Failure-censored data — the constant failure rate from a test that stopped at the r-th failure

Menu: Life Data ▸ Estimate Failure Function ▸ Failure-censored data...

Part 1 — What the function does

What it calculates. You put **n** units on test and stopped the test **at the moment of the r-th failure**, a number decided in advance. You know the r failure ages; the other n − r units were still running when that last failure happened. The function estimates the **constant failure rate** $\hat{\lambda}$ and the **mean time to failure** (MTTF), puts two-sided chi-square (χ^2) confidence intervals on both, and gives the age by which one unit in ten has failed and how long a unit can run at each target reliability. It counts the survivors' running time up to that last failure.

What ReliaEn prints	What it tells you
t_r	The end of the test: the largest failure age you entered
TTT = Σ t + (n − r)·t_r	The total time on test: the failure ages plus the survivors' time up to t_r
$\hat{\lambda}$ = r / TTT	Failures per unit of operating time
MTT$\hat{F}$ = 1 / $\hat{\lambda}$	The mean life of a unit
λ and MTTF intervals	The range that holds the true rate and the true mean life at your confidence level; both ends use 2r degrees of freedom, because the last failure is fully observed
B10 life and **SERVICE INTERVALS**	The age by which 10% of units fail, and the longest run that keeps each target reliability from 95% down to 5%

From which data. The r failure ages in one worksheet column, one row per failure, each above 0; the number of units on test n is typed in the form. The form has no test-end field: ReliaEn takes t_r as the largest age. The survivors are not typed in: n counts them.

When an engineer uses it. When every unit started at time 0, every survivor ran until the r-th failure, and the failure rate is constant with age (no wear-out, no early failures) - a test planned as "stop when four have failed".

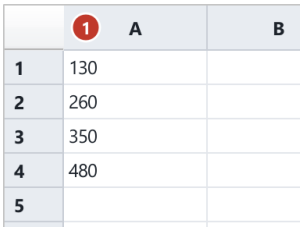
When not to use it.

Situation	Use instead
Every unit failed	Life Data ▸ Estimate Failure Function ▸ Complete data...
The test stopped at a fixed, planned time	Life Data ▸ Estimate Failure Function ▸ Time-censored data...
The survivors were removed at different ages	Life Data ▸ Time Dependence ▸ Exponential distribution..., with a censored column
The rate may not be constant	Life Data ▸ Goodness of Fit Testing...; Life Data ▸ Time Dependence ▸ Weibull (2P) distribution...

Part 2 — The example's input data

Setting. Ten pumps start an endurance run together. The plan is to stop the run the moment the fourth pump fails. The fourth failure comes at 480 hours, and six pumps are still running. The reliability engineer wants the pumps' failure rate and mean life with honest bounds.

Input	Value
Failure ages, operating hours (r = 4)	130, 260, 350, 480
File in the worked-example zip	2-Failure-Censored-Data/Example-1.csv — one column, heading Failure times, 4 rows
n — total units on test	10 — typed in the form
Confidence % (two-sided)	95 — the value the form opens with



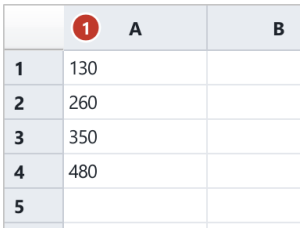
	A	B
1	130	
2	260	
3	350	
4	480	
5		

The example data in the worksheet

- ① Column A: the 4 failure ages, one per row, in operating hours. The six survivors are not in the worksheet.

Part 3 — How to use it, step by step

1. **Put the failure ages in column A.** Copy the 4 values of Example-1.csv that stand under its heading Failure times into column A of the worksheet, starting at row 1. Enter only the failures.

