NASA Boeing 737 Aircraft Test Results from 1996 Joint Winter Runway Friction Measurement Program

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SUMMARY

A description of the joint test program objectives and scope is given together with the performance capability of the NASA Langley B-737 instrumented aircraft. The B-737 test run matrix conducted during the first 8 months of this 5-year program is discussed with a description of the different runway conditions evaluated. Some preliminary test results are discussed concerning the Electronic Recording Decelerometer (ERD) readings and a comparison of B-737 aircraft braking performance for different winter runway conditions. Detailed aircraft parameter time history records, analysis of ground vehicle friction measurements and harmonization with aircraft braking performance, assessment of induced aircraft contaminant drag, and evaluation of the effects of other factors on aircraft/ground vehicle friction performance will be documented in a NASA Technical Report which is being prepared for publication next year.

INTRODUCTION

The 5-year NASA/Transport Canada/FAA Winter Runway Friction Measurement Program includes the following as primary objectives: (1) evaluate aircraft and ground vehicle friction harmonization; (2) validate James Brake Index (JBI) tables for landing distances using an Electronic Recording Decelerometer (ERD); and (3) measure induced aircraft contaminant drag under a variety of winter runway conditions. This paper summarizes some of the preliminary test results obtained earlier this year with the NASA B-737 aircraft and future test plans are indicated.

NASA B-737 TEST AIRCRAFT

The instrumented Boeing 737-100 jet transport test aircraft was operated by NASA Langley flight crews. Figure 1 shows the NASA B-737 aircraft during a dry loose snow-covered runway test at North Bay Airfield, Ontario. The aircraft is equipped with a dual- wheel nose gear with 24 X 7.7, 16 P.R., type VII aircraft tires, and the dual-wheel main gear used 40 X 14, 24 P.R., type VII aircraft tires. The maximum authorized landing weight for this aircraft is 89 700 lb with 40 deg. landing flaps. For purposes of these tests, the aircraft gross weight was maintained between 75 and 85K lb. Maximum brake application ground speed varied with weight and with test-section length and conditions from 110 knots down to 25 knots.

New wheel brake units and new (unworn) tires were installed on the main gear prior to testing at North Bay Airfield. The dual-wheel nose gear was also equipped with new tires prior to testing. The tire inflation pressures were 155 psi for the main-gear tires and 135 psi for the nose-gear tires. If tread wear reached 50 percent on a given tire, both tires on the landing gear would be replaced with new ones. This tire wear level was not reached in the testing conducted to date.

An extensive instrumentation package was used aboard the aircraft to monitor the position of flight control surfaces, brake-system performance, engine speed and throttle settings, and aircraft acceleration, heading, attitude and forward speed. All instrumentation sensors and transducers were properly calibrated prior to conducting test runs and after completion of a test series to document any change. Although the NASA B-737 aircraft system can provide a maximum data sample rate of 100 samples per second, most parameter data were evaluated at a rate of 40 samples per second.

Aircraft data reduction included generation of parameter data time history records in appropriate engineering units. From careful review of these time history records, uniformity in pilot brake

application and proper aircraft configuration for a given series of test runs was determined. For a given runway surface condition, longitudinal acceleration data from nonbraking tare runs were analyzed to identify incremental components attributable to aerodynamic drag, tire rolling resistance, engine idle thrust, and a change in the zero value of the accelerometer as the result of runway contaminant displacement/impingement drag. These tare run values of aircraft longitudinal acceleration were then used to correct the measured values recorded during maximum-braking test runs. The aircraft effective braking friction coefficients for a given run were derived by using an average percentage of the aircraft gross weight supported on the main-gear braking wheel; this percentage varied as a function of the nominal center-of-gravity position.

For comparison with readings collected in a ground test vehicle under similar runway conditions, an Electronic Recording Decelerometer (ERD) was installed aboard the B-737 aircraft near its center-of-gravity position and the longitudinal centerline of the aircraft. This instrument was only used during the snow and ice-covered runway tests performed at North Bay Airfield.

The extent of the NASA B-737 aircraft test run matrix completed to date is given in figure 2. In the landing configuration, spoilers are deployed but in the takeoff configuration, the spoilers are stowed. The wet and flooded runs performed at NASA Wallops Flight Facility were on grooved and nongrooved concrete test sections with a total length of 700 feet. At North Bay Airfield, the snow-covered test section was 1500 feet long and the ice-covered test section was 1000 feet long.

PRELIMINARY TEST RESULTS

A comparison of the ERD readings measured onboard the NASA B-737 aircraft with ground vehicle readings under the same runway conditions is shown in figure 3. For the two runway conditions available for evaluation, dry loose snow (3 runs) and this ice (1 run),

the data indicates the average aircraft ERD readings are consistently lower than the ground vehicle ERD readings. More data under different runway conditions are needed to verify this relationship and in terms of the James Brake Index (JBI), ERD correlation with mean aircraft effective braking friction coefficient values or aircraft stopping distance would be more meaningful.

