Boiler Efficiency at Low Fire (Burner Turndown)

Boiler efficiency at low fire from full-fire efficiency, the flue gas O_2 and temperature at both loads and the radiation loss, which rises as load falls.

Method: Stack loss from the combustion balance (NIST Shomate gas properties); ASME PTC 4 loss method

Input parameters

Unit system: SI

Parameter	Value	Unit
Carbon	45.000	%
Hydrogen	3.5000	%
Oxygen	5.0000	%
Nitrogen	1.0000	%
Sulphur	0.50000	%
Ash	35.000	%
Moisture	10.000	%
Air humidity (kg water per kg dry air)	0.013000	kg/kg
Gross calorific value of the fuel, as fired	18,600	kJ/kg
O_2 in dry flue gas at full fire	4.0000	%
Flue gas temperature at full fire	180.00	°C
O_2 in dry flue gas at low fire	7.0000	%
Flue gas temperature at low fire	140.00	°C
Combustion air temperature	30.000	°C
Boiler efficiency at full fire (on GCV)	80.000	%
Radiation and unaccounted loss at full fire	1.0000	%
Low fire as a share of full fire	30.000	%

Calculated results

Parameter	Value	Unit
Excess air at full fire	22.852	%
Excess air at low fire	48.591	%
Sensible flue gas loss at full fire	7.1361	%
Sensible flue gas loss at low fire	6.1815	%
Radiation and unaccounted loss at low fire	3.3333	%
Boiler efficiency at low fire	78.621	%
Change from full fire (points)	-1.3787	%

Notes for this case

- The radiation loss in kW is taken as the same at both loads, so its share rises as the load falls; burner purges and on–off cycling add more.

Formula and method

$$L_g = \frac{\dot{m}_g [h_g(T_g) - h_g(T_a)]}{GCV}$$

$$L_{r2} = L_{r1} / x$$

$$\eta_2 = \eta_1 + (L_{g1} - L_{g2}) + (L_{r1} - L_{r2})$$

Variables

C, H, O, N, S, A, M	ultimate analysis of the fuel, as fired	-
ω	air humidity	kg/kg
GCV	gross calorific value, as fired	J/kg
$O_{2,1}$	dry flue gas O_2 at full fire	-
$O_{2,2}$	dry flue gas O_2 at low fire	-
T_{g1}	flue gas temperature at full fire	K
T_{g2}	flue gas temperature at low fire	K
T_a	combustion air temperature	K
T_g	flue gas temperature	K
η_1	efficiency at full fire	-
η_2	efficiency at low fire	-
$\Delta\eta$	change from full fire	-
L_{r1}	radiation and unaccounted loss at full fire	-
L_{r2}	radiation and unaccounted loss at low fire	-
x	low fire as a share of full fire	-
EA_1	excess air at full fire	-
EA_2	excess air at low fire	-
L_{g1}	stack loss at full fire	-
L_{g2}	stack loss at low fire	-
L_g	stack loss	-
$\dot{m}_g$	wet flue gas per kg fuel	kg/kg
h_g	flue gas enthalpy	J/kg

Method and standards

Excess air at each load comes from the measured dry O_2 and the fuel analysis; the wet flue gas per kg fuel and its enthalpy rise from air to stack temperature (NIST Shomate data) give the stack loss at each load. The change in stack loss and the rise in radiation loss, constant in kW and so inversely proportional to load as a share, are applied to the full-fire efficiency.

Assumptions and limits

- Steady firing at each load; purge and cycling losses are not included.
- Radiation loss in kW is the same at both loads; the unaccounted part of the entered loss is scaled the same way.
- Excess air from O_2 assumes complete combustion (no CO), which may not hold at low fire.
- The flue gas losses shown are sensible heat only (dry gas and water vapour from the air to the stack temperature). The latent heat of the water from hydrogen and moisture is the same per kg of fuel at both loads, so it cancels in the efficiency change but is not part of the loss figures.
- Unburnt losses are taken as unchanged.

References

• Stack loss from the combustion balance (NIST Shomate gas properties)
• ASME PTC 4 loss method

Report details

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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/boilers/burner-turndown-efficiency

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.