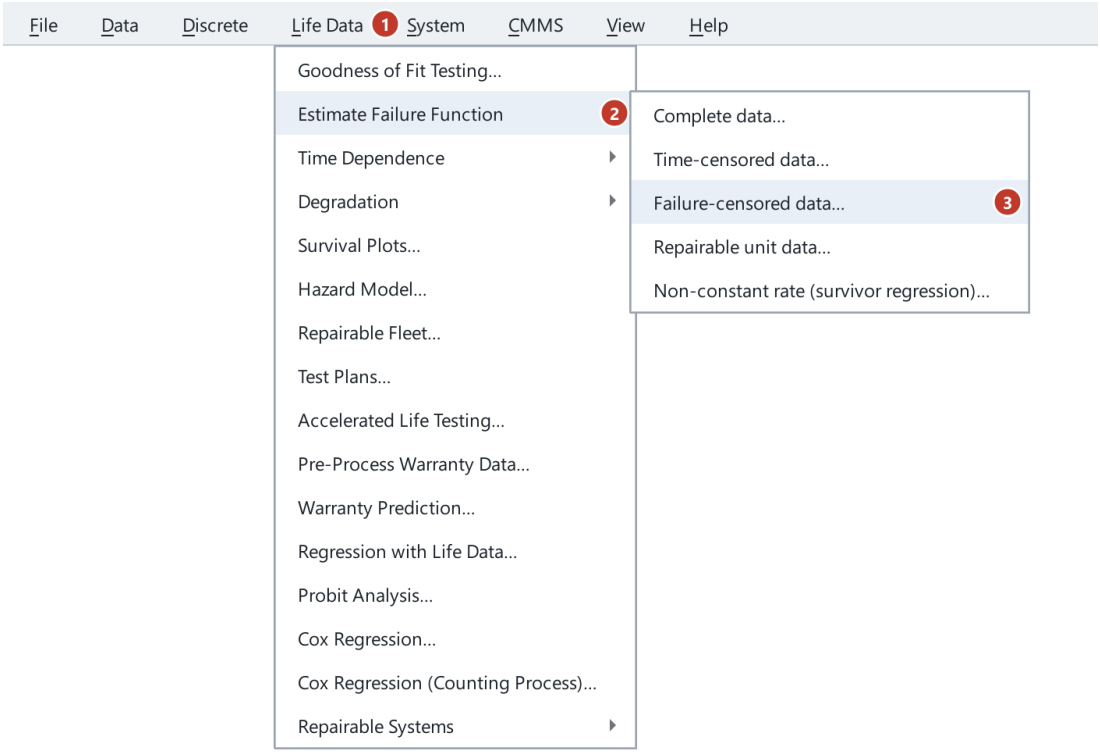


	A	B
1	130	
2	260	
3	350	
4	480	
5		

Step 1 — the failure ages in column A

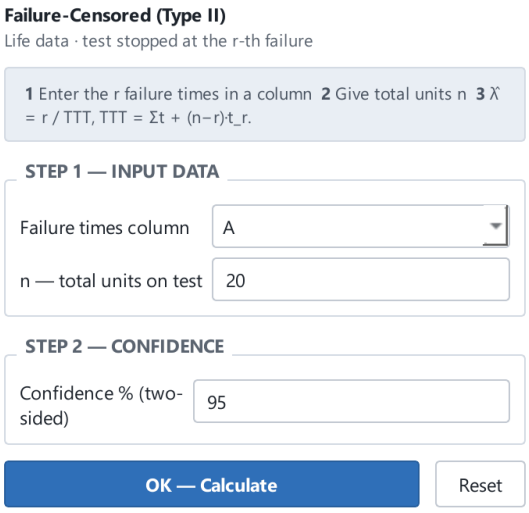
- ① Column A: the 4 failure ages, 130 to 480.

2. **Choose Life Data ▸ Estimate Failure Function ▸ Failure-censored data...** in the menu bar. The form Failure-Censored (Type II) opens in the left panel.



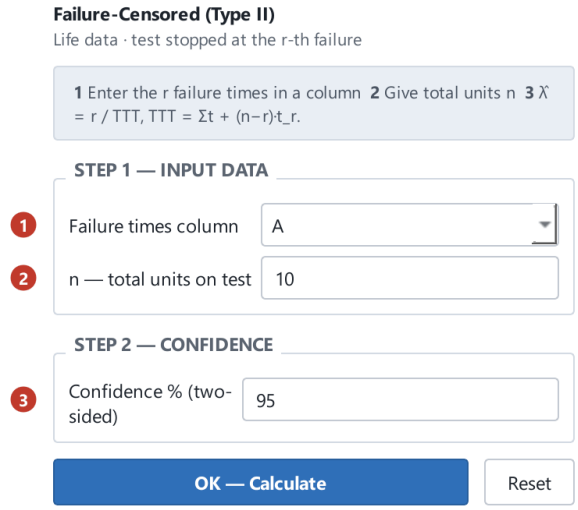
Step 2 — the menu path

- ① Life Data: the menu.
- ② Estimate Failure Function: the submenu.
- ③ Failure-censored data...: the entry to click.



