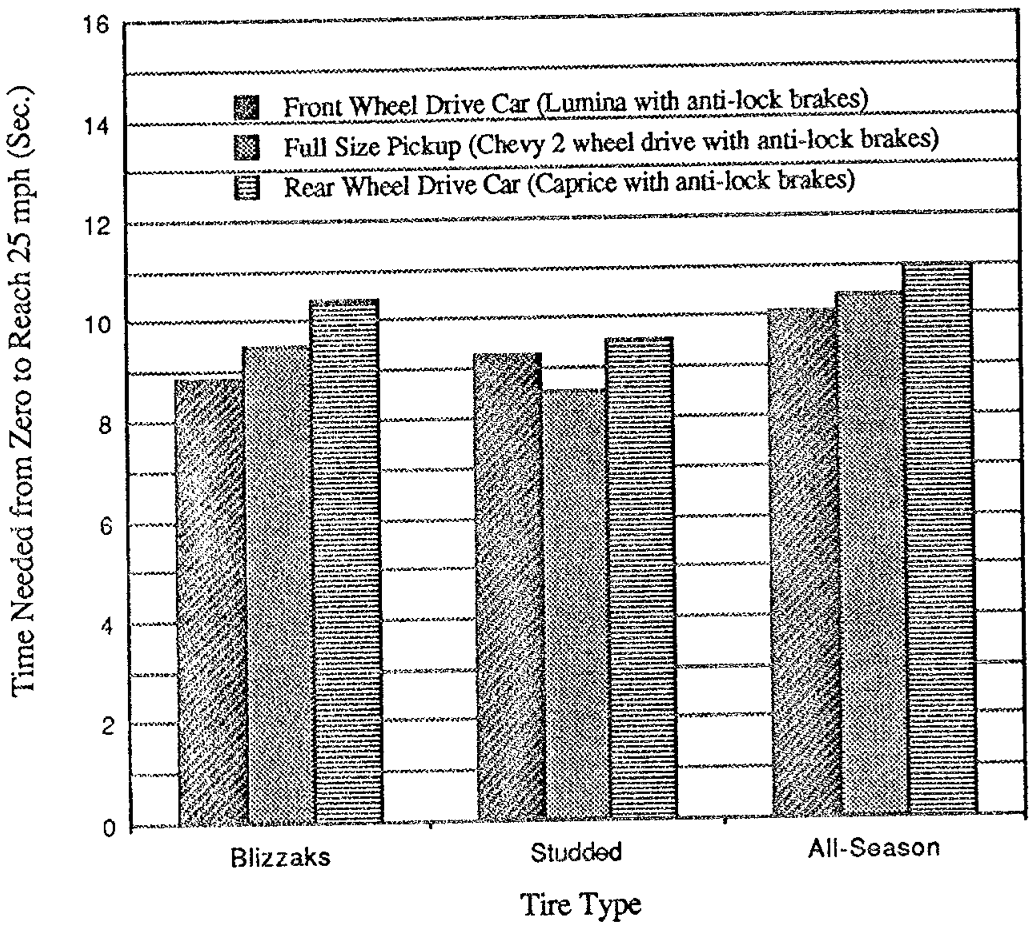

Fig. 4.1. Starting Traction Tests on Packed Snow Surface in Fairbanks (All Test Sites Combined).

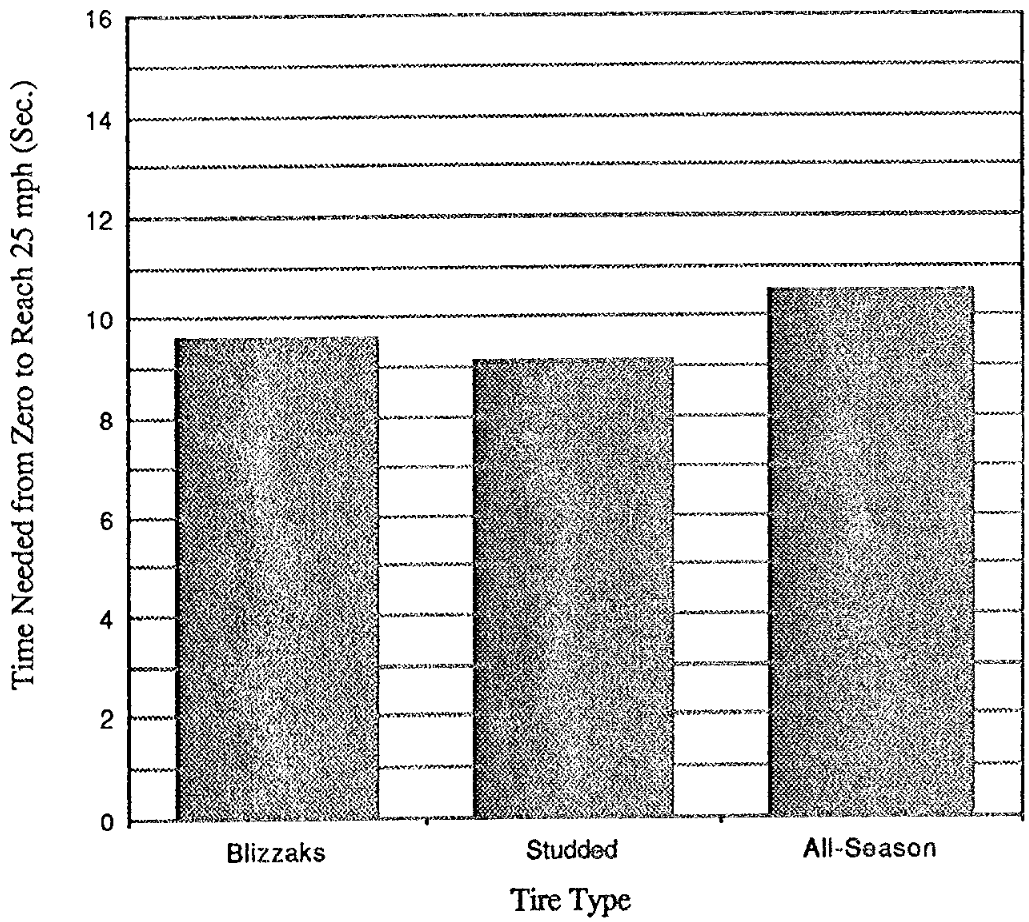

Fig. 4.2. Starting Traction Tests on Packed Snow Surface in Fairbanks (All Test Sites and Vehicles Combined).

