

NATIONAL TRANSPORTATION SAFETY BOARD

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Runway Pavement Macrotexture Retest

I. RUNWAY EXAMINATION

NTSB Number:	DCA12SS002
Description:	Pavement Macrotexture Measurements (NASA Grease Sample Method and Water Outflow Meter)
Location:	Runway 3/21, Roswell, NM (KROW)
Date:	January 9-10, 2012
Time:	2100 – 0400 Mountain Standard Time (MST)

II. MACROTEXTURE TEST TEAM

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1.0 INTRODUCTION

Airplane stopping performance is dependent on many variables, including gross weight, flap configuration, touchdown position and speed, environmental variables, appropriate deceleration device configuration, pavement (material, condition, and drainage) properties, and the presence of surface contaminants (see Ref. 1). For wet runway conditions, higher pavement macrotexture values in the airplane braked wheel paths permit more bulk water to escape from the tire/pavement interface, thereby improving tire/pavement contact and reducing the risk of dynamic hydroplaning at high airplane ground speeds.

In October 2011, a pavement macrotexture survey was conducted on runway 3/21 at Roswell International Air Center (RIAC) (see Ref. 2) to collect data related to observed airplane stopping performance on wet, non-flooded runways by turbine-powered, transport category airplanes during flight test and revenue service operations. The pavement macrotexture values measured were somewhat higher than the value documented in a 1974 Federal Aviation Administration (FAA) technical report¹ (see Ref. 3) and higher than expected based on wet runway stopping performance data collected during several Boeing Commercial Airplane flight test programs since 1999. Moreover, the October 2011 test was the first pavement macrotexture survey conducted by the test participants and was not witnessed by FAA airplane performance or NASA tire/pavement interface specialists. As a result, a runway 3/21 pavement macrotexture retest activity was planned with cooperative participation by representatives from the FAA, NASA, NTSB, Boeing, and RIAC.

On Monday, January 9, 2012, beginning at about 2200, the average pavement macrotexture was retested at 2 ungrooved concrete test stations on runway 3/21 at KROW² using the grease sample test method. In addition, 52 stations were measured using a water outflow meter (Hydrotimer). Test stations were organized by longitudinal distance from the runway 21 threshold and lateral position relative to the centerline. The grease and outflow meter tests were conducted in parallel over a period of about 6 hours. Pavement macrotexture results are reported in millimeters, inches, and using the Engineering Scientific Data Unit (ESDU) runway category A through E scale (see Section 2.5). Both the grease test and water outflow meter results indicate that the KROW runway 3/21 pavement macrotexture is consistent with Class C ESDU for the middle 5,000 to 9,000 feet of runway (which excludes the first 4,000 to 2,000 feet of pavement adjacent to each threshold, respectively, subject to heavier rubber deposits).

2.0 FACTUAL EVIDENCE

The available factual evidence used in this study is defined in this section.

2.1 Runway 3/21 (KROW)

The runway 3/21 pavement is 13,001 feet long and 150 feet wide. The ungrooved pavement consists of a 100-foot-wide concrete section centered on the runway centerline with an adjacent 50-foot-wide asphalt section on each side.³ Related airport overview and runway detail data are provided in Reference 2, Attachment 1.

¹ Wet runway braking tests were performed in October 1973 at Roswell, NM with a B737, L-1011 and four different ground friction measuring vehicles. At that time the average macrotexture value for runway 3/21 was 0.22 mm. None of the test participants in the present retest activity measured pavement macrotexture data during the October 1973 test.

² The International Civil Aviation Organization (ICAO) airport identifier for Roswell International Air Center is KROW.

³ The first 2,000 feet of runways 3 and 21 are each composed of ungrooved concrete full width. The declared runway 3/21 width was modified from 200 feet to 150 feet on 2/22/2006 per NFDD #243 dated 12/20/2005. The RIAC airport manager stated that the airport received an FAA waiver that permits the painted runway outline to remain 200 feet wide. Except as previously noted, the runway pavement still consists of a 100-foot-wide concrete section centered on centerline with an adjacent 50-foot-wide asphalt section on each side.

Many of the Boeing aircraft wet runway stopping performance tests were conducted on the left (South) side of runway 21, which was found to have the higher average transverse slope (1.1 % versus 0.7 % for the North side of the centerline). The concrete portion of the runway is a “tilted slab” with drainage from the North edge to the South edge of the runway, as opposed to draining from a centerline crown. The most recent rubber removal operations on runway 3/21 prior to the pavement macrotexture retest in January 2012 occurred between November 1, 2011 and November 4, 2011.

2.2 Pavement Macrotexture Test Stations

The City of Roswell, NM provided airport vehicle escort services to support the runway 3/21 pavement macrotexture retest activity. A runway visual inspection prior to dark on January 9, 2012 revealed that some of the grease measurement sites from the October 2011 test remained visible and surface wear had exposed concrete aggregate in several locations. Several photographs were taken and a single longitudinal test station located 6,000 feet from the runway 21 threshold was selected to conduct comparison grease sample measurements 17’ and 34’4” left of the runway centerline.

The two lateral stations described in Table 1, representing a subset of the lateral stations selected in the October 2011 study, were chosen to evaluate the effects of test operator, grease type, grease volume, and spreader tool on the measured pavement macrotexture.

Table 1: Runway 3/21 lateral test stations for NASA grease sample test measurements

	Lateral test station position relative to runway 21 centerline		
	34’4” Left	17’ Left	
Description	B737-700 left main gear strut position when nose gear track is shifted 25’ left of centerline	Approximate average of B787-8 and B747-8/F left wing main gear strut position when airplane nose gear tracks runway centerline	Near the expected location of the B737-700 right main gear strut position, assuming the B737-700 nose gear was centered on the 50-foot-wide concrete pavement section left of the runway 21 centerline

Water outflow meter test stations were located at 500- to 1,500-foot intervals, beginning 2,000 feet from the runway 21 threshold. For each longitudinal station, two lateral stations were selected to approximate the position of the left and right wing main gear strut for the B787-8 and B747-8/F, assuming the respective airplane nose gear tracked the runway centerline. In addition, two lateral stations were used to approximate the position of the B737-700 left/right main gear strut, assuming the nose gear was centered on the 50-foot-wide ungrooved concrete pavement section left/right of the runway 21 centerline. Applicable airplane three-view drawings are included in Reference 2, Attachment 2. Finally, one lateral station was selected to periodically sample the concrete/asphalt macrotexture at a left outboard location ranging from 50-67 feet from centerline, which was postulated to be subject to less frequent aircraft wheel traffic. Table 2 summarizes the lateral test stations selected for water outflow meter measurements.

Table 2: Runway 3/21 lateral test stations for outflow meter measurements

	Lateral test station position relative to runway 21 centerline				
	50-67' Left	34'4" Left	17' Left	17' Right	34'4" Right
Description	Outboard concrete/asphalt station subject to less wheel traffic	B737-700 left main gear strut position when nose gear track is shifted 25' left of centerline	Approximate average of B787-8 and B747-8/F left wing main gear strut position when airplane nose gear tracks runway centerline	Approximate average of B787-8 and B747-8/F right wing main gear strut position when airplane nose gear tracks runway centerline	B737-700 right main gear strut position when nose gear track is shifted 25' right of centerline

2.3 Test Equipment and Methods

2.3.1 Grease Sample Test

Each test station on the runway was located longitudinally relative to the runway 21 threshold using runway distance remaining signs and/or centerline paint stripe dimensions and laterally relative to the runway centerline using a metal tape measure. Duct tape was used to define three sides of a 4-inch-wide rectangular area with a floating long-side dimension that was parallel to the runway centerline. Four sets of adjacent 4-inch-wide rectangular areas were outlined for each tool operator to support an assessment of the NASA grease sample test sensitivity to operator, spreader tool, and grease type and volume. The four rectangular areas were reserved for measurements using the Boeing grease/plastic scraper, Boeing grease/rubber squeegee, NASA grease/plastic scraper, and NASA grease rubber squeegee, respectively. Figure 1 illustrates how the grease sample method test areas were allocated for each operator at a given lateral test station.

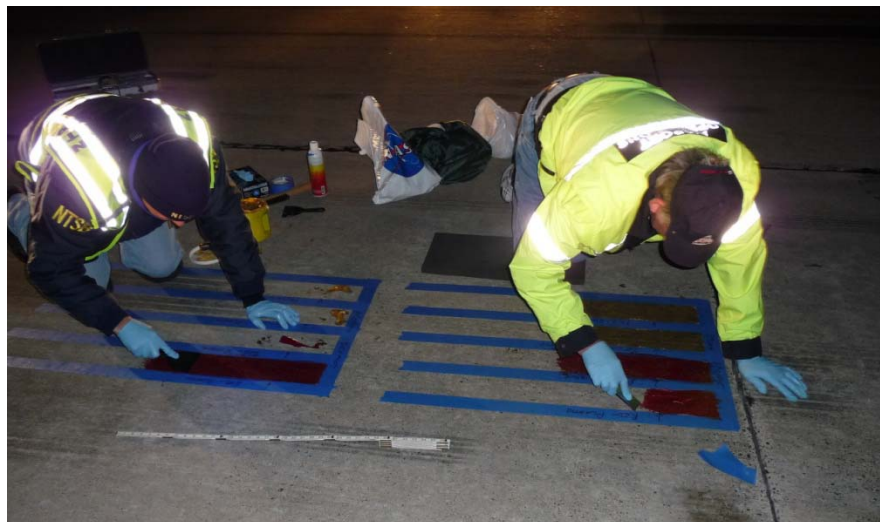


Figure 1: Operator 1 (NTSB, left) and Operator 2 (NASA technical consultant, right) conducting grease test at a given test station using two different grease spreading tools (2-inch-wide rubber squeegee and 4-inch-wide rigid plastic scraper) and two different grease types (NASA grease supply in yellow, Boeing grease supply in red).

Grease⁴ was compressed into either the NASA- or NTSB-supplied metal measurement cylinder until it flowed uniformly from the opposite end. The cylinder was then flipped over and the grease compression and uniform flow check was repeated from the opposite end. A 2-inch-wide plastic scraper was used to remove excess grease from the cylinder sidewall and both ends. The fixed volume of grease was expelled from the cylinder into the designated taped-off test station area using a plunger. Care was taken to ensure that all the grease in the test cylinder was applied to the test station area without introducing additional grease from tools or gloves. The grease sample test method documented in FAA Advisory Circular (AC) 150/5320-12C (see Ref. 4) includes photographs of the NASA-supplied cylinder, plunger, and rubber squeegee tools used for the pavement macrotexture retest. For convenience, the applicable section from Reference 4 is provided in Attachment 1.

Grease was worked into the voids in each pavement test station area from the 4-inch-wide taped-end toward the floating end using either the 4-inch-wide plastic scraper or the 2-inch-wide rubber squeegee. The 4-inch-wide plastic scraper, NASA-supplied rubber squeegee, 2 NTSB metal grease measurement cylinders, and 2 plungers are shown in Figure 2. Care was taken to keep the grease in the test area, off the tape, and uniformly distributed, with no excess grease buildup evident when the scraper/squeegee was dragged at an acute angle (roughly 10° to 20° between the tool and the pavement) across the test area in any direction.



Figure 2: Grease test equipment including, from left to right, 4-inch-wide plastic scraper, NASA 2-inch-wide rubber squeegee, cylinder and rubber-tipped plunger to measure and apply known Boeing grease volume to test station, cylinder and rubber-tipped plunger to measure and apply known NASA grease volume to test station.

Once the grease was uniformly distributed in the test area, the test area dimensions were measured and recorded. The duct tape was subsequently removed from the runway, rags were used to remove the bulk grease in the test area, brake cleaner was applied to the test area as a

⁴ The NASA grease was a supply of Shell Darina number 2. The Boeing grease supply was a 14-ounce can of STA-LUBE STA-PLEX extreme pressure premium red grease by CRC.

degreasing agent, and remaining grease was removed with clean rags. Used tape, rags, and gloves were accounted for and discarded to prevent aircraft/engine foreign object damage.

Pavement macrotexture calculations were performed subsequent to the runway data collection activity using the method outlined in References 4 and 5. In simple terms, the NASA grease sample test method texture depth at a given test station is calculated as the ratio of the known grease supply volume to the measured area of grease spread.

2.3.2 Water Outflow Meter Test

At each test station, the Hydrotimer self-contained outflow meter shown in Figure 3 was used to measure the time required to drain a fixed volume of water beneath the base sealing ring in contact with the pavement. The base sealing ring simulates a tire footprint. Pavement texture voids under the seal allow the water to drain. This precision instrument is designed to collect accurate data independent of the test operator and calibrated to meet the ASTM International E 2380-05 Standard. The current ASTM standard for measuring pavement texture drainage using an outflow meter is included in Attachment 2.

Prior to this study, conversion tables between water outflow meter drainage time and NASA grease sample test method average texture depth (ATD) were constructed based on test data collected on a range of pavements with different material and surface finish properties (see Ref. 6).



Figure 3: Water outflow meter (Hydrotimer) demonstration test on RIAC sidewalk pavement leading to the airport terminal.

2.4 Conversion Tables between Outflow Meter Time and Grease Test ATD

The NASA technical consultant provided the empirically-based data in Reference 6 and Tables 3 and 4 to enable the pavement macrotexture ATD measurements collected with the NASA grease sample test method to be transformed to equivalent water outflow meter time. Measured outflow meter time can be transformed to equivalent grease test ATD using the same empirical data. The relationship between outflow meter drainage time and NASA grease test ATD measurements from Reference 6 (based on the FHWA device) and Tables 3 and 4 are compared in Figure 4. The results reported in this study are based on the FHWA outflow meter and grease sample test data documented in Reference 6.