Figure 4 shows the variation in NASA B-737 aircraft braking performance, as measured by the effective braking friction coefficient, with ground speed for a variety of winter runway conditions. The snow- and ice-covered data were obtained during tests at North Bay Airfield and the dry, wet and flooded data were obtained during tests at NASA Wallops Flight Facility. Runway conditions can significantly effect aircraft braking performance but on snow- and ice-covered runways speed is not as great a factor as on wet or flooded pavements.

CONCLUDING REMARKS

The Joint NASA/Transport Canada/FAA Winter Runway Friction Measurement Program has just started its 5-year schedule. Many more tests with different instrumented aircraft and ground vehicles are planned for several test sites. Considerable NASA B-737 aircraft braking and contaminant drag data has been collected but additional tests have been requested for this coming 1996-97 winter season. It should be noted that NASA plans to "retire" the B-737 aircraft in April 1997. Although this paper described some of the NASA B-737 aircraft preliminary test results, preparation of a more detailed, comprehensive NASA Technical Report on these studies is underway.

NASA INSTRUMENTED B-737 AIRCRAFT

Figure 1

B-737 AIRCRAFT TEST RUN MATRIX

Aircraft Configuration: Mostly landing but some takeoff with idle thrust settings

Types of Runs: Tare (free rolling, no wheel braking) and maximum antiskid braking

Runway Conditions:

NASA Wallops Flight. Facility

- Bare and dry
- Wet, 1 - 1.5 mm (0.04 - 0.06 in.) water depth
- Flooded, 10 - 13 mm (0.4 - 0.5 in.) water depth

North Bay Airfield, Ontario

- Bare and dry
- Loose dry snow, 13 to 76 mm (0.5 to 3 in.) depth
- Patchy thin ice

Total Test Runs: 18 at NASA Wallops and 24 at North Bay

Figure 2

COMPARISON OF B-737 AIRCRAFT AND GROUND VEHICLE ELECTRONIC RECORDING DECEL. READINGS

North Bay Airfield, Ontario; R/W 8/26; loose snow and thin ice surface conditions; March 1996

