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This TOP supersedes TOP 02-2-627 Braking - Tracked Vehicles, dated 18 July 1980.

14. ABSTRACT
This Test Operations Procedure (TOP) describes the procedures used for assessing the brake performance of military tracked vehicles.

15. SUBJECT TERMS
Tracked Vehicle; Brake Effectiveness; Burnish; Pedal Effort; Grade Holding Ability

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure (TOP) 02-2-627A 13 May 2021
DTIC AD No.

STANDARDIZED TESTS FOR ASSESSING TRACKED VEHICLE BRAKING SYSTEMS

* This TOP supersedes TOP 02-2-627 Braking - Tracked Vehicles, dated 18 July 1980.

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1. SCOPE.

This Test Operations Procedure (TOP) provides standardized tests for assessing military tracked vehicle braking system performance.

1.1 Purpose.

a. Braking is a critical automotive system function. Thorough testing and assessment of the vehicle braking system is required to assure personnel safety, dependability, and effectiveness.

b. Factors considered in the assessment of vehicle brake systems include stopping and grade holding ability, vehicle stability and control, and component durability under various operating conditions.

c. This TOP identifies pertinent procedures and requirements for testing military tracked vehicles.

1.2 Limitations.

This TOP applies to tracked vehicles designed for combat or tactical operation. These procedures may be used for both developmental and production tests. This TOP applies to conventional powertrain tracked vehicles, not electric or hybrid electric vehicles.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Level Paved Road	A straight, level, paved road with a lane width of not less than 3.7 meters, a longitudinal gradient ≤ 1 percent, and a side-to-side gradient ≤ 2 percent. Length of the roadway should be sufficient to allow the test vehicle, at its required payload condition, to accelerate to maximum speed and then safely stop.
Longitudinal Grades	Longitudinal slopes ranging from 5- to 60-percent grade and of sufficient length to accommodate the entire vehicle.

Item	Requirement
Hilly Course, Off-road	Cross-country, moderate to rough native soil and stone with grades less than 30% (e.g., Churchville Test Area (CTA) course B and Patton Hilly Trails). Secondary, improved gravel road with Grades less than 10% (e.g., CTA Course C and Patton level gravel).
Level course, Off-road	Improved gravel road (e.g., Munson Test Area gravel course and Kofa level gravel).

2.2 Instrumentation.

Devices for Measuring	Recommended Maximum Error of Combined System
Stopping Distance	± 1% of full scale
Vehicle speed	± 1% of full scale
Sprocket speed	± 1% of full scale
Brake apply pressure	± 1% of full scale
Brake pedal force	± 1% of full scale
Time delta	± 1% of full scale
Acceleration, longitudinal, lateral and vertical	± 2% of full scale
Shaft Torque	± 1% of full scale
Brake pedal travel distance	± 1% of full scale
Brake event count	2 counts
Angle, vehicle roll, pitch, and yaw	± 2.0 degrees
Angular rates, vehicle roll, pitch, and yaw	1% of full scale
Brake fluid temperature	± 2 °Celsius (°C)
Engine speed	± 1% of full scale
Motor speed	± 1% of full scale
Voltage	± 1% of full scale
Current	± 1% of full scale
Meteorological data:	
Atmospheric pressure	± 1% of full scale
Ambient temperature	± 1 °C
Humidity	± 3% of value
Wind speed	± 5% of value
Wind direction	± 50 milliradian

2.3 Specialized Equipment/Facilities.

2.3.1 Specialized Equipment and Instrumentation.

Specialized shop equipment and instrumentation required for vehicle preparation, test, post-test inspection and test observation are as follows. Appendix A provides example photographs of tracked vehicle test instrumentation.

a. Micrometer calipers (inside, outside, and dial types).

b. Surface finish gauges.

c. Torque wrench.

d. Feeler gauge stock.

e. Surface contact temperature gauge.

f. Video camera (to observe track lock-up, vehicle drift, and overall stability).

g. Instrumented transmission hoses/fittings (with thermocouples) in place of existing transmission hoses/fittings into and out of the transmission fluid cooler. These hoses/fittings are only necessary if the test procedure requires burnishing of the brake packs.

h. Instrumented transmission dipstick (with thermocouple) in place of existing dipstick. The dipstick is only necessary if the test procedure requires burnishing of the brake packs.

i. Braking robot or driver capable of applying the brake pedal force with a ramp time within 0.2 seconds to the peak value.

j. (Optional). Braided steel hoses and/or specialized fittings to measure various pressures available from transmission test ports that provide information about transmission status (e.g., control, makeup pump, gear range, and clutch).

k. (Optional). Strain gauge-instrumented final drives to record output shaft torque.

l. (Optional). Encoders on the final drives to record track speed.

m. (Optional). Controller Area Network or Ethernet bus data.

2.3.2 Specialized Facilities.

Specialized facilities include a Surface Friction Measurement Device. It is recommended that the peak friction coefficient (skid number) of the various test course surfaces is measured prior to testing in accordance with American Society for Testing and Materials (ASTM) E1337[1**] using an ASTM E1136[2] standard reference tire.

3. REQUIRED TEST CONDITIONS.

3.1 Preparation for Test.

a. Review all instructional material issued with the test vehicle by the manufacturer, contractor, or government, as well as previous reports of the same vehicle type.

b. Select applicable test procedures based on requirement documents, including the Detailed Test Plan (DTP), and purpose of the test.

c. Prepare data collection sheets to record all pretest information, conditions of test, test results, observations, and measurements that would be valuable for analysis and assessment.

d. Ensure that all test personnel are familiar with the required technical and operational characteristics of the test item and with the required test procedures.

3.2 Test Controls.

Prior to testing, ensure that:

a. The vehicle has been prepared and equipped in accordance with standard use and/or within the specifications presented in the DTP.

b. The vehicle is payloaded in accordance with the DTP.

c. The vehicle has received the proper break-in operation. If the vehicle was recently delivered to the test facility, assume that the brake friction components are new. Before conducting maximum effort braking tests, it is recommended that the vehicle be subjected to a pre-burnish effectiveness test, a burnish procedure comprised of 30 brake stops, and a post-burnish effectiveness test. If the brake burnish procedure is not initially completed and the test vehicle does not meet brake effectiveness specifications during testing, the brake burnish procedure may be conducted, followed by a brake effectiveness retest.

d. The braking system components are inspected per manufactures recommendations and determined to be in good serviceable condition.

** Superscript numbers correspond to those in Appendix G, References.

e. The peak friction coefficient (skid number) of each test track surface meets the requirements of the DTP or the vehicle performance specifications. The skid number is determined in accordance with ASTM E1337.

f. The brakes are adjusted per vehicle manufacturer recommended procedures. Brakes may only be readjusted when specifically indicated in the DTP.

g. The brakes remain within adjustment for the duration of the test, if applicable.

h. A brake cooling procedure is established, based on vehicle manufacturer guidance for the particular brake system design if possible.

i. A safe track temperature operating range or cooling procedure is established based on vehicle or track manufacturer guidance, if possible. As an example, the T158LL Track Durability Guarantee Test Hardware Replacement Criteria[3] states if the track temperature exceeds 54 °C (130 °Fahrenheit (°F)), the track will be allowed time to cool to 54 °C (130 °F) before testing continues.

3.3 Restrictions.

Tests shall not be conducted at night, during inclement weather or when the road surface introduces a hazard. Dry, unobstructed surfaces shall be used unless the DTP provides a specific requirement. Local safety and operational procedures shall be carefully followed. Recommended environmental conditions for test conduct are as follows:

a. Wind speed, ≤ 3 meters per second (m/s) average value.

b. Ambient temperature, 0 °C (32 °F) ≤ T ≤ 37.7 °C (100 °F).

c. Humidity, ≤ 95 percent.

4. TEST PROCEDURES.

Use the following test procedures when the specific test is required in the DTP. Not all tests are required on a given vehicle. When a new vehicle configuration is established that affects the vehicle drivetrain and brakes (e.g., increased weight, new drivetrain components, etc.), it is recommended to execute each of the test procedures presented below to establish a baseline for the new vehicle configuration. Use the test speeds listed below unless the DTP provides other guidance.

4.1 Brake System Inspection/Characterization.

Conduct vehicle and brake system inspections in accordance with the applicable daily preventive maintenance checks and services (PMCS) Technical Manual (TM), semiannual service brake check TM, and service brake adjustment TM.

4.1.1 General Vehicle Characterization

At a minimum, report the following information with the test results.

a. Vehicle identification.

b. Odometer mileage.

c. Vehicle payload condition (amount of payload and location).

d. Vehicle weight distribution.

e. Vehicle center of gravity location.

f. Track description, condition, and track pad thickness.

g. Suspension description, including road arm location of dampers.

h. Brake system component description and condition.

4.1.2 Pedal Effort Characteristics.

Determine brake pedal force versus brake apply (control) pressure characteristics (or vice versa) prior to testing. If brake apply pressure measurements are not possible, record pedal displacement versus force using a string potentiometer or similar sensor. Measure pedal force using a calibrated load cell (mounted on the brake pedal) and read-out system. Apply a constant pedal force while recording brake apply pressure (and any other relevant brake system pressure) or pedal displacement. Conduct measurements at various increments up to the vehicle's maximum system pressure or pedal displacement. In practice, 95 percent of the estimated maximum pedal displacement is sufficient. After completion of these tests, it is recommended that the pedal-mounted load cell be removed to preclude interference with normal driving operations. The number of specific test scenarios (different brake pedal force data points) should be up to the engineer conducting the test to build a curve that adequately characterizes the braking performance. For each scenario tested up to the maximum system pressure or pedal displacement, at least two individual data points should be recorded and then averaged together to provide a single data point.

