



U-Joint Accelerated Durability Test

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. The purpose of this test procedure is to evaluate the durability of driveline U-joints by measuring their B-ten (10) life during an environmental laboratory test, which has been correlated to vehicle durability tests.

1.2 Applicability. This procedure applies to drivelines equipped with Cardan universal joints. This procedure exposes the U-joints to speed, torque, angle, temperature and environmental slurry.

1.3 Remarks. Not applicable.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- Labtech Notebook Program
- PCI DAS1602/16 Model Number
- www.Weibull.com

3 Resources

3.1 Facilities.

3.1.1 A two-station (minimum) test fixture is driven and absorbed by torque and speed controlled dynamometers. The test chamber is heated by electrical heaters and is used to facilitate the slurry dumps and recovery of applied slurry, see Appendix A (Figure A1) and Appendix B (Figure B1, Figure B2, Figure B3, and Figure B4).

3.1.2 The test fixture containing test prop shafts at operating angle, with slurry application capability above the U-joints, under torque and speed control, heating, cooling, temperature controls, and with capability to measure U-joint temperature readings, see Appendix A (Figure A1) and Appendix B (Figure B1, Figure B2, Figure B3, and Figure B4).

3.1.3 The around the clock monitoring/maintenance is required. Any test samples that sit idle for ≥ 4 h must be declared test suspensions.

3.2 Equipment.

Note: The Manufacturer's equipment (or their equivalent) listed in section 3.2 specify the equipment/tool required to run test.

3.2.1 Three Hundred (300) hp/2500 revolutions per minute (RPM) Alternating Current (AC) (Toshiba) electric motor and controller.

3.2.2 Eddy current absorbers (Midwest 1519) comparable in size and performance to preceding motor.

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3.2.3 Input and/or output (Himmelstein) torque meter(s) with a 0 Nm to 2260 Nm (20 000 lb-in) range.

3.2.4 The prop shafts are mounted with a flange on one end and a slip yoke on the opposite end, see Appendix A, the drive shafts must be mounted at the operating angle as specified by the test schedule, see Table 1 and Table 2.

3.2.5 Slurry mixing and application facility.

3.2.6 Water deionizing system, power of hydrogen (pH) level between 7.0 and 8.0 (U.S. Filter).

3.2.7 Air circulation system (Ingersoll Rand).

3.2.8 Programmable controller (Dyne Systems) executing each step of test schedule, see Table 1 and Table 2.

3.2.9 Programmable heaters and liquid nitrogen (LN₂) controller (Lovejoy).

3.2.10 A J-type thermal couples with a 1/8 sheath.

3.2.11 Data acquisition and real time data display (Keithly and Fluke).

3.2.12 Four (4) infrared (IR) temperature sensors and U-joint temperature display (Ircon Modline 3).

3.2.13 Torque meter amplifiers (Himmelstein).

3.2.14 RPM displays (Red Lion).

3.2.15 Eddy current absorber controller (Dyne Systems).

3.2.16 Nine (9), 400 W/240 V, tubular heaters (CVA Incorporated).

Note: The machine and all instrumentation are to be calibrated at the interval required by the equipment manufacturer or yearly at minimum. Record instrumentation and machine details with dates of calibration unless the information is already preserved in the laboratory records.

Note: Equivalent equipment may be substituted with approval by the GM International Test Lab Manager and driveline engineering group, provided the test conditions are met and maintenance and operating procedures are followed.

Note: Deviations from the procedure must be approved by GM driveline engineering group.

3.3 Test Vehicle/Test Piece. A minimum of six (6) test prop shafts per drawing (Figure C1) in Appendix C are needed in order to produce enough data for Weibull analysis to estimate the B-ten (10) life for each U-joint population.

3.4 Test Time. Estimated test time to run this test for six prop shafts using two prop shafts per setup is as follows:

Calendar time: 76 days

Test hours: 1800 hours

The estimated test time is based on a maximum U-joint life of 600 h using the shutdown criterion in 4.3.5.1. It is assumed that testing is run 24 h a day and seven (7) days a week.

3.5 Test Required Information.

3.5.1 System Maintenance.

3.5.1.1 Slurry volume in a holding tank must be maintained at an approximate level of 189 L (50 gal) and corrected daily by adding the required amount of mix and deionized or tap water. Once a day, the conductivity of slurry 53 mS ± 5 mS (milliSiemens) must be checked for control of leaks and water evaporation. Every 160 h ± 20 h the whole volume of slurry must be replaced by a fresh batch.

