Weibull (2P) — the shape tells wear-out from random failure

Menu: Life Data ▸ Time Dependence ▸ Weibull (2P) distribution…

Part 1 — What the function does

What it calculates. The Weibull model gives the share of units failed by age t as F(t) = 1 − e^(−(t/η)^β). The shape β says how the failure risk changes with age: below 1 it falls (early failures), at 1 it stays flat (random failures), above 1 it grows (wear-out). The scale η is the characteristic life, the age by which 63.2 % of units have failed. ReliaEn fits β and η by maximum likelihood, using the ages of the units still running as well as the failures, with bounds, and gives the lives, a fit check, the service intervals and two plots.

What ReliaEn prints	What it tells you
β̂ — shape with bounds, and one sentence	Whether the risk falls, stays flat or grows with age
η̂ — scale (characteristic life) with bounds	The age by which 63.2 % of units have failed
MTTF, **B10 life**, **B50 life (median)**, **λ̄**	The average life, the age by which one unit in ten and half the units have failed, the average failure rate
PPCC fit check	Whether the Weibull model is rejected at the 5 % level
SERVICE INTERVALS	The longest run before service that keeps the reliability at 95 %, 90 %, …
Percentile table with bounds	By what age a share of units has failed
Age Replacement Optimization (with the two costs entered)	The cheapest replacement age and the saving against running to failure

From which data. The failure ages in one worksheet column, one row per failed unit; the ages of units still running, if any, in a different column. The form also reads counts of failures per inspection interval.

When an engineer uses it. When parts that are replaced, not repaired, fail at different ages, and the questions are whether they wear out, by what age one in ten has failed, and whether a planned replacement age pays.

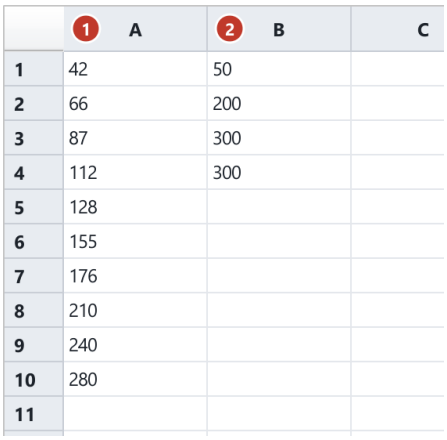
When not to use it.

Situation	Use instead
One repairable system fails again and again, and you have its event log	Life Data ▸ Estimate Failure Function ▸ Repairable unit data…
The part cannot fail before a certain age (a failure-free period)	Life Data ▸ Time Dependence ▸ Weibull (3P) distribution…
Only whether a constant failure rate is enough is wanted	Life Data ▸ Time Dependence ▸ Exponential distribution…

Part 2 — The example's input data

Setting. A pump-seal test rig runs 14 seals: ten fail during the test, four are still sealing when it ends. The reliability engineer wants to know whether the seals wear out, by what age one in ten has failed, and how long a seal can run and still be 90 % sure to hold.

Input	Value
Failure ages, hours (10)	42, 66, 87, 112, 128, 155, 176, 210, 240, 280
Survivor ages, hours (4)	50, 200, 300, 300
File in the worked-example zip	2-Weibull-2P/Example-1.csv — columns Failure times (10) and Censored times (4)
Confidence %	95 — the value the form opens with



	① A	② B	C
1	42	50	
2	66	200	
3	87	300	
4	112	300	
5	128		
6	155		
7	176		
8	210		
9	240		
10	280		
11			

The example data in the worksheet

- ① Column A: the 10 failure ages, one per row, in hours.
- ② Column B: the 4 survivor ages.

