Data Sets Used in Statistical Methods for Reliability Data

Second Edition

William Q. Meeker
Department of Statistics
Iowa State University

Luis A. Escobar
Department of Experimental Statistics
Louisiana State University

Francis G. Pascual
Department of Mathematics and Statistics
Washington State University

This collection contains csv files for the data sets used in the examples and exercises of Meeker, Escobar, and Pascual (2021) (hereafter SMRD2). For each dataset, this document describes the original source (if it appeared in the literature before appearing in SMRD1 or SMRD2), provides some background for the data set, and points to where it is used in SMRD2.

These data sets are archived and publicly available on DataShare, Iowa State University's open data repository, and can be accessed at:
https://doi.org/10.25380/iastate.c.5395665.
The data files and this document are also available from
https://github.com/wqmeeker/SMRD2Data.git
and at the SMRD2 webpage
https://www.wiley.com/go/meeker/reliability2e.

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A. Background

This collection contains reliability data sets that arose from a wide range of applications and includes all of the data sets used for the examples and exercises in Meeker et al. (2021) (hereafter SMRD2). In addition to the traditional failure-time reliability data, we also include degradation (both destructive and repeated measures) and recurrent events reliability data.

Obtaining reliability data is difficult, especially for academic researchers wanting to develop new methodology. Over their careers, the authors have collected and organized reliability data that they used in their teaching and research. Some data were obtained from publications in the statistical and engineering literature, including many of the authors' publications. The many data sets that did not originate in others' publications arose from consulting work in which the authors were engaged. In such situations we were given permission to use the data if sensitive information (like the name of the product and its manufacturer) would not be disclosed. This is the reason that many of the data sets have been given names like Product-A and Component-B. In some cases the response was scaled by multiplying by an arbitrary constant.

First and foremost, the data sets are necessary for doing the exercises and reproducing the results in the examples in SMRD2 and thus will be useful for teaching reliability courses at colleges or universities but also for short courses given to engineers in industry. The data sets will also be useful for researchers who are developing new and better statistical methodology for reliability analysis.

B. Column Naming Conventions

In this collection, we have used the following column naming conventions.

1. The censoring type columns are named "Censoring Indicator" with values like Left, Right, Censored, Interval, Fail, or Exact).
2. The Case weight (or multiplicity) columns are named "Counts."
3. The columns indicating the failure modes are named "Failure Mode."
4. For columnns containing the response variables the naming convention depends on the type of response.
   i. For time-to-event data, we use the time units (e.g., Months, Hours, Thousands of Hours, Cycles, Thousands of Cycles, etc.) as column names.
   ii. When there is interval censoring there are two columns with names like Hours Lower and Hours Upper. For left censoring, the Lower column value should be 0 or blank and for right censoring, the Upper column value should be blank. Although it could be considered to be redundant, we also include a "Censoring Indicator" column for clarity and compatibility with software packages that require such a column.
   iii. For degradation data, we use the response variable name and units, if possible (e.g., Power Drop (dB), Light Output (Proportion) or Strength (MPa)).
5. When there is truncation in the data, the column naming conventions are similar to those used for the response.
   i. If there are only single trunction points, we do as in the response columns but preceding the name with the word Truncation (e.g., Truncation Hours).

   ii. For interval truncation we use the same as in the response but preceding with the word Truncation (e.g., Truncation Hours Lower).

6. The columns indicating the truncation type are named "Truncation Indicator" with values like None, Left, Right, or Interval.
7. Explanatory variable columns are handled in a manner that is similar to how we treat degradation responses. That is, we give name of the variable and units or units alone if it will be clear (e.g., DegreesC, Processing Temperature (F) or just DegreesF, Stroke (mils), Voltage (kV), Current (mA)).
8. For recurrent events data and repeated measures degradation, there is a column like "Unit Number" or "Engine Number" for numeric indicators. If the indicators are alphanumeric, then we use a name like "Machine ID."
9. For recurrent events data, there is a column named "Event" to give the name of the event (e.g., with values like Failure, Return, Replace, Repair) and the value END indicates end-of-observation time.