3.5.1.2 A system shall be designed such that heater failures will be detected and resolved to maintain the integrity of the test. Electric heaters mounted for the test fixture must be able to be quickly replaced within the 4 h time limit.

3.5.1.3 The input and output drive shafts of the test fixture must be greased as required and replaced if necessary.

3.5.1.4 Slurry application valves and actuators must be inspected for leaks periodically and replaced as needed.

3.5.1.5 Lip seals on each input and output to the test chamber must be checked for leaks weekly and replaced as needed.

3.5.1.6 Infrared sensors must be calibrated per manufacturer recommendation. In case of malfunction, spare sensors must be readily available for replacement of faulty sensors.

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3.5.1.7 During shutdown for any maintenance, all test chamber(s) shall be kept at ambient temperature. The system is to restart at Step 1 of the schedule after the shutdown.

3.6 Personnel/Skills. Test must be monitored 24 h per day to assure that test parameters are maintained and test maintenance is performed within the 4 h time limit.

4 Procedure

4.1 Preparation.

4.1.1 This test is usually run to compare the relative durability performance of two (or more) U-joints. Stations A and B shown in Appendix A, Figure A1, allow simultaneous testing of two different U-joints. Shafts tested in each station must be labeled separately.

4.1.2 It is advisable to paint the prop shafts to minimize corrosion. However, U-joint seals must not be painted. It is also suggested that U-joint bearing cap ends be painted (flat) black to facilitate IR temperature measuring. Remove any debris from the test chamber(s).

4.1.3 If heaters are located in the chamber, remove clay deposits off all heating elements to assure full temperature capability and to prolong heater's life.

4.1.4 Install spline shaft fixtures on the dyno output flanges, if applicable.

4.1.5 Using a dial indicator, measure spline runout on the dyno flange. Spline runout must be taken 25 mm (1 in) from the end of the spline and the Total Indicated Runout (TIR) is to be less than 1.02 mm (0.040 in). Record the final runout.

4.1.6 Clean all IR sensor lenses and check for air bleeding from the purge adapters.

4.1.7 Install and properly torque to production specification the pinion flange washer and bolt.

4.1.8 Pinion flange must be within 0.127 mm (0.005 in) TIR. If not, index pinion flange 180 degrees. If the prop shaft TIR is not less than 1.02 mm (0.040 in) by indexing, shim the pinion flange as needed.

4.1.9 Lubricate all test fixture lip seals and splined shafts as required, see Appendix A.

4.1.10 Install all prop shafts assuring the universal joint bearings are fully seated in the pinion flanges. Also, make sure the pinion flanges in the test machine are all oriented in the same direction, maintaining proper yoke phasing.

4.1.11 Install and properly torque to production specification new bearing straps and bolts to attach U-joint bearing cap to the pinion flange.

4.1.12 A guard is attached on each station and secured with safety pins.

4.1.13 Measure TIR between the yoke weld and balance weight. The TIR must be no more than 1.02 mm (0.040 in), see Appendix C, Figure C1 for details.

4.1.14 Verify installation of prop shaft and phasing of samples and check that no sample damage has occurred during installation, especially damage to seals.

4.1.15 Slurry Preparation. Mix slurry based on the following composition:

- 189 L (50 gal) of deionized or tap water (pH Level is between 7.0 and 8.0)
- 5660 g (12.5 lb) of Fire Clay
- 4840 g (10.7 lb) of Sodium Chloride
- 570 g (1.3 lb) of Calcium Chloride
- 440 g (1.0 lb) of Sodium Bicarbonate

Note: See Appendix C, Table C1 for the slurry mix detail. Contact GM Corrosion Engineering Group for any questions regarding slurry preparation.

4.2 Conditions.

4.2.1 Environmental Conditions. The laboratory ambient conditions are defined as a temperature of 23 °C ± 10 °C (75 °F ± 20 °F).

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 Test Schedule (1330/1344 U-Joint).

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4.2.2.1.1 For testing 1330/1344 U-joints follow Table 1.

4.2.2.1.1.1 Shaft inclination shall be set so that all U-joints operate at the specified angle (4°) for the duration of the test.

4.2.2.1.1.2 The slurry dowse over center of U-joint at 56.8 lpm (15 gpm) per 1 in National Pipe Thread nozzle must be activated for 2 s to 3 s. Total volume per dowse per U-joint is 1.89 L (0.5 g), see Appendix A.

4.2.2.1.1.3 See Appendix D for ramp condition for Torque (Figure D1), Speed (Figure D2), and Temperature (Figure D3 or Figure D4).

