Boiler Warm-Up Time with Hot Gas

Time for hot gas to heat a boiler's water and steel between two temperatures, from the water equivalent, gas flow and UA, by Ganapathy's warm-up balance.

Method: Ganapathy; Steam Plant Calculations Manual; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Steel mass (tubes, drums, casing)	50,000	kg
Steel specific heat	0.50240	kJ/(kg·K)
Water mass	30,000	kg
Gas flow	20.000	t/h
Gas specific heat	1.1300	kJ/(kg·K)
Gas inlet temperature	500.00	°C
Initial water/steel temperature	30.000	°C
Final water/steel temperature	180.00	°C
Overall conductance of the heating surface	40.000	kW/K

Calculated results

Parameter	Value	Unit
Water equivalent (heat per kelvin)	150.72	MJ/K
e^(UA/W_g c_pg)	585.04	
Warm-up time	2.5681	h
Average heating rate	58.409	°C/h

Notes for this case

- The average warm-up rate, 58 K/h, is above the 55 K/h that drum makers often allow; throttle the gas flow or temperature to keep thermal stress down.
- Above 100 °C the boiler must be under pressure to stay unboiled; heat into steaming and venting is not included, and the water specific heat rises above 4.19 kJ/(kg·K) (about 4.4 at 180 °C), so the time is somewhat short.

Formula and method

$$z = \frac{MC\,K}{W_g c_{pg}(K-1)} \ln \frac{T_{g1} - t_1}{T_{g1} - t_2}, \quad K = e^{UA/(W_g c_{pg})}, \quad MC = M_s c_s + M_w c_w$$

Variables

M_s	Steel mass (tubes, drums, casing)	kg
c_s	Steel specific heat	J/(kg·K)
M_w	Water mass	kg
W_g	Gas flow	kg/s
c_{pg}	Gas specific heat	J/(kg·K)
T_{g1}	Gas inlet temperature	K
t_1	Initial water/steel temperature	K
t_2	Final water/steel temperature	K
UA	Overall conductance of the heating surface	W/K
MC	Water equivalent, heat per kelvin (displayed in MJ, read as MJ/K)	J/K

K	e^(UA/W_g c_pg)	-
Z	Warm-up time	s
dt/dz	Average heating rate	K/s
c_w	Water specific heat 4 186.8	J/(kg·K)

Method and standards

Ganapathy's integrated warm-up balance.

Assumptions and limits

- Water and metal at one temperature; no losses.
- Constant water specific heat 4.1868 kJ/(kg·K) and no steaming: the final temperature should be below saturation at the boiler pressure. Above 100 °C the time is somewhat short because the specific heat rises.
- A warning appears when the average rate exceeds 55 K/h, a common drum maker's limit.

References

- Ganapathy
- Steam Plant Calculations Manual
- 2nd ed. (Marcel Dekker, 1993)
- Q4.44
- Eqs. (77)–(80)

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-heat-up-time-gas

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Reopens the calculator with the inputs of this report.