Repairable fleet: the growth curve — three trend tests and the time-on-test plot

Menu: Life Data ▸ Repairable Fleet…

Part 1 — What the function does

What it calculates. The growth test of the Repairable fleet report (chapter 3.3) asks one question of the pooled power law: is β different from 1? The same report looks at the repairs in other ways too, so that a trend verdict does not rest on one test: a Laplace test that assumes no model, an Anderson-Darling test on the repair ages scaled to each machine's window, the power law's λ with its standard error, an event plot of every repair on its machine's timeline, and a scaled total-time-on-test (TTT) plot.

What ReliaEn prints	What it tells you
Trend verdict (growth test of β = 1)	Whether the pooled power law departs from a constant repair rate
Laplace trend test u and p	u above 0: repairs come late in the windows (wearing); below 0: early (improving)
Anderson-Darling trend test A^2 and p	How far the scaled repair ages are from an even spread
Pooled λ (per machine) with SE and bounds	The power law's scale, conditional on the fitted β
Event plot	One bar per machine up to its observation end, one dot per repair
Total time on test plot	Above the diagonal: wearing; below: improving

From which data. The Repairable fleet worksheet of chapter 3.3: one row per repair with the machine and its age, and the machine's observation end if it is known. With Model set to Nonparametric MCF only, the λ, Laplace and Anderson-Darling rows leave the report; the plots stay.

When an engineer uses it. When a fleet's trend decides a maintenance policy, and one test alone is too thin to act on: the three tests read together, and the event plot shows which machines drive a pattern.

When not to use it.

Situation	Use instead
One machine's log only, with its renewal MTBF	Life Data ▸ Estimate Failure Function ▸ Repairable unit data…
The repair is to be measured: how much it restores the machine	Life Data ▸ Repairable Systems ▸ GRP / Kijima…

Part 2 — The example's input data

Setting. A pump log holds seventeen repair ages, shared between two pumps PA and PB in turn. There is no observation-end column, so each pump is watched up to its last repair. The reliability engineer wants to know whether the repairs are coming faster, before choosing between a constant-rate plan and an overhaul programme.

Input	Value
Repair ages, hours (17), PA and PB in turn	31.3, 36.9, 53.3, 97.6, 163.4, 215.3, 321.5, 361.4, 414.4, 483.5, 588.9, 660.2, 723.1, 774.4, 831.2, 920.1, 954.0
Observation-end column	(none)
File in the worked-example zip	3-Repairable-Fleet-Growth/Example-2.csv — columns Machine and Age, 17 rows

	① A	② B	C
1	PA	31.3	
2	PB	36.9	
3	PA	53.3	
4	PB	97.6	
5	PA	163.4	
6	PB	215.3	
7	PA	321.5	
8	PB	361.4	
9	PA	414.4	
10	PB	483.5	
11	PA	588.9	
12	PB	660.2	
13	PA	723.1	
14	PB	774.4	
15	PA	831.2	
16	PB	920.1	
17	PA	954.0	
18			

The example data in the worksheet

- ① Column A: the pump of each repair, PA or PB.
- ② Column B: the age at the repair, in hours.

Part 3 — How to use it, step by step

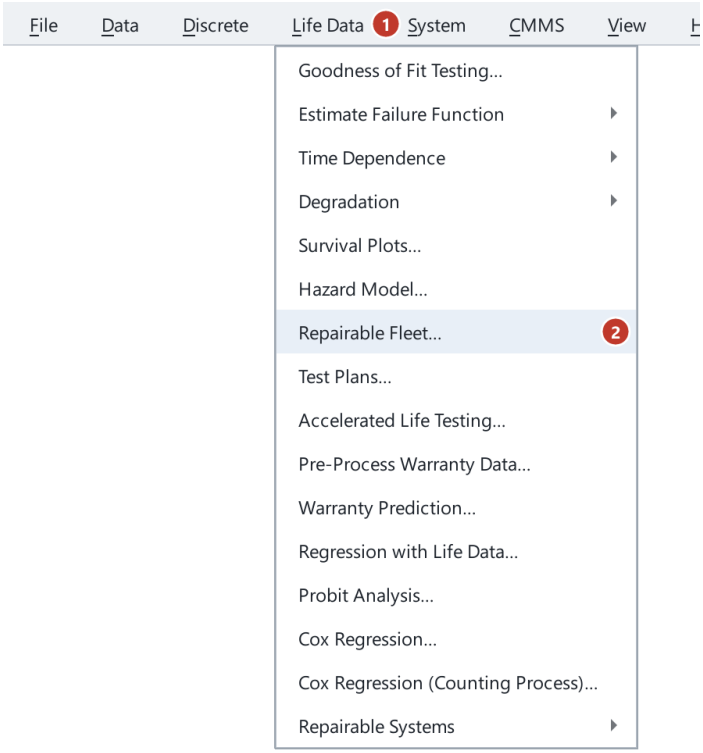
1. **Put the repair log in columns A and B.** Copy the 17 rows of Example-2.csv - its columns Machine and Age - into columns A and B of the worksheet, starting at row 1: one row per repair.