4.2 Safety/Performance Evaluation.

All brake effectiveness events listed below should be conducted with the vehicle initially operating at a speed above the target brake apply speed and then coasting to the target speed before brake application.

4.2.1 Brake Burnish.

If brake friction material burnishing is required, use the following procedure consisting of 30 stop events. It is recommended that transmission fluid temperature does not exceed 149 °C (300 °F), or as otherwise specified in TMs or oil specifications. Prior to and following burnishing, conduct the brake effectiveness test described in paragraph 4.2.3 for comparison to indicate if the friction materials have been sufficiently burnished.

a. Conduct the burnish procedure on a level, straight, hard-surfaced roadway (with proper skid number) at the vehicle payload condition listed in the DTP.

b. Drive the vehicle at 32 to 40 kilometers per hour (km/h) (20 to 25 miles per hour (mph)) for 15 minutes prior to the first brake stop to warm the system to normal operating temperatures. At the end of the warm-up period, document all thermocouple readings and refer to them as the normal operating temperatures of the system.

c. Perform the first brake stop event from an initial speed of 32 km/h (20 mph) with a target deceleration of 2.4 m/s^2 (8 ft/s^2), avoiding track lock-up. Record any occurrence of vehicle slew and determine if it is within the performance specification of the test vehicle as listed in the DTP.

d. After the stop event, follow the brake cooling procedure provided by the vehicle manufacturer for the particular brake system design.

e. Regardless of the brake cooling procedure used, monitor the thermocouple data to ensure temperatures have returned to normal operating conditions at the end of the cool-down period. If the ambient temperature changed since the time the normal operating temperatures were established, adjust the target normal operating temperatures accordingly by increasing/decreasing the target thermocouple data one degree for each degree of ambient temperature change.

f. Repeat the steps in paragraphs 4.2.1.c through 4.2.1.e until 15 brake stops are completed.

g. After the first 15 stop events, with the vehicle at rest on level ground, place the vehicle transmission in Neutral without setting the parking brake or applying the service brake pedal to inspect the vehicle tracks. If the track temperature is higher than the normal safe operating temperature established prior to testing, allow time to cool the track.

h. Repeat the steps in paragraphs 2.4.1.c through 2.4.1.e for an additional 15 brake stops, bringing the total number of brake stops to 30. Follow the appropriate cooling procedure after the last brake stop.

i. If parking the test vehicle is required for any duration other than the cooling procedure, place the transmission in Neutral without setting the parking brake or applying the

service brake pedal. To reduce the risk of the vehicle moving, position the vehicle on level ground, keeping an operator in the driver's seat for safety reasons.

j. If any of the thermocouples in the transmission system approach the oil temperature limit, follow the appropriate cooling procedure to reach safe operating temperatures. Observe measurements from the pressure transducers installed on the transmission test ports for elevated pressures that may indicate a transmission problem.

4.2.2 Grade Holding Ability.

Conduct grade holding ability testing in accordance with TOP 02-2-610A[4]. Unless other guidance is provided in the DTP, the criterion for grade holding ability for both service and parking brake systems of tracked vehicles is that each system, independent of the other, holds the vehicle stationary in both ascending and descending attitudes on the maximum longitudinal slope over which the vehicle is required to operate.

4.2.3 Brake Effectiveness.

a. Conduct brake effectiveness tests from 32 and 48 km/h (20 and 30 mph) to characterize vehicle-stopping distance versus brake pedal force or brake apply (control) pressure. Test at additional vehicle speeds if required in the DTP. Use of a brake pedal robot is recommended to provide a precise brake pedal application force. Target brake pedal forces, or apply pressures, represent the average values, not the peak. Measure stopping distances over the input force/pressure range up to the point of track lock-up. It is recommended that transmission fluid temperature does not exceed 149 °C (300 °F), or as otherwise specified in TMs or oil specifications.

b. The following procedures are used.

(1) Conduct the tests on a level, straight, hard-surfaced roadway (with proper skid number) at the vehicle payload condition listed in the DTP.

(2) Drive the vehicle at 32 to 40 km/h (20 to 25 mph) for 15 minutes prior to the first brake stop to warm the system to normal operating temperatures. At the end of the warm-up period, document all thermocouple readings and refer to them as the normal operating temperatures of the system.

(3) Perform the first stop event from a target speed of 32 km/h (20 mph), while measuring stopping distance and brake pedal force (or apply pressure). The first stop is performed using a relatively low pedal force (or apply pressure), generating a low average deceleration (approximately 1.5 m/s^2 (5 ft/s^2)). Apply and hold the target pedal force with a ramp time within 0.2 second. Use a trained operator or a robot system to apply the brake pedal to meet this criterion. Record any occurrence of vehicle slew and determine if it is within the performance specification of the test vehicle as listed in the DTP.

(4) After the stop event, follow the brake cooling procedures described in paragraphs 4.2.1.d and 4.2.1.e.

(5) Perform the second brake effectiveness stop from 32 km/h (20 mph) while applying an incrementally higher pedal force (or apply pressure), generating a slightly greater deceleration (approximately 1.8 m/s^2 (6 ft/s^2)). Follow the cooling procedure again.

(6) Continue stops at incrementally higher pedal forces (or apply pressures) until at least 10 stops have been conducted producing decelerations ranging from approximately 1.5 m/s^2 (5 ft/s^2) to the maximum achievable value prior to track lock-up. If necessary to produce a complete characterization curve, generate additional data points below the recommended initial deceleration of 1.5 m/s^2 (5 ft/s^2). Follow the cooling procedure after each stop event.

(7) After the first five brake effectiveness stops, with the vehicle at rest on level ground, place the vehicle transmission in Neutral without setting the parking brake or applying the service brake pedal to inspect the vehicle tracks. If the track temperature is higher than the normal safe operating temperature established prior to testing, allow time to cool the track.

(8) If parking the test vehicle is required for any duration other than the cooling procedure, place the transmission in Neutral without setting the parking brake or applying the service brake pedal. To reduce the risk of the vehicle moving, position the vehicle on level ground, keeping an operator in the driver's seat for safety reasons.

(9) If any of the thermocouples in the transmission system approach the oil temperature limit, follow the appropriate cooling procedure to reach safe operating temperatures. Observe measurements from the pressure transducers installed on the transmission test ports for elevated pressures that may indicate a transmission problem.

(10) Repeat the above procedures from a test speed of 48 km/h (30 mph).

4.2.4 Maximum Pedal Effort Braking (Maximum Safe Speed).

a. Conduct maximum pedal effort brake stops to assess structural integrity of the vehicle brake and track drive systems. Conduct tests in the forward vehicle direction from 32 km/h (20 mph) to the maximum safe speed, or as otherwise specified in the DTP. Conduct tests in the reverse vehicle direction from 8 km/h (5 mph) and at additional speeds if specified in the DTP. Maximum pedal effort means an application of the brake pedal in which at least 95 percent of the estimated maximum pedal displacement is achieved, without track lock-up. Maximum safe speed means the maximum vehicle speed or the highest safe test speed. Estimate maximum pedal displacement using the procedure described in paragraph 4.1.2, plotting pedal displacement versus pedal force and extrapolating the curve.

b. For each stop event, apply and hold the target pedal force, pressure, or displacement with a ramp time within 0.2 second. It is recommended that transmission fluid temperature does not exceed 149 °C (300 °F), or as otherwise specified in TMs or oil specifications.

c. The following procedures are used.

(1) Conduct the tests on a level, straight, hard-surfaced roadway (with proper skid number) at the vehicle payload condition listed in the DTP.

(2) Drive the vehicle at 32 to 40 km/h (20 to 25 mph) for 15 minutes prior to the first brake stop to warm the system to normal operating temperatures. At the end of the warm-up period, document all thermocouple readings and refer to them as the normal operating temperatures of the system.

(3) Perform the first maximum pedal effort stop in the forward direction from a target speed of 32 km/h (20 mph). Use a trained operator or a robot system to apply the brake pedal. Record any occurrence of vehicle slew. The operator should not apply any steer corrections during the stop, except for safety reasons. Avoid track lock-up. Record any occurrence of vehicle slew and determine if it is within the performance specification of the test vehicle as listed in the DTP.

(4) After the stop event, follow the brake cooling procedures described in paragraphs 4.2.1.d and 4.2.1.e.

(5) Perform the first maximum pedal effort stop in the reverse direction from a target speed of 8 km/h (5 mph). Record any occurrence of vehicle slew. The operator should not apply any steer corrections during the stop, except for safety reasons. Avoid track lock-up. Record any occurrence of vehicle slew and determine if it is within the performance specification of the test vehicle as listed in the DTP.

(6) After the stop event, follow the brake cooling procedures described in paragraphs 4.2.1.d and 4.2.1.e.

(7) Repeat the steps in paragraphs 4.2.4.c(3) through 4.2.4.c(6) to complete three stops from 32 km/h (20 mph) in the forward direction and 8 km/h (5 mph) in the reverse direction (six total).

(8) After the first six stops, with the vehicle at rest on level ground, place the vehicle transmission in Neutral without setting the parking brake or applying the service brake pedal to inspect the vehicle tracks. If the track temperature is higher than the normal safe operating temperature established prior to testing, allow time to cool the track.

