Boiler Start-up Heat, Time and Heating Rate

Heat to bring a boiler's water and steel from cold to working pressure, the time it takes at a start-up firing rate, and the average heating rate (IAPWS-IF97).

Method: IAPWS R7-97(2012) IF97; first law of thermodynamics

Input parameters

Unit system: SI

Parameter	Value	Unit
Water in the boiler	12.000	t
Pressure-part steel heated with the water	25.000	t
Mean specific heat of the steel Carbon steel is about 0.45–0.52 kJ/(kg·K) over this range.	0.48000	kJ/(kg·K)
Starting temperature (water and steel)	30.000	°C
Working pressure (absolute)	10.500	bar
Start-up firing rate (fuel heat input)	2,000.0	kW
Share of the firing heat that reaches water and steel	60.000	%

Calculated results

Parameter	Value	Unit
Time to reach working pressure	2.2151	h
Average heating rate	68.629	°C/h
Heat needed	9.5691	GJ
Of which to the water	7.7449	GJ
Of which to the steel	1.8242	GJ
Saturation temperature at working pressure	182.02	°C

Notes for this case

• Compare the heating rate with the boiler maker's start-up curve: thick drums and headers limit how fast the saturation temperature may rise.

Formula and method

$$Q_w = M_w \left[h_f(p) - h(p, T_0)\right] \qquad Q_m = M_m\, c_m\, (T_{sat} - T_0) \qquad Q = Q_w + Q_m$$

$$t = \frac{Q}{\eta_s\, \dot{Q}_f} \qquad \dot{T} = \frac{T_{sat} - T_0}{t}$$

Variables

M_w	water in the boiler	kg
M_m	steel heated with the water	kg
c_m	mean specific heat of the steel	J/(kg·K)
T_0	starting temperature	K
p	working pressure, absolute	Pa
$\dot{Q}_f$	start-up firing rate	W
η_s	share of firing heat reaching water and steel	–
t	time to working pressure	s
$\dot{T}$	average heating rate	K/s

Q	heat needed	J
Q_w	heat to the water	J
Q_m	heat to the steel	J
T_{sat}	saturation temperature at working pressure	K
$h_f\$, \$h$	water enthalpies (IF97)	J/kg

Method and standards

Energy balance of the water and steel from the starting temperature to saturation at working pressure; water enthalpies from FireCAD's IAPWS-IF97. Steam vented during start-up and refractory heat are not included.

Assumptions and limits

- Water mass constant; uniform temperature of water and steel; no venting or refractory heat.
- The heating rate is an average from T_0 to T_{sat}. The saturation temperature does not rise linearly in time, and the boiler maker's limit applies to the instantaneous rate, which can be higher than the average.

References

- IAPWS R7-97(2012) IF97
- first law of thermodynamics

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/boilers/boiler-start-up-heat

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.