	① A	② B	C
1	PA	31.3	
2	PB	36.9	
3	PA	53.3	
4	PB	97.6	
5	PA	163.4	
6	PB	215.3	
7	PA	321.5	
8	PB	361.4	
9	PA	414.4	
10	PB	483.5	
11	PA	588.9	
12	PB	660.2	
13	PA	723.1	
14	PB	774.4	
15	PA	831.2	
16	PB	920.1	
17	PA	954.0	
18			

Step 1 — the repair log in columns A and B

- ① Column A: the pump of each repair, PA and PB in turn.
- ② Column B: the age at the repair, 31.3 to 954.0 hours.

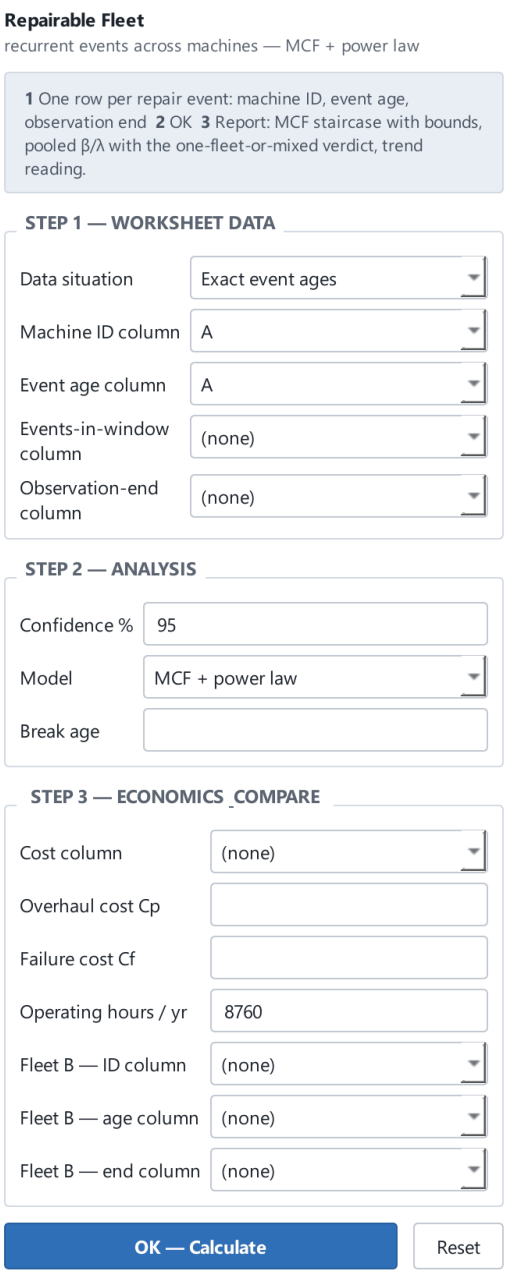
2. **Choose Life Data ▸ Repairable Fleet...** in the menu bar. The form Repairable Fleet opens in the left panel.