Part 3 — How to use it, step by step

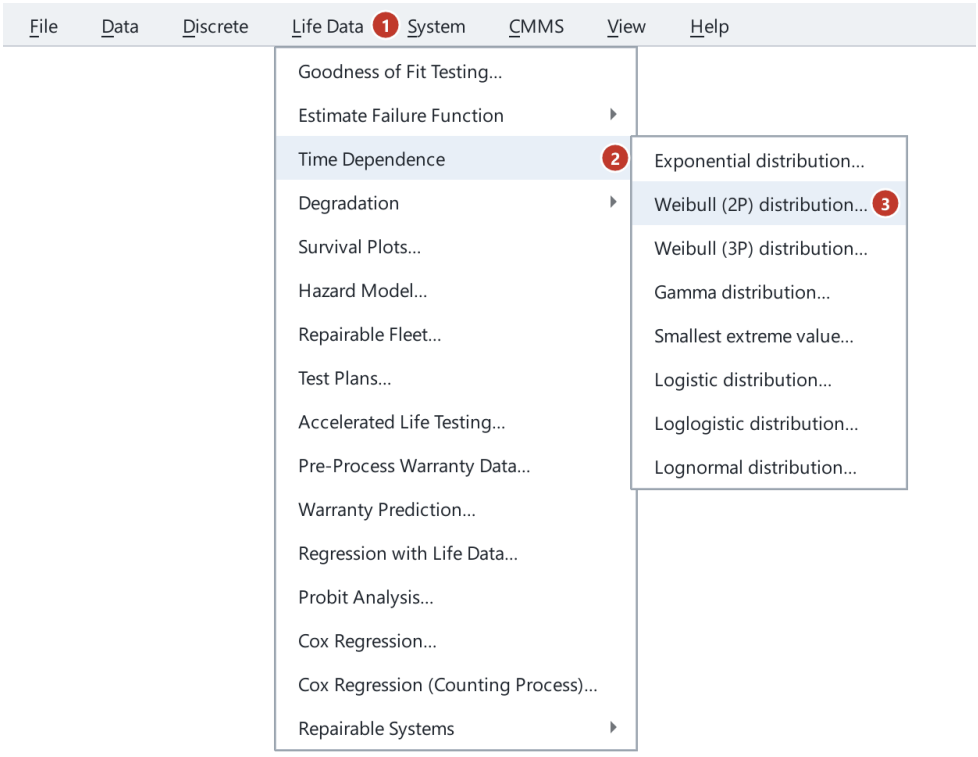
1. **Put the failure ages in column A and the survivor ages in column B.** Copy the values of Example-1.csv that stand under its headings Failure times and Censored times into columns A and B of the worksheet, starting at row 1.

	① A	② B	C
1	42	50	
2	66	200	
3	87	300	
4	112	300	
5	128		
6	155		
7	176		
8	210		
9	240		
10	280		
11			

Step 1 — the failure and survivor ages in columns A and B

- ① Column A: the 10 failure ages, 42 to 280.
- ② Column B: the 4 survivor ages, 50 to 300.

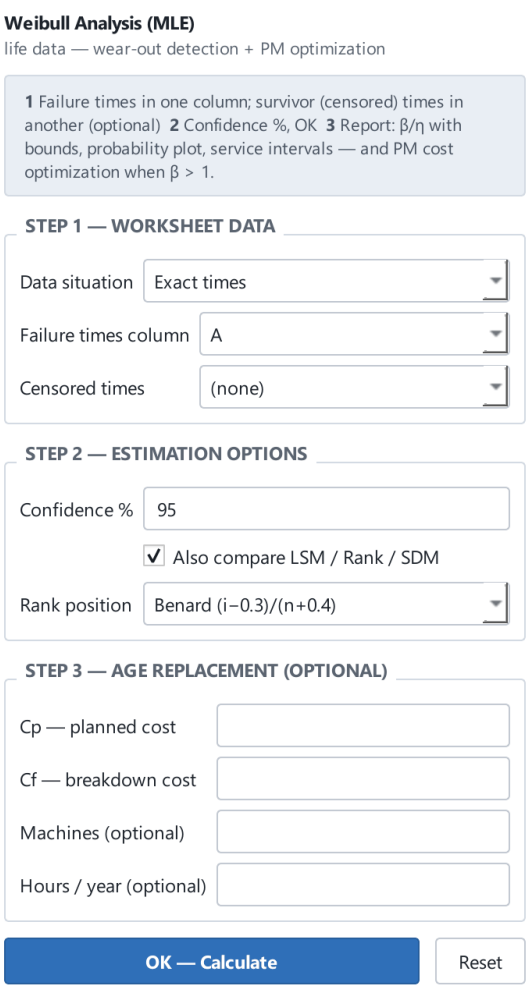
2. **Choose Life Data ▸ Time Dependence ▸ Weibull (2P) distribution...** in the menu bar. The form Weibull Analysis (MLE) opens in the left panel.