Table 3: Conversion of Outflow Meter Time Intervals to Grease Test ATD Values

Outflow Meter Time Seconds	Grease Test ATD	
	in.	mm
1.0	0.079	2.00
2.0	0.055	1.39
2.5	0.045	1.14
3.0	0.035	0.90
3.5	0.028	0.70
4.0	0.020	0.50
4.5	0.019	0.47
5.0	0.018	0.45
6.0	0.017	0.43
7.0	0.016	0.40
8.0	0.015	0.38
9.0	0.014	0.36
10.0	0.013	0.34
15.0	0.013	0.32
20.0	0.012	0.30
25.0	0.011	0.27
30.0	0.010	0.25
35.0	0.009	0.23
40.0	0.008	0.22
50.0	0.008	0.20
60.0	0.006	0.15
70.0	0.005	0.13
80.0	0.004	0.11
90.0	0.004	0.09
100.0	0.003	0.07

Table 4: Conversion of Grease Test ATD Values to Outflow Meter Time Intervals

Grease Test ATD		Outflow Meter Time Seconds
in.	mm	
0.200	5.08	0.40
0.150	3.78	0.45
0.100	2.52	0.50
0.090	2.26	0.75
0.080	2.02	1.01
0.070	1.76	1.30
0.060	1.51	1.60
0.050	1.26	1.90
0.040	1.01	2.20
0.030	0.76	2.60
0.020	0.51	5.10
0.010	0.25	30.00
0.009	0.23	37.00
0.008	0.20	45.00
0.007	0.18	55.00
0.006	0.15	60.00
0.005	0.13	63.00
0.004	0.10	66.00
0.003	0.08	69.00
0.002	0.050	72.00
0.001	0.030	75.00

The red and blue NASA grease test ATD data in Figure 4 correspond to the data in Tables 3 and 4, respectively. The red, blue, and FHWA gray curves do not collapse throughout the data range plotted even though the respective curves accurately reflect the measured and reported data.⁵ However, these data do collapse for outflow meter drainage times between 3 and 50 seconds, which includes the grease sample test ATD range of primary interest for this wet runway stopping performance study. The green curve in Figure 4 is similar to the gray curve, but includes one additional data point (from Reference 6) in the curve fit.

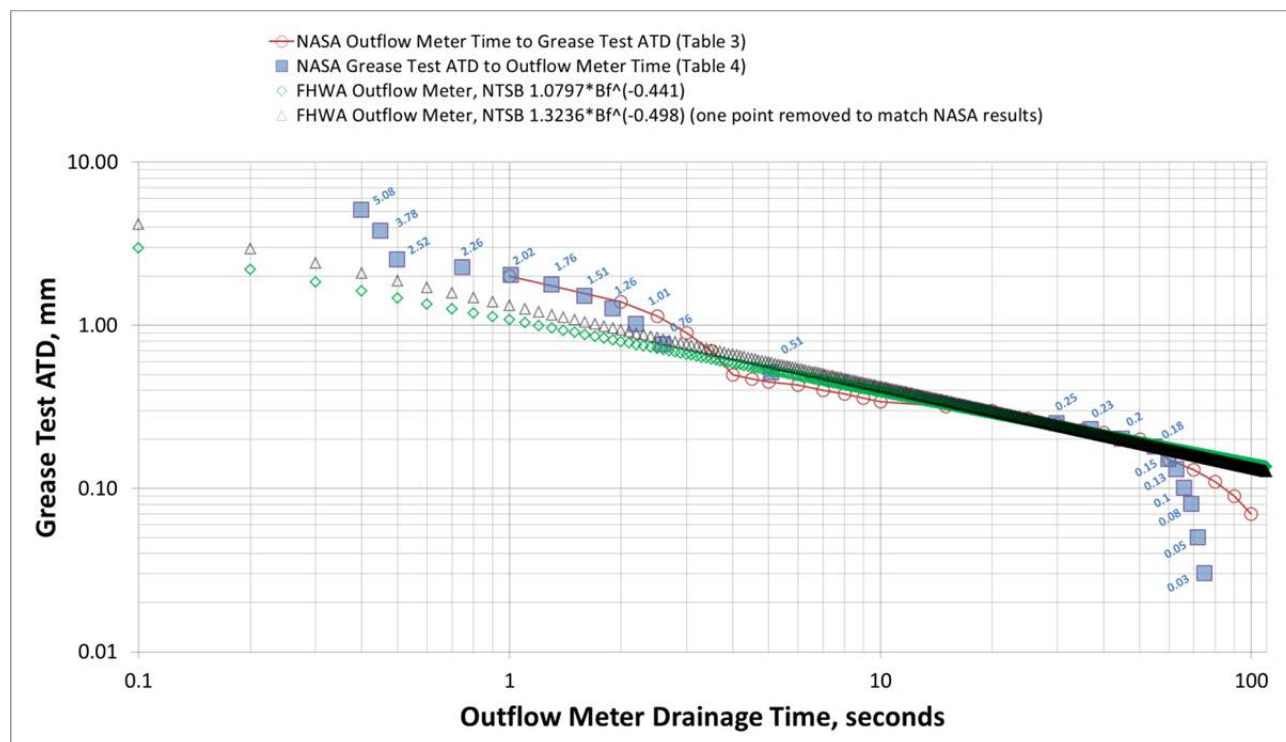


Figure 4: Relationship between grease sample test ATD and outflow meter drainage time.

The baseline grease sample data correlation with the Hydrotimer on a variety of surfaces is contained in Reference 6. The data were obtained in 1981-82 prior to development of the Hydrotimer in 2005. During the NASA Wallops friction workshops in 1994 - 2008, additional NASA grease and FHWA outflow meter data were collected. A one-to-one relationship between the FHWA outflow meter and the Skidabrader Hydrotimer was established in 2005. For this study, the Hydrotimer data is equated to existing FHWA outflow meter data.⁶

2.5 Pavement Classification Scales

The pavement macrotexture survey measurements and calculated results for each test station are reported in millimeters, inches, and using the ESDU runway Class A through E scale summarized

⁵ The NASA tables computed for converting the Hydrotimer measurements to grease ATD values were partly based on a large file of grease texture measurements taken by many individuals (other than Operator 2), whereas Operator 2 collected the data in Reference 6. Grease texture measurements may be operator sensitive (different values can be obtained by different operators on the same surface). Further, the grease tube volume used in the Reference 6 data compilation was not the same as the one used at Roswell, NM. Consequently, the grease volumes used may be slightly different.

⁶ Hundreds of comparative tests on several different pavement surfaces have been used to establish the relationship between outflow meter, sand patch, grease test and laser macrotexture depth, permitting a measurement from one device to be converted to measurements with the other three devices.

in Table 5 (see Ref. 7). Separately, for comparative purposes, an excerpt of the NASA runway pavement classification scale is included in Table 6. In general terms, higher pavement surface macrotexture values yield greater tire to ground friction when wet than a lower macrotexture surface, with other variables held constant.

Table 5: ESDU runway pavement classification scale

	Pavement Macrotexture		Estimated Outflow Meter Time*
ESDU Class	inches	mm	seconds
A	0.004 – 0.006	0.10 – 0.15	> 90
B	0.006 – 0.010	0.15 – 0.25	30 – 90
C	0.01 – 0.02	0.25 – 0.51	5 – 30
D	0.02 – 0.04	0.51 – 1.02	2 – 5
E	0.04 – 0.10	1.02 – 2.54	< 2

* Based on linear curve fit to FHWA data in Reference 6.

Table 6: Excerpt of NASA runway pavement classification table

	Pavement Macrotexture Depth Grease Sample Method		Outflow Meter Time
NASA Class	Inches	mm	seconds
I	> 0.04	> 1.0	< 2
II	0.02 – 0.04	0.5 – 1.0	2 – 5
III	0.01 – 0.02	0.3 – 0.5	5 – 20
IV	0.004 – 0.01	0.01 – 0.3	20 – 80
V	< 0.004	< 0.01	> 80

2.6 Weather Conditions

Weather conditions for January 9, 2012 and January 10, 2012 were extracted from the Weather Underground online archive and documented in Attachment 3. During the October 2011 test, the maximum, minimum, and ambient air temperatures were 61, 50, and 55 °F, respectively. The comparable ambient air temperature values during the January 2012 test were about 25 °F colder at 34, 24, and 29 °F, respectively.

3.0 RESULTS

Runway 3/21 rubber removal treatment in the runway touchdown areas occurred in November 2011, between the October 2011 grease sample test measurements and the January 2012 grease sample test and water outflow meter (Hydrotimer) measurements. Consequently, data comparisons between the October 2011 and the January 2012 grease sample test measurements do not include the aircraft runway touchdown areas located within 4,000 feet from either threshold. That is, direct comparisons will focus on the runway mid-section of 5,000 feet.

3.1 Grease Sample Test

The January 2012 grease sample test measurement results are shown in Figures 5 and 6 and tabulated by operator (NASA and NTSB), lateral test station, grease type, grease volume, and spreader tool in Attachment 4 (pages A4.3-A4.4). These comparative grease sample test measurements were all obtained 6,000 feet from the runway 21 threshold. The direct measurement results indicate that the KROW runway 3/21 pavement macrotexture was consistent with Class C ESDU, independent of test operator.



Figure 5: Grease sample test results at the station 6,000 feet from the runway 21 threshold, 17' left of centerline for Operator 2 (NASA technical consultant, left) and Operator 1 (NTSB, right).

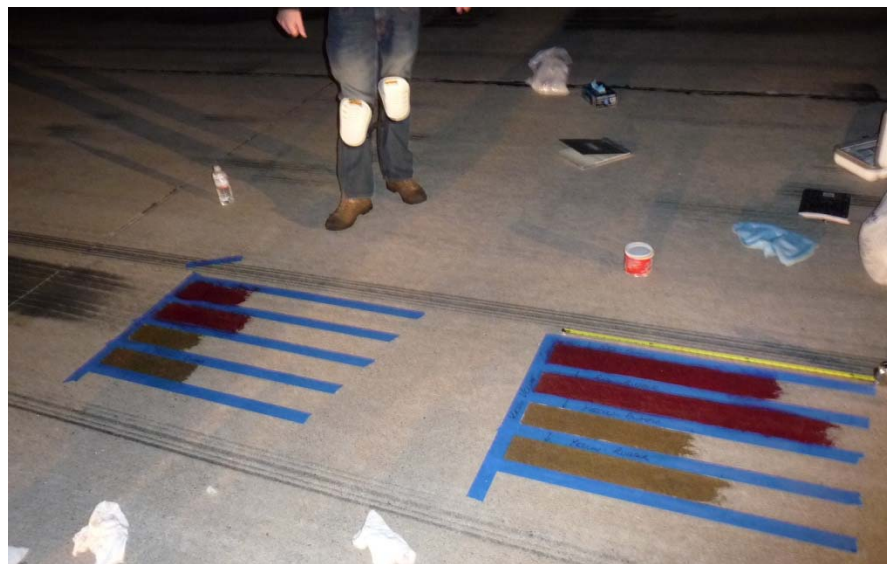


Figure 6: Grease sample test results at the station 6,000 feet from the runway 21 threshold, 34'4" left of centerline for Operator 2 (NASA technical consultant, left) and Operator 1 (NTSB, right).

Regarding the October 2011 and January 2012 grease sample test method measurements:

1. None of the October 2011 measurements were made with the NASA yellow grease or the rubber squeegee tool.
2. The same NTSB operator who spread the “red” grease during the October 2011 test spread both the “red” Boeing and “yellow” NASA grease in January 2012.
3. For the January 2012 retest work, a NASA 2-inch-wide rubber squeegee and a 4-inch-wide rigid plastic putty knife were available to both operators to spread both types of grease.
4. A NASA operator and the NTSB operator spread both types of grease in January 2012 using both spreader tools at 17’ and 34’4” left of centerline, 6,000 feet from the runway 21 threshold (see Figures 5 and 6).
5. The October 2011 grease measurements were spread in a transverse direction from the runway centerline whereas the January 2012 measurements were spread in the normal longitudinal direction (parallel to the runway centerline).
6. Careful micrometer measurements of the grease sample tube dimensions by two different individuals revealed the following average dimensions and volumes:
 - NTSB Tube: Diameter, 1.0435 in.; length, 1.4695; Volume, 1.256 cubic in. (20.58 cc)
 - NASA Tube: Diameter, 0.863 in.; length, 1.655 in.; Volume, 0.968 cubic in. (15.86 cc)

The NTSB grease volume penalty of 0.95 documented under Cylinder Dimensions/ Adjustments in Appendix 4 was used to conservatively account for reduced grease volume due to unfinished surface protrusions remaining on the interior wall of the two NTSB measurement cylinders.

7. Using the adjusted grease tube volume values, the ATD values calculated in October 2011 and January 2012 did not significantly change (-0.001 in.).

The October 2011 and January 2012 differences in grease ATD values at the same location (6,000 feet from the runway 21 threshold) are summarized in Table 7 for the NTSB operator using the Boeing grease and plastic scraper.

Table 7: Runway 3/21 grease sample test measurement comparison (Boeing grease, plastic scraper)

	Lateral test station position relative to runway 21 centerline	
	34’4” Left	17’ Left
October 2011	0.0167 in. (0.4242 mm)	0.0137 in. (0.3491 mm)
January 2012	0.0108 in. (0.2752 mm)	0.0136 in. (0.3456 mm)
Delta Difference	35% ⁷	2%

⁷ Based on a visual inspection of the three sites (see Figure 6) tested at this pavement station (in October 2011 by the NTSB Operator and in January 2012 by the NASA and NTSB Operators), the large delta difference in this grease ATD measurement is due in part to exposed aggregate differences in the local pavement surface macrotexture.

A correlation factor was derived to define a conversion from the Boeing red grease/plastic scraper values from the October 2011 test to the NASA yellow grease/rubber squeegee data from the January 2012 retest. The NTSB operator using the Boeing grease/plastic scraper versus using the NASA grease/rubber squeegee produced an average correlation factor (at 17' and 34'4" left of centerline at 6,000 feet from the runway 21 threshold) of 0.79, as depicted by the linear curve fit (blue dashed line) to the NTSB operator data (blue triangles) in Figure 7. This correlation assumes "grease is grease" per the applicable FAA Advisory Circular guidance, such that the primary variable is spreading tool, not grease type or grease volume.