Step 2 — the menu path

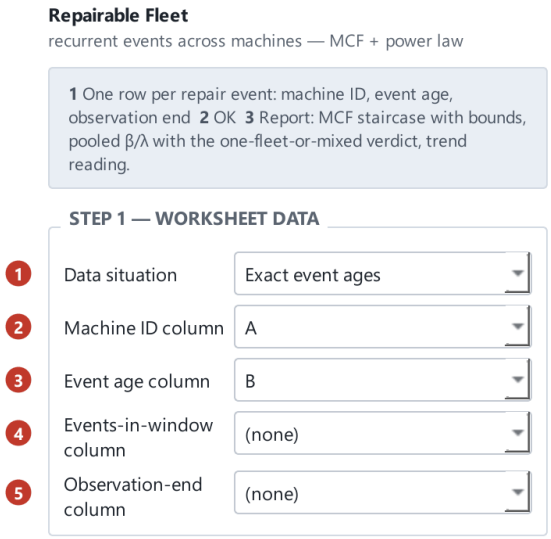
- ① Life Data: the menu.
- ② Repairable Fleet...: the entry to click.

The form as it opens, before any box is set:

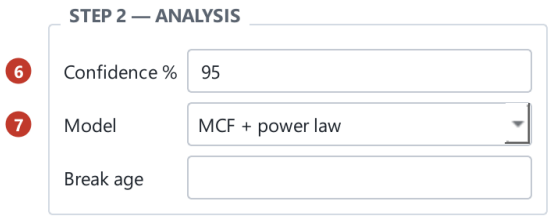


Step 2 — the form as it opens

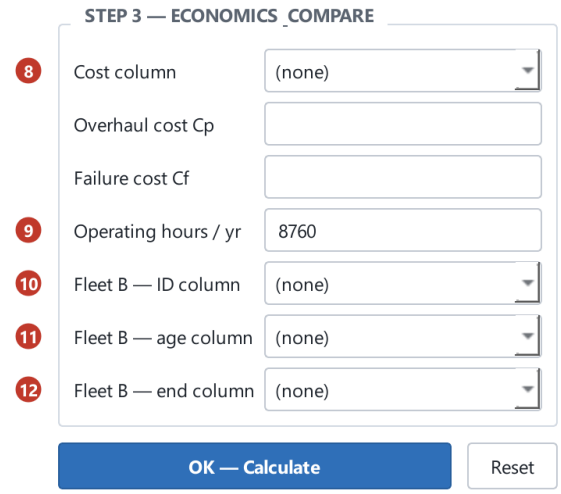
Steps 3 to 14 set or check the form's twelve boxes, shown in three pictures, one per group of the form - ① to ⑤, ⑥ and ⑦, ⑧ to ⑫:



Steps 3 to 7 — the worksheet boxes set for this example



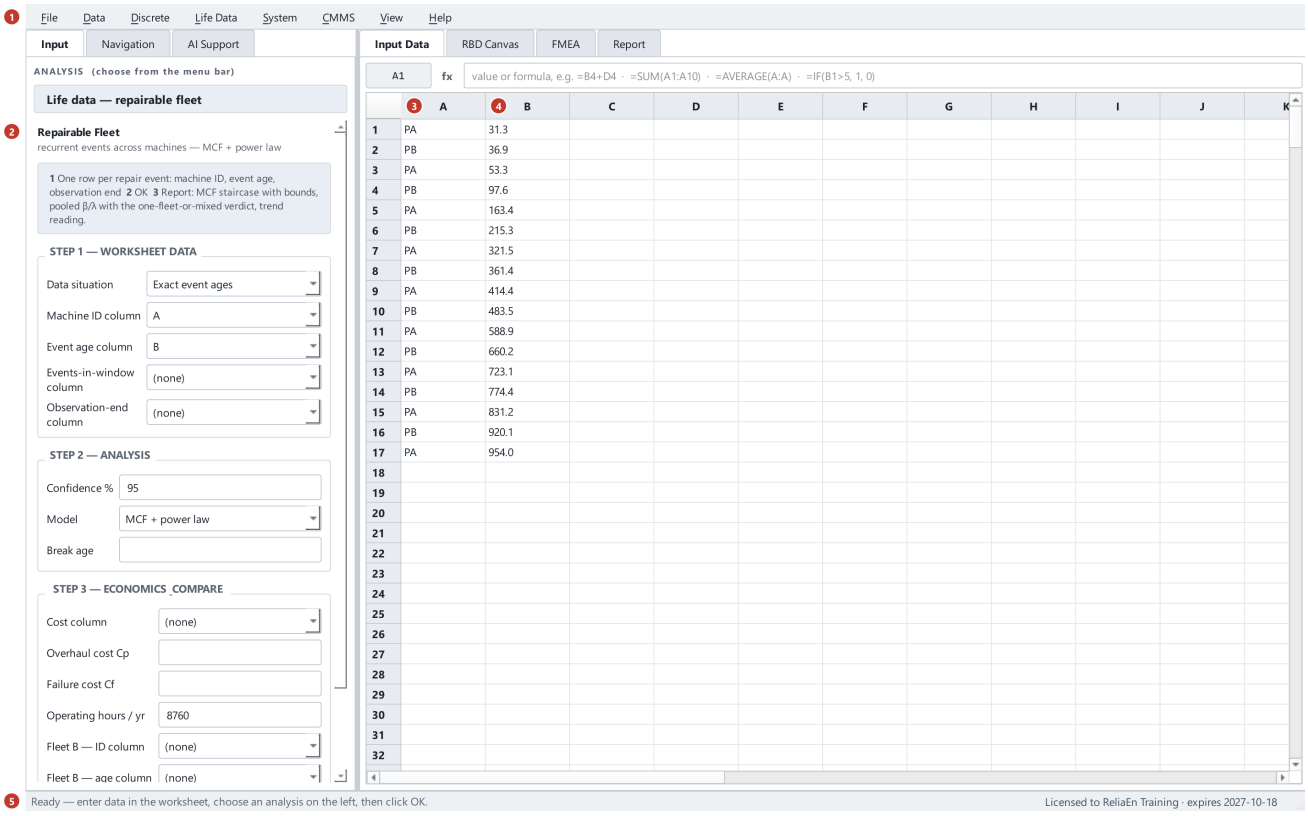
Steps 8 and 9 — the analysis boxes



Steps 10 to 14 — the third group's boxes

3. ① **Check that Data situation reads Exact event ages.**
4. ② **Check that Machine ID column reads A.**
5. ③ **In Event age column, choose B.**
6. ④ **Check that Events-in-window column reads (none).**
7. ⑤ **Check that Observation-end column reads (none).** This log has no observation ends: each pump is watched up to its last repair.
8. ⑥ **Check that Confidence % reads 95.**
9. ⑦ **Check that Model reads MCF + power law.** Break age below it stays empty.
10. ⑧ **Check that Cost column reads (none).** Overhaul cost Cp and Failure cost Cf stay empty: this example asks about the trend only.
11. ⑨ **Check that Operating hours / yr reads 8760.**
12. ⑩ **Check that Fleet B — ID column reads (none).**
13. ⑪ **Check that Fleet B — age column reads (none).**
14. ⑫ **Check that Fleet B — end column reads (none).**

15. **Click OK — Calculate** at the foot of the form (② in the picture below). ReliaEn calculates and shows the report.



Step 15 — the window just before OK

- ① The menu bar: File, Data, Discrete, Life Data, System, CMMS, View, Help.
- ② The form, set as in steps 3 to 14; OK — Calculate at its foot.
- ③ Column A: the pumps.
- ④ Column B: the repair ages.
- ⑤ The status bar: Ready — enter data in the worksheet, choose an analysis on the left, then click OK. and Licensed to ReliaEn Training · expires 2027-10-18.

Part 4 — The report, card by card

Life Data — Repairable Fleet

```
2026-11-04 07:20:21
MCF: ΔMCF = d/r per event age ; power law: E[N(t)] = λt^β, β̂ = N/ΣΣ ln(T_q/t_iq)
```

The report's head

- The title Life Data — Repairable Fleet, the date and time of the run, and the two models in one line: MCF: ΔMCF = d/r per event age; power law: E[N(t)] = λt^β, β̂ = N/ΣΣ ln(T_q/t_iq).

INPUT DATA

1	Fleet	`2 machines, 17 repair events`
2	Observation windows	`to age 954 (longest)`
3	Confidence level	`95%`
4	Model	`MCF + power law`

Input data

- ① Fleet 2 machines, 17 repair events.
- ② Observation windows to age 954 (longest): PA's last repair.
- ③ Confidence level 95%.
- ④ Model MCF + power law.

