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NASA Tire/Runway Friction Projects

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NASA TIRE/RUNWAY FRICTION PROJECTS

by

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SUMMARY

This paper describes several NASA Langley Research Center tire/runway friction projects including:

- -Second annual NASA tire/runway friction workshop
- -Shuttle runway surface modification
- -Improved tire life program
- -C-17 aircraft soil runway tests
- -Joint winter runway friction measurement program

Test equipment and procedures are discussed and some test results are reviewed from the Shuttle runway evaluation and the improved tire life program. The presentation concludes with an overview of a proposed comprehensive 5-year winter runway friction measurement program.

INTRODUCTION

Research findings and technological advances in recent years have helped alleviate, but not eliminate, the hazards associated with adverse weather aircraft operations. Conversely, better avionics, growth in aircraft fleet, airport/runway congestion, and economics are factors which have increased the frequency of aircraft ground operations during inclement weather. However, to a pilot, happiness is still landing into the wind on a long, clean, dry runway keeping to a minimum the number of challenging situations which can arise during operations on slippery runways with fluctuating crosswinds. Improvements in aircraft braking systems, pilot simulator training programs, and runway surface treatments have tended to increase safety margins but weather-related aircraft accidents continue to occur. Unpredictable and rapidly changing weather conditions that may be encountered at a given airport further complicate the problems associated with aircraft takeoff and landing maneuvers.

Gaining a better understanding of the many factors influencing the tire/runway interface is the aim of several NASA Langley research programs described in this paper. The workshop activities and test programs have added greatly to NASA Langley's tire friction, wear and runway properties data base. The proposed joint winter runway friction measurement program is expected to produce new data to enhance the safety of aircraft ground operations in adverse weather conditions.

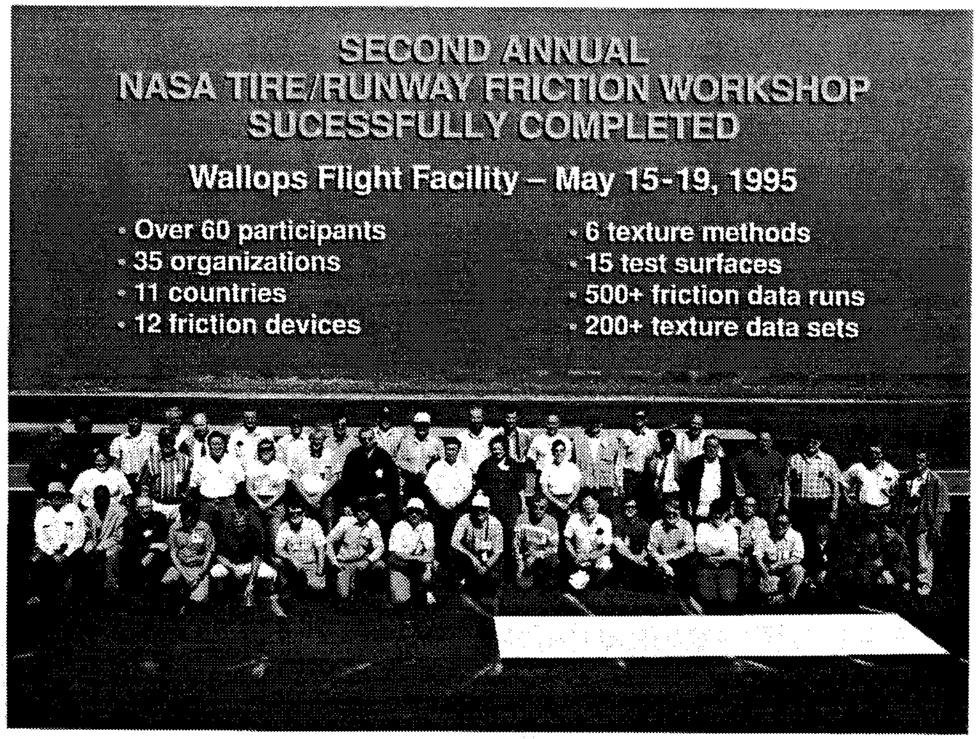

Figure 1

The Second Annual NASA Tire/Runway Friction Workshop was held at Wallops Flight Facility on the eastern shore of Virginia, May 15-19, 1995. Over 60 engineers participated from 35 organizations representing 11 different countries. Twelve friction measuring devices collected data during over 500 test runs on 15 different surfaces. Six texture methods were also used to obtain over 200 texture data sets. Initial friction and texture measurements were collected on three reference panel surfaces designed for low, medium, and high friction values. Runway roughness profile data were obtained and data comparisons to last year's workshop will be made. A shot peening treatment to enhance surface texture using skidabrader equipment was demonstrated successfully.