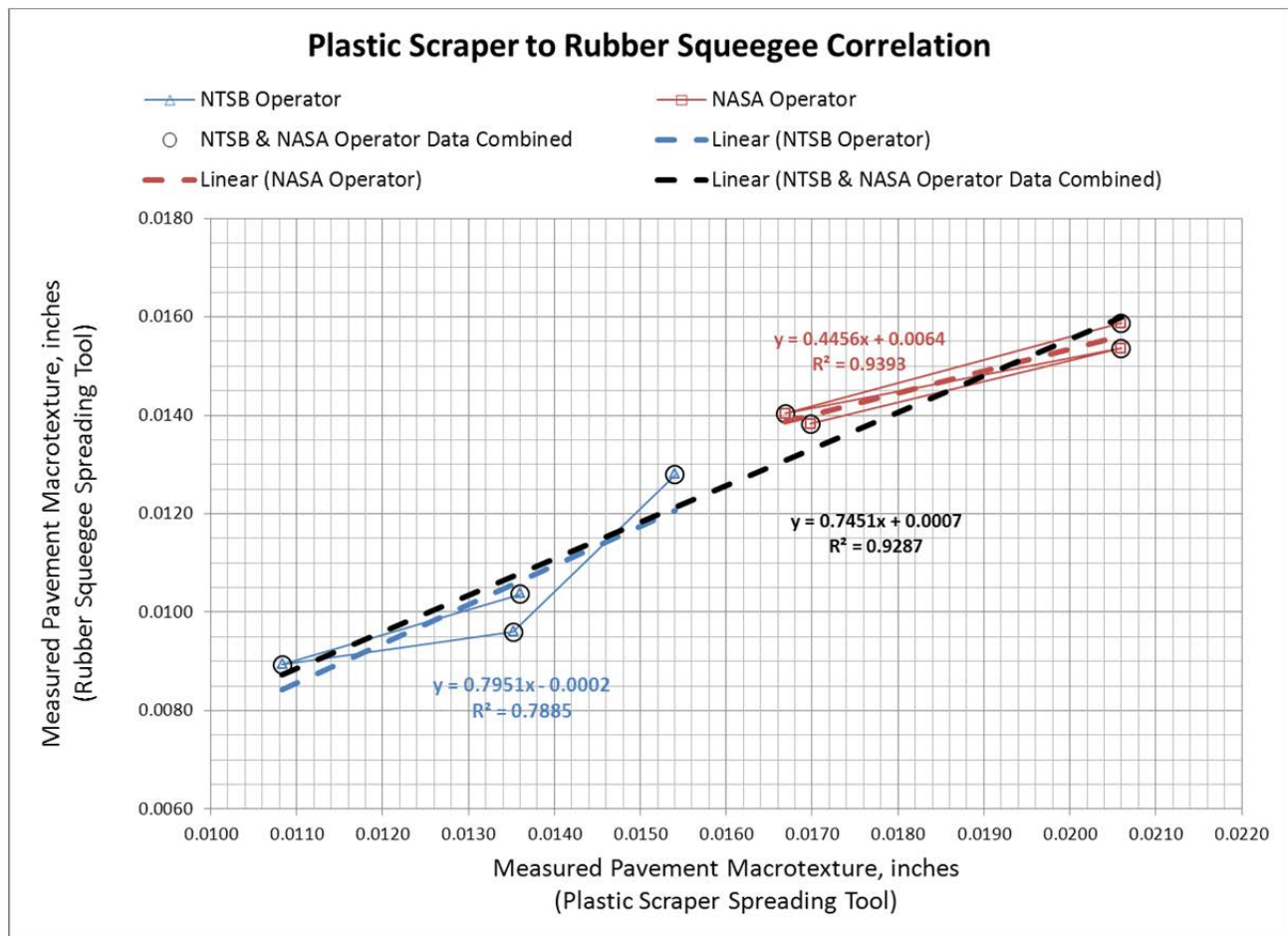


Figure 7: NTSB calculated correlation factors to convert measured pavement macrotexture from plastic scraper to rubber squeegee spreading tool values (assuming "grease is grease" per the applicable FAA Advisory Circular guidance).

The 0.79 correlation factor was selected to convert the October 2011 NTSB operator Boeing grease/plastic scraper measurements into equivalent NASA grease/rubber squeegee longitudinal ATD values. The equivalent January 2012 NASA grease/rubber squeegee value is obtained by multiplying the October 2011 Boeing grease/plastic scraper value by 0.79. The resulting equivalent NASA grease/rubber squeegee longitudinal ATD values (for October 2011 measurements between 4,000 and 9,000 feet on runway 3/21) are presented in Table 8. The average conversion ATD values from the October 2011 tests collected between 4,000 and 9,000 feet from the runway 21 threshold indicate a Class C ESDU (Class III NASA) surface with overall pavement average texture depth of 0.0121 in. (0.3075 mm).

Table 8: Conversion of October 2011 Roswell, NM runway 3/21 grease sample ATD measurements to NASA grease/rubber squeegee criteria

Distance from runway 21 threshold, feet	ATD Units	October 2011 Values (Boeing grease/plastic scraper)				Conversion to NASA Criteria (NASA grease/rubber squeegee)			
		50' left of C/L	34'4" left of C/L	17' left of C/L	17' right of C/L	50' left of C/L	34'4" left of C/L	17' left of C/L	17' right of C/L
4,000	in.	0.0131	0.0100	0.0131	0.0135	0.0103	0.0079	0.0103	0.0107
	mm	0.3320	0.2545	0.3320	0.3432	0.2623	0.2011	0.2623	0.2711
6,000	in.	0.0176	0.0167	0.0137	0.0134	0.0139	0.0132	0.0109	0.0106
	mm	0.4475	0.4242	0.3491	0.3413	0.3535	0.3351	0.2758	0.2696
7,500	in.	-	0.0146	0.0236	0.0148	-	0.0115	0.0186	0.0117
	mm	-	0.3702	0.5989	0.3771	-	0.2925	0.4731	0.2979
9,000	in.	0.0162	0.0194	0.0184	0.0117	0.0128	0.0153	0.0145	0.0093
	mm	0.4127	0.4926	0.4663	0.2980	0.3261	0.3892	0.3684	0.2354

Overall ATD = 0.0121 in. (0.3075 mm); Class C ESDU

3.2 Water Outflow Meter Test

The January 2012 outflow meter (Hydrotimer) measurement results are tabulated in Attachment 5 (pages A5.2-A5.6), followed by an outflow meter data plot and reconstructed ATD to outflow meter time correlation plots (pages A5.7-A5.9) based on the data published in Reference 6. The significant outflow meter measurement findings from the KROW runway 3/21 test include:

1. For 9,000 (2,000 -11,000) feet runway length, 24.99 seconds (Class C ESDU surface).
2. Maximum concrete drainage time at 2,000 feet from runway 21 threshold, 17' right, 92.02 sec.
3. Minimum concrete drainage time at 7,500 feet from runway 21 threshold, 17' left, 7.19 sec.
4. The average outflow meter times and pavement macrotexture classifications summarized in Table 9 for the concrete mid-section (4,000 to 9,000 feet).

Table 9: Runway 3/21 average outflow meter times and corresponding pavement macrotexture classification for concrete mid-section (4,000 to 9,000 feet)

	Water Outflow Time (Seconds)	ESDU Class	NASA Class
34'4" Left	21.90	Low C	IV
17' Left	14.80	Low C	III
17' Right	23.48	Low C	IV
34'4" Right	21.74	Low C	IV

The average Hydrotimer value measured between 4,000 and 9,000 feet from the runway 21 threshold in locations within 34'4" from centerline was 20.48 seconds, which indicates a Class C ESDU surface (and a Class IV NASA surface).

Any buildup of rubber deposits in the first 4,000 feet of either end of KROW runway 3/21 will decrease the ATD values and could justify a macrotexture ATD value in a lower class. For example, the average Hydrotimer values measured within 4,000 feet of the runway 3/21 thresholds was 30.25 seconds which indicates a Class B ESDU surface and a Class IV NASA surface. This lower pavement macrotexture result is driven primarily by the heavy rubber deposits observed 2,000 feet from the runway 21 threshold. Regarding Hydrotimer measurements and pavement classification, the ESDU and NASA scales are not strictly equivalent. For instance, based on the ESDU pavement classification scale, Hydrotimer values between 5 and 30 seconds correspond to a Class C ESDU surface, but this same drainage time period defines the entire Class III and a portion of the Class IV NASA surface classification.

The Hydrotimer measurements were much less operator sensitive than the grease sample test measurements and hence, considered more reliable and repeatable. Although this study focuses on pavement macrotexture characteristics, wet runway pavement effects on aircraft tire friction capability also depend on runway pavement microtexture, roughness, and gradients (both longitudinal and transverse), in combination with rainfall intensity.

4.0 REFERENCES

[1] Yager, T.J., NASA Technical Memorandum (TM) 85652, "Factors Influencing Aircraft Ground Handling Performance," June 1983.

[2] Renze, K. J., Smith, M. H., Stephens, A. T., and Raby, C., "Runway Pavement Macrotexture Study," Pavement Macrotexture Measurements (Grease Method), Runway 3/21, Roswell, NM (KROW), National Transportation Safety Board (NTSB) Public Docket, NTSB No. DCA12SS002, August 2012.

[3] Merritt, L.R., "Concorde Landing Requirement Evaluation Tests," U.S. Department of Transportation, Federal Aviation Administration, FAA-FS-160-74-2, August 1974.

[4] FAA Advisory Circular (AC) 150-5320/12C, "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces," dated 3/18/97.

[5] Leland, T. J. W., Yager, T. J., and Joyner, U.T., NASA Technical Note (TN) D-4323, "Effects of Pavement Texture on Wet-Runway Braking Performance," NASA Langley Research Center, January 1968.

[6] Yager, T. J. and Buhlmann, F., "Macrotexture and Drainage Measurements on a Variety of Concrete and Asphalt Surfaces," Pavement Surface Characteristics and Materials, ASTM STP 763, C. M. Hayden, Ed., American Society for Testing and Materials, 1982, pp. 16-30.

[7] Engineering Sciences Data Unit (ESDU) document 71026, "Frictional and Retarding Forces on Aircraft Tyres, Part II: Estimation of Braking Force," issued October 1971 with Amendments A to D, June 1995.

5.0 ATTACHMENTS

Attachment 1: Grease Test Method Excerpt, FAA Advisory Circular (AC) 150/5320-12C

Attachment 2: Outflow Meter Test Method, ASTM E2380/E2380M - 09

Attachment 3: Weather Data Obtained from Weather Underground Online Archive

Attachment 4: Grease Method Measurements and Calculated Macrottexture (KROW)

Attachment 5: Outflow Meter Measurements and Calculated Macrottexture (KROW)

Attachment 1: Grease Test Method Excerpt, AC 150/5320-12C

b. Friction Deterioration Below the Maintenance Planning Friction Level (1000 ft).

When the averaged Mu value on the wet runway pavement surface is less than the Maintenance Planning Friction Level in Table 3-2 for a distance of 1000 feet (305 m) or more, the airport operator should conduct extensive evaluation into the cause(s) and extent of the friction deterioration and take appropriate corrective action.

c. Friction Deterioration Below the Minimum Friction Level.

When the averaged Mu value on the wet pavement surface is below the Minimum Friction Level in Table 3-2 for a distance of 500 feet (152 m), and the adjacent 500 foot (152 m) segments are below the Maintenance Planning Friction Level, corrective action should be taken immediately after determining the cause(s) of the friction deterioration. Before undertaking corrective measures, the airport operator should investigate the overall condition of the entire runway pavement surface to

determine if other deficiencies exist that may require additional corrective action.

d. New Design/Construction Friction Level for Runways.

For newly constructed runway pavement surfaces (that are either saw cut grooved or have a PFC overlay) serving turbojet aircraft operations, the averaged Mu value on the wet runway pavement surface for each 500 foot (152 m) segment should be no less than the New Design/Construction Friction Level in Table 3-2.

3-21.COMPUTER EVALUATION OF FRICTION TEST DATA. A manual evaluation of friction test data as required by the criteria above can be tedious and prone to human error. An IBM PC-compatible computer program which performs this evaluation is available free of charge. The computer program may be downloaded from the FAA Airports Internet web site at <http://www.faa.gov/arp/software.htm>.

Section 4. Conducting Texture Depth Measurements

3-22.RECOMMENDED TESTING. When friction values meet the criteria in paragraphs 3-20.(a), 3-20.(b), and 3-20.(c), no texture depth measurements are necessary. When friction values do not meet the criteria in paragraphs 3-20.(a), 3-20.(b), or 3-20.(c), and the cause is not obvious (e.g. rubber deposits), the airport operator should perform texture depth measurements.

3-23 RECOMMENDED TEXTURE DEPTHS.

a. Newly Constructed Pavements. The recommended average texture depth to provide good skid-resistance for newly constructed concrete and asphalt pavements is 0.045 inch (1.14 mm). A lower value indicates a deficiency in macrotexture that will require correction as the surface deteriorates.

b. Existing Pavements.

(1) When the average texture depth measurement in a runway zone (i.e., touchdown, midpoint, and rollout) falls below 0.045 inch (1.14 mm), the airport operator should conduct texture depth measurements each time a runway friction survey is conducted.

(2) When the average texture depth measurement in a runway zone is below 0.030 inch (0.76 mm) but above 0.016 inch (0.40 mm), the airport operator should initiate plans to correct the pavement texture deficiency within a year.

(3) When the average texture depth measurement in a runway zone (i.e., touchdown, midpoint, and rollout) falls below 0.010 inch (0.25 mm), the airport operator should correct the pavement texture deficiency within 2 months.

c. Retexturing. Retexturing of the pavement surface should improve the average texture depth to a minimum of 0.030 inch (0.76 mm).

3-24.LOCATION OF MEASUREMENTS. Groove depths are never included in texture depth measurements. For grooved runway pavements, texture depth measurements should always be located in nongrooved areas, such as near transverse joints or light fixtures, but as close as possible to heavily trafficked areas.