RESULTS

1	Pooled β (fleet shape)	`0.8551 [0.4982, 1.3070]`
2	Pooled λ (per machine)	`0.02444 (SE 0.005928) [0.01424, 0.03913] — conditional on the fitted shape`
3	MTBF now — instantaneous, per machine	`129.2`
4	MTBF cumulative, per machine	`110.5`
5	Trend verdict	`no-trend (growth test p = 0.458)`
6	Laplace trend test	`u = -0.3071, p = 0.7588`
7	Anderson-Darling trend test	`A² = 1.0197, p = 0.3471 (asymptotic)`
8	MCF at the last event	`9.000 repairs/machine by age 954`

Results

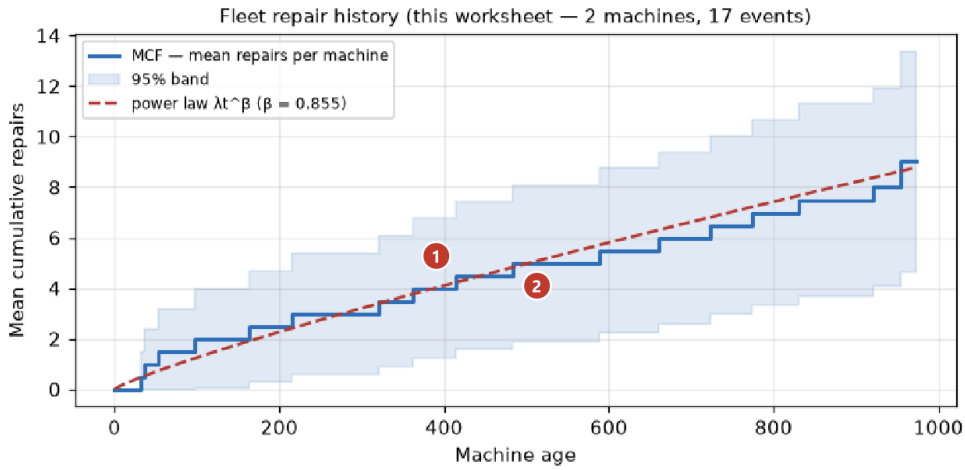
- ① Pooled β (fleet shape) 0.8551 [0.4982, 1.3070]: below 1, but the bounds contain 1.
- ② Pooled λ (per machine) 0.02444 (SE 0.005928) [0.01424, 0.03913] — conditional on the fitted shape.
- ③ MTBF now — instantaneous, per machine 129.2.
- ④ MTBF cumulative, per machine 110.5.
- ⑤ Trend verdict no-trend (growth test p = 0.458).
- ⑥ Laplace trend test u = -0.3071, p = 0.7588.
- ⑦ Anderson-Darling trend test A^2 = 1.0197, p = 0.3471 (asymptotic).
- ⑧ MCF at the last event 9.000 repairs/machine by age 954.

INTERPRETATION

1 The staircase is the fleet's actual repair history — mean repairs per machine vs age, no model assumed; the risk set shrinks as shorter observation windows end. The power-law curve is the pooled fit over every machine: β < 1 means repairs are spacing out (improving), β > 1 means they are bunching up (wearing), β ≈ 1 means a stable fleet where renewal analysis applies.

