AFBC Bed Heat Balance and In-Bed Tube Duty

Heat the in-bed tubes of a bubbling fluidised bed boiler must remove to hold the bed temperature, and the tube area for it, from an energy balance on the bed.

Method: Energy balance on the fluidised bed

Input parameters

Unit system: SI

Parameter	Value	Unit
Fuel firing rate	10.000	t/h
Net calorific value, as fired	14,000	kJ/kg
Share of the fuel's heat released in the bed The rest burns in the freeboard above the bed; from the boiler maker or a test.	85.000	%
Combustion air per kg fuel (with excess air)	6.5000	kg/kg
Ash in fuel, as fired	30.000	%
Mean specific heat of the flue gas, air to bed temperature	1.1500	kJ/(kg·K)
Bed temperature to hold	850.00	°C
Fluidising air and fuel temperature	30.000	°C
Water or steam temperature in the in-bed tubes	255.00	°C
Overall heat transfer coefficient, bed to tube contents Overall value including the tube-side film and wall, because it is applied to the bed-to-fluid temperature difference; from the boiler maker or a test on a similar bed.	250.00	W/(m²·K)

Calculated results

Parameter	Value	Unit
Heat released in the bed	33,056	kW
Heat carried up by the flue gas	18,860	kW
Heat in the bed ash drained	572.20	kW
Heat the in-bed tubes must take	13,623	kW
In-bed duty as a share of the fuel heat	35.031	%
In-bed tube surface needed	91.586	m²

Notes for this case

- Radiation from the bed surface to the freeboard and the wall losses are not included; they lower the in-bed duty a little.

Formula and method

$$Q_{rel} = \dot{m}_f NCV \beta$$

$$Q_g = \dot{m}_f (a + 1 - A)\, c_{p,g} (T_b - T_a)$$

$$Q_{ash} = \dot{m}_f A\, c_{ash} (T_b - T_a)$$

$$Q_t = Q_{rel} - Q_g - Q_{ash}, \quad A_t = \frac{Q_t}{U(T_b - T_w)}$$

Variables

$\dot{m}_f$	fuel firing rate	kg/s
NCV	net calorific value, as fired	J/kg

β	share of the fuel heat released in the bed	-
a	combustion air per kg fuel	kg/kg
A	ash in fuel	-
$c_{p,g}$	mean specific heat of the flue gas	J/(kg·K)
c_{ash}	specific heat of ash, 0.2 Btu/(lb·°F)	J/(kg·K)
T_b	bed temperature	K
T_a	air and fuel temperature	K
T_w	water or steam temperature in the tubes	K
U	overall heat transfer coefficient, bed to tube contents (includes tube-side film and wall)	W/(m²·K)
Q_{rel}	heat released in the bed	W
Q_g	heat carried up by the gas	W
Q_{ash}	heat in the bed ash	W
Q_t	in-bed tube duty	W
Q_f	fuel heat input (NCV)	W
Q_t/Q_f	in-bed duty as a share of the fuel heat	-
A_t	in-bed tube surface	m²

Method and standards

A steady energy balance on the bed: the heat released by the share of fuel burning in the bed (on NCV) equals the heat the gas carries up at bed temperature, the heat in the ash drained, and the duty of the in-bed tubes. The tube area follows from the bed-to-tube coefficient and the temperature difference between bed and tube contents. Ash specific heat is 0.2 Btu/(lb·°F), the value FireCAD uses for coal and biomass ash.

Assumptions and limits

- Steady state; radiation from the bed surface and wall losses not included.
- All ash leaves at bed temperature, whether drained from the bed or carried out as fly ash; unburnt carbon in the ash is neglected.
- All the fuel is taken to devolatilise in the bed, so the gas term uses the whole fuel mass heated to bed temperature, while only the share β of the heat is credited to the bed.
- Gas specific heat is a mean value between air and bed temperatures.

References

- Energy balance on the fluidised bed

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/fluidised-bed/afbc-bed-heat-balance

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.