3-25.TEST METHODS. A minimum of three texture depth measurements should be taken in any area noted as deficient. More measurements should be taken when obvious textural changes in the pavement surface

are observed. An average texture depth should be computed for each area. Descriptions of the equipment and methods used and the computations involved in determining texture depths are as follows:

a. Equipment. The NASA Grease Smear Method is used to determine the macrotexture of the pavement surface by measuring the average distance between the peaks and valleys in the pavement texture. This method cannot be used to evaluate the pavement microtexture. On the left in Figure 3-1 is shown the tube which is used to measure the 1 cubic inch (15 cc) volume of grease. On the right is shown the tight-fitting plunger which is used to expel the grease from the tube, and in the center is shown the rubber squeegee which is used to work the grease into the voids in the runway surface.

The sheet rubber on the squeegee is cemented to a piece of aluminum for ease in use. Any general purpose grease can be used. As a convenience in the selection of the length of the measuring tube, Figure 3-2 gives the relation between the tube inside diameter and tube length for an internal tube volume of one cubic inch (15 cu cm). The plunger can be made of cork or other resilient material to achieve a tight fit in the measuring tube.

b. Measurement. The tube for measuring the known volume of grease is packed full with a simple tool, such as a putty knife, with care to avoid entrapped air, and the ends are squared off as shown in Figure 3-3. A general view of the texture measurement procedure is shown in Figure 3-4. The lines of masking tape are placed on the pavement surface about 4 inches (10 cm) apart. The grease is then expelled from the measuring tube with the plunger and deposited between the previously placed lines of masking tape. It is then worked into the voids of the runway pavement surface with the rubber squeegee, with care that no grease is left on the masking tape or the squeegee. The distance along the lines of masking tape is then measured and the area that is covered by the grease is computed.

3-26. COMPUTATION. After the area is completed, the following equations are used to calculate the average texture depth of the pavement surface:

$$\text{Texture depth (inches)} = \frac{\text{Volume of Grease (cu. in.)}}{\text{Area Covered by Grease (sq. in.)}}$$

$$\text{Average Texture Depth} = \frac{\text{Sum of individual Tests}}{\text{Total Number of Tests}}$$

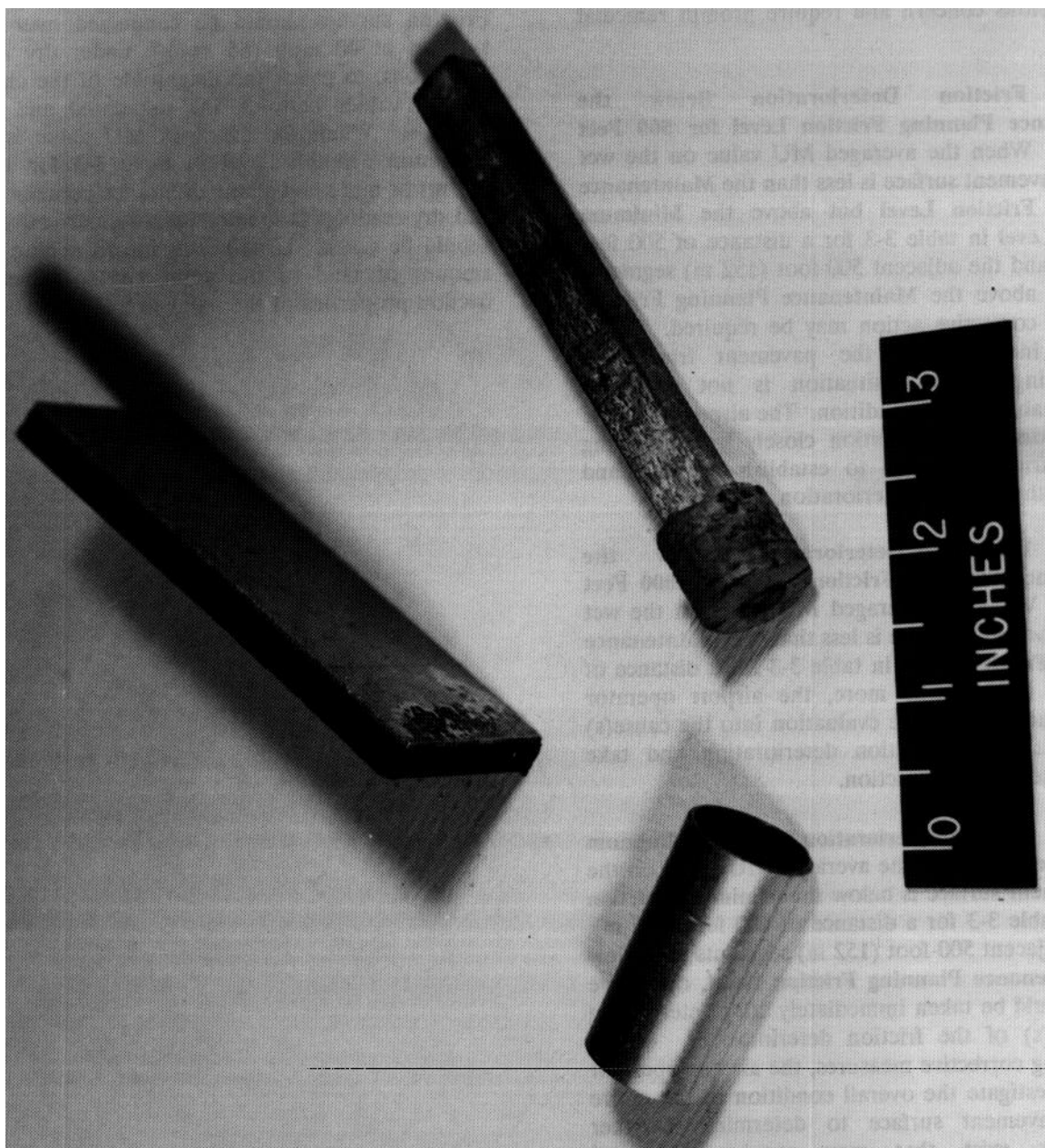


FIGURE 3-1. GREASE-VOLUME MEASURING TUBE, PLUNGER, AND RUBBER SQUEEGEE

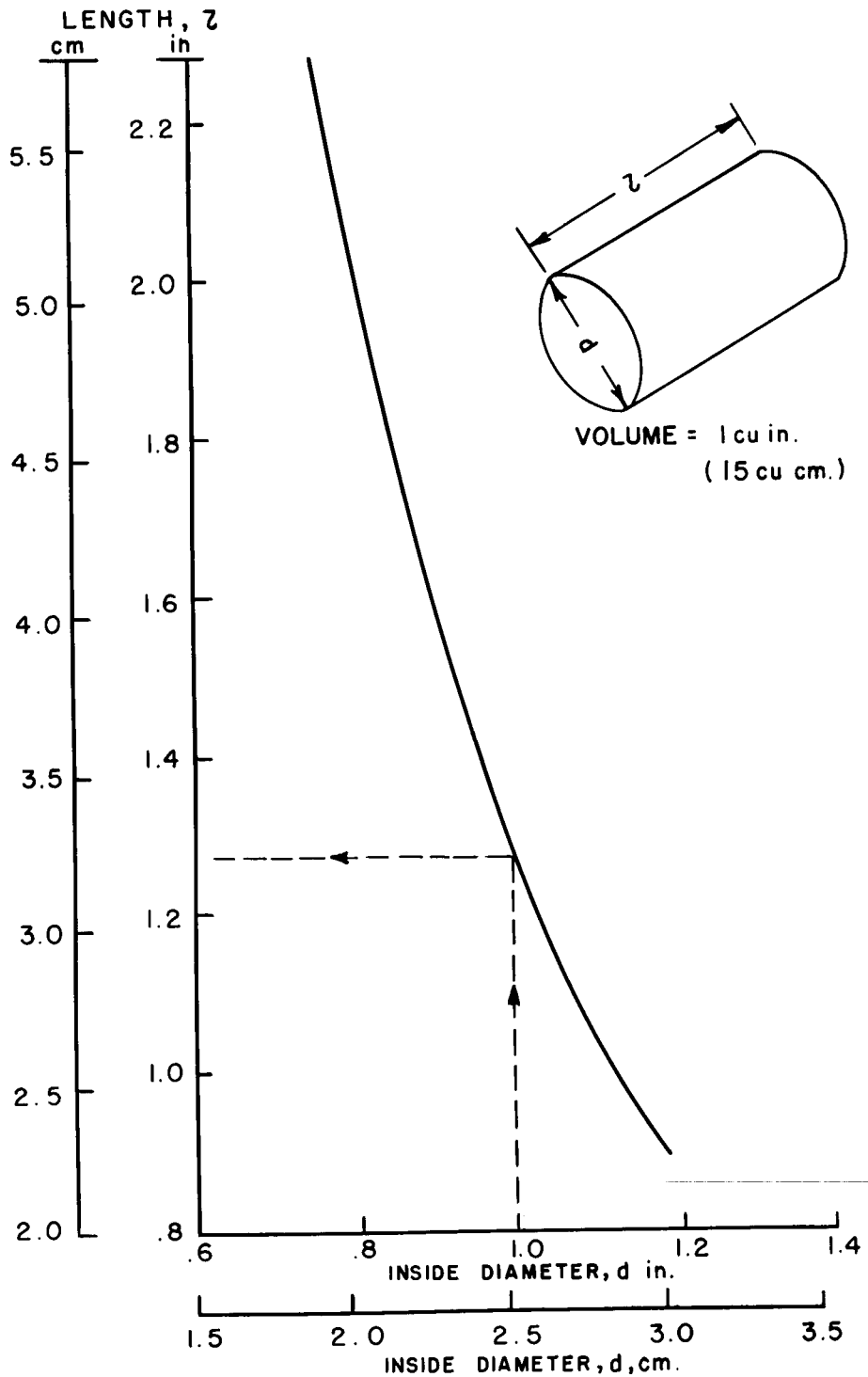


FIGURE 3-2. MEASURING TUBE DIMENSIONS TO MEASURE
ONE CUBIC INCH OR FIFTEEN CUBIC CENTIMETERS

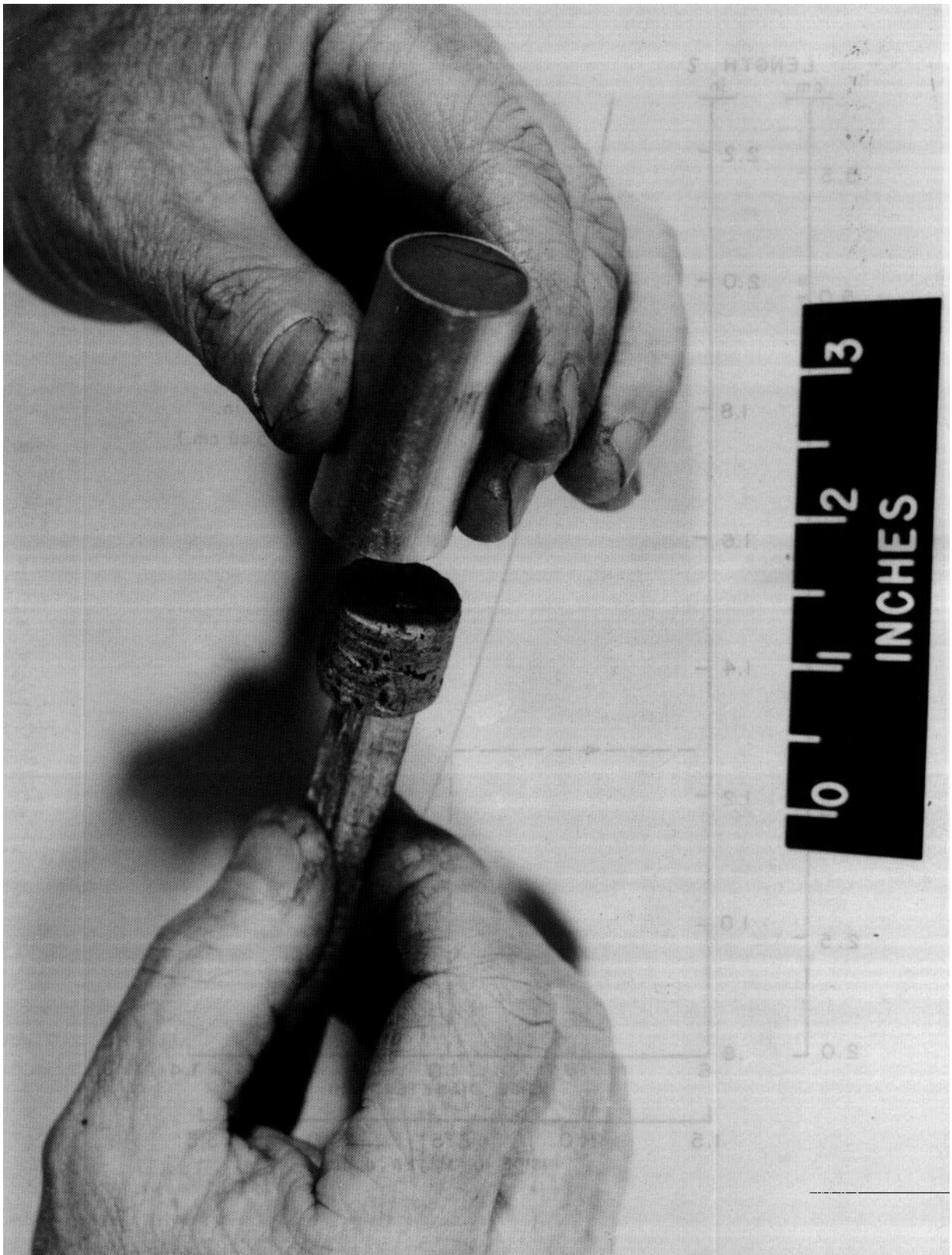


FIGURE 3-3. MEASURING TUBE FILLED WITH GREASE



FIGURE 3-4. ILLUSTRATION OF APPARATUS USED IN GREASE APPLICATION TECHNIQUE FOR MEASURING PAVEMENT SURFACE TEXTURE DEPTH

**Attachment 2: Outflow Meter Test Method,
ASTM E2380/E2380M - 09**



Standard Test Method for Measuring Pavement Texture Drainage Using an Outflow Meter¹

This standard is issued under the fixed designation E2380/E2380M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the connectivity of the texture as it relates to the drainage capability of the pavement through its surface and subsurface voids. This is a specific device that times how long it takes a known quantity of water, under gravitational pull, to escape through voids in the pavement texture of the structure being tested. The technique is intended to provide a measure of the ability of the pavement to relieve pressure from the face of vehicular tires and thus an indication of hydroplaning potential under wet conditions. A faster escape time indicates a thinner film of water may exist between the tire and the pavement, thus more micro-texture could be exposed to indent the face of the tire and more surface friction available to the tire. The lower the number of seconds it takes to evacuate the water, the lower the water pressure under the tire. It will be up to the operator to compare the results of this test to other pertinent factors such as expected rainfall intensity and frequency, aggregate type, consistency of texture, grade, slope, expected vehicular speed, and accident history, to determine the relationship between the outflow meter reading and the likelihood of hydroplaning on a given surface. Comparing the outflow meter reading of a pavement known to have a history of hydroplaning, against one with a good history, with all other factors similar, will give the operator an indication of the outflow meter number that will be necessary to promote wet weather safety.