C. Laboratory Failure-Time and Single-Time Strength Data

1. `AlloyA.csv`
   This file contains data on fatigue crack length as a function of number of cycles. These data were obtained visually from Figure 4.5.2 in Bogdanoff and Kozin (1985, page 242). These data were analyzed in Lu and Meeker (1993) and are used in SMRD2 Example 1.10 and Sections 21.1–21.3.

2. `AlloyC.csv`
   These data are from an experiment to measure long transverse tensile strength (ksi) of a 7475-T651 aluminum plate (0.5–1.0 inch thick) and are used in SMRD2 Section 11.6.

3. `AlloyT7987.csv`
   This file contains fatigue lives of 67 specimens of Alloy T7987. There were also five specimens that were tested to 300 thousand cycles but that did not fail. These data are used in SMRD2 Sections 6.4, 11.6, and Exercise 11.17.

4. `ApplianceB.csv`
   This file contains use-rate accelerated test data presented in Meeker, Escobar, and Hong (2009) and used in SMRD2 Example 1.6.

5. `ApplianceCord.csv`
   This file contains data from a life test electric cords for a small appliance. The purpose of the test was to compare a standard cord with a less expensive alternative. These data were first given in Nelson (1982, page 121) and used in SMRD2 Exercise 12.10.

6. `BearingA.csv`
   These data came from a small bench test of a roller bearing with three early failures (defective units). These data first appeared in Genschel and Meeker (2010) and are used in SMRD2 Example 8.17.

7. `Berkson10220.csv`
   This file contains interval-censored data for 10,220 times between Americium-241 α-particle arrivals. The time unit for these data is 1/5000 second. These data originally appeared in Berkson (1966) and are used in SMRD2 Sections 7.1–7.6.

8. `Berkson200.csv`
   This file contains a random sample of size 200 from the data in `Berkson10220.csv`. These data are used in SMRD2 Sections 7.1–7.6.

9. `BKfatigue10.csv`
   This file contains fatigue-failure data from Bogdanoff and Kozin (1985, pages 224–225) and they are used in SMRD2 Example 11.3.

10. `Bulb.csv`
    This file contains incandescent light bulb life-test data from Davis (1952) and used in SMRD2 Exercise 6.14.

11. `CeramicBearing02.csv`
    This file contains life test results on rolling contact fatigue of ceramic ball bearings given by McCool (1980) and are used in SMRD2 Exercise 17.3.

12. `ChainLink.csv`
    This file contains the results of a load-controlled high-cycle fatigue test conducted on chain links from Parida (1991) and used in SMRD2 Exercises 3.6, 6.8, and 8.3.

13. `CircuitPack05.csv`
    This file contains data from a life test data conducted to compare the failure-time distributions of circuit packs manufactured by two different vendors. These data were first reported by Hooper and Amster (1998, Table 9.2) and are used in SMRD2 Exercise 12.9.

14. `ConnectionStrength.csv`
    This file contains data on breaking strength of 20 wire connections given in Nelson (1982, page 348) and used in SMRD2 Exercise 16.6.

15. `ConnectorStress.csv` and `ConnectorStrength.csv`
    These files contain stress-strength data from Liu and Abeyratne (2019, Section 6.2) and are used in SMRD2 Section 23.2.2.

16. `DetonatorSensitivity.csv`
    This file contains test data to estimate a detonator's sensitivity (probability of detonating as a function of voltage) and were first reported in Dror and Steinberg (2008). These data are used in SMRD2 Exercise 8.28.

17. `DeviceA.csv`
    These data are from an accelerated life test for an electronic device from Hooper and Amster (1998, Table 9.3) and used in SMRD2 Sections 18.3 and 18.4 and Exercises 18.7–18.9, 18.14, and 18.17.

18. `DeviceC.csv`
    These data are from am accelerated life test of an integrated circuit device and are used in SMRD2 Exercise 18.3.