Step 2 — the form as it opens

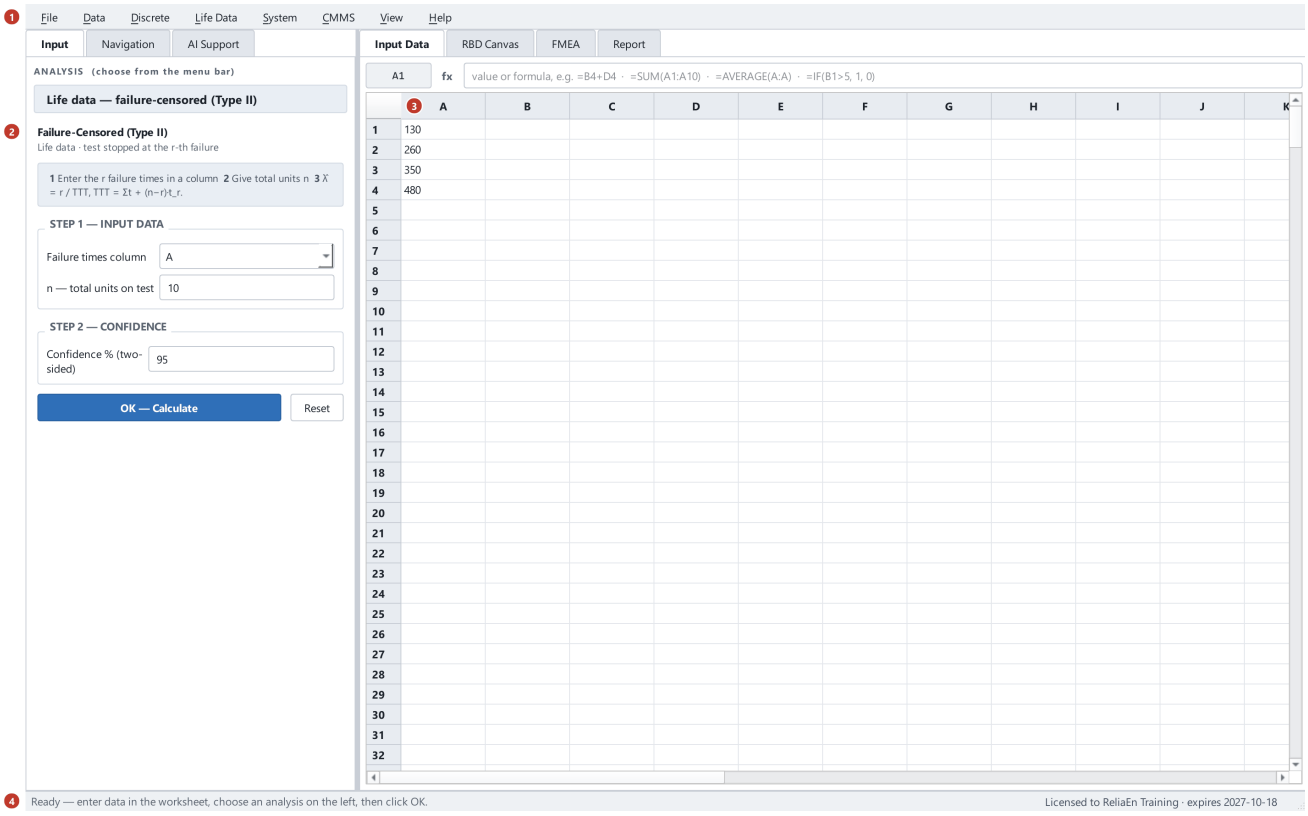
Steps 3 to 5 set the form's three boxes, marked ① to ③ in the picture:



Steps 3 to 5 — the form set for this example

3. ① **In Failure times column, choose A.** This is the column that holds the failure ages.
4. ② **In n — total units on test, type 10.** All the units on test, the six survivors included. The form opens with 20.
5. ③ **Check that Confidence % (two-sided) reads 95.** The confidence level of every interval in the report, on the rate and on the mean life.