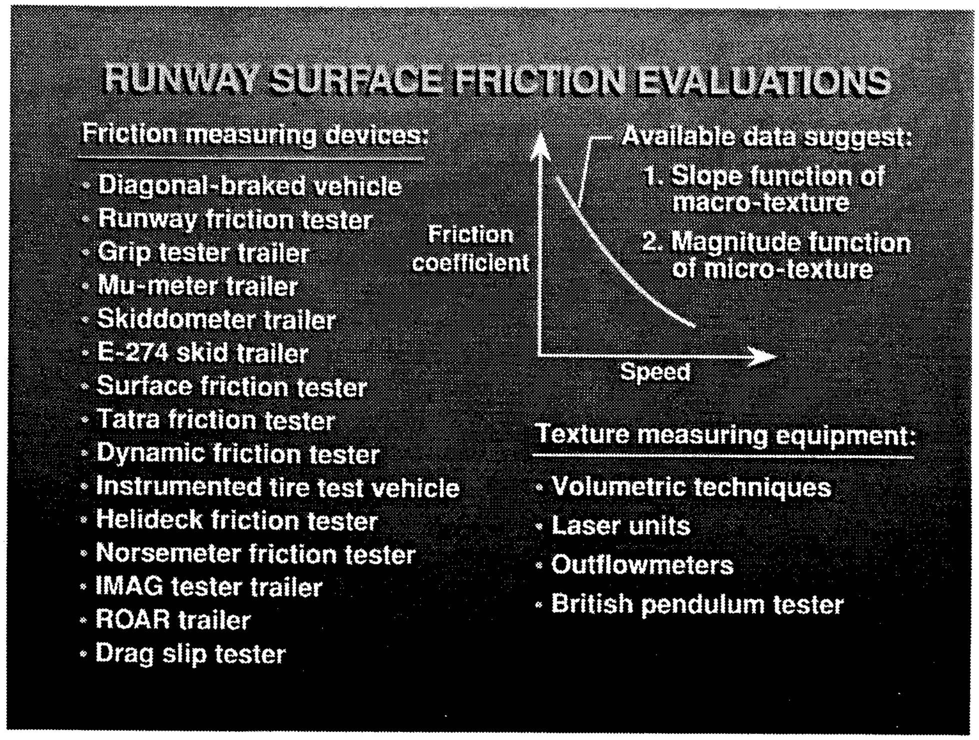

Figure 2

The range of friction and texture measuring equipment used during the NASA Tire/Runway Friction Workshop includes 12 different friction devices and four texture measurement techniques. The available friction/speed gradient data and texture measurements suggests that the friction speed gradient slope is a function of macro-texture (large scale) and the magnitude is a function of micro-texture (small scale). The NASA data reduction and analysis effort involves determining the correlation between the different friction and texture measurement equipment.

Figure 3

In early 1994, an extensive effort was started to determine a suitable Kennedy Space Center Shuttle Landing Facility (SLF) runway modification that would permit Shuttle landings to occur safely up to 20 knots crosswinds from the current 15 knots crosswind limitation. NASA Langley's Instrumented Tire Test Vehicle (ITTV) and NASA Dryden's Landing System Research Aircraft (LSRA) CV-990, were involved in evaluating several different surface modifications. Four different techniques were tried which included grinding, shot peening, rotopeening, and a methacrylate coating. On the basis of both friction and tire wear performance, the shot peening modification produced by the Skidabrader equipment was selected the best, and the SLF runway modification was completed in September 1994.