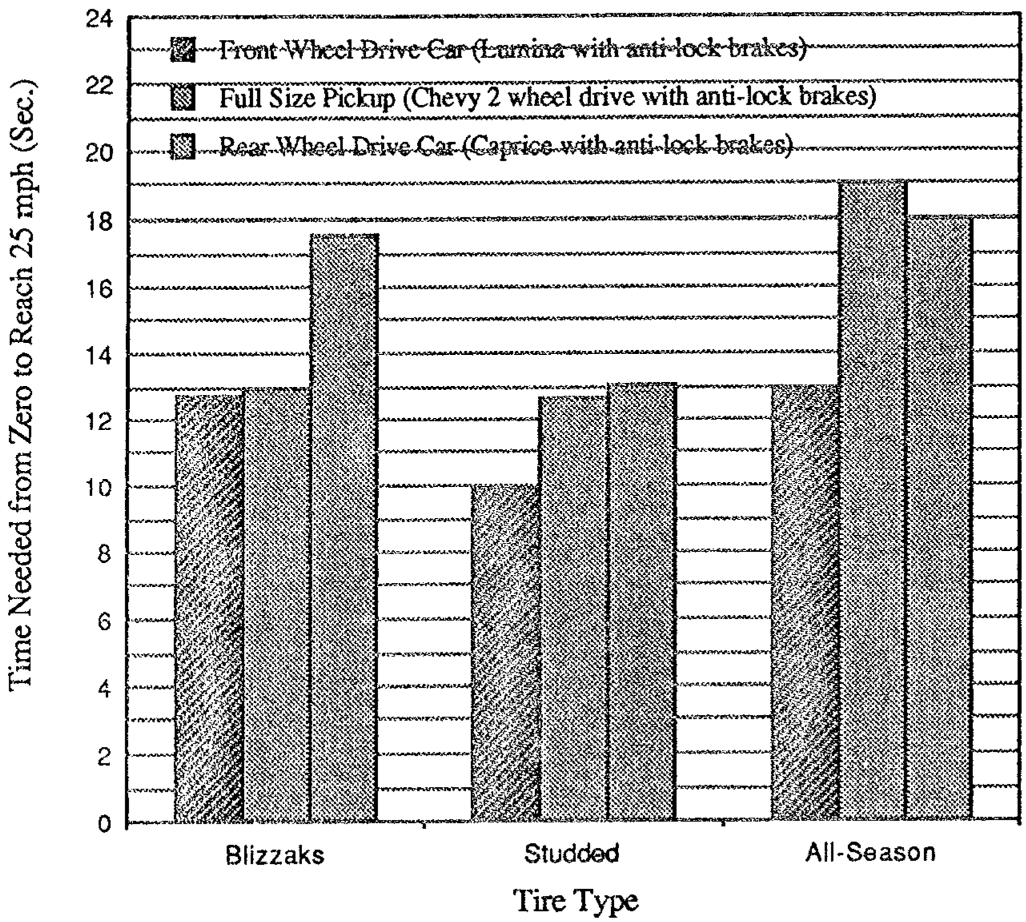

Fig. 4.3. Starting Traction Tests on Icy Surface in Fairbanks
(All Test Sites Combined).

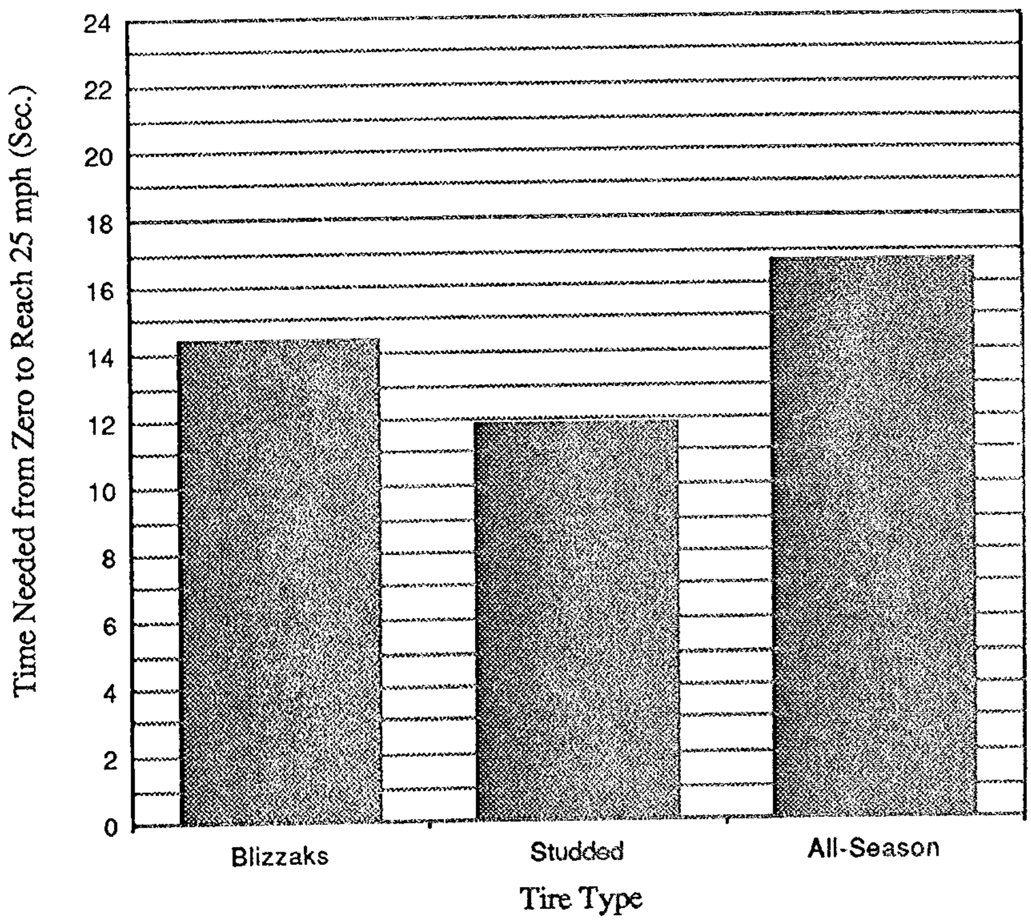

Fig. 4.4. Starting Traction Tests on Icy Surface in Fairbanks
(All Test Sites and Vehicles Combined).