Step 2 — the menu path

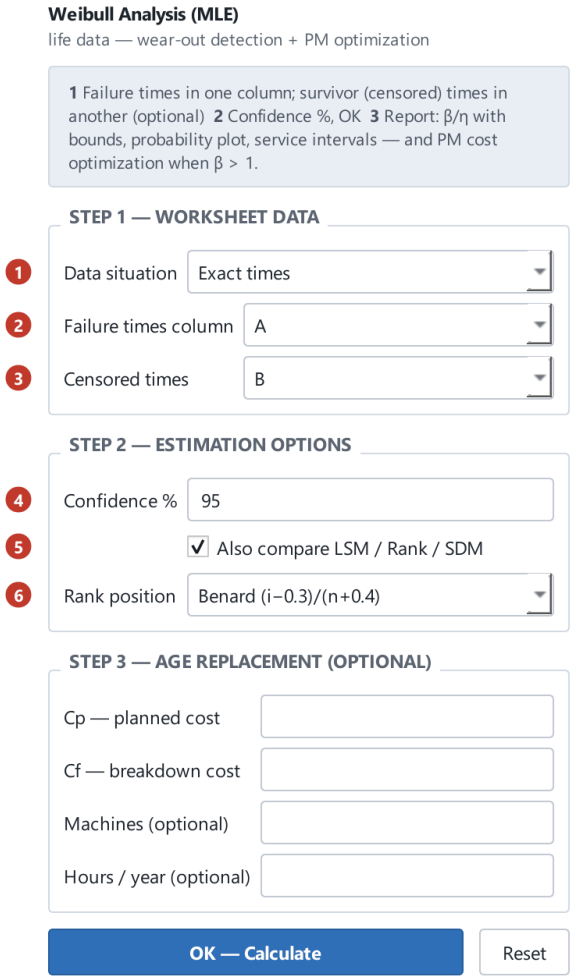
- ① Life Data: the menu.
- ② Time Dependence: the submenu.
- ③ Weibull (2P) distribution...: the entry to click.

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



Step 2 — the form as it opens

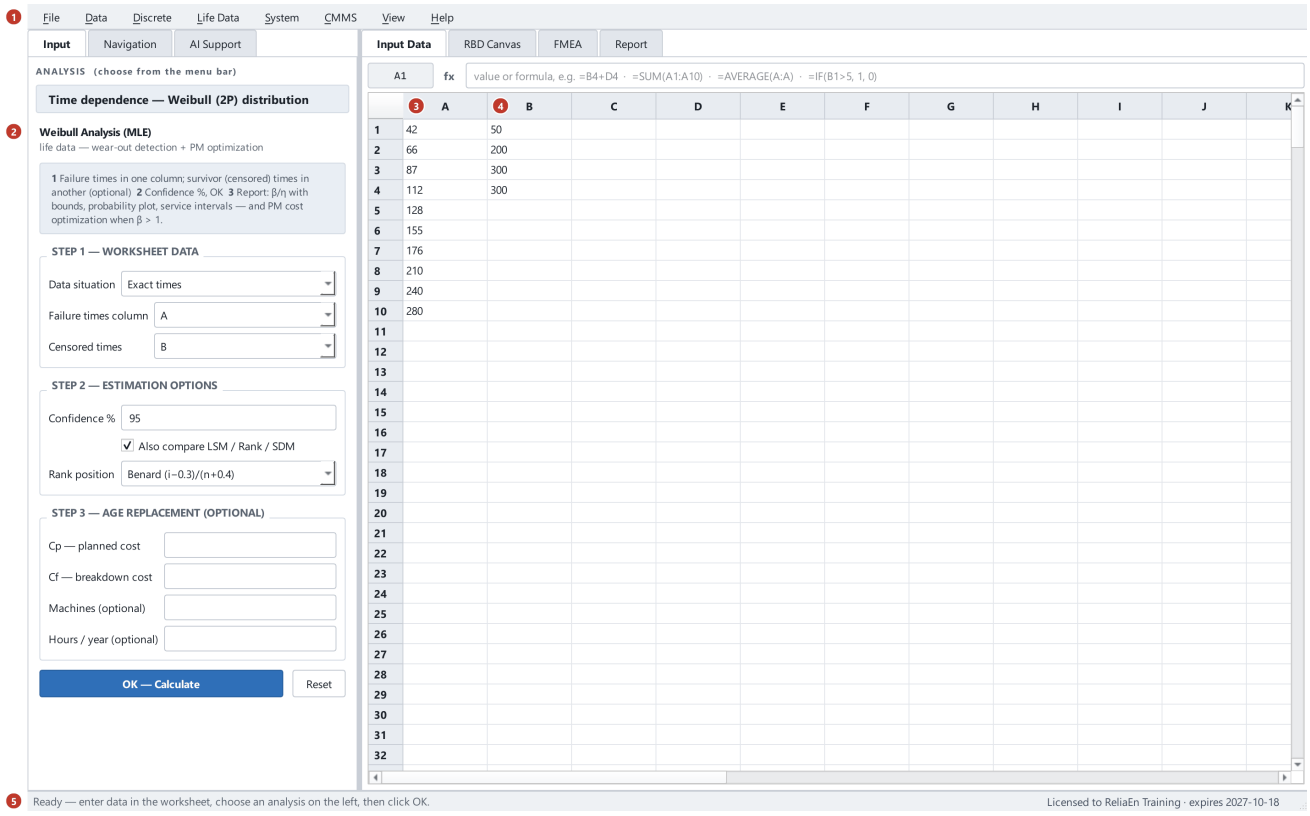
Steps 3 to 8 set or check the form's six boxes, marked ① to ⑥ in the picture:



Steps 3 to 8 — the form set for this example

3. ① **Check that Data situation reads Exact times.**
4. ② **In Failure times column, choose A.**
5. ③ **In Censored times, choose B.** Column B holds the four seals still sealing when the test ended.
6. ④ **Check that Confidence % reads 95.**
7. ⑤ **Check that Also compare LSM / Rank / SDM is ticked.** It asks for the least-squares, rank and SDM fits beside the MLE; with survivors in column B the report withholds them and says why (Part 4).
8. ⑥ **Check that Rank position reads Benard (i−0.3)/(n+0.4).** It places the failures on the probability plot. The boxes of STEP 3 — AGE REPLACEMENT (OPTIONAL) stay empty in this example.

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



Step 9 — 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 8; OK — Calculate at its foot.
- ③ Column A: the 10 failure ages.
- ④ Column B: the 4 survivor 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 — Weibull (2P) — Time Dependence

2026-11-04 07:17:52

$R(t) = e^{-(t/\eta)^{\beta}}$; $h(t) = (\beta/\eta)\cdot(t/\eta)^{\beta-1}$

The report's head

- The title Life Data — Weibull (2P) — Time Dependence, the date and time of the run, and the model in one line: R(t) = e^{−(t/η)^β}; h(t) = (β/η)·(t/η)^{β−1}.

INPUT DATA

1	n — units on test	14
2	r — failures	10
3	censored (survivors)	4
4	Estimation	Maximum likelihood (right-censored)

Input data

- ① n — units on test 14.
- ② r — failures 10.
- ③ censored (survivors) 4: the seals still sealing at the end of the test.
- ④ Estimation Maximum likelihood (right-censored).

RESULTS

1	$\hat{\beta}$ — shape	1.8157 [1.08449, 3.03994]
2	$\hat{\eta}$ — scale (characteristic life)	223.278 [158.705, 314.123]
3	MTTF = η·Γ(1 + 1/β)	198.477
4	B10 life	64.6524
5	B50 life (median)	182.465
6	Average failure rate $\bar{\lambda}$ (0→MTTF)	0.00406858