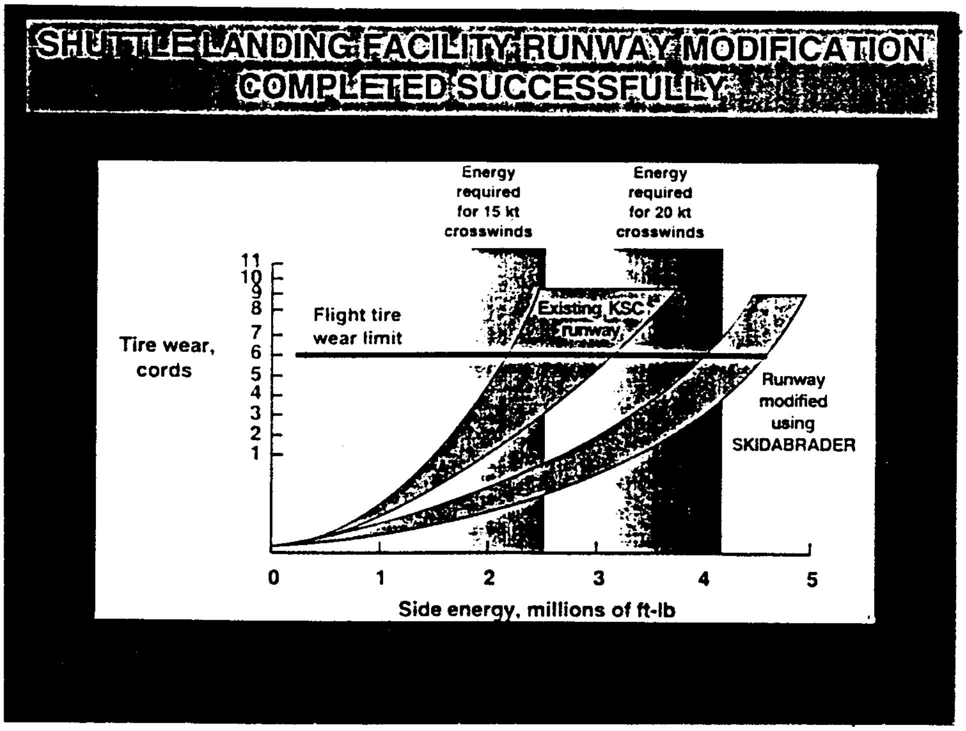

Figure 4

The variation of Space Shuttle main gear tire wear with side energy, produced during crosswind landing operations, is plotted in figure 4. The 6 cord, flight tire wear limit is indicated together with the side energy required to accommodate 15 and 20 knot crosswinds. The existing early 1994 Kennedy Space Center runway was found to wear the Shuttle tires beyond the 6 cord limit at side energy levels equivalent to 20 knots but the modified Skidabrader surface did not permit the tires to reach 6 cords wear until side energies exceed that produced at 20 knots. Hence, the entire 4575 m long, 91 m wide Shuttle Landing Facility runway was modified using the Skidabrader in September 1994.

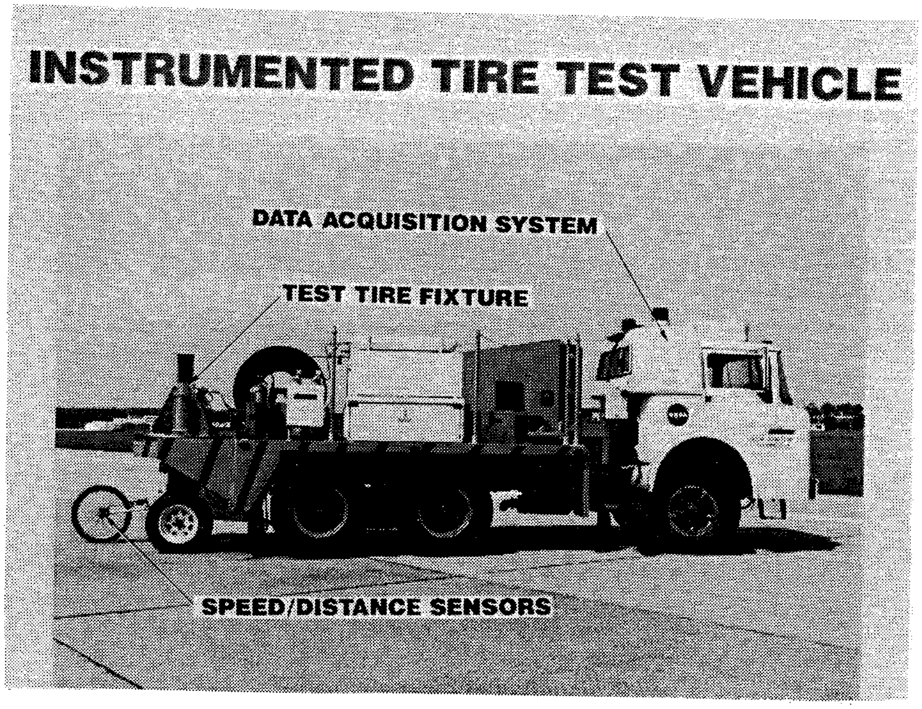

Figure 5

NASA Langley's Instrumented Tire Test Vehicle (ITTV) is a specially designed test device with an instrumented tire test fixture mounted on the rear and the data acquisition system located in the cab behind the operators. The test fixture can accommodate loads up to 22.2kN and test tire friction and wear performance can be evaluated in straight ahead rolling, yawed rolling, fixed slip braking, and cambered rolling. The maximum forward speed is 105 km/h. The ITTV speed and elapsed distance traveled are displayed on digital meters to the operators and also recorded on the onboard computer/CRT display data acquisition system. The ITTV performed over 800 test runs in a recently completed joint NASA/USAF/Industry Improved Tire Life Program.