Bare Pavement Surface

Tests were conducted at the Old Nenana Highway tests site. The testing vehicle was the pickup truck run by a male driver and a female driver, respectively. Figure 4.5 shows the test results with all drivers combined. As indicated in this figure, the Blizzaks gave slightly quicker starts, with a 7% reduction in the time needed to reach 25 mph, in comparison to the studded tires and all-season tires. The studded tires and All-season tires had the same starting traction performance.

b. Tests Conducted by University of Alaska Anchorage (UAA)

Packed Snow Surface

Field tests were conducted at the Birchwood Airport test site. Results were shown in Figure 4.6. Again, the front wheel drive car showed the best starting traction, compared to the rear wheel drive pickup and rear wheel drive car. Figure 4.7 shows the average data from all vehicles, indicating that the average starting time for Blizzaks, studded tires, and all-season tires were about 6.2 sec., 6.8 sec., and 8.1 sec., respectively. The Blizzaks gave slightly quicker starting, by about a 9% reduction in the time needed to reach 25 mph, compared to the studded tires.

Icy Surface

In Anchorage, field data were obtained only for Blizzaks and studded tires. Field tests were conducted at the Jewel Lake test site on polished lake ice. As shown in Figure 4.8, significant differences were observed, meaning starting times on ice were very vehicle dependent. Figure 4.9 shows the average data from all vehicles. From this figure, it is seen that the Blizzaks showed about 12% longer starting time, in comparison to the studded tires.

Bare Pavement Surface

Only the full size Ford Crown Victoria Sedan was used in the tests at the Birchwood Airport test site in Anchorage. Test results are summarized and shown in Figure 4.10. The Blizzaks and all-season tires showed the same starting traction performance and were better than the studded tires by about a 10% reduction in the time needed to reach 25 mph.

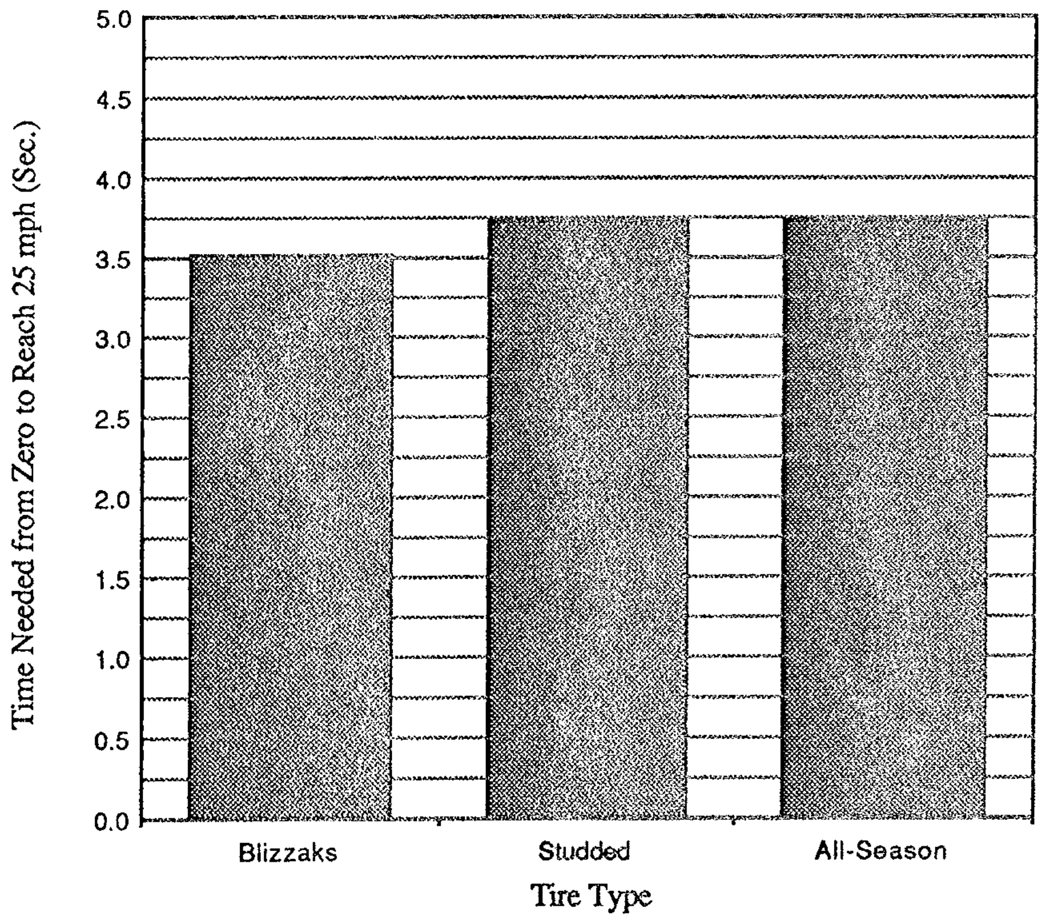

Fig. 4.5. Starting Traction Tests on Bare Pavement Surface in Fairbanks (Pickup only and All Drivers Combined).