4.2.2.1.2 Test Schedule for 1310 U-joint. For testing 1310 U-joints, follow Table 1, except change the torque in Step 4 to 478 Nm $\pm$ 2.26 Nm (4230 lb-in $\pm$ 20 lb-in). This test specification for 1310 U-joints was not correlated to a vehicle durability test schedule. Since the same bearing caps are used on 1330-U joint and 1310 U-joint, the torque was calculated by a linear comparison of torque radii. Torque radius is the distance from the center of the cross to the centroid of the projected bearing area on the cross trunion.

4.2.2.2 Test Schedule (1350/1355).

4.2.2.2.1 For testing 1350/1355 U-joints follow Table 2.

4.2.2.2.1.1 Shaft inclination shall be set so that all U-joints operate at the specified angle (6°) for the duration of the test.

4.2.2.2.1.2 The slurry dowse over center of U-joint at 56.8 lpm (15 gpm) per 1 in National Pipe Thread nozzle must be activated for 2 s to 3 s. Total volume per dowse per U-joint is 1.89 L (0.5 g) (see Appendix A).

4.2.2.2.1.3 See Appendix D for ramp condition for Torque (Figure D1), Speed (Figure D2), and Temperature (Figure D3 or Figure D4).

4.2.2.2.2 Test Schedule for 1410 U-Joint. For testing 1410 U-joints, follow Table 2, except change the torque in Step 4 to 735.5 Nm $\pm$ 2.26 Nm (6510 lb-in $\pm$ 20 lb-in). This test specification for 1410 U-joints was not correlated to durability test schedules. Since the same bearing caps are used on 1350 U-joints and 1410 U-joints, the torque was calculated by a linear comparison of torque radii. Torque radius is the distance from the center of the cross to the centroid of the projected bearing area on the cross trunnion.

Table 1: Test Schedule for 1330/1344 U-joints

STEP	OPERATING ANGLE	INPUT TORQUE	INPUT SPEED	CHAMBER TEMPERATURE Note 2	SLURRY DOWSE	TIME Minutes
		Nm (lb-in) See Figure D1	RPM See Figure D2	°C (F) See Figure D3 or D4		
1	4 $\pm$ 0.1 degrees	135.6 $\pm$ 2.26 (1200 $\pm$ 20)	100 $\pm$ 5	21 $\pm$ 5 (70 $\pm$ 9)	1/Min.	20
2	4 $\pm$ 0.1 degrees	0	0	93 $\pm$ 5 (200 $\pm$ 9)	None	20
3	4 $\pm$ 0.1 degrees	67.8 $\pm$ 2.26 (600 $\pm$ 20)	1000 $\pm$ 5	21 $\pm$ 5 (70 $\pm$ 9)	1/Min.	20
4	4 $\pm$ 0.1 degrees	555.9 $\pm$ 2.26 (4920 ^{Note 1} $\pm$ 20)	2300 $\pm$ 5	93 $\pm$ 5 (200 $\pm$ 9)	None	60

Note 1: For 1310 U-joint, use 478 Nm (4230 lb-in).

Note 2: Assure that this temperature is representative of ambient temperature around U-joint.

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Table 2: Test Schedule for 1350/1355 U-joints

STEP	OPERATING ANGLE	INPUT TORQUE Nm (lb-in) See Figure D1	INPUT SPEED RPM See Figure D2	CHAMBER TEMPERATURE Note 2 Degree C (F) See Figure D3 or D4	SLURRY DOWSE	TIME Minutes
1	6 ± 0.1 degrees	135.6 ± 2.26 (1200 ± 20)	100 ± 5	21 ± 5 (70 ± 9)	1/Min.	20
2	6 ± 0.1 degrees	0	0	93 ± 5 (200 ± 9)	None	20
3	6 ± 0.1 degrees	67.8 ± 2.26 (600 ± 20)	1000 ± 5	21 ± 5 (70 ± 9)	1/Min.	20
4	6 ± 0.1 degrees	610.1 ± 2.26 (5400 ^{Note 1} ± 20)	2300 ± 5	93 ± 5 (200 ± 9)	None	60

Note 1: For 1410 U-joint, use 735.5 Nm (6510 lb-in).

Note 2: Assure that this temperature is representative of ambient temperature around U-joint.

4.3 Instructions.

4.3.1 Mix the slurry in the upper tank of the slurry application system and activate air agitation in the tank for duration of test.

4.3.2 Set slurry application system over the test chamber and lower the chamber hood on sealed edge.

4.3.3 Start air circulation inside the chamber and open the main valve to release the liquid nitrogen (LN₂).

4.3.4 Start data acquisition system with real time data display and start the test. The estimated test time to run one prop shaft is about 600 h.