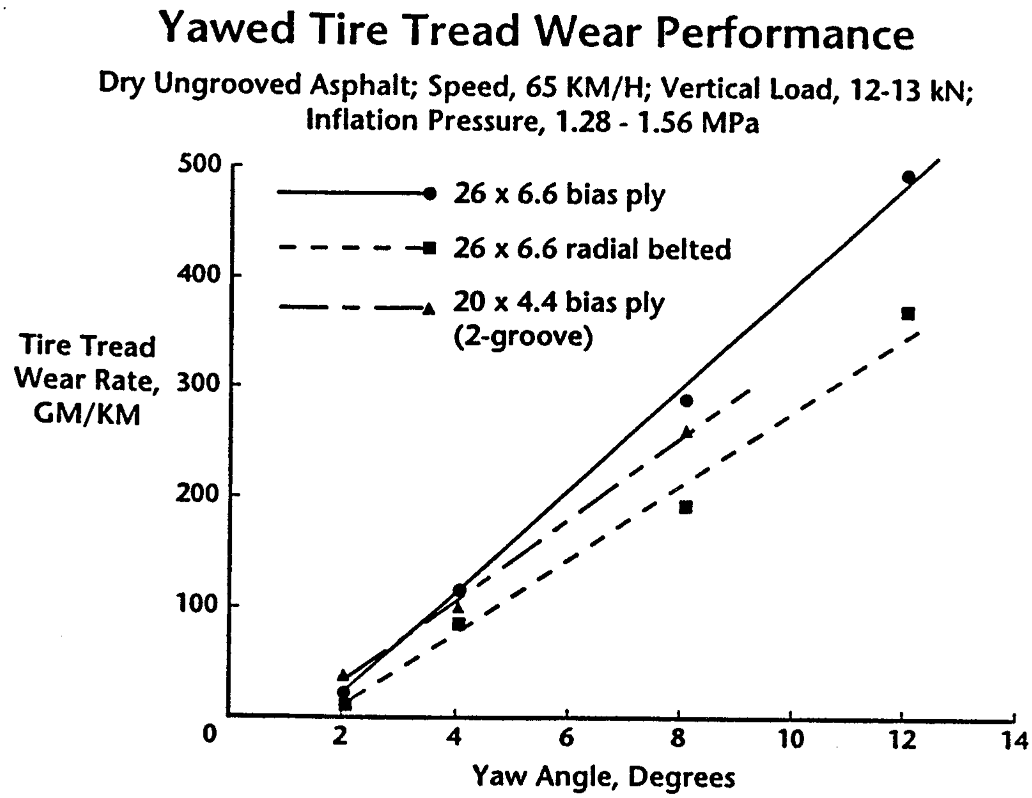

Figure 6

The effect of cornering measured by yaw angle on tread wear performance of three different aircraft nose gear tires is shown in figure 6. On the dry ungrooved asphalt at 65 km/h, the 26x6.6 radial-belted tire produced the best wear performance. One possible explanation for this result is that the tire tread temperature data indicated a difference in peak tread temperature of 100 degrees C (188 vs 88 degrees C) between the bias-ply and radial-belted tires operating at 12 degrees yaw with the radial-belted tire exhibiting the lowest temperature. Similar yawed tire tread wear performance data trends were observed throughout the range of loading, inflation pressure and speed values as well as on concrete test surfaces.