19. `HeaterComparison.csv`
    These data come from an accelerated life test comparing two suppliers of tubular heaters used in ovens and are used in SMRD2 Exercise 12.12.

20. `HypoidPinionGear.csv`
    These data come from an accelerated life test to estimate the relationship between fatigue life and torque and are used in SMRD2 Exercise 18.28.

21. `ICData.csv`
    This file contains the results of an accelerated life test, conducted at one level of elevated temperature, to study an electromigration-related failure mode. These data are used in SMRD2 Exercises 8.5 and 18.25.

22. `InkjetPenA.csv`
    These data are from a life test of an inkjet pen, comparing two different ink formulations and are used in SMRD2 Example 12.14.

23. `InkjetPrintheadB.csv`
    This file contains data from a life test of an inkjet printhead that resulted in two failure modes and is used in SMRD2 Exercise 16.9.

24. `JEP118.csv`
    These interval-censored data come from an accelerated life test for an electronic device from Whitman (2003) and are used in SMRD2 Exercise 19.1.

25. `KevlarWrappedPressureVessels.csv`
    This file contains accelerated life test data originally from Gerstle and Kunz (1983), but re-analyzed in many other places, including Section 23.4 of SMRD2.

26. `LaminatePanel.csv`
    This file contains data on the fatigue life of panel specimens tested at five different levels of stress that were analyzed in Shimokawa and Hamaguchi (1987) and Pascual and Meeker (1999). These data are analyzed in SMRD2 Section 17.6.

27. `LEDLife.csv`
    This file contains pseudo failure times derived from the LED-A accelerated repeated measures degradation data in `LED.A.full.csv`. These data were first analyzed in Pascual, Meeker, and Escobar (2006) and also studied in SMRD2 Section 21.7.

28. `LEDLifeSubset.csv`
    These accelerated life-test data were derived from `LEDLife.csv` by excluding data from a different failure mode at 130°C and 40 mA. These data were first analyzed in Pascual et al. (2006) and also studied in SMRD2 Section 21.7.

29. `LFP1370.csv`
    These limited-failure-population accelerated life test data were first analyzed in Meeker (1987) and are used in SMRD2 Examples 1.2 and 3.7, Section 11.5, and Exercise 11.3.

30. `LZbearing.csv`
    These data, from fatigue endurance tests, were first given in Lieblein and Zelen (1956) and were analyzed in Lawless (1982) and SMRD1. The data are used in SMRD2 Section 3.4, Examples 1.1, 8.3, and 11.1, and Exercise 3.1.

31. `MechanicalSwitch.csv`
    This file contains competing-risk failure-time data, with two failure modes, on mechanical switches are from Nair (1984) and are used in SMRD2 Exercise 16.8.

32. `MetalWear.csv`
    These data are from sliding-metal wear tests to study the wear resistance of a metal alloy and used in SMRD2 Example 11.1 and Exercises 21.13 and 21.15.

33. `Mylarpoly.csv`
    These data, given in Kalkanis and Rosso (1989), were from an accelerated life test of a Mylar-polyurethane insulating structure and are used in Section 18.5 and Exercises 18.22 and 18.23 in SMRD2.

34. `NewSpring.csv`
    These data were obtained from a factorial accelerated life test experiment to study the relationship between spring lifetimes and a processing temperature, the amount of displacement in the spring test (Stroke in mils), and processing method (New or Old). The data were first used in Meeker, Escobar, and Zayac (2003) to illustrate a sensitivity analysis and is used in SMRD2 Section 19.3 and Exercise 19.17.

35. `NewTechnology.csv`
    These data are from a temperature-accelerated life test on an IC device and is presented or used in SMRD2 Section 19.1, Exercises 19.4, 19.6, and 19.7.

36. `NiCdBattery.csv`
    These accelerated test data on rechargeable nickel-cadmium battery cells were presented in Brown and Mains (1979) and used in SMRD2 Example 1.9 and Exercise 19.16.