Interpretation

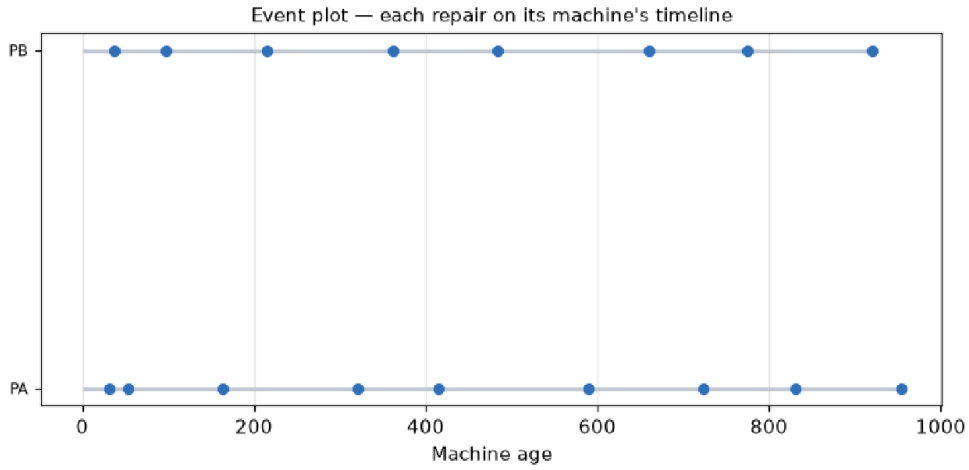
- ① ReliaEn's reading: The staircase is the fleet's actual repair history — mean repairs per machine vs age, no model assumed; the risk set shrinks as shorter observation windows end. The power-law curve is the pooled fit over every machine: β < 1 means repairs are spacing out (improving), β > 1 means they are bunching up (wearing), β ≈ 1 means a stable fleet where renewal analysis applies.



Interactive Plot

Fleet repair history (this worksheet — 2 machines, 17 events)

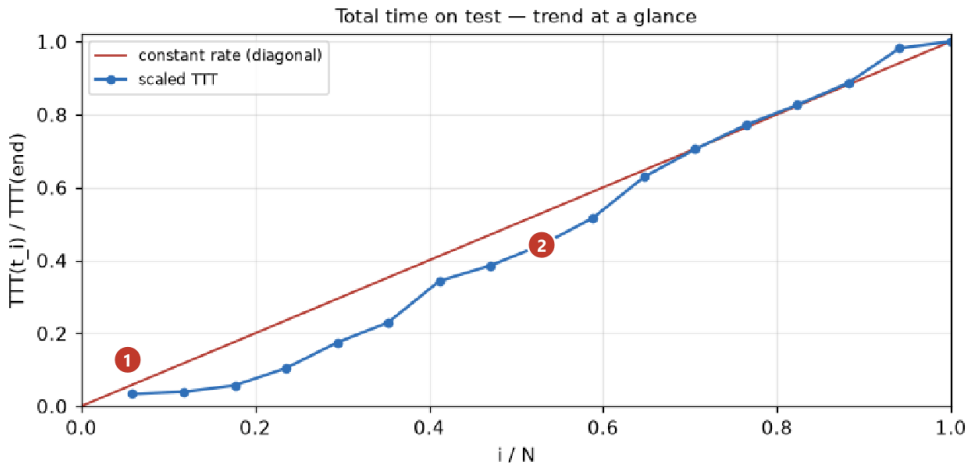
- ① MCF — mean repairs per machine: the staircase, with its 95% band shaded.
- ② power law λt^β (β = 0.855): the pooled fit, bending slightly downwards.



Interactive Plot

Event plot — each repair on its machine's timeline

- Each pump's record as a grey line to its last repair, each repair as a dot: PA's line ends at 954, PB's at 920.1.



Interactive Plot

Total time on test — trend at a glance

- ① constant rate (diagonal).
- ② scaled TTT: under the diagonal over the first half - the early repairs come a little early in their windows - then on it; the tests find no trend.

MCF LIFE TABLE (THIS WORKSHEET — 2 MACHINES, 17 EVENTS)

1 ΔMCF = 1/(machines still observed at that age); variance is the naive Poisson form Σ d/r² with normal bounds (convention stated, single-machine identity: MCF = its cumulative count).