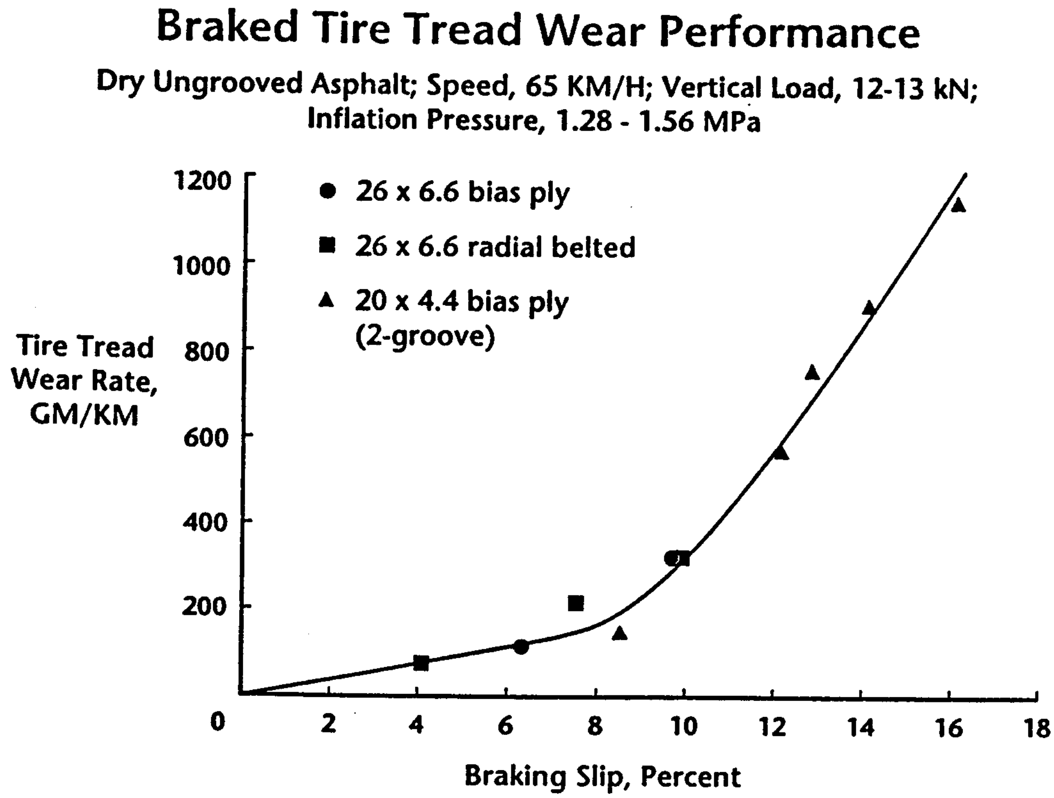

Figure 7

Figure 7 shows the effect of braking on tread wear performance of three different aircraft nose gear tires at 65 km/h on dry ungrooved asphalt at similar load and inflation pressure ranges. These braking data suggest that tire wear is independent of tire size, tread design, and construction and is directly dependent on percent braking slip. The ambient weather conditions during these braking tests were nearly the same in air temperature, humidity, cloud cover and wind.

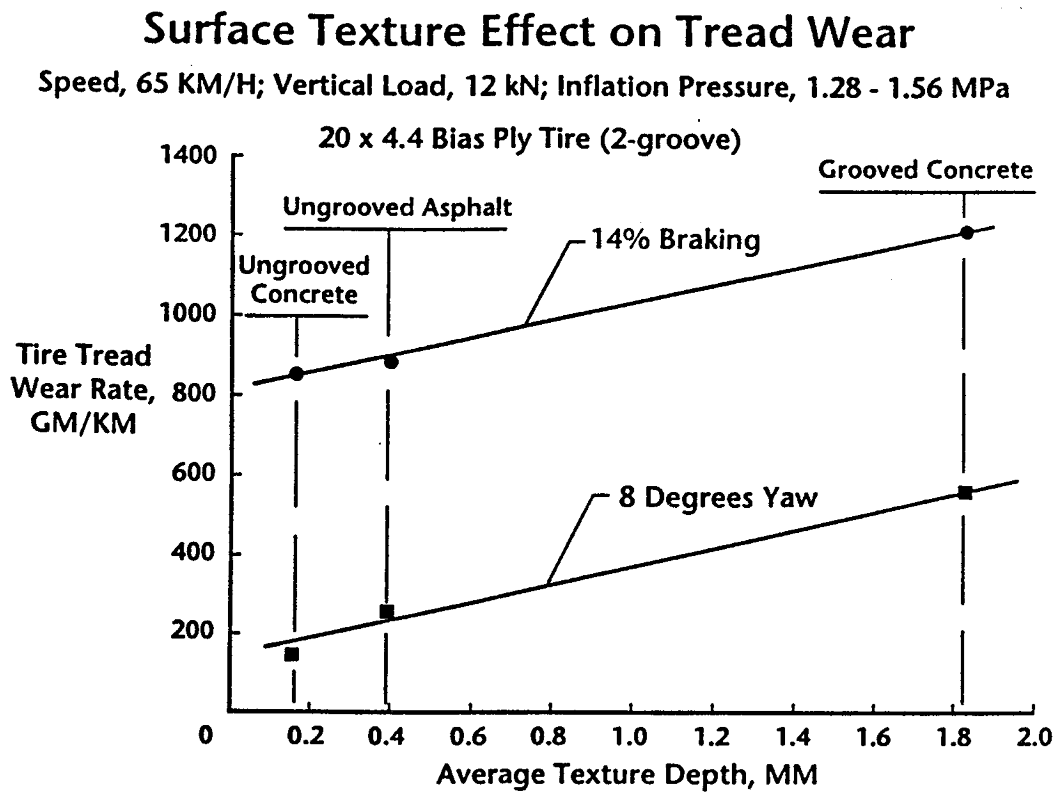

Figure 8

The effect of pavement surface texture on tread wear performance of the 20x4.4 bias-ply nose gear tire is shown in figure 8 for three different dry test surfaces. The general data trend of tire tread wear rate increasing with average surface texture depth is apparent for both 8 degree yawed rolling as well as 14 percent fixed braking slip at 65 km/h. Similar data trends were found for the two 26x6.6 test tires evaluated in the Improved Tire Wear Program.

Figures 9

The photograph in figure 9 shows a head-on view of the United States Air Force C-17 transport aircraft on an unprepared soil runway at Pope AFB, North Carolina, in March 1995. The ambient weather conditions for these landing and takeoff performance tests at aircraft gross weights varying from 1557 to 1860 kN were approximately 24 degrees C air temperature, light winds, partly cloudy, and no precipitation in previous 24 hours. The top 13cm soil layer consisted of a very dense clay soil which produced California bearing ratios close to 30 (very hard, e.g. brick).