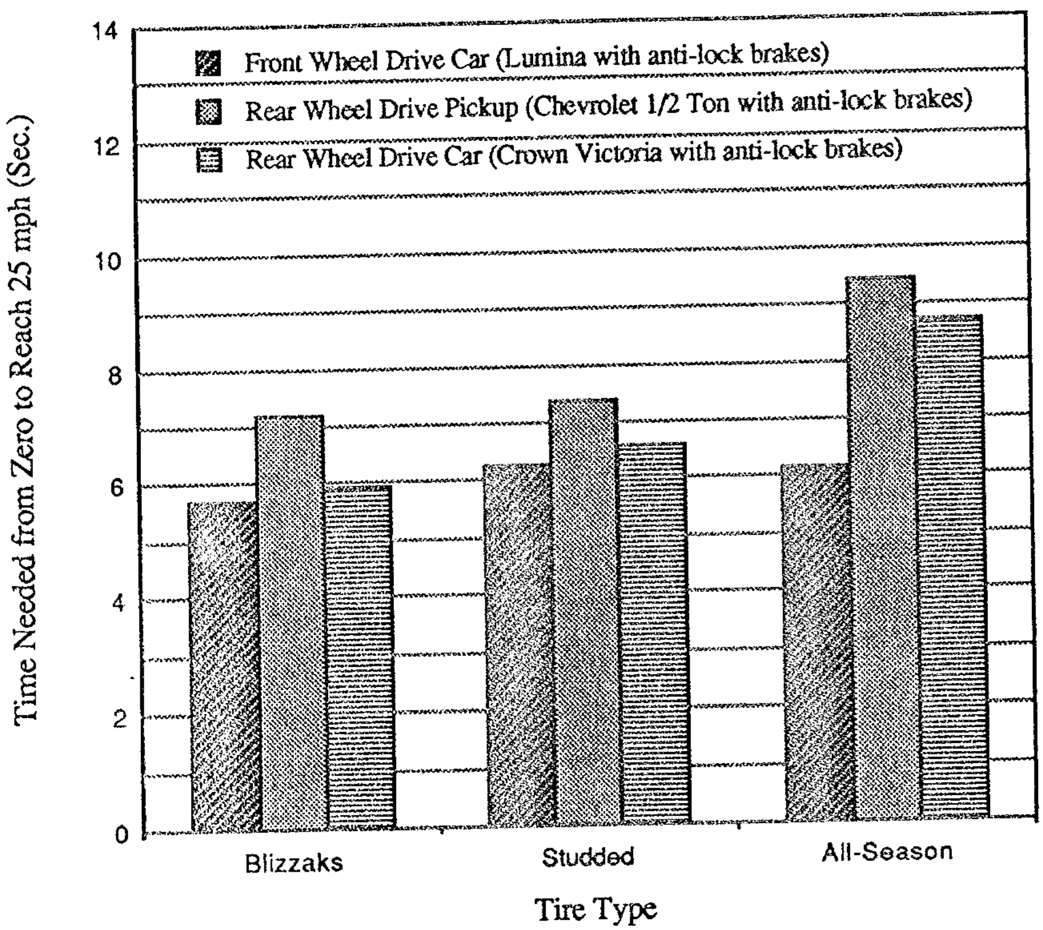

Fig. 4.6. Starting Traction Tests on Packed Snow Surface in Anchorage.

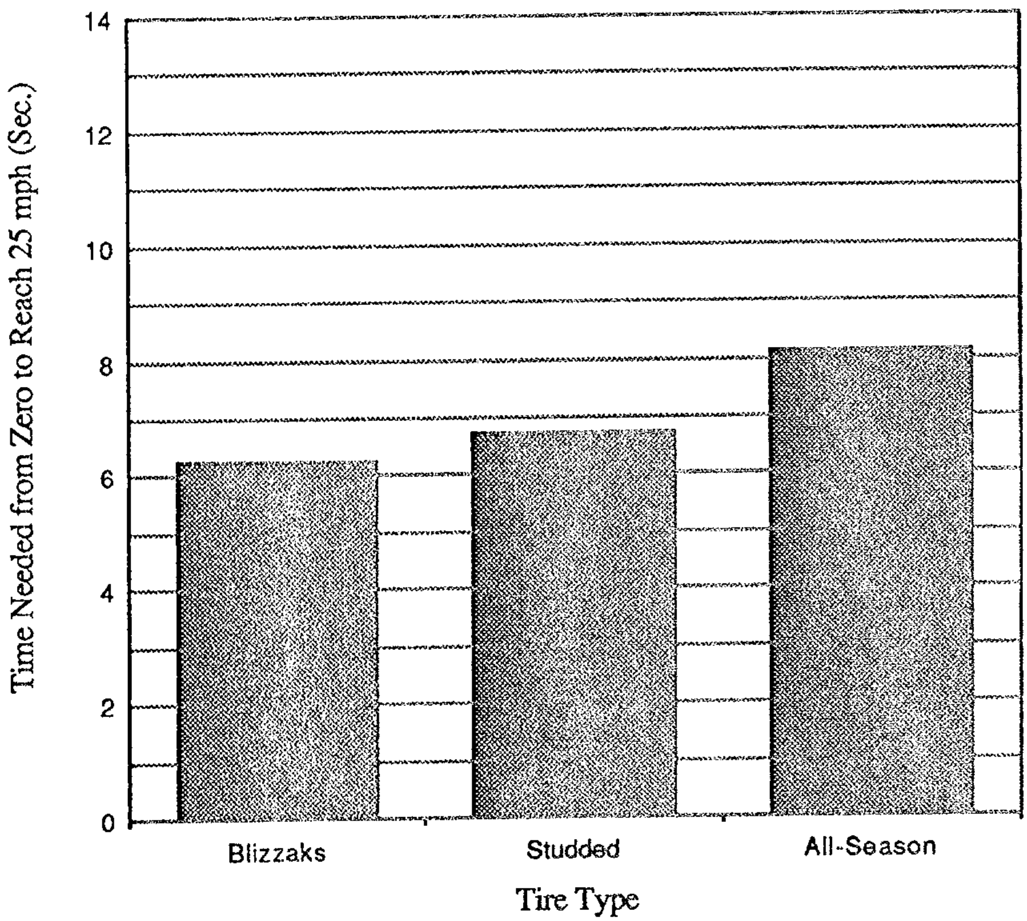

Fig. 4.7. Starting Traction Tests on Packed Snow Surface in Anchorage (All Vehicles Combined).