37. `PartA.csv`
    These data data are from an experiment to compare three operators who performed life tests on a component in a cutting tool and are used in SMRD2 Example 12.2, Sections 12.2 and 12.5, and Exercises 12.7 and 12.8.
38. `PhotoDetector.csv`
    These data, reported by Weis, Caldararu, Snyder, and Croitoru (1986), were from a life test on silicon photodiode detectors and used in SMRD2 Exercises 3.12 and 6.9.
39. `PrintedCircuitBoard.csv`
    These data, given in Meeker and LuValle (1995), were from humidity-accelerated life test of printed circuit boards and are used in SMRD2 Example 1.8 and Exercise 1.11.
40. `Snubber.csv`
    These data, first given in Nelson (1981), were obtained from an accelerated test comparing two toaster snubber designs. The data are used in SMRD2 Examples 12.1, 12.3, 12.5, 12.6, 12.7, 12.8, 12.9, and 12.10 and Exercises 12.3, 12.4, and 12.5.
41. `SuperAlloy.csv`
    This data set, given in Nelson (1984) and Nelson (2004), contains fatigue life-test results from a strain-controlled test of a nickel-base superalloy. The data are used in Examples 17.7, 17.8, 17.9, and 17.10 and Exercises 17.9 and 17.12.
42. `Tantalum.csv`
    These data, from Singpurwalla, Castellino, and Goldschen (1975), resulted from a temperature- and voltage-accelerated life test of tantalum capacitors and are used in SMRD2 Exercise 19.15.
43. `TireDataSet.csv`
    These data, given in Krivtsov, Tananko, and Davis (2002), were from an experiment that was designed to reproduce automobile tire failures that had been seen in the field. They are use in SMRD2 Exercise 17.5.
44. `Titanium01.csv`
    These data were obtained from a fatigue test of titanium alloy specimens and are used in SMRD2 Exercise 6.7.
45. `Transistor.csv`
    These data, given in Wilk, Gnanadesikan, and Huyett (1962), were from an accelerated test of transistors and are used in SMRD2 Exercise 6.5.
46. `TurbineDevice.csv`
    These data were from a life test of a newly designed turbine device and are used in SMRD2 Exercise 16.7.
47. `ZelenCap.csv`
    These data were obtained from a factorial experiment to study the effect that voltage and temperature have on capacitor lifetime. The data were first analyzed in Zelen (1959) and used in SMRD2 Examples 17.15 and 17.16 and Exercises 17.16 and 17.20.
48. `ZelenCapSub.csv`
    These data are a subset of `ZelenCap.csv` with the bad data at 180C and 200 volts removed. They are used in SMRD2 Example 17.17.

D. Field Failure-time Data

1. `ApplianceBField.csv`
   This file contains failure-time data obtained from warranty return information. These data were first presented in Meeker et al. (2009) and are used in SMRD2 Exercise 16.10.
2. `Backblaze1Q2016.csv`
   This file contains Backblaze disk drive failure data as of 1Q2016 and used in Mittman, Lewis-Beck, and Meeker (2019).
3. `BackblazeDrive14.csv`
   Subset of `Backblaze1Q2016.csv` containing drive model 14 and used in SMRD2 Section 23.1.
4. `BearingCage.csv`
   This file contains bearing-cage field-failure data consisting of fracture times for failed units and running times for units that have not failed. These data were abstracted from Abernethy, Breneman, Medlin, and Reinman (1983) and they are used in SMRD2 Example 8.18, Exercise 8.27, Section 10.2, Examples 10.8 and 10.9, and Section 15.7.
5. `BleedSystem.csv`
   This file contains failure and running times for 2256 aircraft engine bleed systems. These data were abstracted from Abernethy et al. (1983) and are used in SMRD2 Example 6.5 and Exercise 8.20.
6. `BondStrength.csv`
   Failures in a microelectronic device were caused by weakened wire bonds. The data are from devices in three separate manufacturing batches and they are used in SMRD2 Exercise 12.13.
7. `CircuitPack04.csv`
   This file contains interval-censored field tracking data for circuit packs in a telecommunications system. The data were first reported by Hooper and Amster (1998, Table 9.1) and are used in SMRD2 Exercise 8.23.
8. `CircuitPack06.csv`
   This file contains data giving the number of failures observed during periodic inspections in a field trial of early production circuit packs and used in SMRD2 Examples 1.7, and 11.8.
9. `ComponentA.csv`
   This file contains data giving number of failures of a component type that is used numerous times in a large electronic system and are used in SMRD2 Exercises 7.4 and 8.6.
10. `ComponentB.csv`
    This file contains failure-free running times for early production metal components that had been introduced into service over time. The data are used in SMRD2 Example 8.17.
11. `CompTime.csv`
    This file contains the times to complete a computing task at a centralized computer service at Louisiana State University and used in SMRD2 Sections 17.1–17.3.

