Steam–Water Sampling: Line Lag Time and Sample Cooler Duty

Transit time of a sample line from bore, length and flow, and the sample cooler duty and cooling water for a hot sample (IF97 enthalpy).

Method: Continuity for the lag; energy balance with IAPWS-IF97 enthalpies for the cooler

Input parameters

Unit system: SI

Parameter	Value	Unit
Sample line bore	6.0000	mm
Line length	40.000	m
Sample flow (cold)	0.50000	L/min
Sample pressure (absolute)	70.000	bar
Sample	Water (liquid; saturated water at the saturation temperature)	
Sample temperature (steam or water)	285.00	°C
Cooled sample temperature	25.000	°C
Cooling water rise	8.0000	K

Calculated results

Parameter	Value	Unit
Transit time in the line	2.2619	min
Sample velocity in the line (cold)	0.29473	m/s
Cooler duty	9.6218	kW
Cooling water	1,034.2	kg/h

Notes for this case

- Transit time is for cold liquid; hot or steam samples move faster before the cooler. A velocity near 1.5–2 m/s (common practice, not a cited limit) limits deposits in the line.
- The line velocity is only 0.29 m/s: iron and copper particles may settle. A smaller bore or more flow raises it.

Formula and method

$$t_l = \frac{\pi d^2 L}{4\dot{V}}, \quad v = \frac{4\dot{V}}{\pi d^2}, \quad \dot{m} = \dot{V}\rho(T_2), \quad \dot{Q} = \dot{m}[h(p,T_1) - h(T_2)], \quad \dot{m}_w = \frac{\dot{Q}}{c_w \Delta T_w}$$

Variables

d	Sample line bore	m
L	Line length	m
$\dot{V}$	Sample flow (cold)	m³/s
p	Sample pressure (absolute)	Pa
sample	Water (liquid) or steam (dry saturated or superheated)	–
T_1	Sample temperature (steam or water)	K
T_2	Cooled sample temperature	K
ΔT_w	Cooling water rise	K
t_l	Transit time in the line	s

v	Sample velocity in the line (cold)	m/s
$\dot{Q}$	Cooler duty	W
$\dot{m}_w$	Cooling water	kg/s
$\dot{m}$	Sample mass flow	kg/s
$\rho(T_2)$	Density of the cooled sample	kg/m³
c_w	Cooling water specific heat, 4 186.8	J/(kg·K)

Method and standards

Continuity; energy balance.

Assumptions and limits

- Steady flow.
- The cooled sample is at 1 atm; cooling water c_w = 4 186.8 J/(kg·K).
- The 1.5–2 m/s velocity is common practice, not a cited limit; lower velocities are flagged.
- At the saturation temperature the sample choice decides the state: saturated water, or dry saturated steam (the duties differ by the latent heat). A water sample above, or a steam sample below, the saturation temperature is rejected. Above the critical pressure the state follows from pressure and temperature alone.

References

• Continuity for the lag; energy balance with IAPWS-IF97 enthalpies for the cooler

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/water-treatment/sample-line-lag-and-cooler

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.