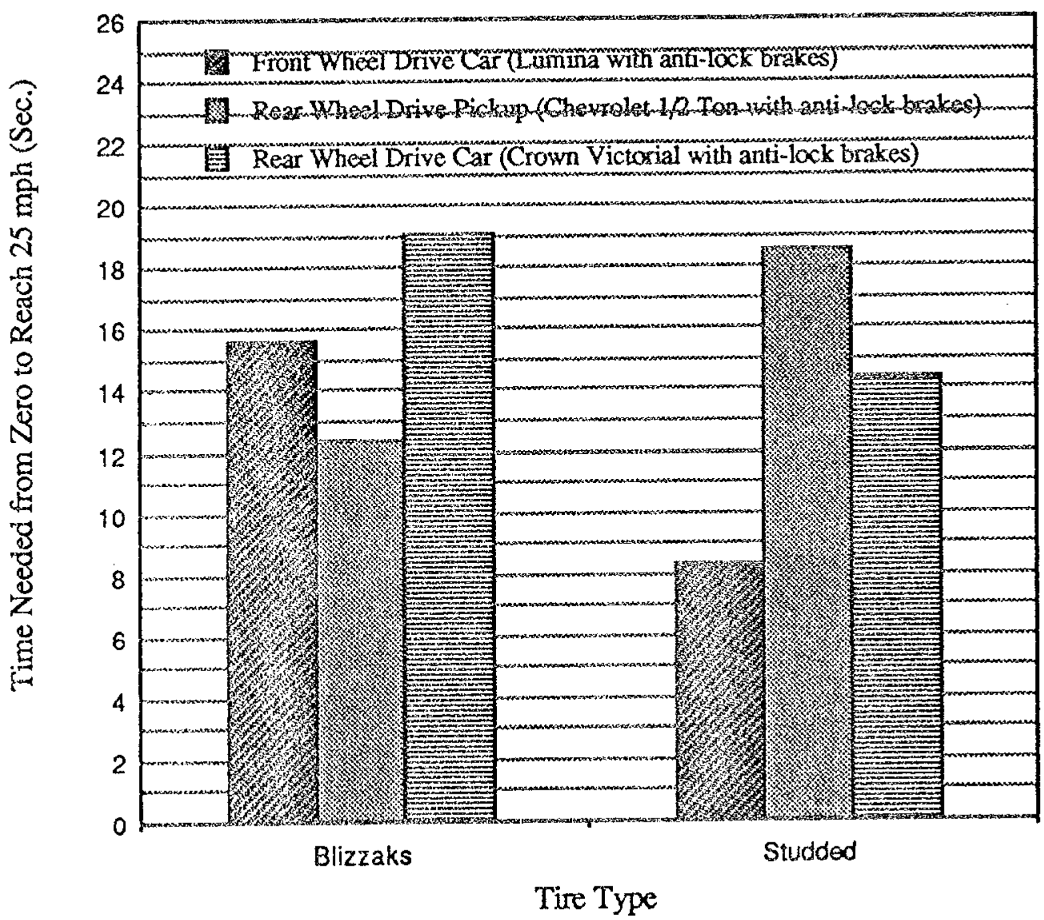

Fig. 4.8. Starting Traction Tests on Icy Surface in Anchorage.

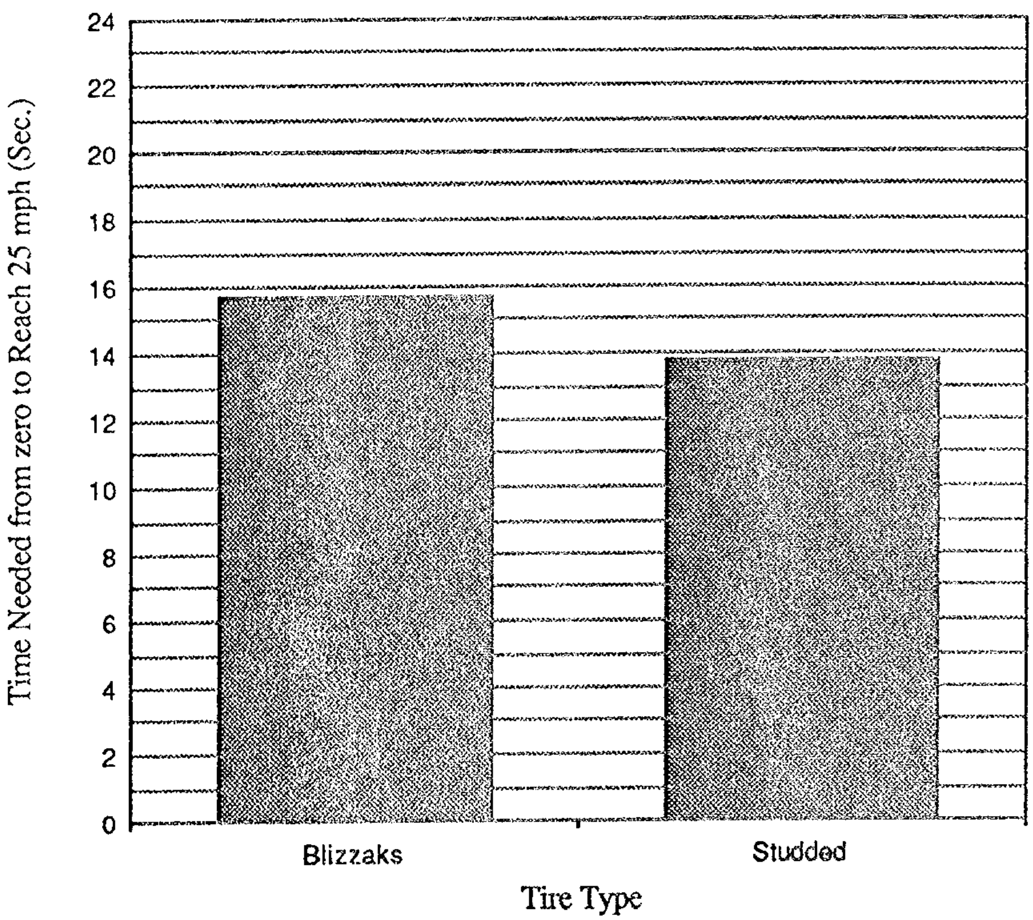

Fig. 4.9. Starting Traction Tests on Icy Surface in Anchorage (All Vehicles Combined).

