Power-Law (Non-Newtonian) Fluid Pressure Drop in a Pipe

Pressure drop of a power-law fluid in a pipe: Metzner–Reed Reynolds number, laminar f = 16/Re, and the Wilson–Thomas turbulent friction factor (Perry's sec. 6).

Method: Perry's Chemical Engineers' Handbook; 9th ed. (McGraw-Hill, 2019); ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Consistency index K (Pa·s^n) Always in Pa·s^n: 1 lbf·s^n/ft² = 47.880 Pa·s^n; 1 dyn·s^n/cm² (poise-type) = 0.1 Pa·s^n.	5.0000	
Flow behaviour index n	0.50000	
Density	1,100.0	kg/m³
Pipe inside diameter	77.900	mm
Mean velocity	1.5000	m/s
Pipe length	100.00	m

Calculated results

Parameter	Value	Unit
Generalised consistency K' (Pa·s^n)	5.5902	
Metzner–Reed Reynolds number	285.38	
Fanning friction factor	0.056066	
Wall shear stress	69.382	Pa
Pressure drop	356.26	kPa
Regime (0 laminar, 1 turbulent)	0	

Notes for this case

- Smooth pipe; for time-dependent or viscoelastic fluids the transition may move to higher Re.

Formula and method

$$Re_{MR} = \frac{D^n V^{2-n} \rho}{K' 8^{n-1}}, \quad K' = K\left(\frac{1+3n}{4n}\right)^n, \quad f = \frac{16}{Re_{MR}} \ \text{(laminar)}$$

$$\frac{1}{\sqrt{f}} = \frac{1}{\sqrt{f_N}} + 8.2\frac{1-n}{1+n} + 1.77\ln\frac{1+n}{2}, \quad \Delta p = 4f\frac{L}{D}\frac{\rho V^2}{2}$$

Variables

K	Consistency index K (Pa·s^n)	-
n	Flow behaviour index n	-
ρ	Density	kg/m³
D	Pipe inside diameter	m
V	Mean velocity	m/s
L	Pipe length	m
K'	Generalised consistency K' (Pa·s^n)	-
Re_{MR}	Metzner–Reed Reynolds number	-
f	Fanning friction factor	-
τ_w	Wall shear stress	Pa

Δp	Pressure drop	Pa
regime	Regime (0 laminar, 1 turbulent)	-

Method and standards

Metzner–Reed generalised Reynolds number; Wilson–Thomas turbulent correction; f_N for a Newtonian fluid at the wall viscosity.

Assumptions and limits

- Time-independent power-law fluids; smooth pipes.
- K is entered in Pa·s^n in every unit system.
- Laminar–turbulent switch at a fixed Re_MR of 2 100; the critical Reynolds number of power-law fluids depends on n (it rises for strongly shear-thinning fluids), so results near the switch are uncertain.

References

- Perry's Chemical Engineers' Handbook
- 9th ed. (McGraw-Hill, 2019)
- sec. 6
- Eqs. (6-64) to (6-69) (Metzner and Reed; Wilson and Thomas)
- Smooth-pipe Newtonian friction 1/√f = 4 log(Re√f) − 0.4 (Prandtl–Kármán)

Report details

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

This calculator online

https://calc.firecad.com/mechanical/fluid-mechanics/power-law-fluid-pipe-flow

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Reopens the calculator with the inputs of this report.