(9) Repeat the steps above at incrementally higher speeds until reaching the maximum safe speed. For the forward direction, use 16 km/h (10 mph) increments. If reverse test speeds higher than 8 km/h (5 mph) are required in the DTP, test to the indicated speeds, but do so in increments no more than 5 mph. Complete three stops for each target speed and course direction.

(10) If parking the test vehicle is required for any duration other than the cooling procedure, place the transmission in Neutral without setting the parking brake or applying the service brake pedal. To reduce the risk of the vehicle moving, position the vehicle on level ground, keeping an operator in the driver's seat for safety reasons.

(11) If any of the thermocouples in the transmission system approach the oil temperature limit, follow the appropriate cooling procedure to reach safe operating temperatures. Observe measurements from the pressure transducers installed on the transmission test ports for elevated pressures that may indicate a transmission problem.

(12) Unless otherwise specified in the DTP or vehicle performance specifications, the vehicle shall be capable of performing maximum pedal effort brake stops in both the forward and reverse directions at the speeds tested without:

(a) Internal or external damage to the transmission, brake system, road wheels, track or suspension system.

(b) Loss of positive engagement of the track and final drive.

4.2.5 Brake Durability and Wear.

a. Use mileage accumulated during vehicle endurance tests (see TOP 02-2-506A[5]) for brake endurance assessment. Various components of a tracked vehicle braking system are subject to potential failures during endurance tests, some resulting from foreign abrasives or lubricant contamination. Appendix E highlights other potential failure modes. Test personnel shall report incipient failures during the conduct of these tests to aid in the determination of causes of specific malfunctions. Unless other guidance is provided, retain and label all failed parts for analysis, along with samples of brake fluids and contaminating elements.

b. It is recommended that brake effectiveness tests (as outlined in paragraph 4.2.3) be performed at the start, at prescribed test mileage intervals, and at the conclusion of each designated endurance phase, for brake performance comparison.

c. Unless otherwise specified in the DTP, the following criteria apply.

(1) Brake component wear attributable to abrasives accumulated in the brake system during normal vehicle endurance testing shall not reduce vehicle stopping ability to a point below the minimum system specification. Brake performance following accumulated spans of 805 km (500 miles) of operation on test course surfaces in various conditions (i.e. dry, wet, muddy) shall be comparable with, and not significantly degraded from, initial effectiveness test results.

(2) Damage to brake, track, and suspension components, such as bending, twisting, or breakage, shall not occur because of endurance test operations.

4.2.6 Repetitive Service Brake Performance.

a. Perform repetitive service brake stops in the forward vehicle direction from 48 km/h (30 mph), unless otherwise specified in the DTP. The vehicle shall provide consistent performance without signs of significant degradation as identified in the performance specification of the test vehicle listed in the DTP. Record any occurrence of vehicle slew and determine if it is within the performance specification of the test vehicle without steer corrections over 25 consecutive stops as listed in the DTP. Record any occurrence of vehicle slew and determine if it is within the performance specification of the test vehicle as listed in the DTP. It is recommended that transmission fluid temperature does not exceed 149°°C (300°°F), or as otherwise specified in TMs or fluid specifications.

b. The following procedures are used:

(1) Conduct the tests on a level, straight, hard-surfaced roadway (with proper skid number) at the vehicle payload condition listed in the DTP.

(2) Drive the vehicle at 32 to 40 km/h (20 to 25 mph) for 15 minutes prior to the first brake stop to warm the system to normal operating temperatures. At the end of the warm-up period, document all thermocouple readings and refer to them as the normal operating temperatures of the system.

(3) Perform the first of 25 consecutive stops from an initial speed of 48 km/h (30 mph). Bring the vehicle to a stop using a pre-determined target deceleration between 8 and 12 ft/s^2 without steering corrections or track lock-up. Record any occurrence of vehicle slew.

(4) After the stop event, follow the brake cooling procedures described in paragraphs 4.2.1.d and 4.2.1.e.

(5) Perform the next brake stop from an initial speed of 48 km/h (30 mph). Bring the vehicle to a stop using a deceleration comparable with the initial brake stop. Repeat the cooling procedure.

(6) Repeat steps in paragraphs 4.2.6.b(3) through 4.2.6.b(5) to complete 25 consecutive brake stops.

(7) Follow the brake cooling procedure after the last brake stop.

(8) Complete all 25 consecutive brake stops in one test setting.

(9) If any of the thermocouples in the transmission system approach the oil temperature limit, follow the appropriate cooling procedure to reach safe operating temperatures. Observe measurements from the pressure transducers installed on the transmission test ports for elevated pressures that may indicate a transmission problem.

4.2.7 Brake Fade Performance.

Conduct brake fade tests to assess hot condition performance, such as after repeated brake applications during an extended mountain descent. Perform brake fade tests in the forward direction from 80 percent of the rated maximum speed of the vehicle, not to exceed 60 km/h (37 mph), unless otherwise specified in the DTP. International Test Operating Procedure (ITOP) 2-2-627(1)[6] was used as a general guide for this test. It is recommended that transmission fluid temperature does not exceed 149 °C (300 °F), or as otherwise specified in TMs or oil specifications.

a. Conduct the tests on a level, straight, hard-surfaced roadway (with proper skid number) at the vehicle payload condition listed in the DTP.

b. Drive the vehicle at 32 to 40 km/h (20 to 25 mph) for 15 minutes prior to the first brake stop to warm the system to normal operating temperatures. At the end of the warm-up period, document all thermocouple readings and refer to them as the normal operating temperatures of the system.

c. Perform the first brake stop from an initial speed corresponding to 80 percent of the rated maximum speed of the vehicle, referred to as V_1, using a deceleration of 3 m/s^2. Record any occurrence of vehicle slew.

d. Once brought to a complete stop, hold the vehicle motionless for 1 to 3 seconds and then accelerate to V_1.

e. After 60 seconds of operation at V_1, conduct a brake snub with a target deceleration of 3 m/sec^2. The speed at the end of the brake snub is V_2, defined as ½ of V_1. Do not exceed critical fluid temperatures. If critical fluid temperatures are exceeded, terminate the test to cool the system.

f. After the initial brake snub is completed, immediately accelerate the vehicle to V_1 to prepare for the next brake snub.

g. Perform brake snubs 60 seconds apart, based on the time between brake snub initiation.

h. Repeat the steps in paragraphs 4.2.7.e through 4.2.7.g to complete 20 consecutive brake snubs.

i. Sixty seconds after last brake snub, a final brake stop is performed from an initial speed of V_1 using a deceleration of 3 m/s^2, bringing the vehicle to a complete stop. Record any occurrence of vehicle slew.

j. If the vehicle cannot accelerate to V_1 in the 60 seconds between brake snubs, increase the time between brake snubs as required.

k. Conduct the initial and final brake stops using approximately the same brake application force (maximum pedal effort as defined in paragraph 4.2.4), avoiding track lock-up. Analyze the braking performance (stopping distance and deceleration) to determine if any signs of brake fade are evident.

l. If testing needs to be halted for any reason preventing brake events from occurring consecutively, the test will begin again at paragraph 4.2.7c once the vehicle has been cleared to test.

5. DATA REQUIRED.

5.1 Brake System Inspection/Characterization.

5.1.1 General Vehicle Characterization.

a. Type of test.

b. Dates of test.

c. Vehicle identification.

d. Odometer mileage.

e. Vehicle payload condition (amount of payload and location).

f. Vehicle weight distribution.

g. Vehicle center of gravity location.

h. Track description, condition, and track pad thickness.

i. Suspension description, including road arm location of dampers.

j. Brake system component description.

k. Brake lining friction element visual inspection results, before and after testing, including unusual coloration (e.g., from overheating), deformation, flaws or damage to the lining materials, and wear condition.

5.1.2 Pedal Effort Characteristics.

a. Pedal force.

b. Brake input (control) pressure, if applicable.

c. Pertinent individual system pressures, if required.

d. Pedal travel distance, if applicable.

5.2 Safety/Performance Evaluation.

5.2.1 Brake Burnish.

a. Average vehicle deceleration.

b. Brake application force/pressure.

c. Vehicle stopping distance.

d. Observations of vehicle slew, instability, brake noise, and track lock-up.

e. Brake fluid temperature for each stop event.

f. Final drive torque and track speed (optional).

g. Report data using the Brake Burnish and Brake Effectiveness Data Sheets provided in Appendices B and C. Each brake stop event begins when the brake pedal force reaches 5 lbf and ends when the vehicle speed reaches 0.1 mph. Normalize stopping distance measurements in accordance with Society of Automotive Engineers (SAE) International Recommended Practice J299[7], with stopping distances corrected to the target speed using Equation 1.

$$SD_{Normalized} = SD_{Measured} \times \frac{V_{Target}^2}{V_{Actual}^2} \qquad \textit{(Equation 1)}$$

where:

V= Vehicle velocity
SD = Stopping distance.

h. Calculate the average vehicle deceleration using Equation 2.

$$D_x = \frac{V_{Initial}^2}{2\,(SD_{Normalized})} \qquad \textit{(Equation 2)}$$

5.2.2 Grade Holding Ability.

a. Percent grade and direction of travel.

b. Vehicle attitude.

c. Observations/measurements of vehicle movement (note track roll or slide).

d. Test duration.

e. Brake control force, if required.

f. Brake fluid temperatures, if required.

g. Comments on vehicle behavior.