Results

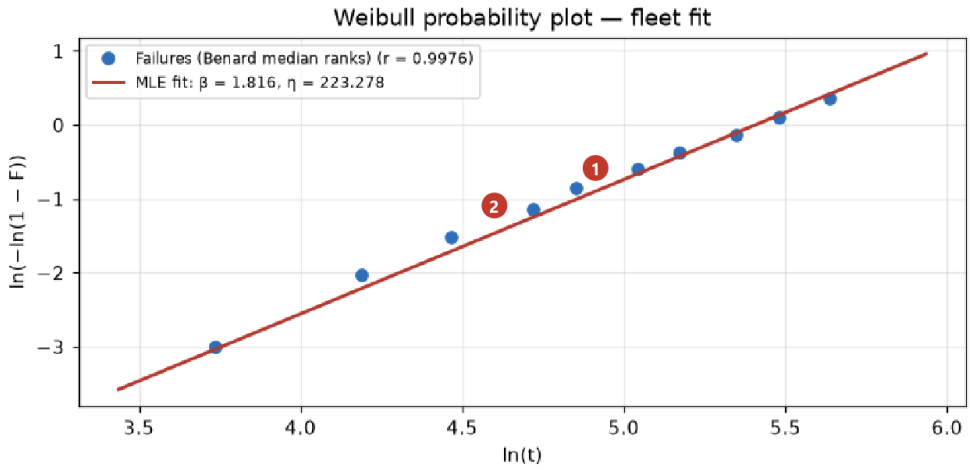
- ① $\hat{\beta}$ — shape 1.8157 [1.08449, 3.03994]: the bounds lie wholly above 1 - the seals wear out.
- ② $\hat{\eta}$ — scale (characteristic life) 223.278 [158.705, 314.123]: the age by which 63.2 % of the seals have failed.
- ③ MTTF = η·Γ(1 + 1/β) 198.477.
- ④ B10 life 64.6524: one seal in ten has failed by this age.
- ⑤ B50 life (median) 182.465.
- ⑥ Average failure rate $\bar{\lambda}$ (0→MTTF) 0.00406858: failures per hour, averaged from new to the MTTF.

INTERPRETATION

1 The Weibull fit gives shape β = 1.8157 and characteristic life η = 223.278 (63.2% of units fail by η). Interpretation: wear-out (β > 1 with confidence): failure risk grows with age — preventive replacement can pay. MTTF = 198.477; 10% of units fail by B10 = 64.6524.

Interpretation

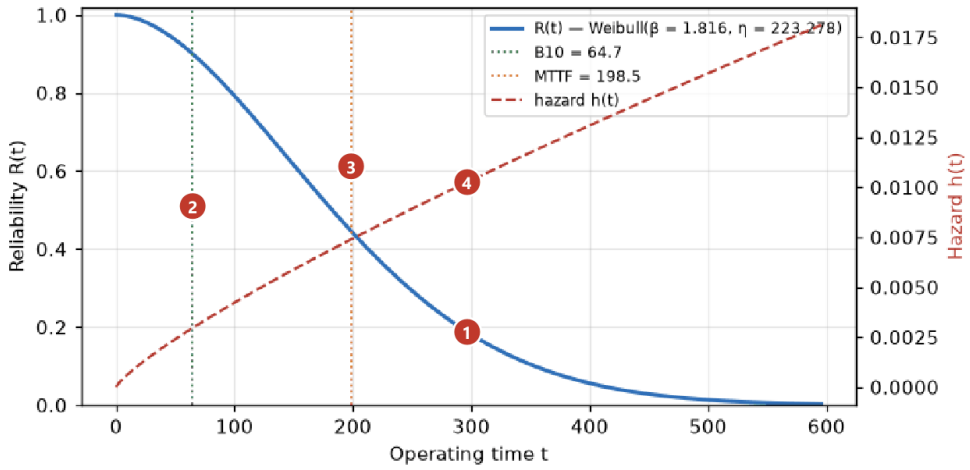
- ① ReliaEn's reading: The Weibull fit gives shape β = 1.8157 and characteristic life η = 223.278 (63.2% of units fail by η). Interpretation: wear-out (β > 1 with confidence): failure risk grows with age — preventive replacement can pay. MTTF = 198.477; 10% of units fail by B10 = 64.6524.



Interactive Plot

Weibull probability plot — fleet fit

- ① Failures (Benard median ranks) (r = 0.9976): the 10 failure ages on Weibull paper.
- ② MLE fit: β = 1.816, η = 223.278: the fitted line; the points lie close along it.



Interactive Plot

Reliability and hazard

- ① R(t) — Weibull(β = 1.816, η = 223.278): the share of seals still sealing at each age.
- ② B10 = 64.7: where R crosses 90%.
- ③ MTTF = 198.5: R is about 0.45 there - the mean life is not the age by which half have failed.
- ④ hazard h(t): rising with age, the mark of wear-out.