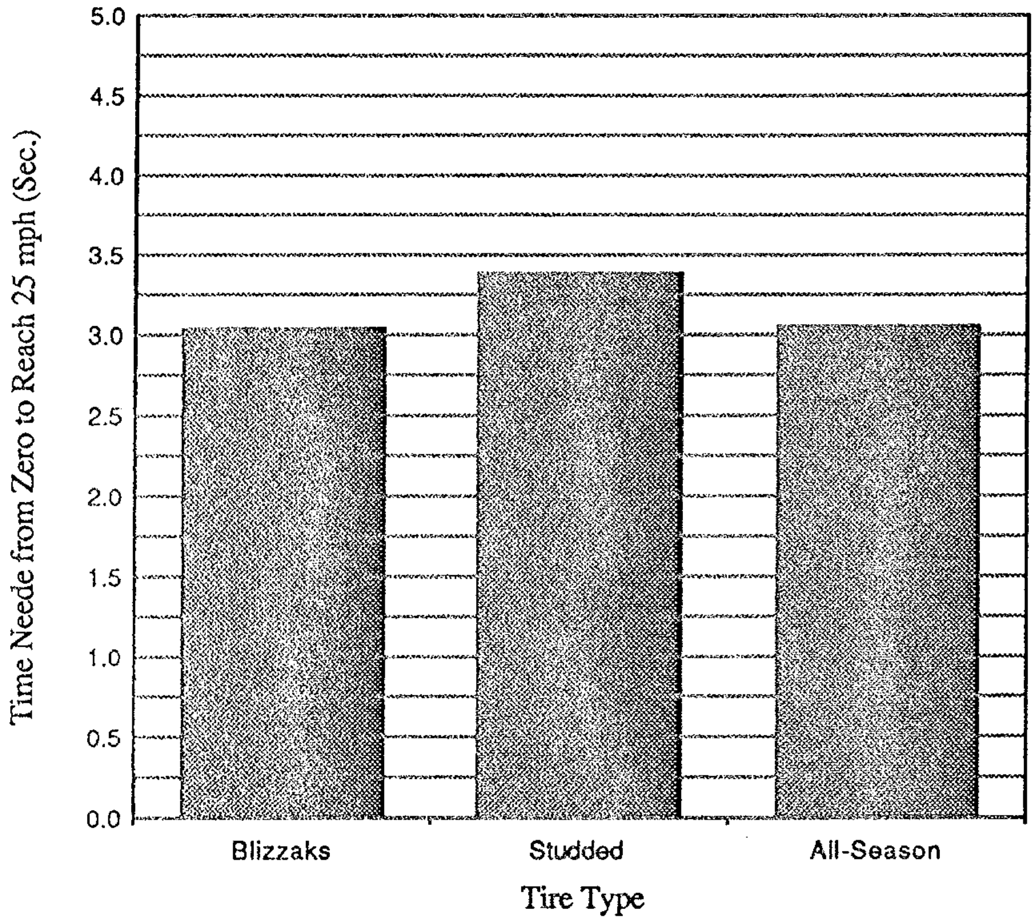

Fig.4.10. Starting Traction Tests on Bare Pavement Surface in Anchorage (Crown Victoria only).

5. CORNERING TESTS

The main purpose of running cornering tests was to estimate the maximum speed of a vehicle moving around a given curve with packed snow or icy surfaces. The effects of tire type can be evaluated from cornering tests. Vehicles used for cornering tests were the same ones for stopping distance and starting traction tests. Maximum cornering speeds for different types of tires were tested on curves with inside radii of 25 and 50 ft. in Fairbanks and Anchorage. Longer radius curves were not possible due to the widths of the available test areas, but speeds for any other curve can be easily calculated by the equation shown in Eq. 5.1. Observed speeds were reported by the vehicle operators but were not extremely precise due to wheel spin and to the dual tasks of avoiding skidding while checking speeds. Data on the maximum speeds observed and the maximum G-forces measured came from three to six test runs for each combination of tires and vehicles. The G-force data were measured by the instrument called "g Analyst" made by Valentine Research Inc. The calculated maximum cornering speeds were based on the maximum cornering G-force measurements recorded during testing. Conversions were made by the following equation from the AASHTO Policy Manual on Geometric Design of Highways (1990):

$$\text{Maximum Cornering Speed (mph)} = \sqrt{\text{Radius(ft)} \times G \times 15} \quad (5.1)$$

The lateral G-forces on snow typically were between 0.25 and 0.4 while G-forces on ice were between 0.1 and 0.2. At the point of skidding these forces are equivalent to the side friction factors as used for highway curve designs. Because of tire spin and errors on the observed speeds, the G-forces and calculated speeds based on Eq. 5.1 are considered more accurate and were used for analysis and reporting of test results as summarized in Tables 5.1 and 5.2 for the Fairbanks and Anchorage tests. The data shown in these tables were obtained by averaging data from all vehicles and runs for both right and left turns. From Tables 5.1 and 5.2, it can be concluded that the Blizzaks out cornered all other tires on both snow and ice in the Fairbanks trials, and also on snowpack in the Anchorage tests. The only exception was the testing on glare ice in Anchorage where maximum cornering speeds for the studded tires were about 0.9 mph higher in cornering speed than the Blizzak tires. On all other surfaces there were no very significant differences, although the non-studded tire types out-cornered the studs by about one mph on average.

Tab. 5.1. Maximum Cornering Speeds during Cornering - Fairbanks Tests.

25 ft. Curve:	Packed Snow	Ice on Pavement
Blizzak Tires	12.1 mph	10.1 mph
Studded Tires	10.9	9.8
All-Season Tires	11.8	10.3
50 ft. Curve	Packed Snow	Ice on Pavement
Blizzak Tires	17.2 mph	14.2 mph
Studded Tires	15.9	13.6
All-Season Tires	17.2	13.7

Tab. 5.2. Maximum Cornering Speeds during Cornering - Anchorage Tests.

25 ft. Curve:	Packed Snow	Ice on Pavement
Blizzak Tires	12.0 mph	N/A
Studded Tires	11.2	N/A
All-Season Tires	11.4	N/A
50 ft. Curve:	Packed Snow	Lake Ice - Glazed
Blizzak Tires	14.7 mph	10.2 mph
Studded Tires	14.7	11.1
All-Season Tires	14.8	N/A

6. HILL CLIMBING ABILITY TESTS

The hill climbing ability of a vehicle can be evaluated from maximum G-forces recorded during acceleration. As shown in Figure 6.1, for the maximum slope that a vehicle can climb, the following equation is obtained:

$$m\, g\, \mu \operatorname{Cos} \beta_{max} = m\, g \operatorname{Sin} \beta_{max} \quad (6.1)$$

where

- m - mass of the vehicle
- g - natural acceleration
- μ - Coefficient of rolling resistance
- β_{max} - degree of maximum slope

The maximum traction or maximum G-force, G_{max}, can be obtained when β is zero as shown in Figure 6.2. In this case, the following equation is obtained:

$$m\, G_{max}\, g = m\, g\, \mu$$

or

$$\mu = G_{max} \quad (6.2)$$

By combining Eqs. 6.1 and 6.2, the following relationship is obtained:

$$G_{max} = tg\, \beta_{max} \quad (6.3)$$

Maximum highway grades or hill climbing ability of a vehicle can be calculated from Eq. 6.3 if the maximum G-forces are available.