1.2 The results obtained using this test method are related to the mean hydraulic radius of a paved surface and may correlate with other methods to measure texture.

1.3 The results obtained using this test method are related to the mean texture depth (MTD).

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:²

- E178 Practice for Dealing With Outlying Observations
- E867 Terminology Relating to Vehicle-Pavement Systems
- E965 Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique
- E1845 Practice for Calculating Pavement Macrotexture Mean Profile Depth
- E2157 Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter

3. Terminology

- 3.1 For definitions of terms, see Terminology E867.

4. Summary of Test Method Operations

4.1 The main body of the outflow meter is a vertical cylinder for containing water. It has an open top and a rubber ring mounted centrally around an orifice or opening on the bottom of the device to form a seal against the pavement surface. Water discharge is through the opening in the center of the seal and is controlled by a spring-loaded plunger suspended from a cap mounted on the upper end of the cylinder. Upper and lower float switches are suspended from the cap into the cylinder and mounted vertically. An electronic timer is provided and is wired to the float switches.

4.2 The outflow meter is placed on the pavement with the plunger sealing the water discharge opening. Sufficient water is then poured into the cylinder to raise the switch floats to their raised or top position, which will prevent the timer from operating. The timer is reset to zero and the plunger is released to allow discharge of the water. As water flows out of the opening and through the pavement voids, the water level in the

¹ This test method is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.23 on Surface Characteristics Related to Tire Pavement Slip Resistance.

Current edition approved Nov. 1, 2009. Published December 2009. Originally approved in 2005. Last previous edition approved in 2005 as E2380-05. DOI: 10.1520/E2380_E2380M-09.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

cylinder falls past the upper float switch, which activates, causing the electronic timer to begin counting. As the water level continues to fall past the level of the lower float switch, the lower float switch then activates, causing the timer to stop. The time required for the water level in the cylinder to fall from the level of the upper float switch to the level of the lower float switch is indicated on the timer. This is recorded as the outflow time.

4.3 Calibrations over a temperature range of 40 to 120°F [4 to 49°C] show no temperature affects.

5. Significance and Use

5.1 This test method is suitable as a field test to evaluate the surface drainage, and in some cases, the internal drainage of the surface course of a pavement. When used with other tests, the outflow time may be used to evaluate the texture produced by an asphalt concrete mix, a finishing method used on Portland cement concrete pavement, and refinishing operations on an old pavement surface. Test results will correlate with other methods such as the CTMeter (Test Method [E2157](#)), MPD (Practice [E1845](#)), and MTD (Test Method [E965](#)).

NOTE 1—The reciprocal of the outflow time is highly correlated with the MPD except when the surface is highly porous since the MPD is a measure of the surface texture and does not account for the water flowing through the surface pores.

5.2 The outflow times measured by this method are an indication only, and are not meant to provide a complete assessment of the pavement surface friction, or wet weather safety characteristics.

5.3 This test method does not necessarily correlate or agree with other methods of measuring pavement surface characteristics. It is up to the operator to determine the correlation of each method considered.

6. Apparatus and Materials

6.1 The essential elements of the apparatus, shown in [Fig. 1](#), consists of the following:

6.1.1 *Upper and Lower Float Switch*—Suspended from a cap into the cylinder.

6.1.2 *Plunger*—Suspended from a cap mounted on the upper end of the cylinder.

6.1.3 *Rubber Sealing Ring*—The sealing rings shall be made of neoprene rubber and have a durometer level of 70 ± 5 .

6.1.4 *Timer*—An electrical timer with at least a three-digit display indicating the elapsed time to the nearest 1.0 s, or in case of calibration or research to 0.01 s or better.

6.1.5 *Water*—Water shall be clean and have no wetting agents or detergents added, and when calibrated, distilled water shall be used.

6.1.6 *Brushes*—A broom or a hand-held wire brush shall be used to clean the test area, if needed.

7. Calibration

7.1 Calibration of the outflow meter is as follows:

7.1.1 Water volume shall be no less than 650 cc [39.7 cu in.] and no greater than 700 cc [42.7 cu in.].

7.1.2 Outlet orifice shall be made of synthetic sapphire material.

7.1.3 The bore diameter shall be 4.877 ± 0.0254 mm [0.192 $\pm$ 0.001 in.].

7.1.4 The bore length shall be 2.54 ± 0.00254 mm [0.100 $\pm$ 0.0001 in.].

7.1.5 Bore concentricity within 0.0508 mm [0.002 in.].

7.1.6 Edge sharpness within 0.0508 mm [0.002 in.].

7.1.7 Bore finish to 50.8 μ m [2 μ in].

7.1.8 Bottom seal thickness shall be no less than 6 mm [0.2362 in.] or more than 7 mm [0.2756 in.].

7.1.9 Bottom seal ID shall be no less than 60 mm [2.362 in.] or more than 65 mm [2.559 in.].

7.1.10 Bottom seal OD shall be no less 100 mm [3.937 in.] or more than 105 mm [4.134 in.].

7.1.11 Bottom seal shall be neoprene rubber with a 70 ± 5 durometer.

7.1.12 Lower switch shall contact at 89.9 to 101.6 mm [3.50 to 4 in.] from the lower extremities of the bottom seal.

7.1.13 Upper switch shall contact at 190.5 to 203.2 mm [7.50 to 8 in.] from the lower extremities of the bottom seal.

7.1.14 A 4.877-mm [0.192-in.] wire lapped orifice shall be put in a 4-mm [0.16-in.] thick flat metal plate for sealing purposes. The outflow time must be at least 22 s but less than 23 s on five consecutive tests to qualify for calibration status on the calibration plate. When measuring to $\frac{1}{1000}$ of a second, a CV of 0.65 % shall be met.

8. Procedure

8.1 *Test Area*—Inspect the pavement surface to be measured and select a homogeneous area that contains no unique, localized features such as paint, holes, bumps, cracks, or joints. If there is any loose or semi-adhered dirt, debris, or deteriorated surface material, thoroughly clean the pavement surface in the area where the test is to be taken using a broom or stiff wire brush. On pavements that have just been under traffic, tests performed without cleaning will give actual drainage capability.

8.2 *Measurement*—Place the outflow meter on the pavement making sure that it is stable and uniformly contacts the rubber sealing ring to the pavement. On the first test, wet the plunger sealing ring by holding it close to the seat and pour in a little water. Set the plunger by pushing down on the handle until the plunger seal enters the seat, and fill the cylinder with water. For accurate measurement, the water level must extend over the top float switch sufficiently to allow air bubbles trapped between the pavement surface and the plunger to escape, and the surface water shall have a chance to settle down before the water level reaches the top float switch. Make sure the timer is reset to zero. Carefully pull the plunger up while applying an equal counter force downward on the handle. When the plunger seal is released from the seat, this becomes a hands-off operation. A spring will return the plunger to its most upright position. From this point, the outflow meter works automatically and should not be touched until the test is over. When the lower float switch is activated and the timer stops, the plunger may be reset to save water and be ready to be filled with water for the next test. After each test, the outflow meter timer reading and the location of the test should be recorded.

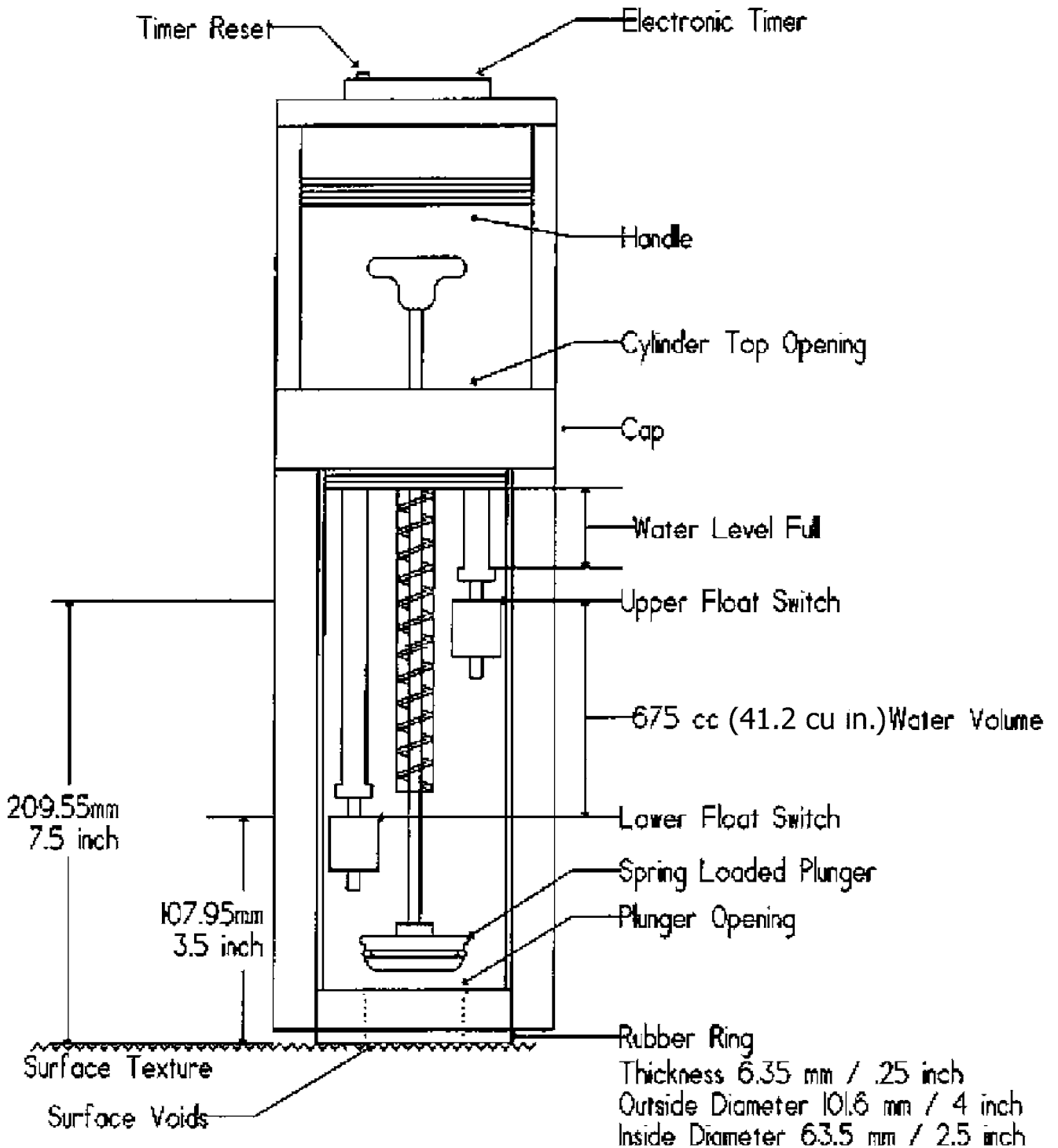


FIG. 1 Outflow Meter

8.3 *Number of Measurements*—The more tests that are performed, the better the average pavement drainage information will be. In any case, a minimum of four randomly spaced tests shall be performed and the arithmetic average of the test times shall be reported as the average time for the section of the pavement being evaluated.

8.4 For each pavement test section, the arithmetic average of all outflow meter test times will be determined and recorded to the 0.01 s. The following equation will be used to estimate the mean texture depth:

$$MTD = 3.114/OFT + 0.636 \quad (1)$$



where:

MTD = volumetric texture depth defined in Terminology
E867.

9. Faulty Tests

9.1 Tests that are manifestly faulty, or that give outflow times differing by more than 10 s from the average of all tests on the same pavement surface, shall be treated in accordance with Practice **E178** on outlying observations.

10. Report

10.1 The report for each pavement test surface shall contain data on the following items:

10.1.1 Location and identification of test pavement surface,

10.1.2 Date,

10.1.3 Ambient air temperature,

10.1.4 Pavement temperatures (optional),

10.1.5 Number of measurements, and

10.1.6 Outflow times recorded.

11. Precision and Bias

11.1 *Precision*—The precision (the standard deviation) of the outflow meter that reads only whole seconds is 0.187 s and has a coefficient variation (CV) of 0.85 % when run on the calibration plate. The unit that reads to $\frac{1}{1000}$ of a second has a standard deviation of 0.143 s (CV of 0.63 %).

11.2 *Bias*—Because the whole second unit truncates, it has a bias of 0.6 s as compared to the $\frac{1}{1000}$ of a second unit.

REFERENCES

- (1) Wambold, J. C., Antle, C. E., Henry, J. J., and Rado, Z., “International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements,” Final report, Permanent International Association of Road Congresses (PIARC), Paris, 1995.
- (2) Abe, H., Henry, J. J., Tamai, A., and Wambold, J. C., “Measurement of Pavement Macrotexture Using the Circular Texture Meter (CTMeter),” Transportation Research Board Annual Meeting, Washington DC, 2001.
- (3) Wambold, J. C. and Henry, J. J., “NASA Wallops Tire/Runway Friction Workshops 1993-2002,” Report TP 14190E, Transportation Development Centre (TDC) of Transport Canada (TC), September 2002.
- (4) Wambold, J. C., and Henry, J. J., “NASA Tenth Tire/Runway Friction Workshop 2003 NASA Wallops Flight Facility,” National Aeronautics and Space Administration (NASA), September 29 to October 3, 2003.

