Francis Turbine Velocity Triangles, Blade Angles and Efficiency

Inlet and outlet velocity triangles, guide vane and blade angles, Euler work, hydraulic efficiency and power of a Francis runner with radial discharge.

Input parameters

Unit system: SI

Parameter	Value	Unit
Net head	60.000	m
Flow	43,200	m^3/h
Speed	250.00	rpm
Runner inlet diameter	2.0000	m
Runner inlet width	0.30000	m
Runner outlet diameter	1.4000	m
Runner outlet width (axial area = $\pi D_2 B_2$)	0.50000	m
Guide vane angle	18.000	°
Area factor for blade thickness	95.000	%
Water density	1,000.0	kg/m^3

Calculated results

Parameter	Value	Unit
Runner inlet peripheral speed	26.180	m/s
Inlet flow velocity	6.7013	m/s
Inlet whirl velocity	20.624	m/s
Absolute inlet velocity	21.686	m/s
Runner blade inlet angle	129.66	°
Outlet peripheral speed	18.326	m/s
Outlet flow velocity	5.7439	m/s
Runner blade outlet angle	17.403	°
Hydraulic efficiency $u_1V_w1/(gH)$	91.765	%
Power developed by the runner	6,479.3	kW
Speed ratio	0.76316	
Flow ratio	0.19535	

Notes for this case

- Radial (whirl-free) discharge is assumed, so the Euler work is u_1V_w1. A blade inlet angle above 90° marks a fast runner.

Formula and method

$$u = \frac{\pi D N}{60}, \quad V_f = \frac{Q}{k\pi D B}, \quad V_{w1} = \frac{V_{f1}}{\tan\alpha_1}, \quad \tan\beta_1 = \frac{V_{f1}}{V_{w1} - u_1}, \quad \tan\beta_2 = \frac{V_{f2}}{u_2}$$

$$\eta_h = \frac{u_1 V_{w1}}{gH}, \quad P = \rho Q u_1 V_{w1}$$

Variables

H	Net head	m
Q	Flow	m^3/s
N	Speed	rad/s
D_1	Runner inlet diameter	m
B_1	Runner inlet width	m
D_2	Runner outlet diameter	m
B_2	Runner outlet width (axial area = $\pi D_2 B_2$)	m
α_1	Guide vane angle	rad
k	Area factor for blade thickness	-
ρ	Water density	kg/m^3
u_1	Runner inlet peripheral speed	m/s
V_{f1}	Inlet flow velocity	m/s
V_{w1}	Inlet whirl velocity	m/s
V_1	Absolute inlet velocity	m/s
β_1	Runner blade inlet angle	rad
u_2	Outlet peripheral speed	m/s
V_{f2}	Outlet flow velocity	m/s
β_2	Runner blade outlet angle	rad
η_h	Hydraulic efficiency $u_1V_w1/(gH)$	-
P	Power developed by the runner	W
$u_1/\sqrt{2gH}$	Speed ratio	-
$V_{f1}/\sqrt{2gH}$	Flow ratio	-

Method and standards

Euler turbine equation with one-dimensional velocity triangles.

Assumptions and limits

- One-dimensional flow, radial discharge.

Report details

Report reference	FCC-CQVY-BWTE (the same inputs always give the same reference)
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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/boilers-power-plant/hydro-power/francis-turbine-velocity-triangles

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Reopens the calculator with the inputs of this report.