12. `DetonatorA.csv`
    This file contains shelf-life data for explosive detonators manufactured in 14 different batches. A component of the detonator was tested destructively and graded as pass or fail. The data are used in SMRD2 Exercise 12.11.

13. `DeviceG.csv`
    These data are from a field-tracking study of an electro-mechanical subsystem that had two failure modes and are used in Sections 16.1, 16.3, 16.4, and 16.6 and in Exercises 16.2–16.4 in SMRD2.

14. `DeviceG-sim-pseudo-joint-dependent.csv`
    This file contains joint pseudo data derived from the DeviceG data under a strong dependence assumption and is used in Section 16.6 and Exercise 16.2 in SMRD2.

15. `DeviceG-sim-pseudo-joint-independent.csv`
    This file contains joint pseudo data derived from the DeviceG data under an independence assumption and is used in Section 16.6 and Exercise 16.2 in SMRD2.

16. `DeviceH.csv`
    This file contains field-failure data for an electro-mechanical device. The data were first presented in Doganaksoy, Hahn, and Meeker (2000). They are used in Exercises 6.15 and 10.17 in SMRD2.

17. `DeviceJ40.csv`, `DeviceJ55.csv`, `DeviceJ69.csv`
    These files contain field-failure data where a small proportion of units had failed at data-freeze dates 40, 55, and 69 months after introduction of units to the field. These data are used in Section 23.3 of SMRD2.

18. `DeviceN.csv`
    This file contains current-status warranty-replacement data for a component in a larger product. The data are used in SMRD2 Exercises 8.25 and 15.15.

19. `ElectronicSystem.csv`
    This file contains failure data on devices in electronic systems that have been deployed in Earth orbit. The data are used in SMRD2 Exercise 3.8.

20. `Fan.csv`
    This file contains failure data for diesel-generator fans from Nelson (1982, page 133) and are used in SMRD2 Examples 1.3, 7.13, 11.2, and 11.19.

21. `HeatExchanger.csv`
    These data are from nuclear power plant heat exchangers and are used in SMRD2 Examples 1.4, 3.2, 3.8, and Exercises 8.1, 8.2, and 10.16.

22. `MotorA.csv`
    This file contains field-failure data of a motor that is part of a larger system and is used in SMRD2 Exercises 11.6 and 15.15.

23. `ProductE.csv`
    The data were derived from warranty returns of a product subjected to 19 different failure modes and are used in SMRD2 Sections 16.4 and 16.5 and Exercises 16.5, 16.17, 16.18, and 16.19.

24. `RocketMotor.csv`
    The data were from a field-performance assessment of missile rocket motors. The failures were thought to be caused by thermal cycling. The data were given in Olwell and Sorell (2001) and used in SMRD2 Section 10.5.

25. `ShockAbsorber.csv`
This file contains failure times (in kilometers driven) of vehicle shock absorbers and were reported in O'Connor (1985). The data are used in SMRD2 Sections 8.2, 8.3, 9.3, and 9.4, Examples 3.10, 3.11, 3.12, 6.2, 8.1, 8.2, 9.10, and 9.11 and Exercise 8.13

26. `TurbineWheel.csv`
Nelson (1982) presented these current status data from a study to estimate the time-to-crack initiation in turbine wheels. They are used in SMRD2 Examples 1.5, 3.14, and 6.4 and Exercise 1.9.