5.2.3 Brake Effectiveness.

a. Vehicle speed.

b. Observations/measurements of vehicle slew (yaw movement). Note, if the vehicle stayed within the lane of travel or deviated from a straight line, determine if it is within the performance specification of the test vehicle as listed in the DTP.

c. Stopping distance. See paragraph 5.2.1 for the calculation method.

d. Average brake apply force/pressure. The pedal apply force (or pressure) is calculated from a pedal force versus stopping distance curve using Equation 3.

$$F_{p_{avg}} = \frac{\sum_{i=a}^{b}(F_{p_i} * \Delta d_i)}{SD} \qquad \textit{(Equation 3)}$$

where:

$F_{p_{avg}}$ = Average pedal force or pedal pressure, as applicable
a = initial time when or pedal force is 5 lbf or pedal pressure is 5 psi
b = time when vehicle speed initially reaches 0.1 mph
Δd_i = distance traveled for each measurement basic time.

e. Deceleration. See paragraph 5.2.1 for the calculation method.

f. Brake fluid temperature.

g. Steering correction, if observed.

h. Observations of vehicle behavior or brake noise.

i. Test course skid number.

j. Final drive torque and track speed (optional).

k. Report data using the Brake Effectiveness Data Sheet provided in Appendix C (or similar).

5.2.4 Maximum Pedal Effort Braking (Maximum Safe Speed).

a. Vehicle speed and direction of travel.

b. Stopping Distance. See paragraph 5.2.1 for the calculation method.

c. Deceleration. See paragraph 5.2.1 for calculation method.

d. Observations of track lock-up.

e. Observations/measurements of vehicle slew (yaw movement). Note if the vehicle stayed within the lane of travel or deviated from a straight line.

f. Final drive torque and track speed (optional).

g. Observations during vehicle/track inspections.

h. Transmission fluid temperature (minimum, maximum, and average).

5.2.5 Brake Durability and Wear.

a. Vehicle mileage.

b. Test course description/conditions.

c. Brake stopping distance measurements prior to, during, and after the endurance test.

d. Observations of any damage sustained by braking system components.

e. Brake/transmission fluid sample data reports.

5.2.6 Repetitive Service Brake Performance.

a. Vehicle speed and direction of travel.

b. Stopping Distance. See paragraph 5.2.1 for the calculation method.

c. Deceleration. See paragraph 5.2.1 for calculation method.

d. Observations of track lock-up.

e. Observations/measurements of vehicle slew (yaw movement). Note if the vehicle stayed within the lane of travel or deviated from a straight line.

f. Final drive torque and track speed (optional).

g. Observations during vehicle/track inspections.

h. Transmission fluid temperature (minimum, maximum, and average).

5.2.7 Brake Fade Performance.

a. Vehicle speed and direction of travel.

b. Stopping Distance. See paragraph 5.2.1 for the calculation method.

c. Deceleration. See paragraph 5.2.1 for calculation method.

d. Observations of track lock-up.

e. Observations/measurements of vehicle slew (yaw movement). Note if the vehicle stayed within the lane of travel or deviated from a straight line.

f. Final drive torque and track speed (optional).

g. Observations during vehicle/track inspections.

h. Transmission fluid temperature (minimum, maximum, and average).

6. PRESENTATION OF DATA.

6.1 Brake System Inspection/Characterization.

a. Listing of vehicle and brake system descriptions.

b. Listing of brake component pre- and post-inspections, if possible, including friction element diameter, number of friction elements, friction lining nomenclature, material, condition, diameter, and thickness.

d. Tabulation of service and parking brake forces.

e. Graph depicting brake pedal effort force versus input pressure or pedal travel, as applicable.

6.2 Safety/Performance Evaluation.

a. Graphs.

(1) Stopping distance and deceleration versus input pedal force or pressure. See Appendix D.

(2) Stopping distance and deceleration versus road speed. See Appendix D.

(3) Brake effectiveness curves from 20 and 30 mph; stopping distance and deceleration versus input pedal force or pressure. See Appendix D.

b. Tabulations.

(1) Brake Burnish data sheet (See Appendix B).

(2) Brake Effectiveness data sheet (See Appendix C).

(3) Maximum grade holding ability for each brake applied (service and parking) and vehicle direction.

(4) Stopping distance and deceleration rate versus road speed.

(5) Target stopping distance, normalized stopping distance, and deceleration rate versus test course surface friction condition.

(6) Notation of vehicle behavior, brake noise, track lock-up, steering correction, slew, etc.

(7) Brake effectiveness from 32 and 48 km/h (20 and 30 mph); stopping distance and deceleration rate versus input pedal force or pressure. Transmission fluid temperatures and pressures before and after the brake event.

APPENDIX A. PHOTOGRAPHS.

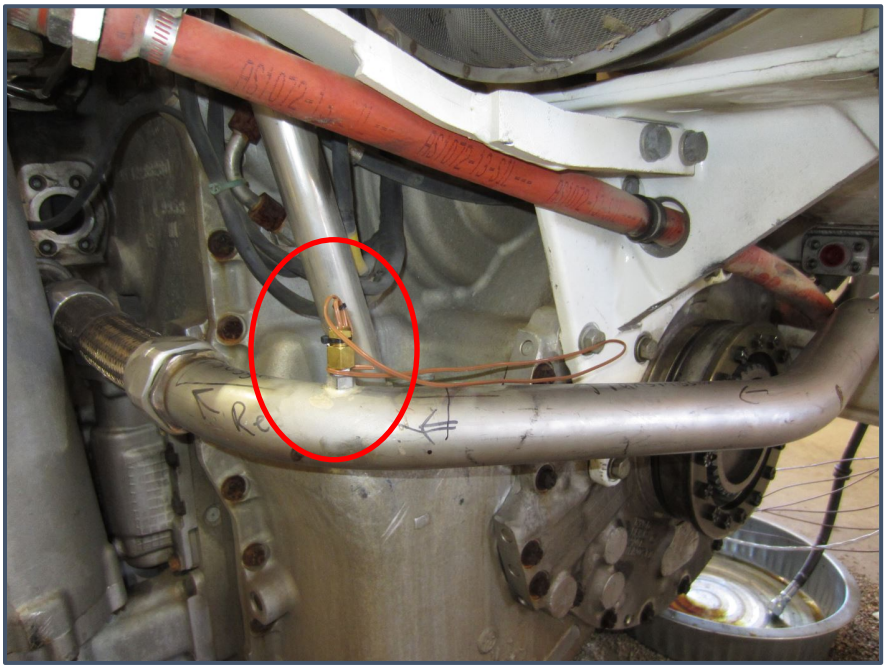

Figure A-1. Thermocouple measuring oil temperature into transmission primary cooler.

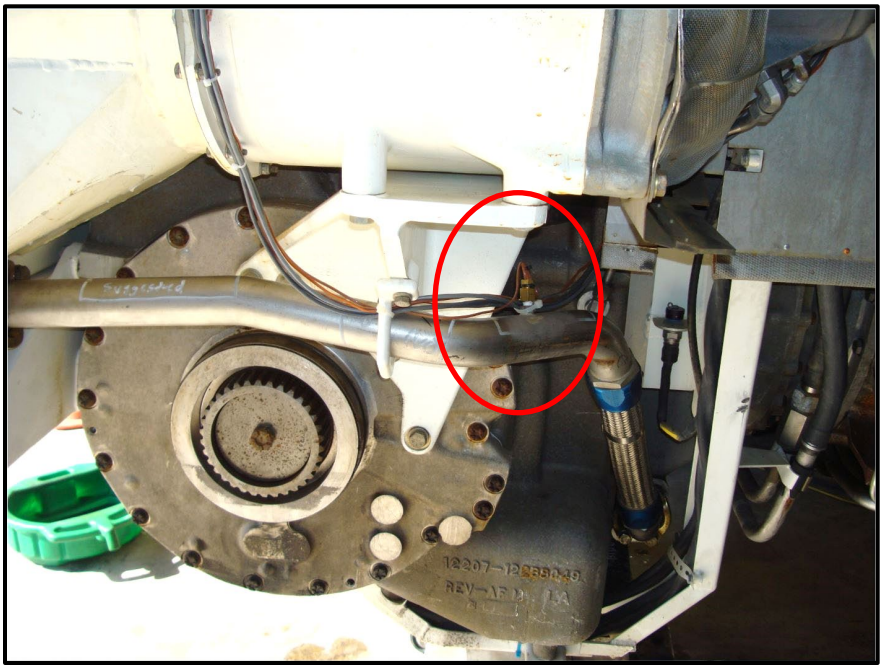

Figure A-2. Thermocouple measuring oil temperature out of transmission secondary cooler.

APPENDIX A. PHOTOGRAPHS.

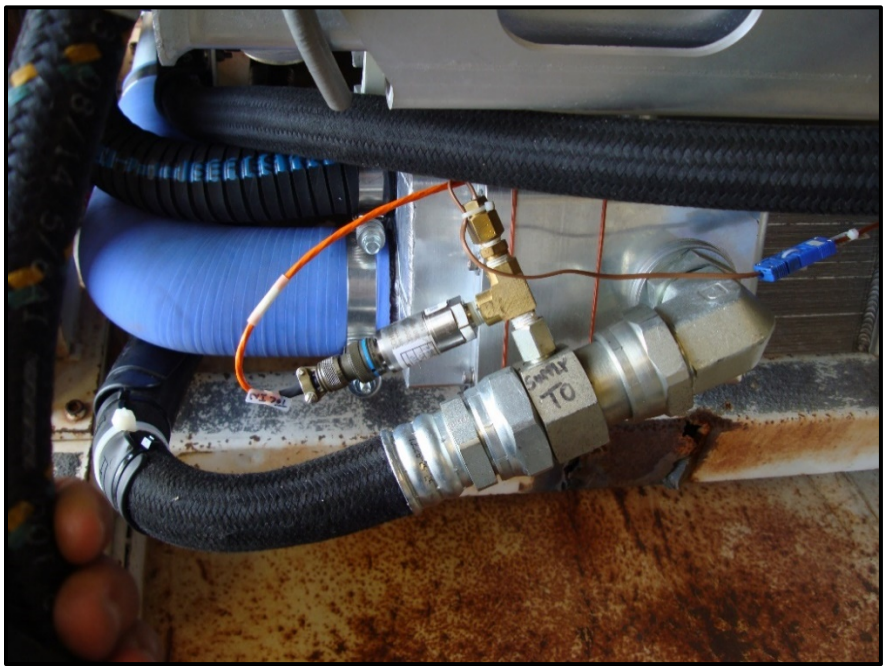

Figure A-3. Thermocouple and pressure transducer measuring oil temperature and pressure into transmission cooler.

