Effect of Scale on Boiler Tube Metal Temperature

Rise in boiler tube metal temperature caused by a layer of scale on the water side, from the heat flux, scale thickness and conductivity, by conduction through layers in series.

Method: One-dimensional conduction through layers in series (Fourier's law)

Input parameters

Unit system: SI

Parameter	Value	Unit
Heat flux through the tube wall	60.000	kW/m²
Boiler water temperature (saturation)	184.00	°C
Water-side (boiling) coefficient	20,000	W/(m²·K)
Tube wall thickness	4.0000	mm
Conductivity of the tube steel	45.000	W/(m·K)
Scale thickness	1.0000	mm
Conductivity of the scale Depends strongly on the scale: porous silicate scale conducts far less than dense carbonate. Use a measured or published value for your scale.	1.0000	W/(m·K)

Calculated results

Parameter	Value	Unit
Water-side metal temperature, clean tube	187.00	°C
Gas-side metal temperature, clean tube	192.33	°C
Gas-side metal temperature with scale	252.33	°C
Metal temperature rise caused by the scale	60.000	K
Thermal resistance of the scale t_s / k_s	0.001000	m²·K/W

Notes for this case

- Flat-wall layers in series at the same heat flux: for thin tubes the curvature changes the result by only a few per cent. Overheating, not fuel loss, is the main danger of scale.

Formula and method

$$T_{in} = T_w + \frac{q}{h_w}, \quad T_{o,0} = T_{in} + q\,\frac{t_m}{k_m}$$

$$\Delta T_s = q\,\frac{t_s}{k_s}, \quad T_o = T_{o,0} + \Delta T_s, \quad T_{in,s} = T_{in} + \Delta T_s$$

Variables

q	Heat flux through the tube wall	W/m²
T_w	Boiler water temperature (saturation)	K
h_w	Water-side (boiling) coefficient	W/(m²·K)
t_m	Tube wall thickness	m
k_m	Conductivity of the tube steel	W/(m·K)
t_s	Scale thickness	m
k_s	Conductivity of the scale	W/(m·K)
T_{in}	Water-side metal temperature, clean tube	K
$T_{o,0}$	Gas-side metal temperature, clean tube	K

T_o	Gas-side metal temperature with scale	K
ΔT_s	Metal temperature rise caused by the scale	K
R_s	Thermal resistance of the scale t_s / k_s	m²·K/W
$T_{in,s}$	water-side metal temperature behind the scale (not an output)	K

Method and standards

At one heat flux each layer's temperature drop is q × its thermal resistance; scale adds a resistance t_s/k_s between the metal and the water.

Assumptions and limits

- Flat-wall layers; same heat flux with and without scale, and the same flux through every layer. For a thick tube the flux on the inside surface is higher than on the outside by the diameter ratio; enter the inside-surface flux to be on the safe side for the water film and scale.
- A note appears when the gas-side metal is above about 450 °C; compare the result with the allowable temperature of your tube material.
- Scale conductivity entered by the user.

References

- One-dimensional conduction through layers in series (Fourier's law)

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/scale-tube-metal-temperature

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.