Figure 10

The undercarriage configuration on the C-17 transport aircraft is shown in figure 10. The aircraft uses two, 40x16-14, 26PR nose gear tires and twelve, 50x21.0-20,30PR main gear tires. The tire inflation pressures were 0.79 MPa for the nose gear and 0.71MPa for the main gear.

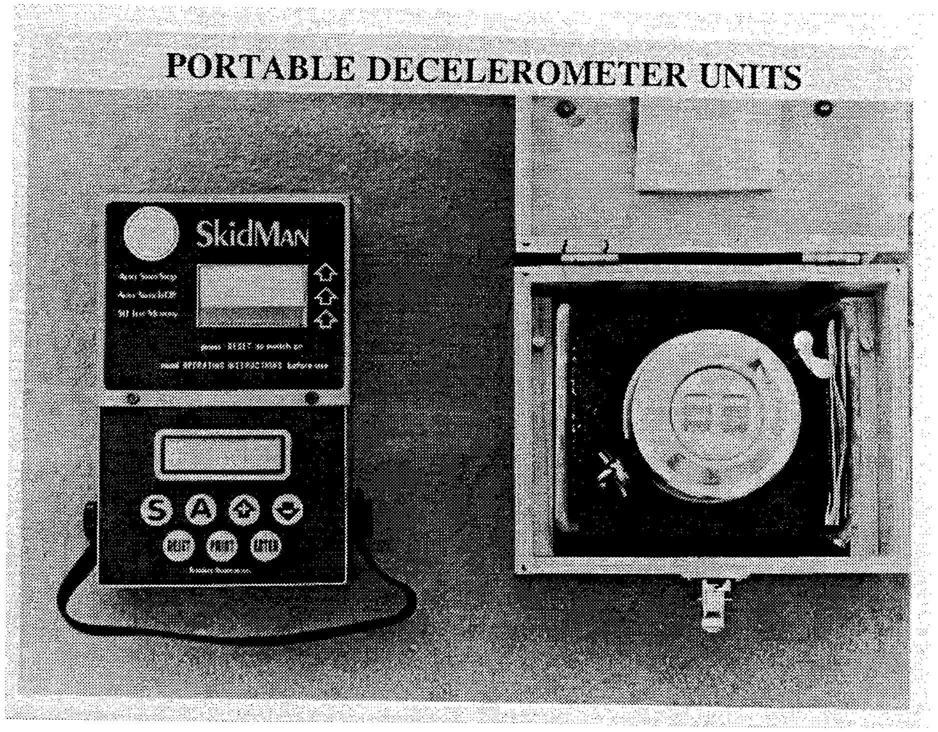

Figure 11

Two different portable decelerometer devices, shown in figure 11, were used in evaluating both the C-17 transport aircraft and the NASA Diagonal-Braked Vehicle stopping performance on the dry soil runway at Pope AFB, North Carolina. The Bowmonk Skidman unit, left side of figure, is an electronic decelerometer which provides a permanent time history record of vehicle acceleration/deceleration up to 1.0 g's. The Tapley decelerometer shown on the right side of figure 11 is a manually operated decelerometer which can indicate the peak deceleration value obtained during a vehicle braking run. Both these decelerometers were used in the ground test vehicles and they measured similar values. Only the Skidman unit was placed on the C-17 aircraft and deceleration values recorded by the Skidman were similar to that recorded by the C-17 data acquisition system.