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



Step 6 — 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 5; OK — Calculate at its foot.
- ③ Column A: the 4 failure ages.
- ④ 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 — Exponential (Failure-censored (Type II))

2026-10-30 14:49:22

λ̂ = r / TTT ; χ² confidence limits

The report's head

- The title Life Data — Exponential (Failure-censored (Type II)), the date and time of the run, and the method in one line: $\hat{\lambda} = r / TTT$; χ^2 confidence limits.

INPUT DATA

1	Data situation	Failure-censored (Type II)
2	n — units on test	10
3	r — failures	4
4	t_r — r-th failure time	480
5	TTT — total time on test	4100
6	Confidence level	95% (two-sided)

Input data

- ① Data situation Failure-censored (Type II): the kind of data ReliaEn used.
- ② n — units on test 10: the units on test, as typed in step 4.
- ③ r — failures 4: the ages ReliaEn read from column A. Check r first: a blank cell is skipped, and r would then be lower than the failures you entered.
- ④ t_r — r-th failure time 480: the end of the test, the largest age in column A.
- ⑤ TTT — total time on test 4100: the four ages (1,220 hours) plus six survivors × 480 hours (2,880 hours).
- ⑥ Confidence level 95% (two-sided): the level set in step 5.

RESULTS

1	$\hat{\lambda} = r / TTT$	0.00097561
2	$MTT\hat{F} = 1 / \hat{\lambda}$	1025
3	λ 95% CI	[0.000265821, 0.00213836]
4	MTTF 95% CI	[467.648, 3761.93]
5	B10 life	107.995

Results

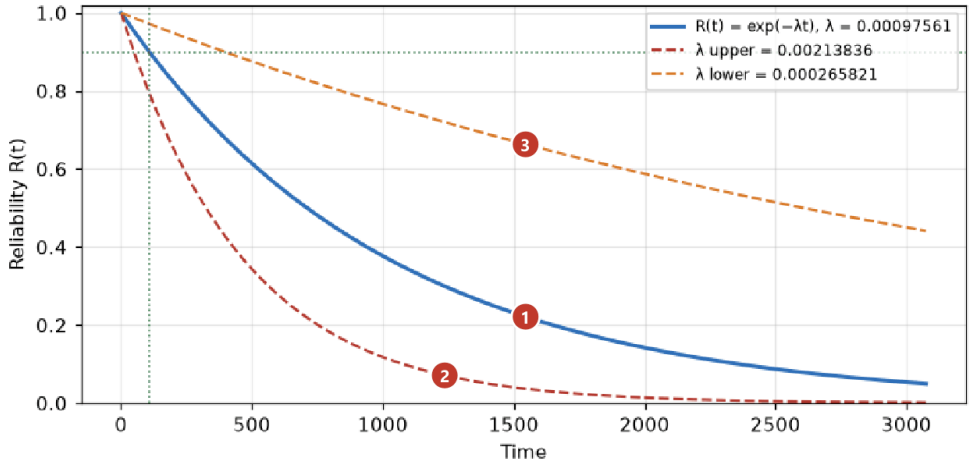
- ① $\hat{\lambda} = r / TTT$ 0.00097561: 4 failures in 4,100 hours, about 0.98 failures per 1,000 operating hours.
- ② $MTT\hat{F} = 1 / \hat{\lambda}$ 1025: the mean life of a pump, in operating hours.
- ③ λ 95% CI [0.000265821, 0.00213836]: the range that holds the true rate with 95% confidence. Both ends use 2r = 8 degrees of freedom.
- ④ MTTF 95% CI [467.648, 3761.93]: the same statement for the mean life - each end is the reciprocal of the other interval's opposite end.
- ⑤ B10 life 107.995: one pump in ten has failed by this age.