Field tests were conducted in Fairbanks by UAF and in Anchorage by UAA on packed snow and icy surfaces. The maximum G-force data were collected during starting traction tests in Fairbanks and Anchorage. Various vehicles with Blizzaks, studded tires, and all-season tires were tested for three to six repeated runs on given test sites. The average data on maximum G-forces or maximum starting grades were obtained from different vehicles and runs and summarized in Table 6.1. For tests in Fairbanks, by converting the maximum G-forces to hill climbing ability, it was concluded that the Blizzaks and studded tires would climb up to a 16% grade on packed snow surface and

11% grade on icy surface. The all-season tires would climb up to a 15% grade on packed snow surface and icy surface. Maximum highway grades are generally 8% or less. Test results in Anchorage were almost identical. The hill climbing ability of a vehicle on bare pavement was controlled more by engine power than by tire type, as none of the test vehicles had the power needed to reach wheelspin on bare pavement.

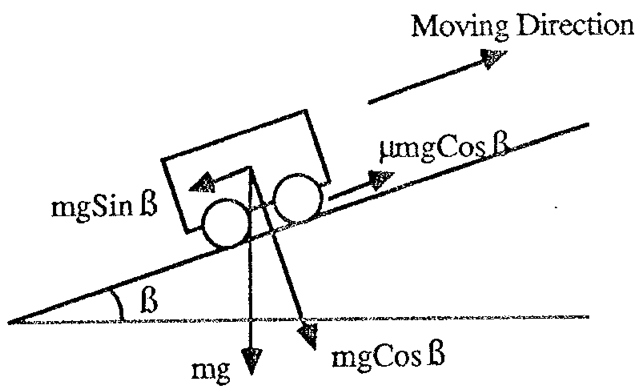

Fig. 6.1. Forces When a Vehicle Reaches to Its Maximum Climbing Ability ($ß = ß_{max}$).

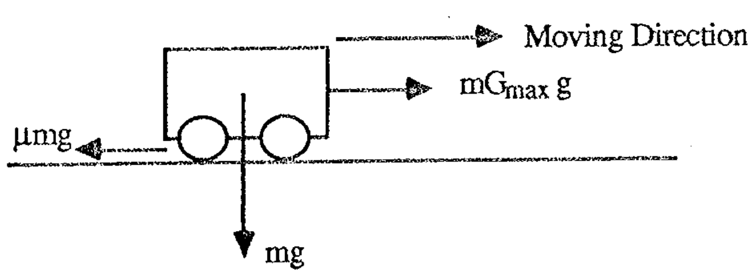

Fig. 6.2. Forces When a Vehicle is on a Level Surface ($ß = 0$).

Tab. 6.1. Maximum Starting Grades (Maximum G-Forces).

Fairbanks Results:

	Packed Snow	Ice on Pavement
Blizzak Tires	16%	11%
Studded Tires	16%	12%
All-Season Tires	15%	10%

Anchorage Results:

	Packed Snow	Lake Ice - Glazed
Blizzak Tires	18%	10%
Studded Tires	16%	11%
All-Season Tires	15%	N/A

7. IMPACTS OF VEHICLE TYPE AND DRIVERS

Results presented previously have shown that vehicle traction performance is not only tire dependent, but also vehicle and driver dependent. Vehicle characteristics, such as weight distribution, front versus rear wheel drive, and anti-lock brakes are the major contributors to the effects of the vehicle. For the driver's impact, a major factor is driving behavior, such as smoothness and response time. At this stage, among the factors of tire type, vehicle type, and driver, it is difficult to conclude which factor is more significant. However, by combining results of all vehicles and running tests by the same driver, the effects of vehicle type and driver can be minimized. This procedure was used in this project and assured the validity of the conclusions obtained. To test the impacts of vehicle type and driver, field data were processed and shown in Figures 7.1 and 7.2. Figure 7.1 presents the hill climbing ability of each vehicle, including the front wheel drive car (Lumina) and rear wheel drive vehicles (pickup and Caprice). Because the data from different tires (Blizzaks, studded tires, and all-season tires) and test sites (Fairbanks International Airport, Chena Lake access road, and Old Nenana Highway) were averaged, the impact of vehicle type on hill climbing ability can be evaluated. Based on this analysis, the front wheel drive car had the best hill climbing ability, followed by the rear wheel drive pickup, then the Caprice. Figure 7.2 shows the impact of driver type on 25 mph stopping distance on bare pavement surface. In this test, only the rear wheel drive pickup truck was used. It can be seen from this figure that for all tire types (Blizzaks, studded tires, and all-season tires), the female driver had significantly shorter stopping distances than the male driver did. The major reason for this might be driver's behavior in applying the brakes.