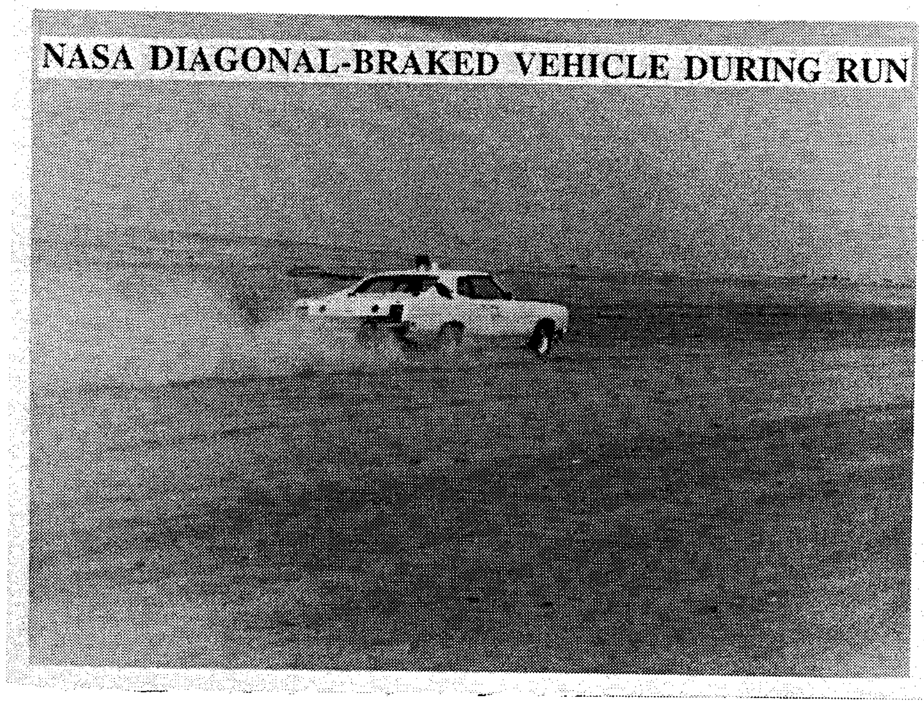

Figure 12

The NASA Diagonal-Braked Vehicle (DBV) is shown in figure 12 during a typical test run on the hard, dry soil runway at Pope AFB, North Carolina. The normal test procedure for evaluating runway friction performance is to conduct a series of DBV test runs with the operator applying brakes at 95km/h, locking a diagonal pair of wheels equipped with smooth tread test tires, and maintaining locked wheels down to a complete stop. The onboard DBV data acquisition systems provides a permanent time history record of deceleration, distance, and speed from which locked wheel friction coefficient data can be obtained together with Runway Condition Readings (RCR'S).

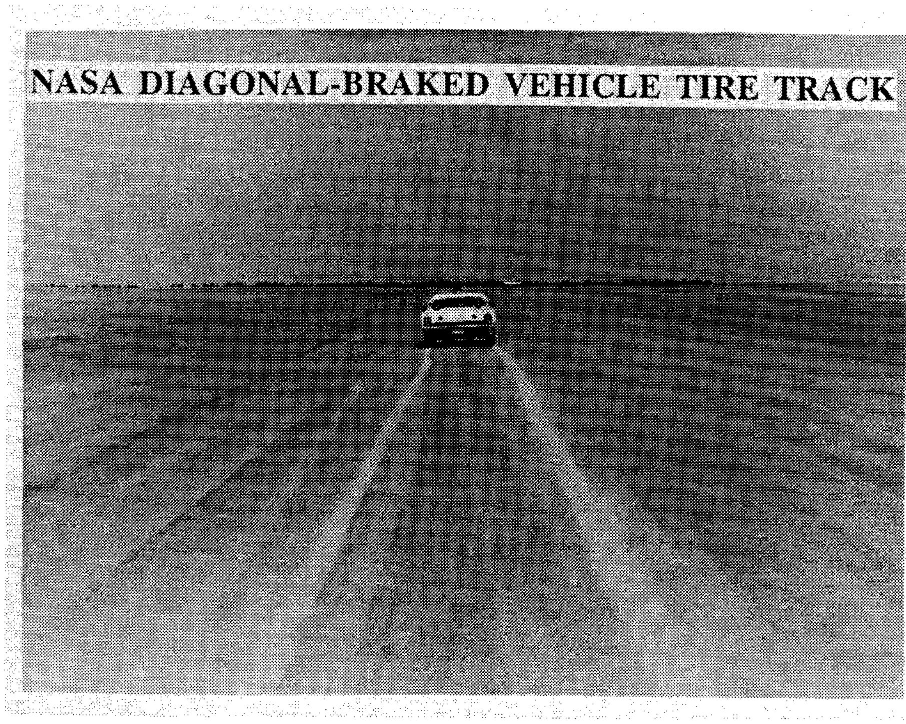

Figure 13

The photograph in figure 13 clearly shows the locked wheel tire tracks on the dry, hard, soil runway at Pope AFB after a Diagonal-Braked Vehicle(DBV) test run has been completed. In all the DBV test runs performed on this approximately 1200 meter long runway, the deepest tire penetration into the clay top soil was 6 mm. The C-17 transport aircraft left main gear tires traveled over a relatively small (15 meters) soft spot and that produced 10 cm deep ruts. Most other runway locations showed little evidence of tire tracks or soil penetration from either the C-17 airplane or the ground test vehicles.