INTERPRETATION

1 The exponential model estimates a failure rate of λ = 0.00097561 per unit time (MTTF = 1025). With 95% confidence the true MTTF lies between 467.648 and 3761.93. 10% of the population is expected to fail by t = 107.995 (B10). Exact χ^2 limits per the censoring type were used (2r dof).

Interpretation

- ① ReliaEn's sentence: The exponential model estimates a failure rate of λ = 0.00097561 per unit time (MTTF = 1025). With 95% confidence the true MTTF lies between 467.648 and 3761.93. 10% of the population is expected to fail by t = 107.995 (B10). Exact χ^2 limits per the censoring type were used (2r dof). The rate, the mean life and its interval, B10, and the χ^2 rule: 2r degrees of freedom at both ends.



Interactive Plot

Reliability against operating time

- ① R(t) = exp(−λt), λ = 0.00097561: the share of pumps still running at each operating time, at the estimated rate.
- ② λ upper = 0.00213836: the curve at the upper rate - the cautious one, falling fastest.
- ③ λ lower = 0.000265821: the curve at the lower rate. The true curve lies between ② and ③ with 95% confidence.

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

1 Model: Exponential(λ = 0.00097561) — 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%	52.6
4 90%	108.0
85%	166.6
80%	228.7
75%	294.9
70%	365.6
65%	441.6
60%	523.6
55%	612.8
50%	710.5
45%	818.5
40%	939.2
35%	1,076.1
30%	1,234.1
25%	1,421.0
20%	1,649.7
15%	1,944.5
10%	2,360.1
5%	3,070.6

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

- ① Model: Exponential(λ = 0.00097561) — service before the unit accumulates this much operating time to keep reliability at or above the target.
- ② Target R: the reliability to keep, from 95% down to 5%.
- ③ Operating time t: the longest run that keeps it, t = −ln(R) / λ̂.
- ④ The 90% row: to keep the reliability at or above 90%, a pump may run 108.0 hours - B10, rounded.

PREVENTIVE-MAINTENANCE OPTIMIZATION — NOT APPLICABLE

1 β = 1 — the exponential model is memoryless: a serviced machine is statistically identical to a repaired one, so preventive replacement cannot reduce failures (D23/D25). If wear-out is suspected, fit the Weibull model instead.

Preventive-Maintenance Optimization — not applicable

- ① β = 1 — the exponential model is memoryless: a serviced machine is statistically identical to a repaired one, so preventive replacement cannot reduce failures (D23/D25). If wear-out is suspected, fit the Weibull model instead. Under a constant rate a used pump is as good as a new one, so the report computes no replacement age.

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 decision. The best estimate of a pump's mean life is 1025 operating hours ($\hat{\lambda}$ = 0.00097561 failures per hour), but four failures only place it between 467.648 and 3761.93 hours at 95% confidence. For a commitment - spares, a warranty reserve, an availability claim - plan with the conservative end: the upper rate 0.00213836 per hour, which is the same statement as the lower mean life 467.648 hours. $\hat{\lambda}$ is the most likely value, not a promise.

Why the kind of test matters. The six pumps still running at the fourth failure add 2,880 of the 4,100 test hours; leaving them out would give a mean life of 305 hours (1,220 / 4). And because the test stopped *at* a failure, nothing was missed after it: both limits use 2r degrees of freedom. Read as a test stopped at a fixed 500 hours, the same four failures give TTT 4220 and an upper limit with 2r + 2 degrees of freedom (chapter 2.3). Declare the test you actually ran.

How much the data can tell. The upper rate is about eight times the lower one. The width of the interval depends on the number of failures r: four failures give a wide interval. If it is too wide to decide on, plan the next test to stop at a later failure; more calculation does not narrow it.

What follows for maintenance. One pump in ten has failed by 107.995 hours (B10). The service-interval table gives the longest run that keeps each target reliability, 108.0 hours for 90%. These rows assume the constant rate. Under a constant rate a used pump is as good as a new one, so replacing pumps early buys nothing - the report says so on its last card. If you suspect wear-out, test the constant rate (Life Data ▸ Goodness of Fit Testing…) or fit the Weibull model.