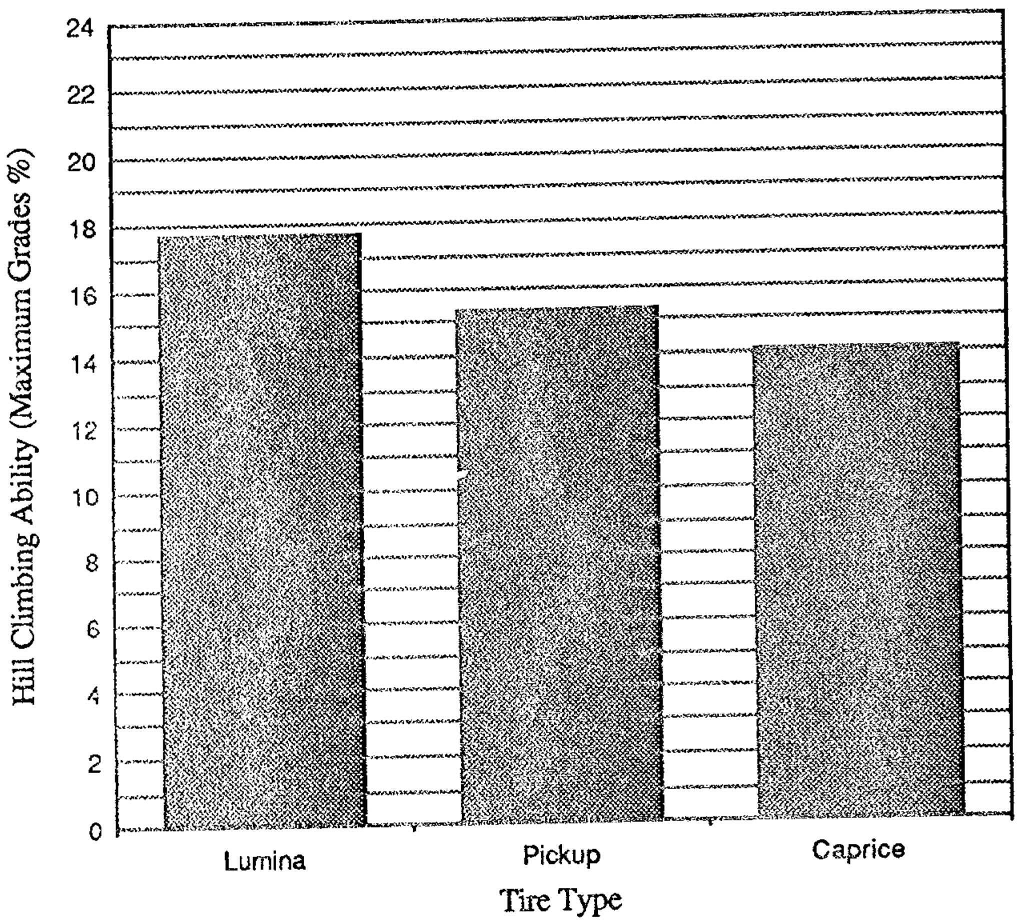

Fig. 7.1. Tests of Impact of Vehicle Type on Hill Climbing Ability in Fairbanks (All Tires and Test Sites Combined).

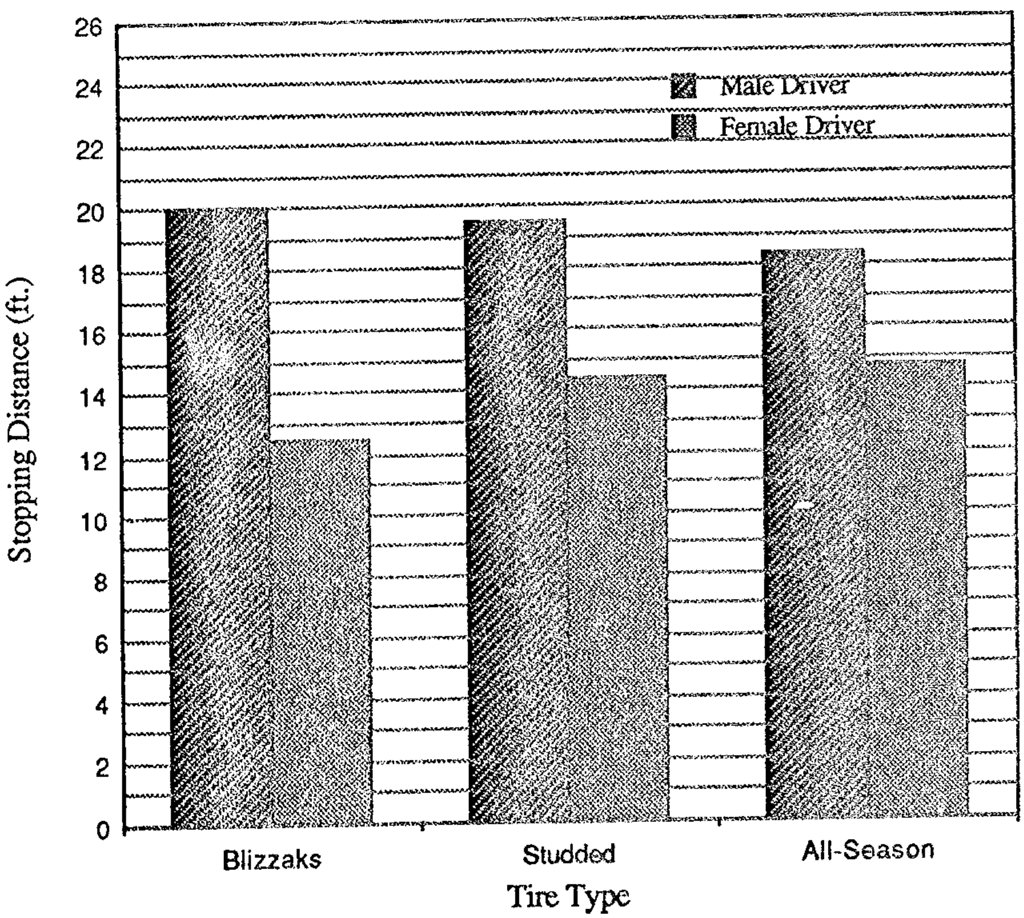

Fig. 7.2. 25 mph Stopping Distances on Bare Pavement Surface at Old Nenana Highway Test Site in Fairbanks (Pick-Up only).

8. CONCLUSIONS

a. Stopping Distance

On packed snow surfaces, all tire types were about equal in stopping distances. On icy surfaces, all stopping distances were about two to three times greater than on packed snow surface and seven to ten times greater than on bare pavement. In comparison to all-season tires, the Blizzaks shortened stopping distances on ice by about 8%, while the studded tires reduced stopping distances on ice by 8 to 10%; On bare pavement, the Blizzaks and all-season tires were superior to studded tires by 2 to 35 %.

b. Starting Traction

On packed snow surfaces, the Blizzaks and studded tires were about equal and gave slightly quicker starts, by about 10 to 20% less time to reach 25 mph, compared to all-season tires; On icy surfaces, the Blizzaks lessened times to reach 25 mph by about 13% and studded tires reduced it by 29% over all-season tires; On bare pavement, the Blizzaks showed slightly better traction performance, by about 6 to 9%, when compared to studded tires, and about the same traction performance, when compared to all-season tires.

c. Cornering Speed

On packed snow and icy surfaces, no significant differences were found among the Blizzaks, studded tires, and all-season tires in terms of maximum cornering speed. Cornering tests were not done on bare pavement due to the vehicle rollover potential.

d. Winter Hill Climbing Ability

The maximum grades which might be climbed by the different tire types during winter season were calculated from the maximum G-forces obtained during starting traction tests. On packed snow surfaces, the Blizzaks, studded tires, and all-season tires would climb grades up to 15 to 16%. On icy surfaces, these tires would climb 10 to 12% grades. Field tests showed only slight differences among these tires with studded tires able to climb 1% and 2 % steeper grades on ice than Blizzaks and all-season tires, respectively.