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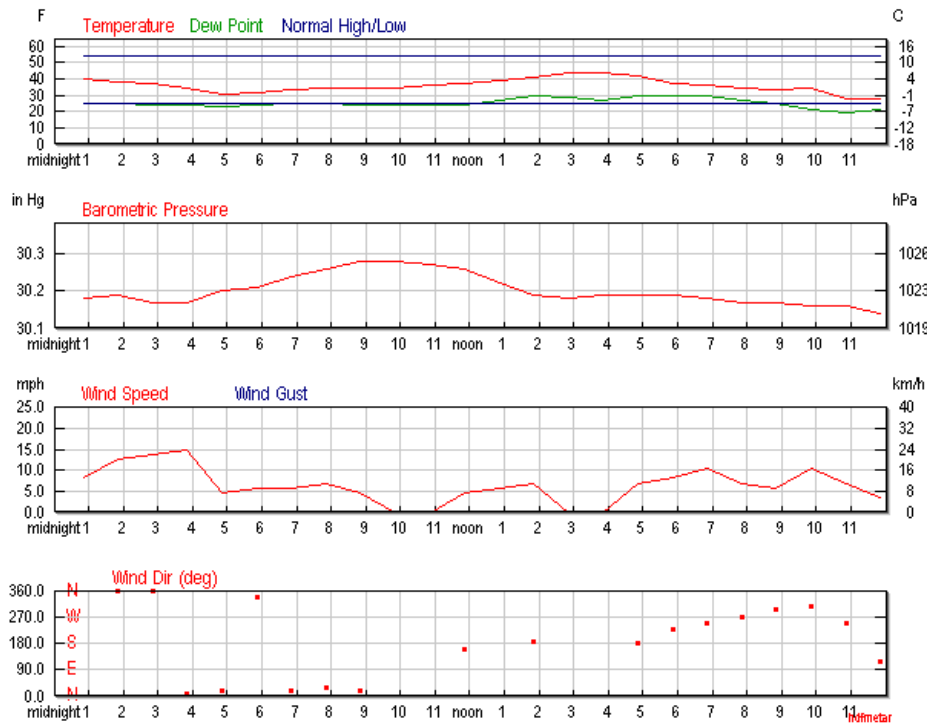
Attachment 3: Weather Data from Weather Underground

History for Roswell, NM

Monday, January 9, 2012 — [View Current Conditions](#)**Monday, January 9, 2012**[« Previous Day](#)[January](#)[9](#)[2012](#)[View](#)[Next Day »](#)[Daily](#)[Weekly](#)[Monthly](#)[Custom](#)

	Actual	Average	Record
Temperature			
Mean Temperature	36 °F	40 °F	
Max Temperature	44 °F	54 °F	81 °F (1909)
Min Temperature	27 °F	25 °F	-10 °F (1913)
Degree Days			
Heating Degree Days	29	25	
Month to date heating degree days	215	231	
Since 1 July heating degree days	1699	1641	
Cooling Degree Days	0	0	
Month to date cooling degree days	0	0	
Year to date cooling degree days	0	0	
Moisture			
Dew Point	25 °F		
Average Humidity	66		
Maximum Humidity	82		
Minimum Humidity	49		
Precipitation			
Precipitation	0.00 in	0.01 in	0.85 in (1900)
Month to date precipitation	0.00	0.12	
Year to date precipitation	0.00	0.12	
Sea Level Pressure			
Sea Level Pressure	30.20 in		
Wind			
Wind Speed	6 mph (NW)		
Max Wind Speed	17 mph		
Max Gust Speed	21 mph		
Visibility	10 miles		
Events			

T = Trace of Precipitation, **MM** = Missing Value**Source:** NWS Daily Summary

[Certify This Report](#)

Hourly Observations

Time (MST)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
12:51 AM	39.9 °F	34.5 °F	25.0 °F	55%	30.18 in	10.0 mi	NNW	8.1 mph	-	N/A		Overcast
METAR KROW 090751Z AUTO 33007KT 10SM OVC044 04/M04 A3023 RMK AO2 SLP220 T00441039 TSNO												
1:51 AM	37.9 °F	30.0 °F	25.0 °F	60%	30.19 in	10.0 mi	North	12.7 mph	-	N/A		Overcast
METAR KROW 090851Z AUTO 36011KT 10SM OVC060 03/M04 A3023 RMK AO2 SLP221 T00331039 55000 TSNO												
2:51 AM	37.0 °F	28.5 °F	24.1 °F	59%	30.17 in	10.0 mi	North	13.8 mph	-	N/A		Overcast
METAR KROW 090951Z AUTO 36012KT 10SM OVC055 03/M04 A3023 RMK AO2 SLP217 T00281044 TSNO												
3:51 AM	34.0 °F	24.2 °F	24.1 °F	67%	30.17 in	10.0 mi	North	15.0 mph	-	N/A		Clear
METAR KROW 091051Z AUTO 01013KT 10SM CLR 01/M04 A3021 RMK AO2 SLP216 T00111044 TSNO												
4:51 AM	30.9 °F	26.2 °F	23.0 °F	72%	30.20 in	10.0 mi	NNE	4.6 mph	-	N/A		Mostly Cloudy
METAR KROW 091151Z AUTO 02004KT 10SM BKN055 M01/M05 A3022 RMK AO2 SLP226 T10061050 10050 21011 55003 TSNO												
5:51 AM	32.0 °F	26.4 °F	24.1 °F	73%	30.21 in	10.0 mi	NNW	5.8 mph	-	N/A		Overcast
METAR KROW 091251Z 34005KT 10SM OVC055 00/M04 A3023 RMK AO2 SLP229 T00001044												
6:51 AM	33.1 °F	27.7 °F	25.0 °F	72%	30.24 in	10.0 mi	NNE	5.8 mph	-	N/A		Overcast
METAR KROW 091351Z 02005KT 10SM OVC055 01/M04 A3026 RMK AO2 SLP238 T00061039												
7:51 AM	34.0 °F	28.0 °F	25.0 °F	70%	30.26 in	10.0 mi	NNE	6.9 mph	-	N/A		Overcast
METAR KROW 091451Z 03006KT 10SM BKN049 OVC060 01/M04 A3028 RMK AO2 SLP246 T00111039 53018												
8:51 AM	34.0 °F	29.8 °F	24.1 °F	67%	30.28 in	10.0 mi	NNE	4.6 mph	-	N/A		Overcast
METAR KROW 091551Z 02004KT 10SM BKN049 OVC060 01/M04 A3030 RMK AO2 SLP254 T00111044												
9:51 AM	34.0 °F	-	24.1 °F	67%	30.28 in	10.0 mi	Calm	Calm	-	N/A		Overcast
METAR KROW 091651Z 00000KT 10SM OVC065 01/M04 A3030 RMK AO2 SLP254 T00111044												
10:51 AM	36.0 °F	-	24.1 °F	62%	30.27 in	10.0 mi	Calm	Calm	-	N/A		Overcast

[Show Hourly Obs Only](#) | [Hide full METARS](#) | [METAR FAQ](#) | [Comma Delimited File](#)

A3.3

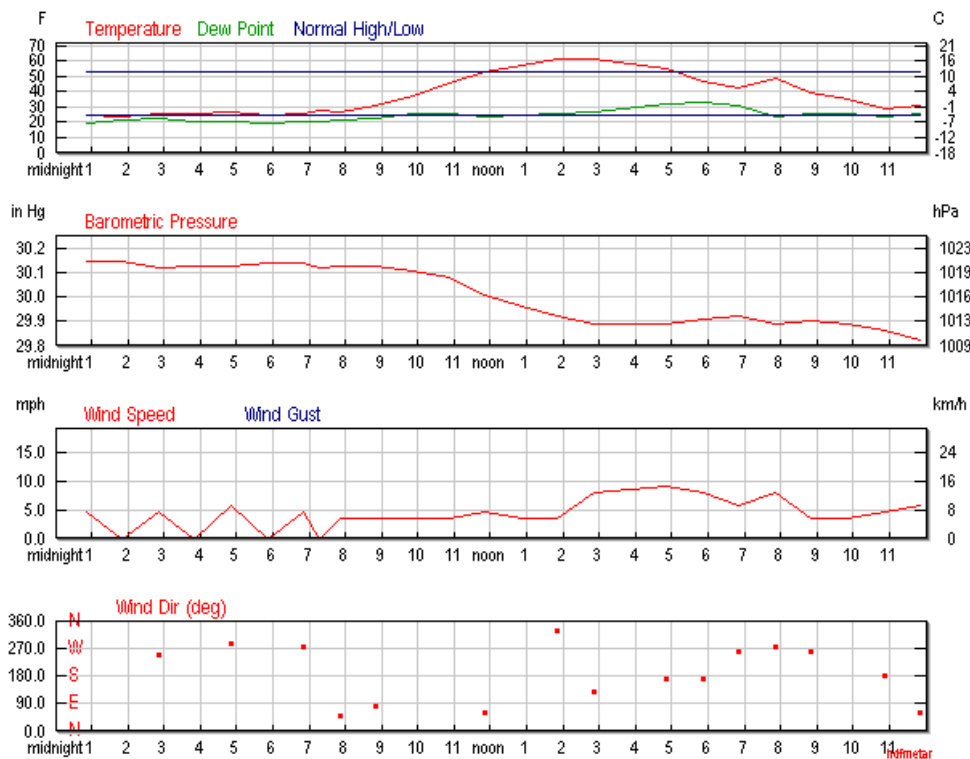
Time (MST)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
METAR KROW 091751Z 00000KT 10SM FEW060 SCT075 OVC100 02/M04 A3029 RMK AO2 SLP251 T00221044 10022 21006 50004												
11:51 AM	37.0 °F	33.3 °F	24.1 °F	59%	30.26 in	10.0 mi	SSE	4.6 mph	-	N/A		Overcast
METAR KROW 091851Z 16004KT 10SM OVC060 03/M04 A3028 RMK AO2 SLP245 T00281044												
12:51 PM	39.0 °F	34.8 °F	27.0 °F	62%	30.22 in	10.0 mi	Variable	5.8 mph	-	N/A		Overcast
METAR KROW 091951Z VRB05KT 10SM OVC065 04/M03 A3025 RMK AO2 SLP232 T00391028												
1:51 PM	41.0 °F	36.4 °F	30.0 °F	65%	30.19 in	10.0 mi	South	6.9 mph	-	N/A		Partly Cloudy
METAR KROW 092051Z 19006KT 10SM FEW065 05/M01 A3022 RMK AO2 SLP223 T00501011 58023												
2:51 PM	44.1 °F	-	28.9 °F	55%	30.18 in	10.0 mi	Calm	Calm	-	N/A		Mostly Cloudy
METAR KROW 092151Z 00000KT 10SM BKN110 07/M02 A3021 RMK AO2 SLP219 T00671017												
3:51 PM	44.1 °F	-	27.0 °F	51%	30.19 in	10.0 mi	Calm	Calm	-	N/A		Overcast
METAR KROW 092251Z 00000KT 10SM OVC100 07/M03 A3021 RMK AO2 SLP223 T00671028												
4:51 PM	42.1 °F	37.7 °F	30.0 °F	62%	30.19 in	10.0 mi	South	6.9 mph	-	N/A		Partly Cloudy
METAR KROW 092351Z 18006KT 10SM FEW120 06/M01 A3020 RMK AO2 SLP222 T00561011 10067 20022 57005												
5:51 PM	37.0 °F	31.0 °F	30.0 °F	76%	30.19 in	10.0 mi	SW	8.1 mph	-	N/A		Mostly Cloudy
METAR KROW 100051Z 23007KT 10SM BKN120 03/M01 A3019 RMK AO2 SLP223 T00281011												
6:51 PM	36.0 °F	28.5 °F	30.0 °F	79%	30.18 in	10.0 mi	WSW	10.4 mph	-	N/A		Clear
METAR KROW 100151Z 25009KT 10SM CLR 02/M01 A3018 RMK AO2 SLP218 T00221011												
7:51 PM	34.0 °F	28.0 °F	27.0 °F	75%	30.17 in	10.0 mi	West	6.9 mph	-	N/A		Clear
METAR KROW 100251Z 27006KT 10SM CLR 01/M03 A3017 RMK AO2 SLP216 T00111028 58010												
8:51 PM	33.1 °F	27.7 °F	25.0 °F	72%	30.17 in	10.0 mi	WNW	5.8 mph	-	N/A		Clear
METAR KROW 100351Z AUTO 30005KT 10SM CLR 01/M04 A3017 RMK AO2 SLP217 T00061039 TSNO												
9:51 PM	34.0 °F	26.0 °F	21.0 °F	59%	30.16 in	10.0 mi	NW	10.4 mph	-	N/A		Clear
METAR KROW 100451Z AUTO 31009KT 10SM CLR 01/M06 A3016 RMK AO2 SLP212 T00111061 TSNO												
10:51 PM	28.0 °F	20.8 °F	19.0 °F	69%	30.16 in	10.0 mi	WSW	6.9 mph	-	N/A		Clear
METAR KROW 100551Z AUTO 25006KT 10SM CLR M02/M07 A3015 RMK AO2 SLP213 T10221072 10056 21028 58006 TSNO												
11:51 PM	28.0 °F	24.2 °F	21.0 °F	75%	30.14 in	10.0 mi	ESE	3.5 mph	-	N/A		Clear
METAR KROW 100651Z AUTO 12003KT 10SM CLR M02/M06 A3013 RMK AO2 SLP204 T10221061 400671028 TSNO												
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History for Roswell, NM

Tuesday, January 10, 2012 — [View Current Conditions](#)**Tuesday, January 10, 2012**[« Previous Day](#)[January](#)[10](#)[2012](#)[View](#)[Next Day »](#)[Daily](#)[Weekly](#)[Monthly](#)[Custom](#)