2 Age	3 Machine	4 At risk	5 ΔMCF	6 MCF	7 SE	8 95% bounds
31.3	PA	2	0.5000	0.5000	0.5000	[0.0000, 1.4800]
36.9	PB	2	0.5000	1.0000	0.7071	[0.0000, 2.3859]
53.3	PA	2	0.5000	1.5000	0.8660	[0.0000, 3.1974]
97.6	PB	2	0.5000	2.0000	1.0000	[0.0400, 3.9600]
163.4	PA	2	0.5000	2.5000	1.1180	[0.3087, 4.6913]
215.3	PB	2	0.5000	3.0000	1.2247	[0.5995, 5.4005]
321.5	PA	2	0.5000	3.5000	1.3229	[0.9072, 6.0928]
361.4	PB	2	0.5000	4.0000	1.4142	[1.2282, 6.7718]
414.4	PA	2	0.5000	4.5000	1.5000	[1.5601, 7.4399]
483.5	PB	2	0.5000	5.0000	1.5811	[1.9010, 8.0990]
588.9	PA	2	0.5000	5.5000	1.6583	[2.2498, 8.7502]
660.2	PB	2	0.5000	6.0000	1.7321	[2.6052, 9.3948]
723.1	PA	2	0.5000	6.5000	1.8028	[2.9666, 10.0334]
774.4	PB	2	0.5000	7.0000	1.8708	[3.3332, 10.6668]
831.2	PA	2	0.5000	7.5000	1.9365	[3.7045, 11.2955]
920.1	PB	2	0.5000	8.0000	2.0000	[4.0801, 11.9199]
954	PA	1	1.0000	9.0000	2.2361	[4.6174, 13.3826]

MCF life table (this worksheet — 2 machines, 17 events)

- ① ΔMCF = 1/(machines still observed at that age); variance is the naive Poisson form Σ d/r² with normal bounds (convention stated, single-machine identity: MCF = its cumulative count).
- ② to ⑧ The columns Age, Machine, At risk, ΔMCF, MCF, SE, 95% bounds: seventeen rows. The last repair, PA's at 954, has 1 pump at risk - PB's record ended at 920.1 - so it adds 1.0000 and the MCF ends at 9.0000.

PER-MACHINE FITS + COMMON-B VERDICT (THIS WORKSHEET — 2 MACHINES, 17 EVENTS)

1 Common-β likelihood ratio = 0.0225 (χ^2, 1 dof) → p = 0.8807: one fleet — pooling is defensible.

2 Machine	3 Events	4 Observed to	5 β (own fit)
6 PA	9	954	0.8268
7 PB	8	920.1	0.8894

Per-machine fits + common-β verdict (this worksheet — 2 machines, 17 events)

- ① Common-β likelihood ratio = 0.0225 (χ^2, 1 dof) → p = 0.8807: one fleet — pooling is defensible.
- ② to ⑤ The columns Machine, Events, Observed to, β (own fit).
- ⑥ PA: 9 events, observed to 954, β 0.8268.
- ⑦ PB: 8 events, observed to 920.1, β 0.8894.

NEXT STEP — RENEWAL PATH (FLEET FIT)

1 The growth test keeps β = 1: repairs are neither bunching nor spacing. The defensible next step is a Weibull analysis of the INTER-ARRIVAL GAPS (Time Dependence ▸ Weibull 2P) — that treats each repair as a renewal, an assumption this verdict just made explicit.

Next step — renewal path (fleet fit)

- ① The growth test keeps β = 1: repairs are neither bunching nor spacing. The defensible next step is a Weibull analysis of the INTER-ARRIVAL GAPS (Time Dependence ▸ Weibull 2P) — that treats each repair as a renewal, an assumption this verdict just made explicit.

1 `Licensed to ReliaEn Training · RL-2026-0017`

The report's foot

- ① The licence line Licensed to ReliaEn Training · RL-2026-0017: the licence the report was made under.

Part 5 — How to interpret the results

The three tests agree. The pooled β is 0.8551 with bounds 0.4982 to 1.3070, and the growth test gives p = 0.458; the Laplace test gives u = -0.3071, p = 0.7588; the Anderson-Darling test gives A^2 = 1.0197, p = 0.3471. None rejects a constant repair rate: plan with a constant rate, and the renewal path the report names - a Weibull fit of the gaps between repairs - is the next step.

Direction and size. The sign of u gives the direction: slightly below 0, repairs a little early in the windows, but well within chance. A^2 gives no direction: two mirror-image logs give the same A^2. The TTT curve shows the same at a glance: a little under the diagonal at first, then on it.

The windows matter. Without an observation-end column each pump's window ends at its last repair: 954 hours for PA, 920.1 hours for PB. Those two repairs lie on the ends of their windows and are left out of the Anderson-Darling test. If the true observation ends are known, enter them: they change the inputs of every trend test.

One fleet. The pumps' own β values, 0.8268 and 0.8894, are close, and the common-β test gives p = 0.8807: the pooled verdict describes both pumps.