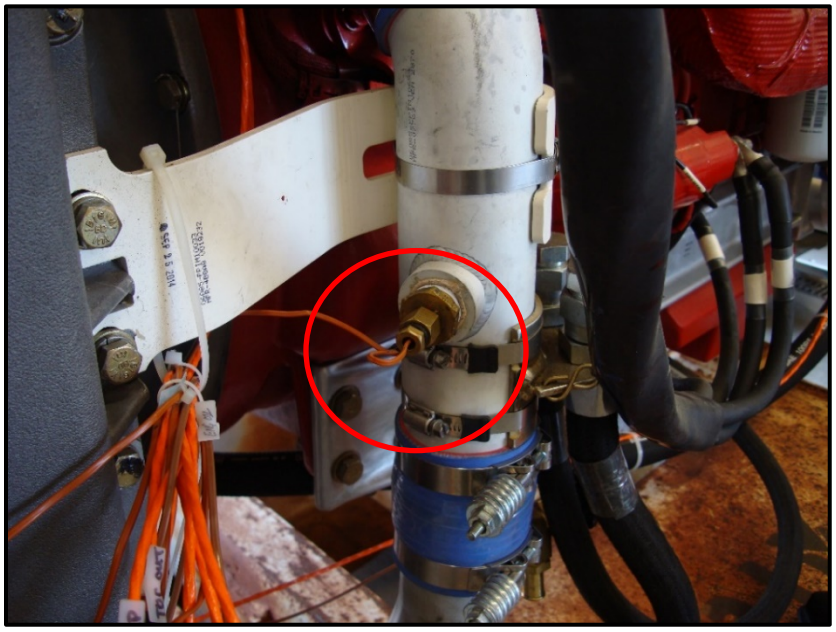

Figure A-4. Thermocouple measuring engine coolant temperature.

APPENDIX A. PHOTOGRAPHS.

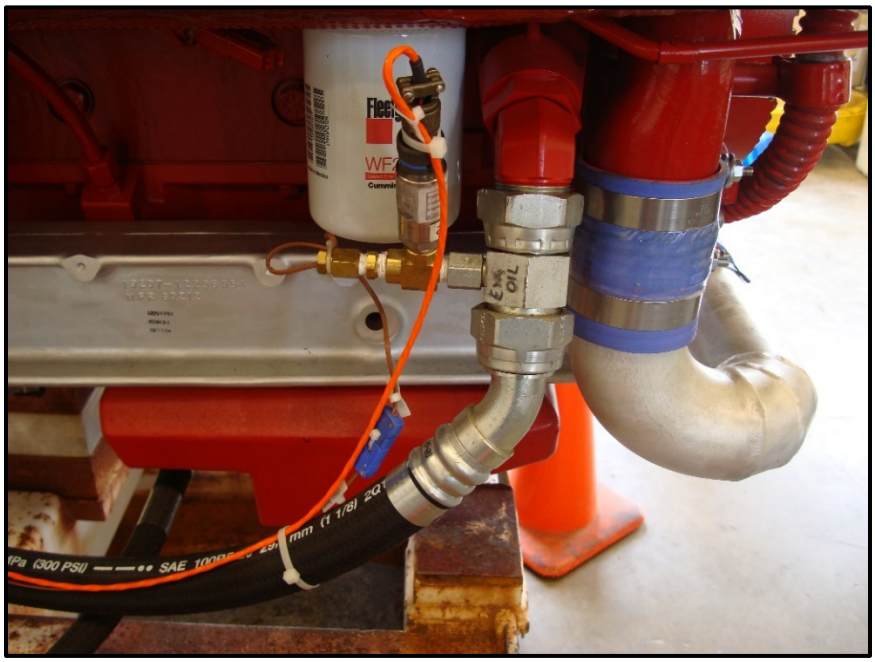

Figure A-5. Thermocouple and pressure transducer measuring engine oil temperature and pressure.

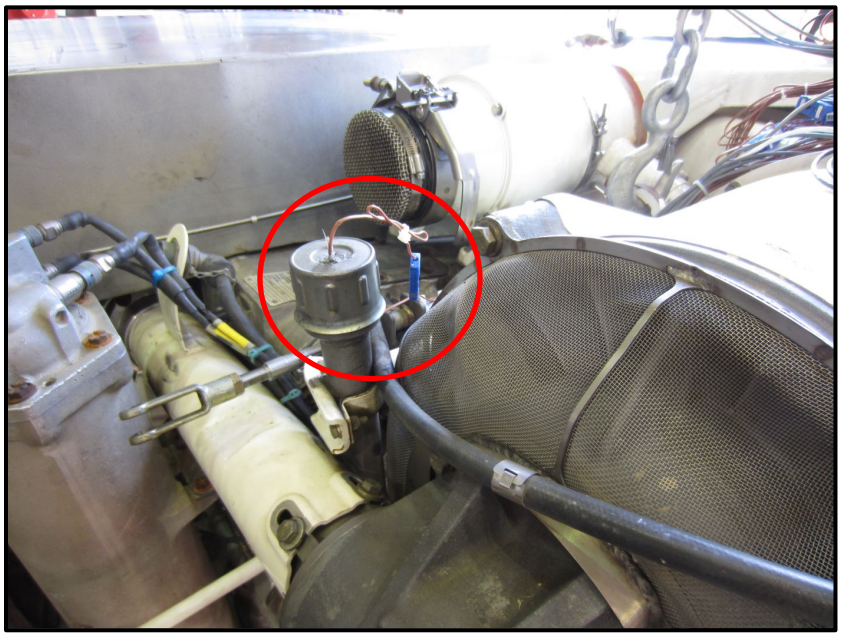

Figure A-6. Thermocouple on dipstick measuring transmission fluid temperature.

APPENDIX A. PHOTOGRAPHS.

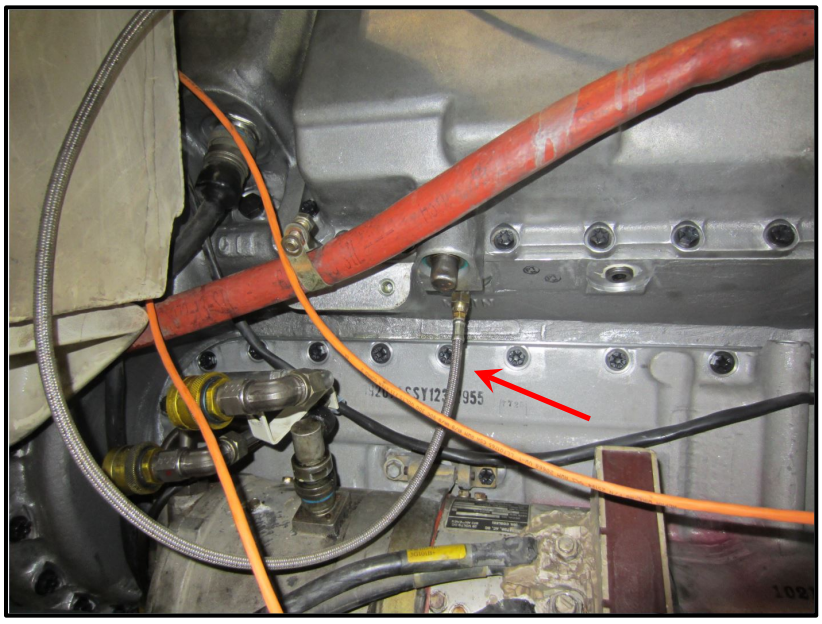

Figure A-7. Quarter-inch braided steel hose connected to the transmission main control pressure port, rated to at least 500 psi with a -4 flare female fitting. The hoses reach from the transmission test port to outside of the engine bay.

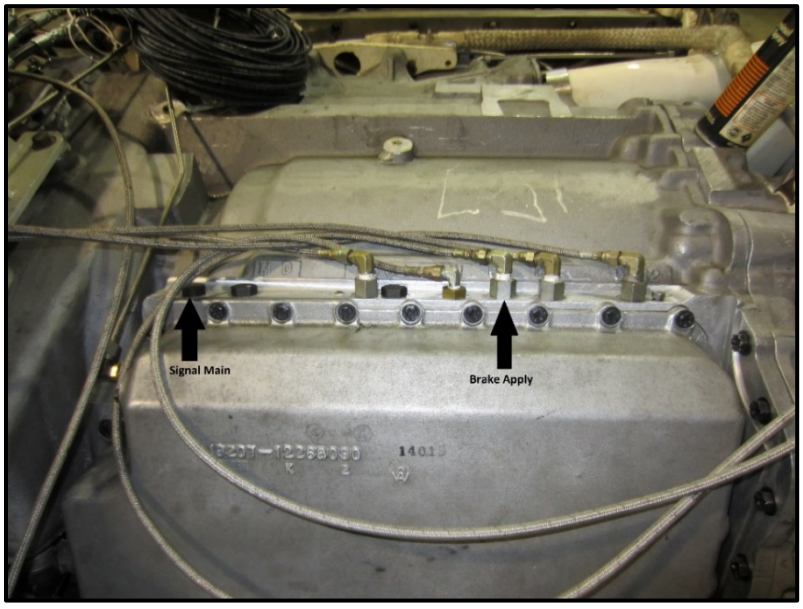

Figure A-8. Braided steel hoses connected to test ports on top of the transmission. Note the Brake Apply (BA) and Signal Main (SM) test ports.