PROBABILITY-PLOT FIT CHECK (PPCC, 5% LEVEL) — FLEET FIT

1. Weibull NOT rejected — points follow the line (r = 0.9976 ≥ critical 0.9095).
2. PPCC = Probability-Plot Correlation Coefficient. r measures how straight the failure points lie on the probability plot (1 = perfectly straight). The critical value is the straightness that TRUE Weibull data of this same sample size would still fall below 5% of the time — so r ≥ critical means the plot is straight enough to trust the Weibull model, and r < critical means the pattern would be unusual for real Weibull data.

Probability-plot fit check (PPCC, 5% level) — fleet fit

- ① Weibull NOT rejected — points follow the line (r = 0.9976 ≥ critical 0.9095).
- ② The note on what the PPCC r and its critical value mean.

ESTIMATION METHOD COMPARISON — NOT SHOWN

1 Method comparison suppressed: censored data present — LSM/Rank/SDM are complete-data methods and would bias short (guide example 2).

Estimation method comparison — not shown

- ① Method comparison suppressed: censored data present — LSM/Rank/SDM are complete-data methods and would bias short (guide example 2). The tick of step 7 is answered here.

SERVICE INTERVALS — OPERATING TIME TO STAY AT OR ABOVE TARGET RELIABILITY

1 Model: Weibull(β = 1.816, η = 223.278) — service before the unit accumulates this much operating time to keep reliability at or above the target.

2 Target R	3 Operating time t
95%	43.5
4 90%	64.7
85%	82.1
80%	97.7
75%	112.4
70%	126.5
65%	140.4
60%	154.2
55%	168.2
50%	182.5
45%	197.3
40%	212.8
35%	229.3
30%	247.3
25%	267.3
20%	290.2
15%	317.7
10%	353.5
5%	408.6

SERVICE INTERVALS — operating time to stay at or above target reliability

- ① Model: Weibull(β = 1.816, η = 223.278) — service before the unit accumulates this much operating time to keep reliability at or above the target.
- ② and ③ The columns Target R and Operating time t, 19 rows from 95% to 5%.
- ④ The 90% row: 64.7 - the B10 of the results card.

PERCENTILE TABLE — B-LIVES WITH BOUNDS

1 B_p = the age by which p% of units fail. Bounds by each family's own interval machinery; a — cell means no bound machinery exists for that family — the point estimate stands alone.

2 Percentile	3 B-life	4 95% bounds
1%	17.72	[4.582, 68.55]
5%	43.49	[17.46, 108.3]
5 10%	64.65	[31.25, 133.8]
25%	112.4	[68.61, 184.2]
50%	182.5	[127.6, 261]
75%	267.3	[187.8, 380.4]
90%	353.5	[233.7, 534.5]
95%	408.6	[258, 647.1]
99%	517.8	[299, 896.7]

Percentile table — B-lives with bounds

- ① B_p = the age by which p% of units fail. Bounds by each family's own interval machinery; a — cell means no bound machinery exists for that family — the point estimate stands alone.
- ② to ④ The columns Percentile, B-life, 95% bounds.
- ⑤ The 10% row: 64.65 [31.25, 133.8] - the B10 with its bounds.

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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

Do the seals wear out? β̂ is 1.8157 and its 95 % bounds, 1.08449 to 3.03994, lie wholly above 1: the risk of failure grows with age. Replacing a seal before it fails can pay; with the planned and breakdown costs entered on the form, the Age Replacement Optimization card gives the cheapest age.

When the seals fail. By the characteristic life η̂ = 223.278 hours about two seals in three have failed. The average life is 198.477 hours and half the seals have failed by 182.465 hours, but one seal in ten has failed by 64.6524 hours (B10) — long before the average. Plan against B10, not against the MTTF.

How long a seal can run. The SERVICE INTERVALS card answers by the consequence of a failure: to stay at 90 % reliability, service before 64.7 hours; at 95 %, before 43.5 hours. When an early failure is costly, plan with the B10 lower bound in the percentile table rather than the estimate.

Never drop the survivors. The four seals still sealing are evidence that a seal lasts at least that long. A fit without them describes a shorter-lived seal than the one on the rig, and with survivors present ReliaEn withholds the least-squares comparison, which would bias the life short.