E. Destructive Degradation Data

1. `AdhesiveBondA.csv`
These adhesive bond strength data came from a destructive degradation test on units that had been in service for different amounts of time. The data are used in SMRD2 Sections 20.4–20.5.

2. `AdhesiveBondB.csv`
These data are from an accelerated destructive degradation test to estimate the failure-time distribution of an adhesive bond. The data were first given in Escobar, Meeker, Kugler, and Kramer (2003) and are used in SMRD2 Sections 20.4–24.9.

3. `AdhesiveFormulationK.csv`
These data are from an accelerated destructive degradation test to estimate the failure-time distribution of an adhesive. The data were first given in Xie, King, Hong, and Yang (2018) and are used in SMRD2 Section 20.10.

4. `InsulationBreakdown.csv`
This file contains accelerated destructive degradation data on an insulation and were first givenin Nelson (2004, page 535) and are used in SMRD2 Exercise 20.11.

F. Repeated Measured Degradation Data

1. `DiskBer.csv`
These data come from an accelerated repeated measured degradation test to study byte error rates (the ratio of number of bytes with errors to the total number of bytes tested) of magneto-optic data storage disks. The data first appeared in Murray (1993) and are used in SMRD2 Exercise 21.6.

2. `GaAsLaser.csv`
This file contains data from a GaAs Laser accelerated repeated measures degradation test and are used in SMRD2 Example 20.2 and Exercise 21.24.

3. `LED-Azerostart.csv`
This file contains accelerated repeated measures degradation test data on an LED. These data are used in SMRD2 Section 21.15.

4. `LED-Afull.csv`
The accelerated repeated measures degradation test data in this file were derived from `LED.A.zero.start.csv` by eliminating readings before 138 hours and renormalizing the data at 138 hours. These data are used in SMRD2 Section 21.15.

5. `LED-Asubset.csv`
   The repeated measures degradation test data in this file were derived from `LED.A.Life.csv` by excluding data from a different failure mode at 130°C and 40 mA. These data are used in SMRD2 Section 21.15.
6. `Resistor.csv`
   These data, given in Suzuki, Maki, and Yokogawa (1993), were from a temperature-accelerated repeated-measures degradation test of carbon-film resistors and are used in SMRD2 Exercise 21.12.
7. `DeviceB.csv`
   These data came from an accelerated repeated measured degradation test of a solid-state RF power amplifier and were first used in Meeker, Escobar, and Lu (1998). The data are used in SMRD2 Sections 21.5–21.6 and Exercise 21.19.

G. Recurrent Events Data

1. `AutomaticTransmission.csv`
   This file contains automatic transmission recurrent events data given in Nelson (2003, Table 1.1) and used in SMRD2 Exercise 22.8.
2. `BrakingGrids.csv`
   These are recurrent events data from two batches of locomotive braking grids, first presented in Doganaksoy and Nelson (1998) and used in SMRD Section 22.3.
3. `ComputerLab.csv`
   This file contains computer lab maintenance recurrent events data used in SMRD2 Exercise 22.1.
4. `Cylinder.csv`
   This file contains locomotive engine cylinder replacement recurrent events data from Nelson and Doganaksoy (1989) and used in SMRD2 Section 22.2.3.
5. `MachineH.csv`
   These recurrent events data are cam from preventive maintenance records for a company's earth-moving machines and are studied in SMRD2 Example 22.5.
6. `SystemE.csv`
   This file contains recurrent events data from an electronic system with three different event types. These data are used in SMRD2 Exercises 22.8 and 22.9.
7. `ValveSeat.csv`
   These recurrent events data on the replacement of locomotive engine valve seats first appeared in Nelson (1995, 2003). They are used in SMRD2 Examples 22.1 and 22.2.
8. `WorkStation.csv`
   This file contains recurrent events data giving trouble reports for computer work stations. They are used in SMRD2 Exercise 16.1.

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