APPENDIX A. PHOTOGRAPHS.

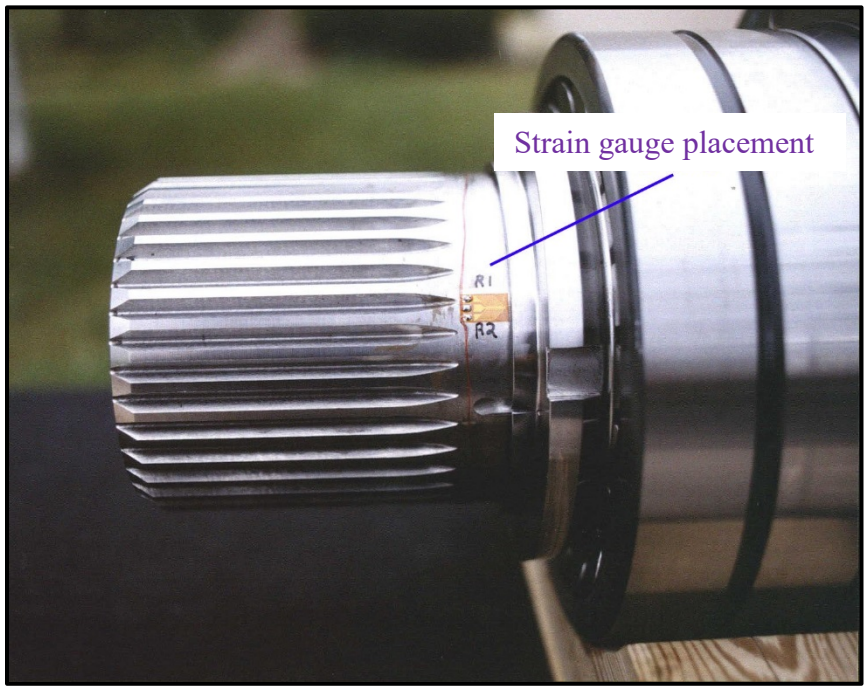

Figure A-9. Final drive shaft instrumented with Micro-Measurements model CEA-06-187UV-350 strain gauges*** to measure torque, using a Wheatstone bridge circuit.

*** The use of brand names does not constitute endorsement by the Army or any other agency of the Federal Government, nor does it imply that it is best suited for its intended application.

APPENDIX A. PHOTOGRAPHS.

Figure A-10. Drive sprocket slip-ring and encoder used to transfer final drive torque and sprocket speed signals.

APPENDIX B. BRAKE BURNISH DATA SHEET

BRAKE BURNISH DATA SHEET	Vehicle:	Date:
	USA Reg. No.:	Sheet No.:
	Brake System:	
	Vehicle Weight:	Ambient: °F
Driver:	Observer:	Odometer Reading: Start: Stop:

Applications at_____Intervals

								Immediately Before Brake Event				Immediately After Brake Event					
Apply	Time, hr	Odometer, mi	Speed at Brake Apply, mph	Stopping Distance, ft	Deceleration Rate, ft/s^2	Average Brake Apply Pressure, psi	Average Brake Pedal Force, lbf	Trans. Sump Temp, °F	Into Primary Trans. Cooler Temp, °F	Out of Primary Trans. Cooler °F	Out of Trans. Secondary Cooler Temp, °F	Trans. Sump Temp, °F	Into Primary Trans. Cooler Temp, °F	Out of Primary Trans. Cooler, °F	Out of Trans. Secondary Cooler Temp, °F	Trans. Control Pressure, psi	Trans. Signal Main Pressure, psi
1																	
2																	
3																	
4																	
5																	
10																	
15																	
20																	
25																	
30																	
35																	
40																	
45																	
50																	

Cooling Period: minutes, transmission fluid returns to normal operating temperature

Notes:

APPENDIX C. BRAKE EFFECTIVENESS DATA SHEET.

APPENDIX C. BRAKE EFFECTIVENESS DATA SHEET.

BRAKE EFFECTIVENESS DATA SHEET

Vehicle:	Date:
Test Phase:	
USA Reg. No.:	Sheet No.:
Vehicle Weight:	Ambient: ºF
Odometer - Start:	Stop:
Driver:	
Observer:	

Seg	Target Pressure, psi/lbf	Speed at Brake Apply, mph	Stopping Distance, ft	Apply Pressure, psi or lbf		Pedal Effort lb	Pedal Travel in.	Deceleration Rate, ft/s^2	Immediately Before Brake Event				Immediately After Brake Event					
				Average	Maximum				Trans. Sump Temp, ºF	Into Primary Trans. Cooler Temp, ºF	Out of Primary Trans. Cooler, ºF	Out of Trans. Secondary Cooler Temp, ºF	Trans. Sump Temp, ºF	Into Primary Trans. Cooler Temp, ºF	Out of Primary Trans. Cooler, ºF	Out of Trans. Secondary Cooler Temp, ºF	Trans. Control Pressure, psi	Trans. Signal Main Pressure, psi

Cooling Period: minutes, transmission fluid returns to normal operating temperature

Notes:

APPENDIX D. SAMPLE GRAPHS.

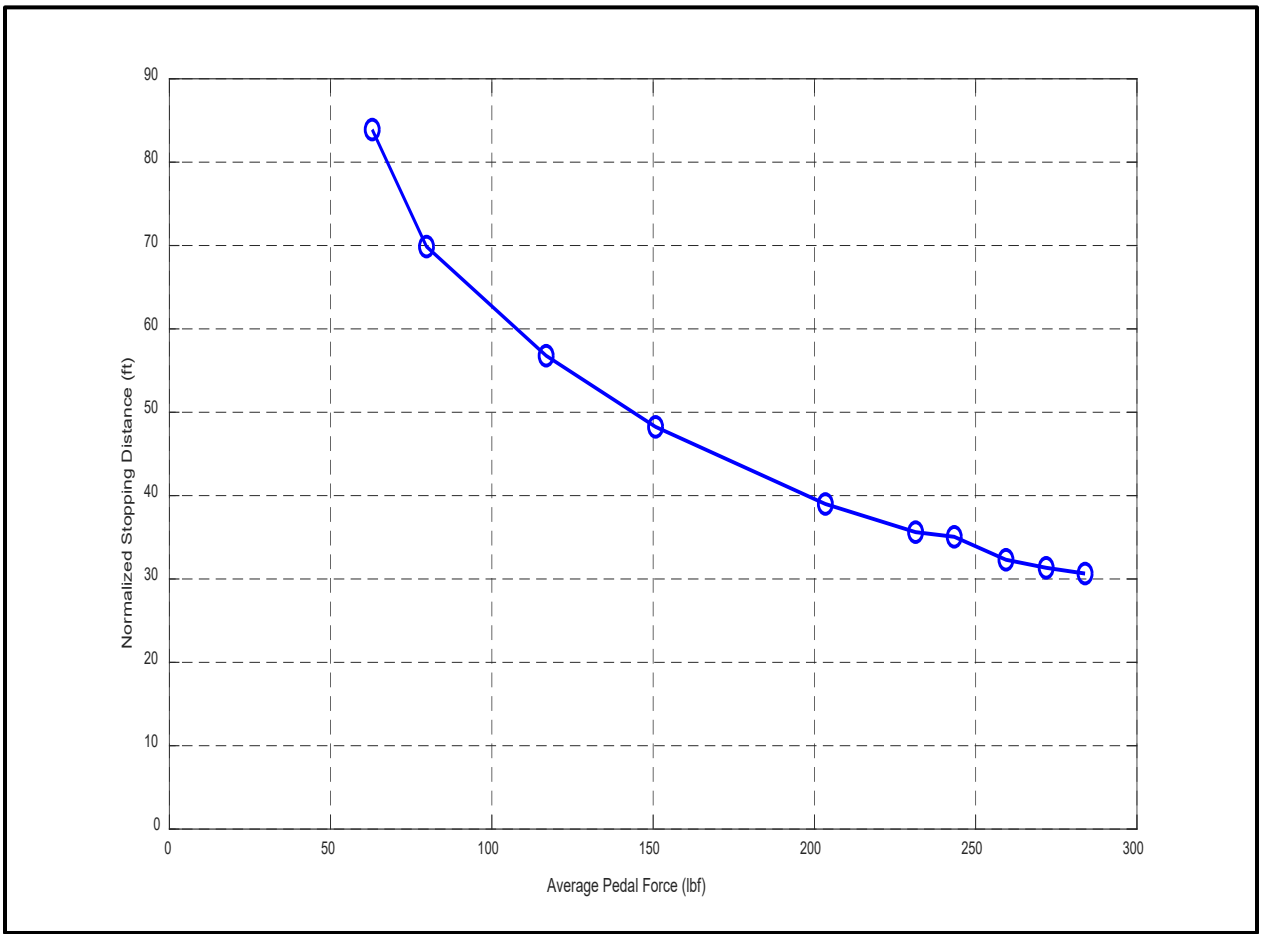

Figure D-1. Stopping distance versus input pedal force curve example.