	Actual	Average	Record
Temperature			
Mean Temperature	44 °F	40 °F	
Max Temperature	64 °F	54 °F	78 °F (1953)
Min Temperature	24 °F	26 °F	-9 °F (1962)
Degree Days			
Heating Degree Days	21	25	
Month to date heating degree days	236	256	
Since 1 July heating degree days	1720	1666	
Cooling Degree Days	0	0	
Month to date cooling degree days	0	0	
Year to date cooling degree days	0	0	
Moisture			
Dew Point	25 °F		
Average Humidity	57		
Maximum Humidity	88		
Minimum Humidity	25		
Precipitation			
Precipitation	0.00 in	0.01 in	0.36 in (1905)
Month to date precipitation	0.00	0.13	
Year to date precipitation	0.00	0.13	
Sea Level Pressure			
Sea Level Pressure	30.02 in		
Wind			
Wind Speed	4 mph (SSW)		
Max Wind Speed	14 mph		
Max Gust Speed	15 mph		
Visibility	10 miles		
Events			

T = Trace of Precipitation, **MM** = Missing Value**Source:** NWS Daily Summary

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Hourly Observations

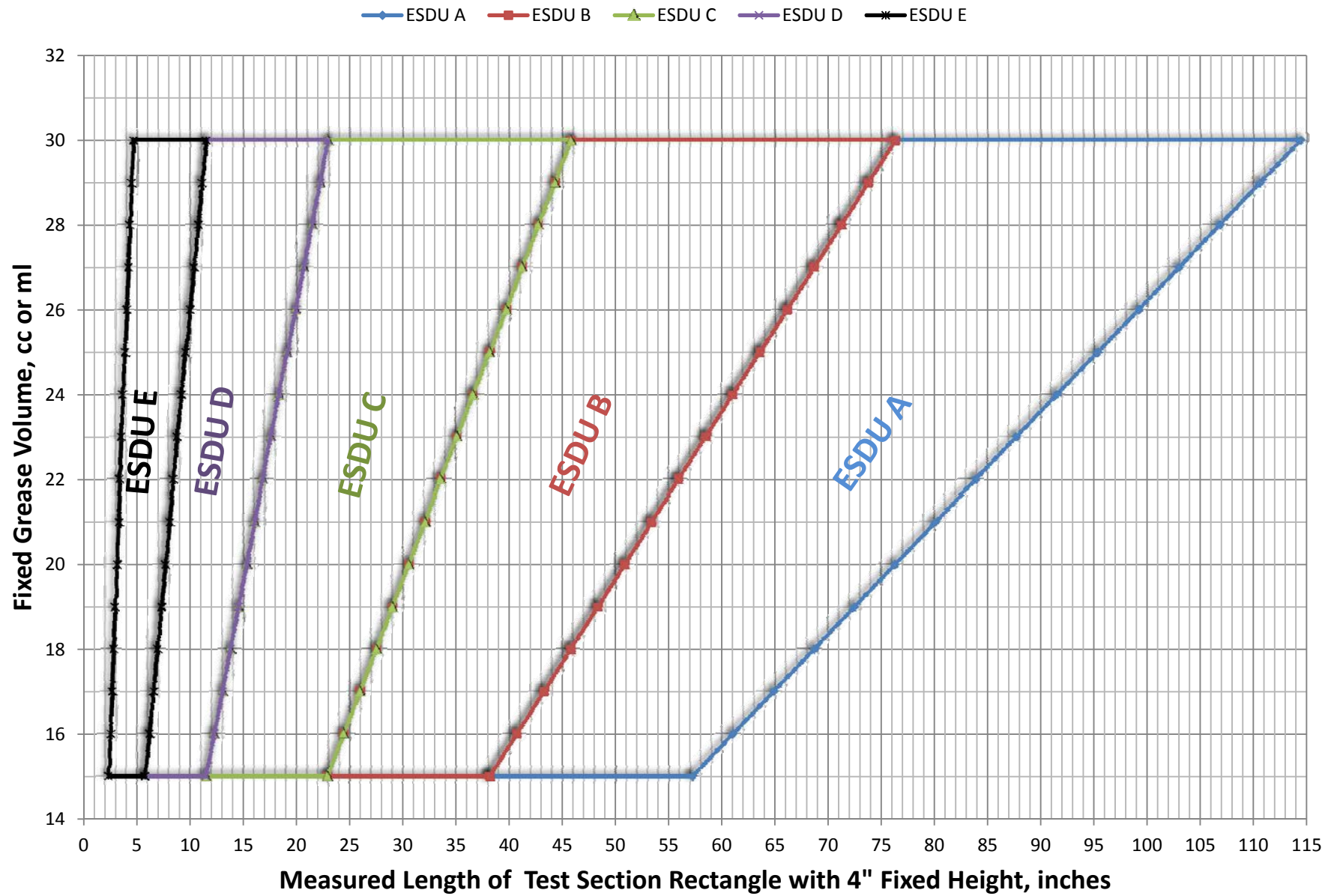
Time (MST)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
12:51 AM	25.0 °F	19.3 °F	19.9 °F	81%	30.15 in	10.0 mi	ESE	4.6 mph	-	N/A		Clear
METAR KROW 100751Z AUTO 12004KT 10SM CLR M04/M07 A3014 RMK AO2 SLP210 T10391067 TSNO												
1:51 AM	24.1 °F	-	21.9 °F	91%	30.15 in	10.0 mi	Calm	Calm	-	N/A		Clear
METAR KROW 100851Z AUTO 00000KT 10SM CLR M04/M06 A3014 RMK AO2 SLP208 T10441056 56003 TSNO												
2:51 AM	27.0 °F	21.6 °F	23.0 °F	85%	30.12 in	10.0 mi	WSW	4.6 mph	-	N/A		Clear
METAR KROW 100951Z AUTO 25004KT 10SM CLR M03/M05 A3013 RMK AO2 SLP198 T10281050 TSNO												
3:51 AM	27.0 °F	-	21.0 °F	78%	30.13 in	10.0 mi	Calm	Calm	-	N/A		Mostly Cloudy
METAR KROW 101051Z AUTO 00000KT 10SM BKN090 M03/M06 A3014 RMK AO2 SLP203 T10281061 TSNO												
4:51 AM	28.0 °F	21.7 °F	21.0 °F	75%	30.13 in	10.0 mi	WNW	5.8 mph	-	N/A		Clear
METAR KROW 101151Z AUTO 29005KT 10SM CLR M02/M06 A3014 RMK AO2 SLP202 T10221061 11011 21044 56002 TSNO												
5:51 AM	25.0 °F	-	19.9 °F	81%	30.14 in	10.0 mi	Calm	Calm	-	N/A		Clear
METAR KROW 101251Z 00000KT 10SM CLR M04/M07 A3013 RMK AO2 SLP206 T10391067												
6:51 AM	26.1 °F	20.5 °F	21.0 °F	81%	30.14 in	10.0 mi	West	4.6 mph	-	N/A		Clear
METAR KROW 101351Z 28004KT 10SM CLR M03/M06 A3013 RMK AO2 SLP206 T10331061												
7:17 AM	28.4 °F	-	21.2 °F	74%	30.12 in	10.0 mi	Calm	Calm	-	N/A		Clear
SPECI KROW 101417Z 00000KT 10SM CLR M02/M06 A3012 RMK AO2												
7:51 AM	28.0 °F	24.2 °F	21.9 °F	78%	30.13 in	10.0 mi	NE	3.5 mph	-	N/A		Clear
METAR KROW 101451Z 05003KT 10SM CLR M02/M06 A3012 RMK AO2 SLP203 T10221056 56005												

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Time (MST)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
8:51 AM	32.0 °F	28.7 °F	23.0 °F	69%	30.13 in	10.0 mi	East	3.5 mph	-	N/A		Clear
METAR KROW 101551Z 08003KT 10SM CLR 00/M05 A3012 RMK AO2 SLP202 T00001050												
9:51 AM	37.9 °F	35.5 °F	26.1 °F	62%	30.11 in	10.0 mi	Variable	3.5 mph	-	N/A		Clear
METAR KROW 101651Z VRB03KT 10SM CLR 03/M03 A3012 RMK AO2 SLP195 T00331033												
10:51 AM	46.9 °F	-	26.1 °F	44%	30.08 in	10.0 mi	Variable	3.5 mph	-	N/A		Clear
METAR KROW 101751Z VRB03KT 10SM CLR 08/M03 A3010 RMK AO2 SLP185 T00831033 10083 21044 58006												
11:51 AM	54.0 °F	-	24.1 °F	31%	30.01 in	10.0 mi	ENE	4.6 mph	-	N/A		Clear
METAR KROW 101851Z 06004KT 10SM CLR 12/M04 A3004 RMK AO2 SLP160 T01221044												
12:51 PM	57.9 °F	-	25.0 °F	28%	29.96 in	10.0 mi	Variable	3.5 mph	-	N/A		Clear
METAR KROW 101951Z VRB03KT 10SM CLR 14/M04 A3000 RMK AO2 SLP143 T01441039												
1:51 PM	62.1 °F	-	26.1 °F	25%	29.92 in	10.0 mi	NNW	3.5 mph	-	N/A		Clear
METAR KROW 102051Z 33003KT 10SM CLR 17/M03 A2997 RMK AO2 SLP131 T01671033 56040												
2:51 PM	62.1 °F	-	28.0 °F	28%	29.89 in	10.0 mi	SE	8.1 mph	-	N/A		Clear
METAR KROW 102151Z AUTO 13007KT 10SM CLR 17/M02 A2995 RMK AO2 SLP122 T01671022 TSNO												
4:51 PM	55.9 °F	-	33.1 °F	42%	29.89 in	10.0 mi	South	9.2 mph	-	N/A		Clear
METAR KROW 102351Z 17008KT 10SM CLR 13/01 A2993 RMK AO2 SLP120 T01330006 10178 20033 \$												
5:51 PM	48.0 °F	-	34.0 °F	58%	29.91 in	10.0 mi	South	8.1 mph	-	N/A		Clear
METAR KROW 110051Z 17007KT 10SM CLR 09/01 A2993 RMK AO2 SLP127 T00890011												
6:51 PM	43.0 °F	39.5 °F	32.0 °F	65%	29.92 in	10.0 mi	West	5.8 mph	-	N/A		Clear
METAR KROW 110151Z 26005KT 10SM CLR 06/00 A2993 RMK AO2 SLP131 T00610000												
7:51 PM	50.0 °F	-	24.1 °F	36%	29.89 in	10.0 mi	West	8.1 mph	-	N/A		Clear
METAR KROW 110251Z 28007KT 10SM CLR 10/M04 A2992 RMK AO2 SLP121 T01001044 58003												
8:51 PM	39.9 °F	37.8 °F	26.1 °F	58%	29.90 in	10.0 mi	West	3.5 mph	-	N/A		Clear
METAR KROW 110351Z AUTO 26003KT 10SM CLR 04/M03 A2991 RMK AO2 SLP124 T00441033 TSNO												
9:51 PM	36.0 °F	33.3 °F	26.1 °F	67%	29.89 in	10.0 mi	Variable	3.5 mph	-	N/A		Clear
METAR KROW 110451Z AUTO VRB03KT 10SM CLR 02/M03 A2991 RMK AO2 SLP120 T00221033 TSNO												
10:51 PM	30.0 °F	25.2 °F	24.1 °F	79%	29.86 in	10.0 mi	South	4.6 mph	-	N/A		Clear
METAR KROW 110551Z AUTO 18004KT 10SM CLR M01/M04 A2989 RMK AO2 SLP112 T01111044 10133 21011 58008 TSNO												
11:51 PM	32.0 °F	26.4 °F	26.1 °F	79%	29.82 in	10.0 mi	ENE	5.8 mph	-	N/A		Clear
METAR KROW 110651Z AUTO 06005KT 10SM CLR 00/M03 A2987 RMK AO2 SLP096 T00001033 401781044 TSNO												
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Attachment 4: Grease Test Measurements and Calculated Pavement Macrotexture (KROW)

Runway Pavement Macrotexture Classification Based on Grease Test Section Length



Grease Method (used at KROW runway 3/21 for non-grooved pavement macrotexture measurements)

Participants: Kevin Renze (NTSB); Tom Yager (NASA Langley); Mark H. Smith, A.Tom Stephens, Paul Giesman (Boeing)
Don Stimson (FAA), Clint Raby (Roswell International Air Center)

NASA Grease Tube/Cylinder Dimensions and Adjustments

Height, inches	1.655	Grease	Volume	Volume	Conversions	
Diameter, inches	0.863	cc	in^3	ml	cc / in^3	ml / in^3
Volume Penalty	1	15.864	0.968	15.864	0.06102374	16.38706

Operator	NASA Langley	(Tom Yager)						
Runway 21	Runway 21		M1	M2	M3	M4	Average of M1, M3	Average of M2, M4
Distance from Threshold	Distance Remaining	Sample Dimension	17 Feet Left of C/L	17 Feet Left of C/L	17 Feet Left of C/L	17 Feet Left of C/L	-	-
feet	feet	-	Boeing Grease; Plastic Scraper	Boeing Grease; Rubber Squeegee	NASA Grease; Plastic Scraper	NASA Grease; Rubber Squeegee	-	-
6,000	7,001	Length, in	14.25	17.5	14.5	17.25	-	-
		Width, in	4	4	4	4	-	-
		Depth, in	0.0170	0.0138	0.0167	0.0140	0.0168	0.0139
		Depth, mm	0.4314	0.3513	0.4240	0.3564	0.4277	0.3538
		ESDU Type	High C	Low C	High C	Low C	High C	Low C

Operator	NASA Langley	(Tom Yager)						
Runway 21	Runway 21		M1	M2	M3	M4	Average of M1, M3	Average of M2, M4
Distance from Threshold	Distance Remaining	Sample Dimension	34 Feet Left of C/L	34 Feet Left of C/L	34 Feet Left of C/L	34 Feet Left of C/L	-	-
feet	feet	-	Boeing Grease; Plastic Scraper	Boeing Grease; Rubber Squeegee	NASA Grease; Plastic Scraper	NASA Grease; Rubber Squeegee	-	-
6,000	7,001	Length, in	11.75	15.75	11.75	15.25	-	-
		Width, in	4	4	4	4	-	-
		Depth, in	0.0206	0.0154	0.0206	0.0159	0.0206	0.0156
		Depth, mm	0.5232	0.3903	0.5232	0.4031	0.5232	0.3967
		ESDU Type	Low D	High C	Low D	High C	Low D	High C

