Free Jet: Centreline Velocity, Spread and Entrainment

Centreline and off-axis velocity of a turbulent free jet from a round nozzle or a slot, and the entrained flow at a distance (Perry's Table 6-7 and Rushton).

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

Input parameters

Unit system: SI

Parameter	Value	Unit
Jet type	Round nozzle	
Nozzle diameter or slot width	50.000	mm
Jet exit velocity	20.000	m/s
Distance from the nozzle	2.0000	m
Distance from the centreline	0.10000	m
Round-jet constant	6.2 (V_0 10–50 m/s)	
Kinematic viscosity (for Rushton)	15.000	cSt

Calculated results

Parameter	Value	Unit
Centreline velocity	3.1000	m/s
Velocity at the off-axis distance	2.4624	m/s
Flow ratio (jet plus entrained)	12.800	
Total flow at x (per metre of slot length for a slot)	1,809.6	m³/h
Centreline velocity by Rushton (round jets)	3.1580	m/s

Notes for this case

- Air into air (Perry's Table 6-7); a water jet spreads at about 14° and entrains about 70 % as much.

Formula and method

$$\frac{V_c}{V_0} = K\frac{D_0}{x}, \quad \log\frac{V_c}{V_r} = 40\left(\frac{r}{x}\right)^2, \quad \frac{q}{q_0} = 0.32\frac{x}{D_0} \ \text{(round)}$$

$$\frac{V_c}{V_0} = 2.28\left(\frac{B_0}{x}\right)^{0.5}, \quad \log\frac{V_c}{V_y} = 18.4\left(\frac{y}{x}\right)^2, \quad \frac{q}{q_0} = 0.62\left(\frac{x}{B_0}\right)^{0.5} \ \text{(slot)}$$

Variables

type	Jet type	-
D_0	Nozzle diameter or slot width	m
V_0	Jet exit velocity	m/s
x	Distance from the nozzle	m
r	Distance from the centreline	m
K	Round-jet constant	-
ν	Kinematic viscosity (for Rushton)	m²/s
V_c	Centreline velocity	m/s
V_r	Velocity at the off-axis distance	m/s
q/q_0	Flow ratio (jet plus entrained)	-
q	Total flow at x (per metre of slot length for a slot)	m³/s

$V_{c,Rushton}$	Centreline velocity by Rushton (round jets)	m/s

Method and standards

Free-jet correlations.

Assumptions and limits

- Free jets into still fluid of the same density.
- Rushton (round jets only): V_c/V₀ = 1.41 (V₀D₀/ν)^0.135 D₀/x. The centreline velocity is capped at V₀ near the nozzle and q/q₀ at 1.
- For a slot the flow is per metre of slot length.

References

- Perry's Chemical Engineers' Handbook
- 9th ed. (McGraw-Hill, 2019)
- sec. 6
- Table 6-7 (turbulent free jets) and Eq. (6-110) (Rushton, AIChE J. 26: 1038, 1980)

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/free-jet-velocity-entrainment

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.