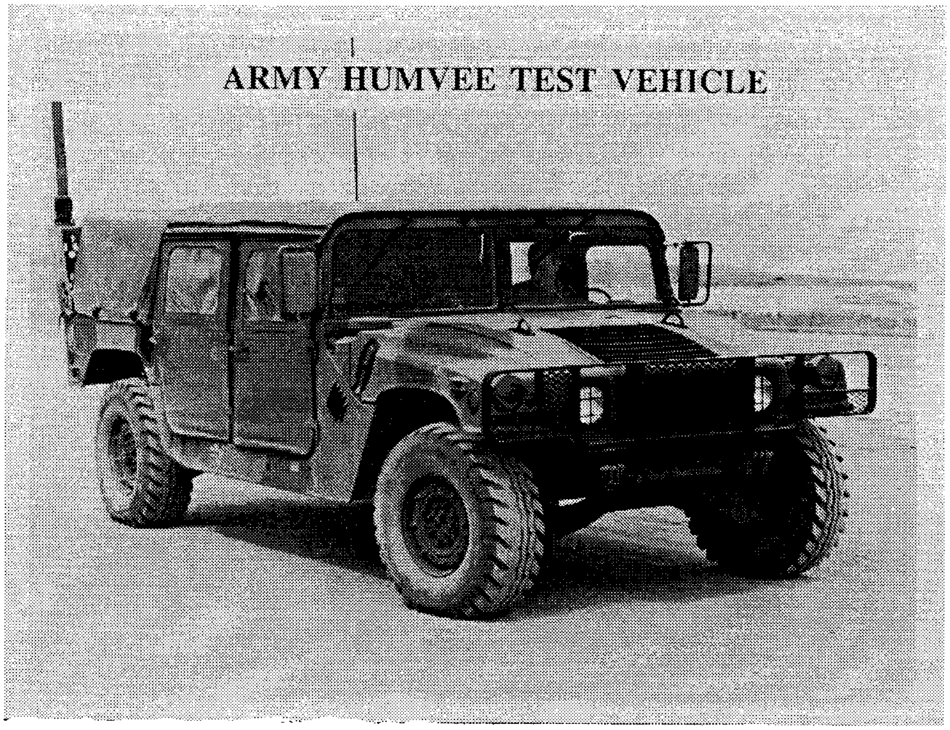

Figure 14

Comparable Diagonal-Braked Vehicle stopping test runs at approximately 35km/h were performed with an Army "Humvee" vehicle equipped with both the Skidman and Tapley meters to record deceleration values. This particular humvee vehicle was similar in weight to the DBV with both vehicles close to 22.2 kN. There was a significant difference, however, in the humvee all terrain tires compared to the smooth tread DBV test tires. Despite this tire tread difference, both the vehicles produced similar deceleration measurements at 35 km/h on the dry, hard soil runway and hence, the Runway Condition Reading (RCR) values were equivalent at 22.

PROPOSED JOINT WINTER RUNWAY FRICTION MEASUREMENT PROGRAM

PARTICIPANTS: NASA, FAA, USAF, Transport Canada, Joint Aviation Authority, and other aviation organizations

OBJECTIVES/SCOPE:

- Evaluate instrumented aircraft and ground vehicle friction harmonization
- Assess effects of both aircraft and runway anti- and de-icing chemicals
- Conduct parameter study at Langley's Aircraft Landing Dynamics Facility
- Configure test run matrices to optimize information useful to pilots, airport operators, equipment manufacturers, and airframe companies
- Implement many of the recommendations from White Paper prepared by Government/Industry Winter Runway Friction Measurement and Reporting Working Group

SCHEDULE: Five (5) years

FUNDING: Estimated $2 -3 M dependent on number of test aircraft
NASA portion approximately $1M

Figure 15

With possibly four major government agencies, the military and several aviation organizations participating in this joint 5-year program, a considerable amount of useful information should be produced to enhance safety of aircraft ground handling operations. The necessary interagency agreements are currently being approved with NASA as lead agency. Testing of instrumented aircraft and ground friction measuring vehicles could commence as early as fall of 1995.

CONCLUDING REMARKS

Considerable progress has been acheived in recent years in gaining a clearer understanding of tire/runway friction performance. The influence of several different factors including tire design and construction, inflation pressure, speed, surface type and texture together with surface contaminant and amount on both tire wear and friction has been better defined. An overview of NASA Langley projects including an annual tire/runway friction workshop, Space Shuttle landing runway modifications to reduce wear and enable landings at higher crosswind limits, an improved tire life program, C-17 transport aircraft and ground vehicle soil runway tests, and a proposed joint winter runway friction measurement program has been given. Some recent test results have been discussed together with future research activities. As new aircraft and ground friction measuring vehicles are introduced together with development of improved tire and pavement surface designs, additional testing, correlation, and evaluation projects will be required.

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The paper reviews several aspects of NASA Langley Research Center's tire/runway friction evaluations directed towards improving the safety and economy of aircraft ground operations. The facilities and test equipment used in implementing different aircraft tire friction studies and other related aircraft ground performance investigations are described together with recent workshop activities at NASA Wallops Flight Facility. An overview of the pending Joint NASA/Transport Canada/FAA Winter Runway Friction Program will be given. Other NASA ongoing studies and on-site field tests are discussed including tire wear performance and new surface treatments. The paper concludes with a description of future research plans.

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