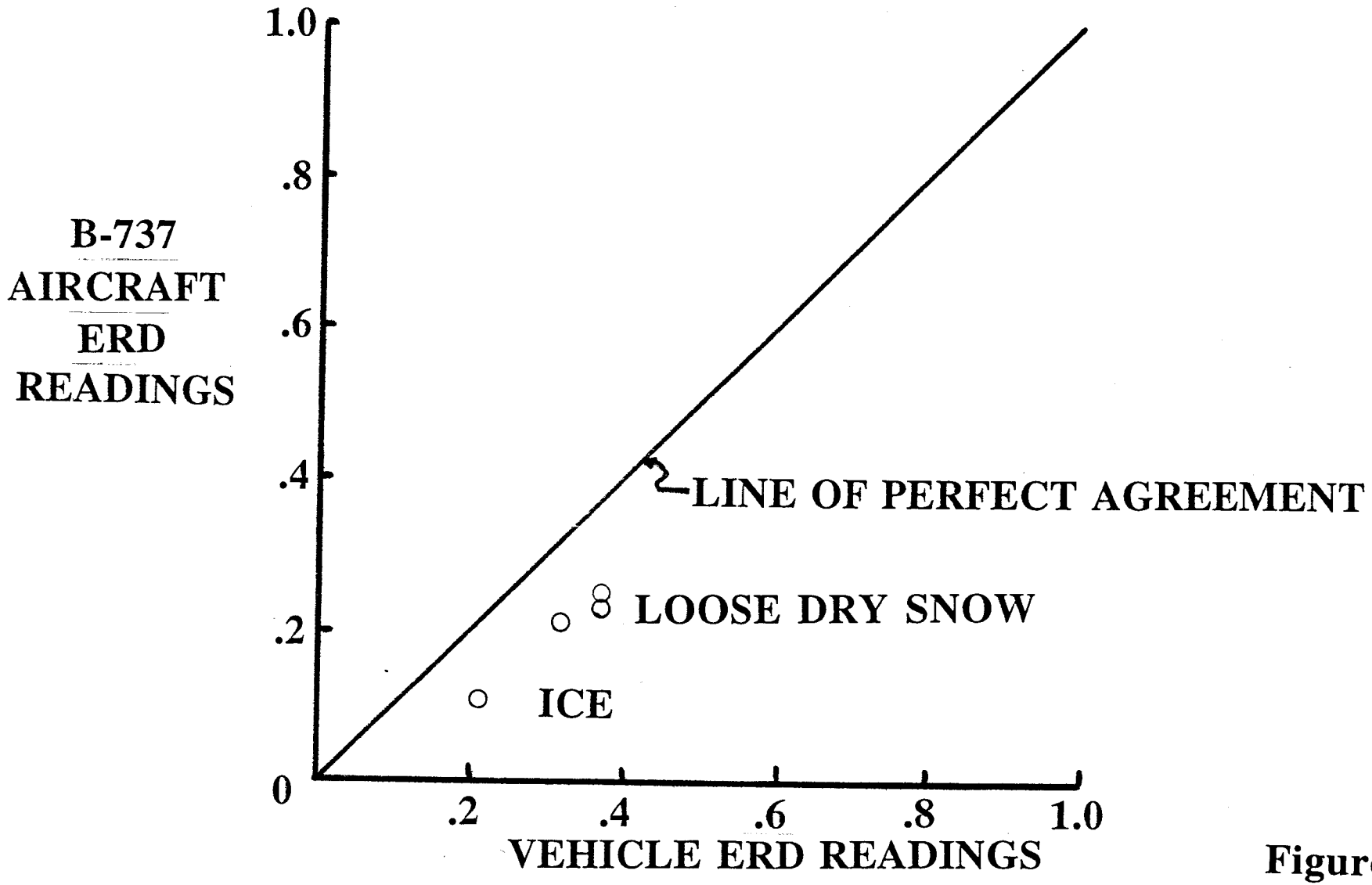

Figure 3

NASA B-737 AIRCRAFT BRAKING PERFORMANCE

Landing Configuration; North Bay, Ontario; R/W 8/26; March 1996
NASA Wallops Flight Facility; R/W 4/22; August 1996

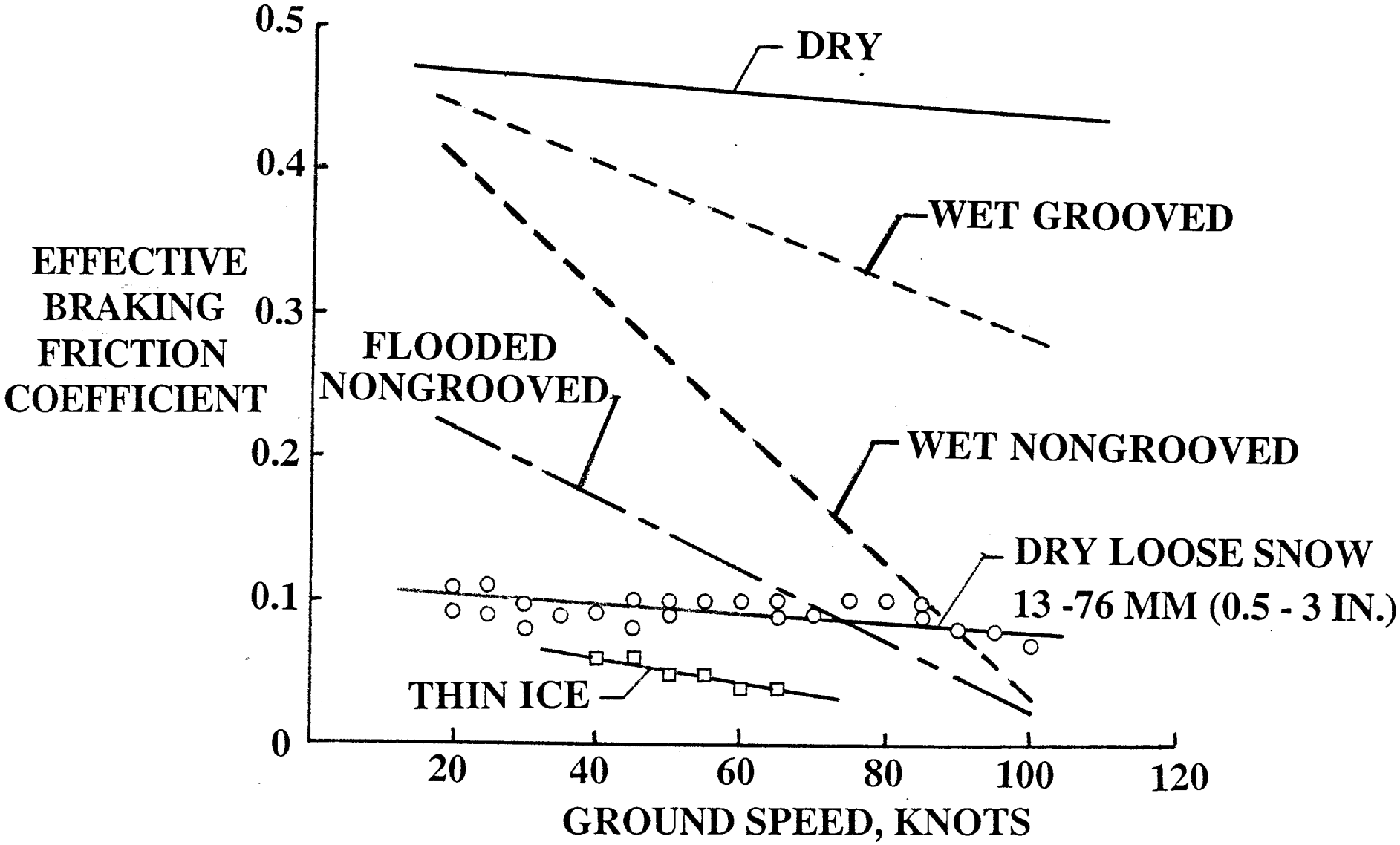

Figure 4