APPENDIX D. SAMPLE GRAPHS.

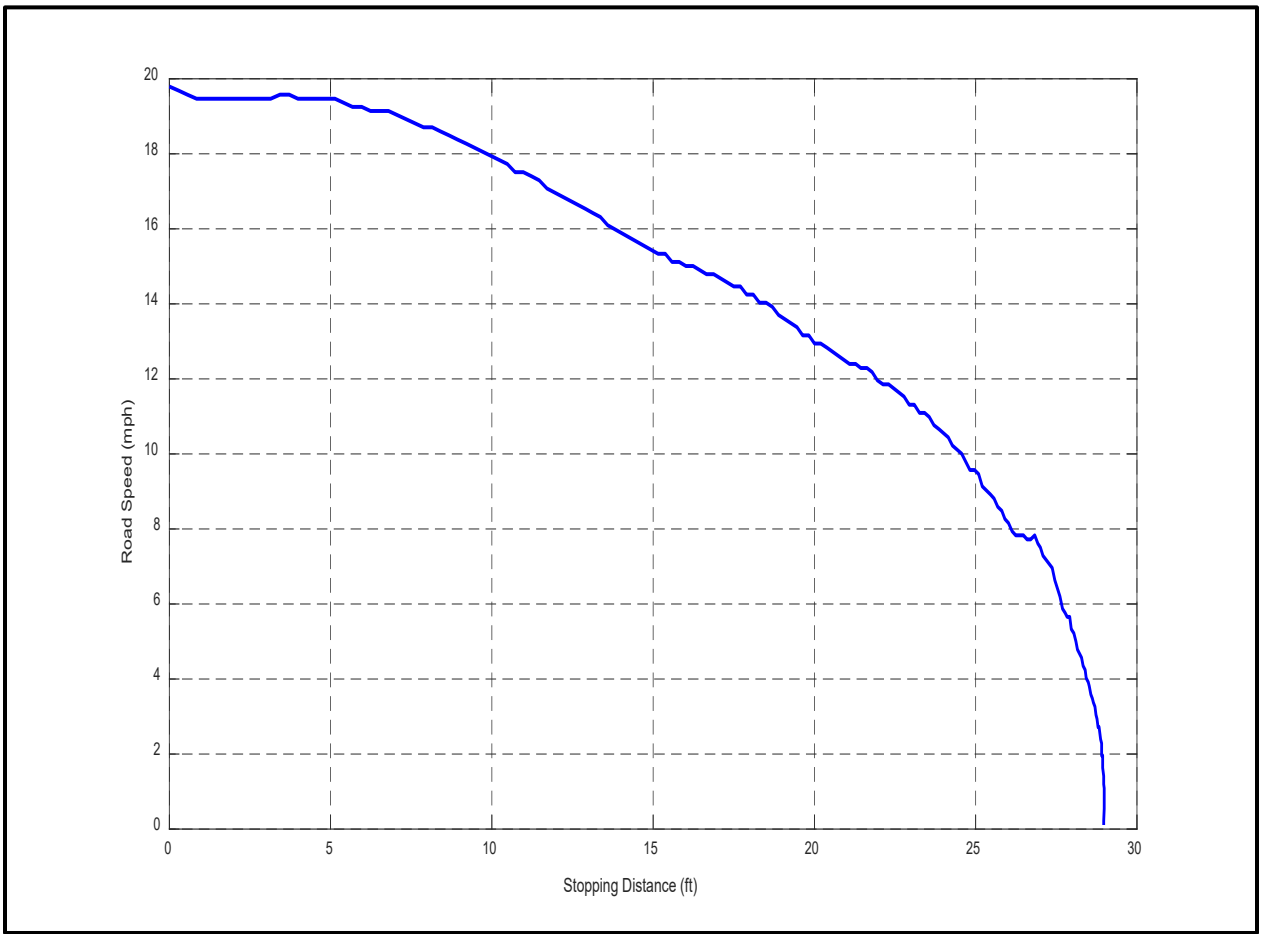

Figure D-2. Stopping distance versus road speed curve example.

APPENDIX D. SAMPLE GRAPHS.

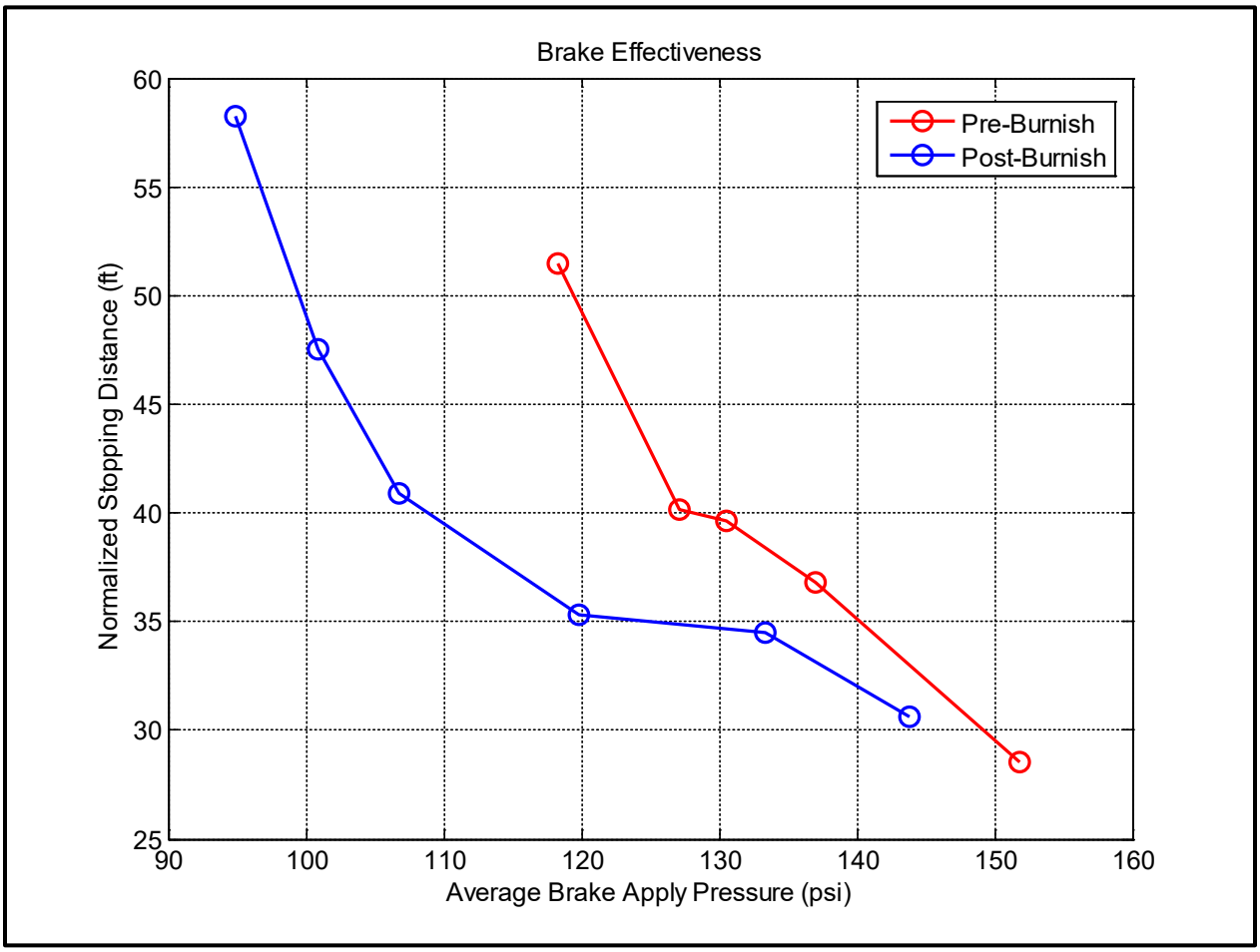

Figure D-3. Brake effectiveness curve example.

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APPENDIX E. POTENTIAL FAILURE MODES.

Figure E-1. Left brake pack case removed, exposing brake pack friction and steel elements (not a failure mode).

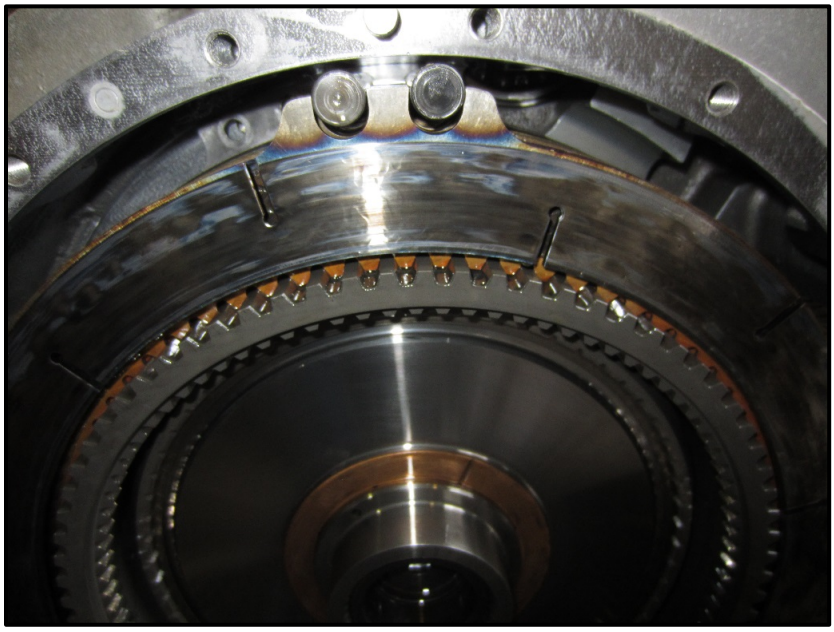

Figure E-2. Tempering colors suggesting brake pack steel element may have reached or exceeded 600 °F.

