Boiler Circulation Ratio, Downcomer and Riser Velocity

Circulation ratio and circulating water flow of a natural-circulation boiler from riser exit quality, with downcomer and riser velocities (IAPWS-IF97).

Method: Definition of circulation ratio; homogeneous two-phase density; IAPWS R7-97 IF97

Input parameters

Unit system: SI

Parameter	Value	Unit
Steam generated	50,000	kg/h
Steam quality at riser exit	10.000	%
Drum pressure (absolute)	68.000	bar
Number of downcomers	4.0000	
Downcomer inside diameter	250.00	mm
Number of risers (evaporator tubes)	400.00	
Riser inside diameter	50.000	mm

Calculated results

Parameter	Value	Unit
Circulation ratio (1/x from the quality entered)	10.000	
Circulating water flow	500,000	kg/h
Downcomer water velocity	0.95163	m/s
Riser inlet velocity	0.23791	m/s
Riser exit mixture velocity (homogeneous)	0.71420	m/s

Notes for this case

- Assumes saturated water in the downcomers and a homogeneous mixture at the riser exit; real slip between phases lowers the mixture velocity.

Formula and method

$$CR = \frac{1}{x} \qquad \dot{m}_c = \frac{\dot{m}_s}{x} \qquad v_{dc} = \frac{\dot{m}_c v_f}{A_{dc}} \qquad v_{r,in} = \frac{\dot{m}_c v_f}{A_r} \qquad v_{r,out} = \frac{\dot{m}_c (x v_g + (1-x) v_f)}{A_r}$$

Variables

$\dot{m}_s$	steam generated	kg/s
x	riser exit quality	–
p	drum pressure	Pa
N_{dc}	downcomers	–
d_{dc}	downcomer bore	m
N_r	risers	–
d_r	riser bore	m
CR	circulation ratio	–
$\dot{m}_c$	circulating flow	kg/s
v_{dc}	downcomer velocity	m/s
$v_{r,in}$	riser inlet velocity	m/s
$v_{r,out}$	riser exit mixture velocity	m/s
v_f, v_g	saturated water and steam specific volume (IF97)	m³/kg

A_{dc}, A_r	total downcomer and riser flow areas	m²

Method and standards

Mass balance of the circuit with saturated water in downcomers and a homogeneous mixture at the riser exit; saturation properties from FireCAD's IAPWS-IF97.

Assumptions and limits

- Saturated water in downcomers; homogeneous flow (no slip) at the riser exit.
- The circulation ratio is $1/x$ from the quality you enter, not from a pressure balance of the circuit; the natural circulation driving head calculator checks whether the circuit can deliver it.
- A note appears for downcomer velocities above about 4 m/s.

References

• Definition of circulation ratio; homogeneous two-phase density
• IAPWS R7-97 IF97

Report details

Report reference	FCC-8D4V-FC3B (the same inputs always give the same reference)
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Release checks	3 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/boilers-power-plant/boiler-pressure-parts/evaporator-circulation

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.