Tube Wall Thermal Stress from Heat Flux

Temperature difference across a boiler tube or shell wall from the heat flux and the resulting thermal stress at the surfaces, E α ΔT / 2(1 − ν).

Method: Thermal stress of a thin wall with a linear temperature gradient (Timoshenko and Goodier, Theory of Elasticity)

Input parameters

Unit system: SI

Parameter	Value	Unit
Heat flux through the wall	250.00	kW/m²
Wall thickness	6.0000	mm
Wall thermal conductivity	40.000	W/(m·K)
Modulus of elasticity at metal temperature From the material standard at the mean metal temperature.	190,000	MPa
Thermal expansion coefficient	13.000	µm/(m·K)
Poisson's ratio	0.30000	

Calculated results

Parameter	Value	Unit
Thermal stress at the surfaces (compressive on the heated side, tensile on the cooled side)	66.161	MPa
Temperature difference across the wall	37.500	K

Notes for this case

- Thermal stress adds to the pressure stress; the boiler code you design to sets how the two are combined and the allowable values.

Formula and method

$$\Delta T = \frac{q'' t}{k} \qquad \sigma_t = \frac{E \alpha \Delta T}{2 (1 - \nu)}$$

Variables

q''	heat flux	W/m²
t	wall thickness	m
k	conductivity	W/(m·K)
E	modulus of elasticity	Pa
α	thermal expansion coefficient	1/K
ν	Poisson's ratio	–
σ_t	thermal stress at the surfaces (compressive on the heated side, tensile on the cooled side)	Pa
ΔT	temperature difference across the wall	K

Method and standards

Linear temperature gradient through a thin wall restrained against bending, giving equal and opposite surface stresses (Timoshenko and Goodier).

Assumptions and limits

- Thin wall, linear gradient, elastic material; no stress concentration at holes.
- For thick drums and headers the logarithmic temperature profile changes the surface stresses: use the thick cylinder thermal stress calculator there.

References

- Thermal stress of a thin wall with a linear temperature gradient (Timoshenko and Goodier, Theory of Elasticity)

Report details

Report reference	FCC-TN43-GC7X (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/tube-thermal-stress

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.