APPENDIX E. POTENTIAL FAILURE MODES.

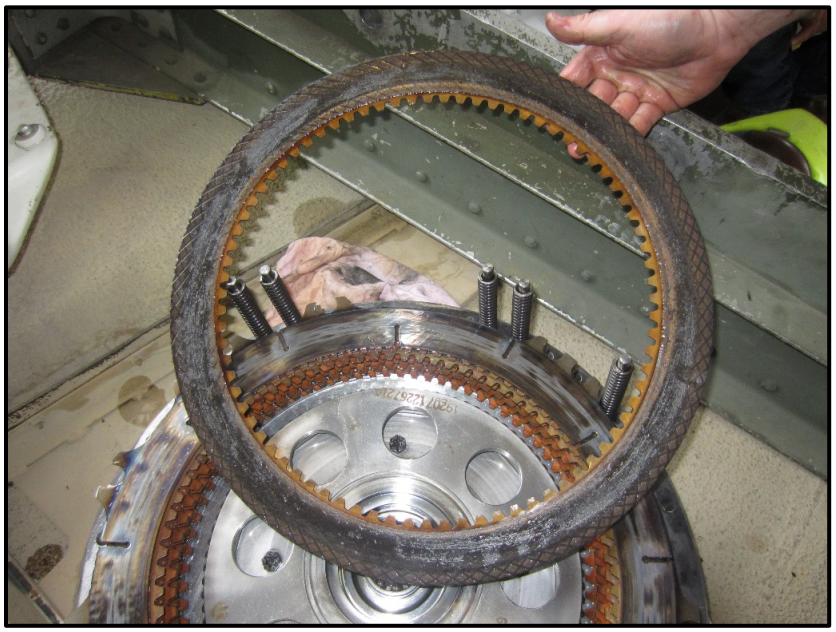

Figure E-3. Brake pack friction element lining material severely worn, disc material pitted.

Figure E-4. Brake pack friction element lining material severely worn, disc material pitted, closer view.

APPENDIX E. POTENTIAL FAILURE MODES.

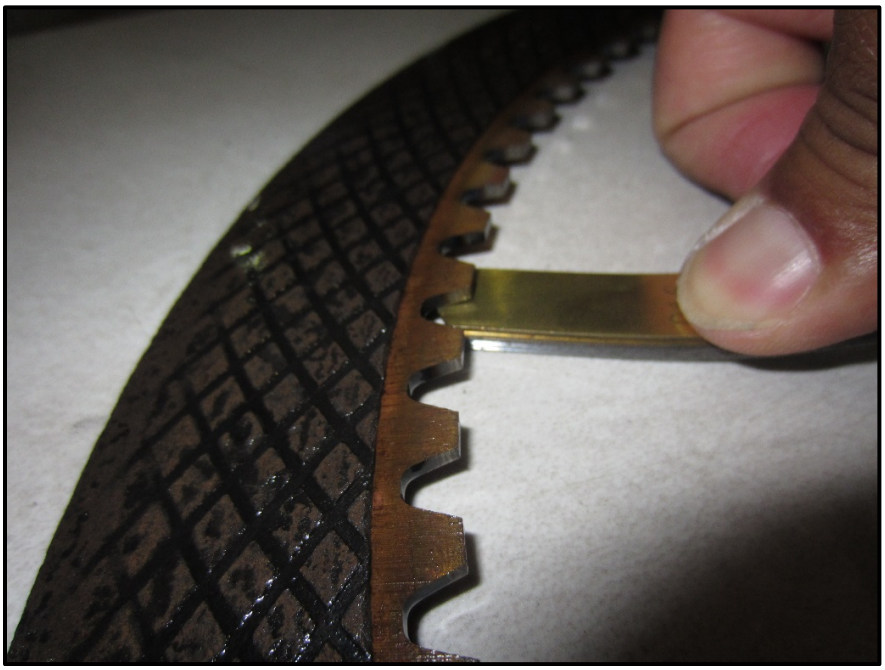

Figure E-5. Brake pack friction element coned (deformed) due to heat.

Figure E-6. Brake pack steel element coned (deformed) due to heat, side view.

APPENDIX E. POTENTIAL FAILURE MODES.

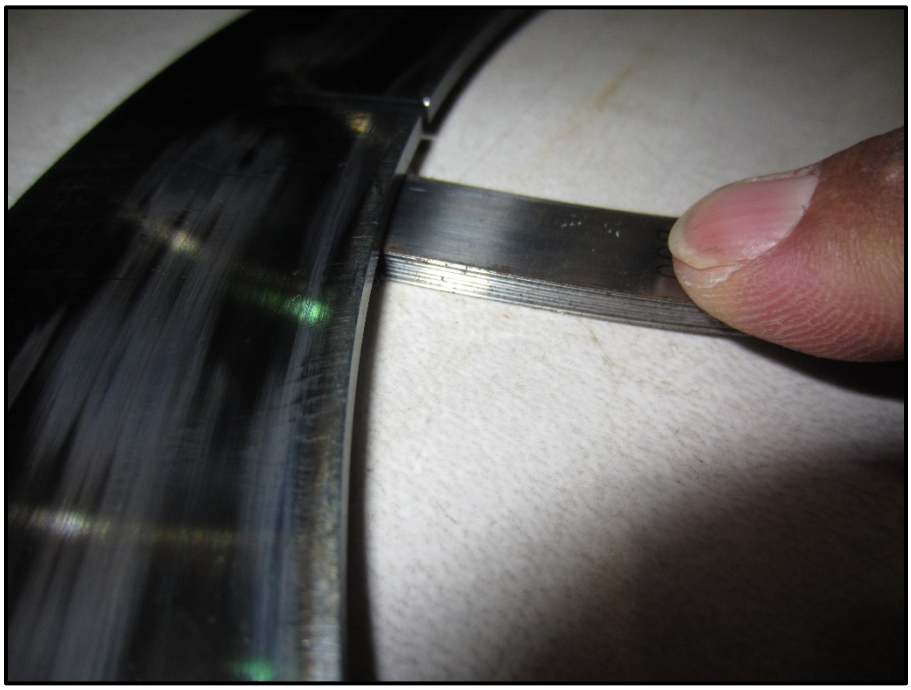

Figure E-7. Brake pack steel element coned (deformed) due to heat, top view.

APPENDIX F. ABBREVIATIONS

ASTM	American Society for Testing and Materials
BA	brake apply
°C	degrees Celsius
CTA	Churchville Test Area
DTP	Detailed Test Plan
°F	degrees Fahrenheit
ITOP	International Test Operations Procedure
km/h	kilometers per hour
m/s	meters per second
mph	miles per hour
PMCS	preventive maintenance checks and services
SAE	Society of Automotive Engineers
SM	signal main
TM	Technical Manual
TOP	Test Operations Procedure

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APPENDIX G. REFERENCES

1. ASTM E1337 (2018), Standard Test Method for Determining Longitudinal Peak Braking Coefficient (PBC) of Paved Surfaces Using Standard Reference Test Tire.

2. ASTM E1136 (2019), Standard Specification for P195/75R14 Radial Standard Reference Test Tire.

3. T158LL Track Durability Guarantee Test Hardware Replacement Criteria, September 2012.

4. TOP 02-2-610A, Gradeability and Side Slope Performance, 20 April 2020.

5. TOP 02-2-506A, Endurance Testing of Tracked and Wheeled Vehicles, 2 October 2014.

6. ITOP 2-2-627(1), Tracked-Vehicle Braking, 21 May 1987.

7. SAE International Recommended Practice J299, Stopping Distance Test Procedure, January 2009.

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APPENDIX H. APPROVAL AUTHORITY.

CSTE-CI 13 May 2021

MEMORANDUM FOR

Commander, U.S. Army Operational Test Command
Director, U.S. Army Evaluation Center
Commanders, ATEC Test Centers
Technical Directors, ATEC Test Centers

SUBJECT: Test Operations Procedure 02-2-627A, Standardized Tests for Assessing Tracked Vehicle Braking Systems, Approved for Publication

1. Test Operations Procedure (TOP) 02-2-627A, Standardized Tests for Assessing Tracked Vehicle Braking Systems, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency.

2. Scope of the document. This TOP provides standardized tests for assessing military tracked vehicle braking system performance. Factors considered in the assessment of vehicle brake systems include stopping and grade holding ability, vehicle stability and control, and component durability under various operating conditions.

3. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

4. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-CI), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

ZWIEBEL.MICHAEL.J.1229197269

MICHAEL J. ZWIEBEL
Director, Directorate for Capabilities Integration (DCI)

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Forward comments, recommended changes, or any pertinent data, which may be of use in improving this publication to the following address: Policy and Standardization Division (CSTE-CI-P), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001 Technical information may be obtained from the preparing activity: Automotive Instrumentation Division (TEAT-ADI), U.S. Army Aberdeen Test Center, 6943 Colleran Road, Aberdeen Proving Ground, MD 21005-5059. Additional copies can be requested through the following website: https://www.atec.army.mil/publications/documents.html, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.