Residence Time Distribution: Tanks-in-Series Number and Conversion

Equivalent number of tanks in series from the mean and variance of a tracer residence time distribution, and the first-order conversion it predicts.

Method: Levenspiel; Chemical Reaction Engineering; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Mean residence time	10.000	min
Standard deviation of the RTD	3.3333	min
First-order rate constant	0.24000	1/min

Calculated results

Parameter	Value	Unit
Equivalent tanks in series	9.0000	
First-order conversion with N tanks	88.087	%
Conversion in plug flow	90.928	%
Equivalent axial Péclet number (closed vessel, large Pe)	18.000	

Notes for this case

- N from the variance: σ²/t_m² = 1/N. For large N the dispersion model gives about the same with Pe ≈ 2N.

Formula and method

$$N = \frac{t_m^2}{\sigma^2}, \quad X_N = 1 - \left(1 + \frac{k t_m}{N}\right)^{-N}$$

Variables

t_m	Mean residence time	s
σ	Standard deviation of the RTD	s
k	First-order rate constant	1/s
N	Equivalent tanks in series	-
X_N	First-order conversion with N tanks	-
X_{PFR}	Conversion in plug flow	-
Pe	Equivalent axial Péclet number (closed vessel, large Pe)	-

Method and standards

Tanks-in-series model.

Assumptions and limits

- First order; N from variance.
- N below 1 (a spread wider than one stirred tank) is outside the model and is flagged; Pe ≈ 2N is flagged as rough for N below 5.

References

- Levenspiel
- Chemical Reaction Engineering
- 3rd ed. (Wiley, 1999)
- ch. 14 (tanks-in-series model)

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/chemical/reactors/rtd-tanks-in-series

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.