4.3.5 Shut Down Criteria.

4.3.5.1 The main criterion for terminating the test shaft is based on IR temperature reading of U-joint bearing caps. Test samples will be stopped when the universal joint temperature readings report a 20 °C (36 °F) rise over the baseline temperature (see Appendix E, Figure E1). The baseline temperature is determined from the average steady state temperature measured during the 20th thru 50th h of testing for each U-joint during Step 4 of the Test Schedule, found in Table 1 and Table 2. A temporary temperature limit may be entered during the first 50 h in order to protect the test. If a shutdown occurs, the sample must be inspected for actual failure before the sample is removed.

4.3.5.2 A potential auxiliary criterion for terminating the test can be based on TIR readings taken on each end of the shaft in an area between flange weld and balance weights (see Appendix C, Figure C1). The test can be stopped if one (1) of the four (4) readings exceeds 1.02 mm (0.040 in). The TIR reading must be taken at the beginning of the test and once in every 24 h after test exceeds 200 h and temperature readings are below the shutdown limit. (It is also recommended that operator check the looseness of the U-joint by hand whenever possible.)

4.3.5.3 Any posttest teardown or documentation, which might be performed on samples, must be done as soon as possible after shut down occurs.

4.3.5.4 Shaft replacement must be conducted at intervals no longer than 4 h and alternating of shafts between stations A and B shall be maintained. If shaft replacement time exceeds 4 h, both shafts will be declared suspended samples and must be replaced with a new set of shafts. For multi-station machine, dummy shafts may be used to complete testing of sample being tested.

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4.3.5.5 The test samples must not be down for more than 4 h. After 4 h the test samples must be declared suspensions.

5 Data

5.1 Calculations. Not applicable.

5.2 Interpretation of Results.

5.2.1 Data Collection.

5.2.1.1 For the duration of the test, it is recommended that speed, input torque or output torque, chamber temperature and all universal joint IR sensor temperature readings be recorded every five (5) minutes on Steps 1, 2, and 3 of the test schedule (Table 1 and Table 2) and once a minute on Step 4 of the test schedule (Table 1 and Table 2) and stored on computer until the test results have been certified.

5.2.1.2 The preceding data (5.2.1.1) should be monitored to assure all test conditions are met. In addition, a duplicate hand temperature measurement of the U-joint bearing caps should be made every 8 h, compared with the IR sensor temperatures, and recorded in the logbook. (This assures that the IR temperatures measured are correct.). The slurry distribution system should be checked a minimum of every 8 h to assure that it is functioning properly and recorded in the logbook. TIR measurements and maintenance records are also written in the logbook. See Appendix F, Data Sheet F1 for a suggested data sheet.

U-joint failures and suspensions must be logged in hours for Weibull analysis.

5.2.2 Data Treatment. The data acquisition hardware and software is to be decided by the testing facility. The data acquired should be plotted as shown in Appendix D (Figures D1, Figure D2, and Figure D3) and Appendix E (Figure E1). It is recommended that the plots shown in Appendix D (Figures D1, Figure D2, and Figure D3) be done at the beginning of the test and at least every 100 h of the test schedule (Table 1 and Table 2), thereafter. Appendix E (Figure E1) should be plotted for each U-joint tested.

Note: For this procedure development, the data acquisition hardware package was supplied by Computer Boards Incorporated, model PCI DAS1602/16. The data collection software used was Labtech Notebook Program. The graphical data plots were done using Excel spreadsheet.

5.3 Test Documentation.

5.3.1 Weibull Analysis. A minimum of six prop shafts (12 U-joints) are needed in order to produce enough data for the Weibull analysis to estimate the B-10 life. Each prop shaft is tested to an event which is normally one U-joint failure. Sometimes both U-joints on the prop shaft are failures. Each U-joint which over temperature shall be considered a failure and those which do not are suspensions. See Appendix G, Data Sheet G1.

This data must be analyzed using two-parameter rank regression on the independent variable (laboratory hours). If two-parameter rank regression does not converge, then other methods such as maximum likelihood method may be used. See Appendix G, Figure G1.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems 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.

6.1 Facility Safety. The safety requirements must be based on the individual test facility and based upon local governmental requirements such as Occupational Safety and Health Administration and Michigan Occupational Safety and Health Administration requirements.

7 Notes

7.1 Glossary. Not applicable.

7.2 Acronyms, Abbreviations, and Symbols.

AC	Alternating Current
F	Failure
g	Gram

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