Grease Method (used at KROW runway 3/21 for non-grooved pavement macrotexture measurements)

Participants: Kevin Renze (NTSB); Tom Yager (NASA Langley); Mark H. Smith, A.Tom Stephens, Paul Giesman (Boeing)
Don Stimson (FAA), Clint Raby (Roswell International Air Center)

NTSB Grease Tube/Cylinder Dimensions and Adjustments

	Boeing Grease	NASA Grease		Grease	Volume	Volume	Conversions	
Height, inches	1.475	1.459		cc	in^3	ml	cc / in^3	ml / in^3
Diameter, inches	1.043	1.0455	Boeing Grease	19.619	1.197	19.619	0.06102374	16.38706
Volume Penalty	0.95	0.95	NASA Grease	19.499	1.190	19.499		

Operator	NTSB	(Kevin Renze)						
Runway 21	Runway 21		M1	M2	M3	M4	Average of M1, M3	Average of M2, M4
Distance from	Distance	Sample	17 Feet Left of C/L	17 Feet Left of C/L	17 Feet Left of C/L	17 Feet Left of C/L	-	-
Threshold	Remaining	Dimension						
feet	feet	-	Boeing Grease; Plastic Scraper	Boeing Grease; Rubber Squeegee	NASA Grease; Plastic Scraper	NASA Grease; Rubber Squeegee	-	-
6,000	7,001	Length, in	22	28.875	22	31	-	-
		Width, in	4	4	4	4	-	-
		Depth, in	0.0136	0.0104	0.0135	0.0096	0.0136	0.0100
		Depth, mm	0.3456	0.2633	0.3435	0.2437	0.3445	0.2535
		ESDU Type	Low C	Low C	Low C	High B	Low C	High B

Operator	NTSB	(Kevin Renze)						
Runway 21	Runway 21		M1	M2	M3	M4	Average of M1, M3	Average of M2, M4
Distance from	Distance	Sample	34 Feet Left of C/L	34 Feet Left of C/L	34 Feet Left of C/L	34 Feet Left of C/L	-	-
Threshold	Remaining	Dimension						
feet	feet	-	Boeing Grease; Plastic Scraper	Boeing Grease; Rubber Squeegee	NASA Grease; Plastic Scraper	NASA Grease; Rubber Squeegee	-	-
6,000	7,001	Length, in	27.625	33.5	19.3125	23.25	-	-
		Width, in	4	4	4	4	-	-
		Depth, in	0.0108	0.0089	0.0154	0.0128	0.0131	0.0109
		Depth, mm	0.2752	0.2269	0.3912	0.3250	0.3332	0.2760
		ESDU Type	Low C	High B	High C	Low C	Low C	Low C

Attachment 5: Outflow Meter Measurements and Calculated Pavement Macrotexture (KROW)

Roswell, NM runway 3/21 HydroTimer outflow meter test, January 9-10, 2012 (Measured outflow time)

Location (feet) from 21 Threshold	50' Left Time Display sec	Time Offset sec	Time Corrected sec	34' Left Time Display sec	Time Offset sec	Time Corrected sec	17' Left Time Display sec	Time Offset sec	Time Corrected sec	17' Right Time Display sec	Time Offset sec	Time Corrected sec	34' Right Time Display sec	Time Offset sec	Time Corrected sec
1,990										82.39	0.01	82.38			
1,990										40.98	0.1	40.88			
2,000				19.69	0.09	19.6	49.14	0.04	49.1	92.1	0.08	92.02	9.55	0.19	9.36
3,000						16' L -->	41.11	0.03	41.08	31.25	0.08	31.17	<-- 22' R skid mark		
3,000				25.58	0.13	25.45	58.43	0.1	58.33	33.28	0.03	33.25	16.95	0.36	16.59
4,000				28.83	0.05	28.78	32.62	0.1	32.52	33.58	0.01	33.57	18.43	0.25	18.18
5,490							9.23	0.17	9.06						
5,000				31.01	0.08	30.93	11.4	0.14	11.26	12.62	0.2	12.42	26.51	0.2	26.31
6,000 67' Left -->	3.78	0.04	3.74							23.49	0.01	23.48	<-- Pavement		
6,000 34' L and 17' L between grease test marks				24.05	0.13	23.92	18.06	0.03	18.03	41.94	0.05	41.89	10.61	0.13	10.48
7,000				10.79	0.08	10.71	12.15	0.14	12.01	10.73	0.09	10.64	20.41	0.09	20.32
7,490				20.53	0.08	20.45	16.25	0.03	16.22				22.65	0.12	22.53
7,500	20.26	0.04	20.22	23.17	0.14	23.03	7.22	0.03	7.19	21.27	0.1	21.17	38.68	0.09	38.59
9,000 67' Left -->	4.37	0.09	4.28	15.57	0.1	15.47	12.27	0.17	12.1	21.3	0.13	21.17	15.93	0.18	15.75
10,000				13.68	0.02	13.66	22.5	0.14	22.36	32.17	0.03	32.14	12.33	0	12.33
11,000				12.96	0.42	12.54	23.93	0.15	23.78	14.38	0	14.38	34.48	0.21	34.27

Roswell, NM runway 3/21 HydroTimer outflow meter test, January 9-10, 2012 (Convert measured outflow time to grease test ATD in mm)

Location (feet) from 21 Threshold	50' Left Equivalent Grease			34' Left Equivalent Grease			17' Left Equivalent Grease			17' Right Equivalent Grease			34' Right Equivalent Grease		
	NTSB mm	NASA mm	Time sec	NTSB mm	NASA mm	Time sec	NTSB mm	NASA mm	Time sec	NTSB mm	NASA mm	Time sec	NTSB mm	NASA mm	Time sec
1,990										0.154	0.147	82.38			
1,990										0.210	0.209	40.88			
2,000				0.291	0.301	19.6	0.194	0.190	49.1	0.147	0.139	92.02	0.403	0.435	9.36
3,000						16' L -->	0.210	0.208	41.08	0.237	0.239	31.17	<-- 22' R skid mark		
3,000				0.259	0.264	25.45	0.180	0.175	58.33	0.230	0.231	33.25	0.313	0.327	16.59
4,000				0.245	0.248	28.78	0.233	0.234	32.52	0.229	0.230	33.57	0.300	0.312	18.18
5,490							0.409	0.442	9.06						
5,000				0.238	0.240	30.93	0.371	0.396	11.26	0.355	0.377	12.42	0.255	0.260	26.31
6,000 67' Left -->	0.603	0.686	3.74							0.268	0.275	23.48	<-- Pavement		
6,000 34' L and 17' L between grease test marks				0.266	0.272	23.92	0.302	0.314	18.03	0.208	0.206	41.89	0.383	0.411	10.48
7,000				0.379	0.406	10.71	0.361	0.384	12.01	0.381	0.408	10.64	0.286	0.295	20.32
7,490				0.285	0.294	20.45	0.316	0.330	16.22				0.273	0.281	22.53
7,500	0.287	0.296	20.22	0.271	0.278	23.03	0.452	0.496	7.19	0.281	0.289	21.17	0.216	0.215	38.59
9,000 67' Left -->	0.569	0.642	4.28	0.323	0.338	15.47	0.360	0.382	12.1	0.281	0.289	21.17	0.320	0.335	15.75
10,000				0.341	0.360	13.66	0.274	0.282	22.36	0.234	0.235	32.14	0.357	0.379	12.33
11,000				0.354	0.376	12.54	0.267	0.273	23.78	0.333	0.351	14.38	0.227	0.228	34.27

Roswell, NM runway 3/21 HydroTimer outflow meter test, January 9-10, 2012 (Convert measured outflow time to grease test ATD in inches)

Location (feet) from 21 Threshold	50' Left Equivalent Grease			34' Left Equivalent Grease			17' Left Equivalent Grease			17' Right Equivalent Grease			34' Right Equivalent Grease		
	NTSB in.	NASA in.	Time sec	NTSB in.	NASA in.	Time sec	NTSB in.	NASA in.	Time sec	NTSB in.	NASA in.	Time sec	NTSB in.	NASA in.	Time sec
1,990										0.006	0.006	82.38			
1,990										0.008	0.008	40.88			
2,000				0.011	0.012	19.6	0.008	0.007	49.1	0.006	0.005	92.02	0.016	0.017	9.36
3,000						16' L -->	0.008	0.008	41.08	0.009	0.009	31.17	<-- 22' R skid mark		
3,000				0.010	0.010	25.45	0.007	0.007	58.33	0.009	0.009	33.25	0.012	0.013	16.59
4,000				0.010	0.010	28.78	0.009	0.009	32.52	0.009	0.009	33.57	0.012	0.012	18.18
5,490							0.016	0.017	9.06						
5,000				0.009	0.009	30.93	0.015	0.016	11.26	0.014	0.015	12.42	0.010	0.010	26.31
6,000 67' Left -->	0.024	0.027	3.74							0.011	0.011	23.48	<-- Pavement		
6,000 34' L and 17' L between grease test marks				0.010	0.011	23.92	0.012	0.012	18.03	0.008	0.008	41.89	0.015	0.016	10.48
7,000				0.015	0.016	10.71	0.014	0.015	12.01	0.015	0.016	10.64	0.011	0.012	20.32
7,490				0.011	0.012	20.45	0.012	0.013	16.22				0.011	0.011	22.53
7,500	0.011	0.012	20.22	0.011	0.011	23.03	0.018	0.020	7.19	0.011	0.011	21.17	0.008	0.008	38.59
9,000 67' Left -->	0.022	0.025	4.28	0.013	0.013	15.47	0.014	0.015	12.1	0.011	0.011	21.17	0.013	0.013	15.75
10,000				0.013	0.014	13.66	0.011	0.011	22.36	0.009	0.009	32.14	0.014	0.015	12.33
11,000				0.014	0.015	12.54	0.011	0.011	23.78	0.013	0.014	14.38	0.009	0.009	34.27

Roswell, NM runway 3/21 HydroTimer outflow meter test, January 9-10, 2012 (Convert grease test ATD in inches to ESDU class)

Location (feet) from 21 Threshold	50' Left Equivalent Grease			34' Left Equivalent Grease			17' Left Equivalent Grease			17' Right Equivalent Grease			34' Right Equivalent Grease		
	NTSB ESDU	NASA ESDU	Time sec	NTSB ESDU	NASA ESDU	Time sec	NTSB ESDU	NASA ESDU	Time sec	NTSB ESDU	NASA ESDU	Time sec	NTSB ESDU	NASA ESDU	Time sec
1,990										Low B	High A	82.38			
1,990										High B	High B	40.88			
2,000				Low C	Low C	19.6	Low B	Low B	49.1	High A	High A	92.02	High C	High C	9.36
3,000						16' L -->	High B	High B	41.08	High B	High B	31.17	<-- 22' R skid mark		
3,000				Low C	Low C	25.45	Low B	Low B	58.33	High B	High B	33.25	Low C	Low C	16.59
4,000				High B	High B	28.78	High B	High B	32.52	High B	High B	33.57	Low C	Low C	18.18
5,490							High C	High C	9.06						
5,000				High B	High B	30.93	Low C	High C	11.26	Low C	Low C	12.42	Low C	Low C	26.31
6,000 67' Left -->	Low D	Low D	3.74							Low C	Low C	23.48	<-- Pavement		
6,000 34' L and 17' L between grease test marks				Low C	Low C	23.92	Low C	Low C	18.03	High B	High B	41.89	High C	High C	10.48
7,000				Low C	High C	10.71	Low C	High C	12.01	Low C	High C	10.64	Low C	Low C	20.32
7,490				Low C	Low C	20.45	Low C	Low C	16.22				Low C	Low C	22.53
7,500	Low C	Low C	20.22	Low C	Low C	23.03	High C	High C	7.19	Low C	Low C	21.17	High B	High B	38.59
9,000 67' Left -->	Low D	Low D	4.28	Low C	Low C	15.47	Low C	High C	12.1	Low C	Low C	21.17	Low C	Low C	15.75
10,000				Low C	Low C	13.66	Low C	Low C	22.36	High B	High B	32.14	Low C	Low C	12.33
11,000				Low C	Low C	12.54	Low C	Low C	23.78	Low C	Low C	14.38	High B	High B	34.27

Roswell, NM runway 3/21 HydroTimer outflow meter test results, January 9-10, 2012

	34' Left			17' Left			17' Right			34' Right			Segment
	Equivalent Grease		Time	Equivalent Grease		Time	Equivalent Grease		Time	Equivalent Grease		Time	Time
	NTSB	NASA	sec	NTSB	NASA	sec	NTSB	NASA	sec	NTSB	NASA	sec	sec
Runway 3/21 segment: Middle 9,000 feet *													
mm	0.286	0.295	20.41	0.265	0.271	24.08	0.225	0.225	35.04	0.285	0.295	20.43	
inches	0.011	0.012		0.010	0.011		0.009	0.009		0.011	0.012		
ESDU Class	Low C	Low C		Low C	Low C		High B	High B		Low C	Low C		24.99

* Stations 2,000 to 11,000 feet from runway 21 threshold, inclusive; excludes stations less than 2,000 feet from either threshold.

Runway 3/21 segment: Middle 7,000 feet **

mm	0.280	0.288	21.38	0.277	0.285	21.83	0.256	0.261	26.09	0.287	0.297	20.12	
inches	0.011	0.011		0.011	0.011		0.010	0.010		0.011	0.012		
ESDU Class	Low C	Low C		Low C	Low C		Low C	Low C		Low C	Low C		22.36

** Stations 3,000 to 10,000 feet from runway 21 threshold, inclusive; excludes stations less than 3,000 feet from either threshold.

Runway 3/21 segment: Middle 5,000 feet ***

mm	0.277	0.285	21.90	0.329	0.346	14.80	0.268	0.275	23.48	0.278	0.286	21.74	
inches	0.011	0.011		0.013	0.014		0.011	0.011		0.011	0.011		
ESDU Class	Low C	Low C		Low C	Low C		Low C	Low C		Low C	Low C		20.48

*** Stations 4,000 to 9,000 feet from runway 21 threshold, inclusive; excludes stations less than 4,000 feet from either threshold.

Yager and Buhlmann, Volumetric and Outflow Meter Test Trend

