Void Fraction and Two-Phase Density (Homogeneous and Zivi)

Homogeneous and Zivi void fractions and the two-phase mixture density of steam–water at a pressure and quality, with saturated densities from IF97.

Method: Homogeneous model; Zivi (1964) slip S = (ρ_l/ρ_v)^1/3; saturated densities from IAPWS-IF97 (Collier and Thome, Convective Boiling and Condensation)

Input parameters

Unit system: SI

Parameter	Value	Unit
Pressure (absolute)	70.000	bar
Steam quality (mass)	10.000	%

Calculated results

Parameter	Value	Unit
Saturated water density	739.72	kg/m³
Saturated steam density	36.524	kg/m³
Void fraction, homogeneous	69.234	%
Mixture density, homogeneous	252.87	kg/m³
Void fraction, Zivi slip	45.223	%
Mixture density, Zivi	421.72	kg/m³

Notes for this case

- Zivi's slip ratio (ρ_l/ρ_v)^1/3 suits annular-type flow; the homogeneous model assumes no slip.

Formula and method

$$\alpha = \frac{1}{1 + \frac{1-x}{x}\frac{\rho_v}{\rho_l}S}, \quad \rho = \alpha\rho_v + (1-\alpha)\rho_l, \quad S_Z = (\rho_l/\rho_v)^{1/3}$$

Variables

p	Pressure (absolute)	Pa
x	Steam quality (mass)	-
ρ_l	Saturated water density	kg/m³
ρ_v	Saturated steam density	kg/m³
α_h	Void fraction, homogeneous	-
ρ_h	Mixture density, homogeneous	kg/m³
α_Z	Void fraction, Zivi slip	-
ρ_Z	Mixture density, Zivi	kg/m³

Method and standards

Void fraction from the quality and the saturated densities (IAPWS-IF97) with a slip ratio S: S = 1 for the homogeneous model and S = (ρ_l/ρ_v)^1/3 for Zivi; the mixture density is the void-weighted mean. At zero quality the void fraction is zero and the density that of saturated water.

Assumptions and limits

- Saturated two-phase flow.
- Zivi's slip is derived for annular flow; in bubbly and churn flow at low quality (typical of risers) it tends to underpredict the void, so the mixture density and circulation head it gives are on the high side. Use a drift-flux model for those regimes.

References

• Homogeneous model; Zivi (1964) slip S = (ρ_l/ρ_v)^1/3; saturated densities from IAPWS-IF97 (Collier and Thome, Convective Boiling and Condensation)

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/boilers-power-plant/boiler-pressure-parts/void-fraction-two-phase-density

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.