HEAT BALANCE - BOILER

UNIT - 5

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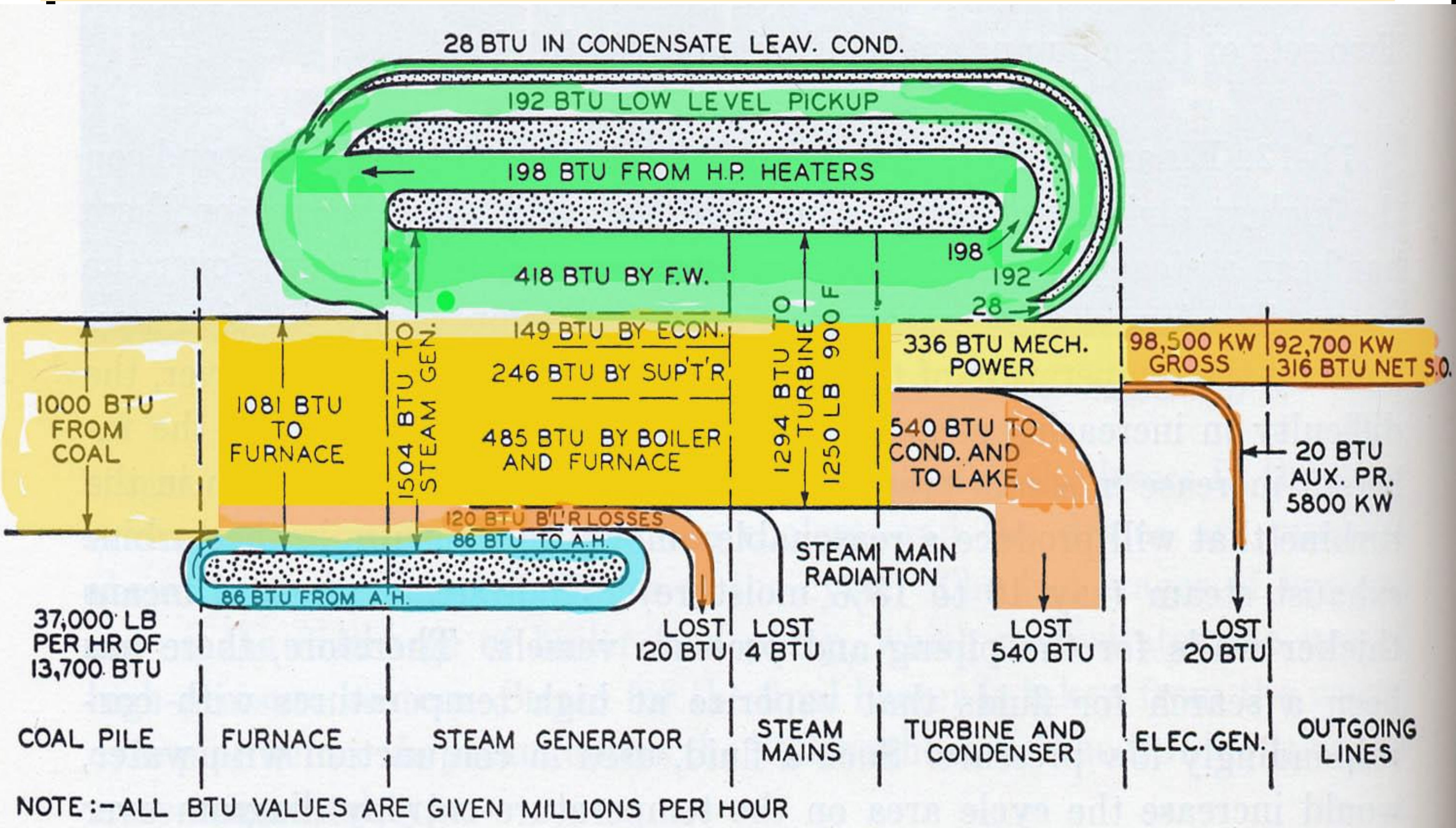
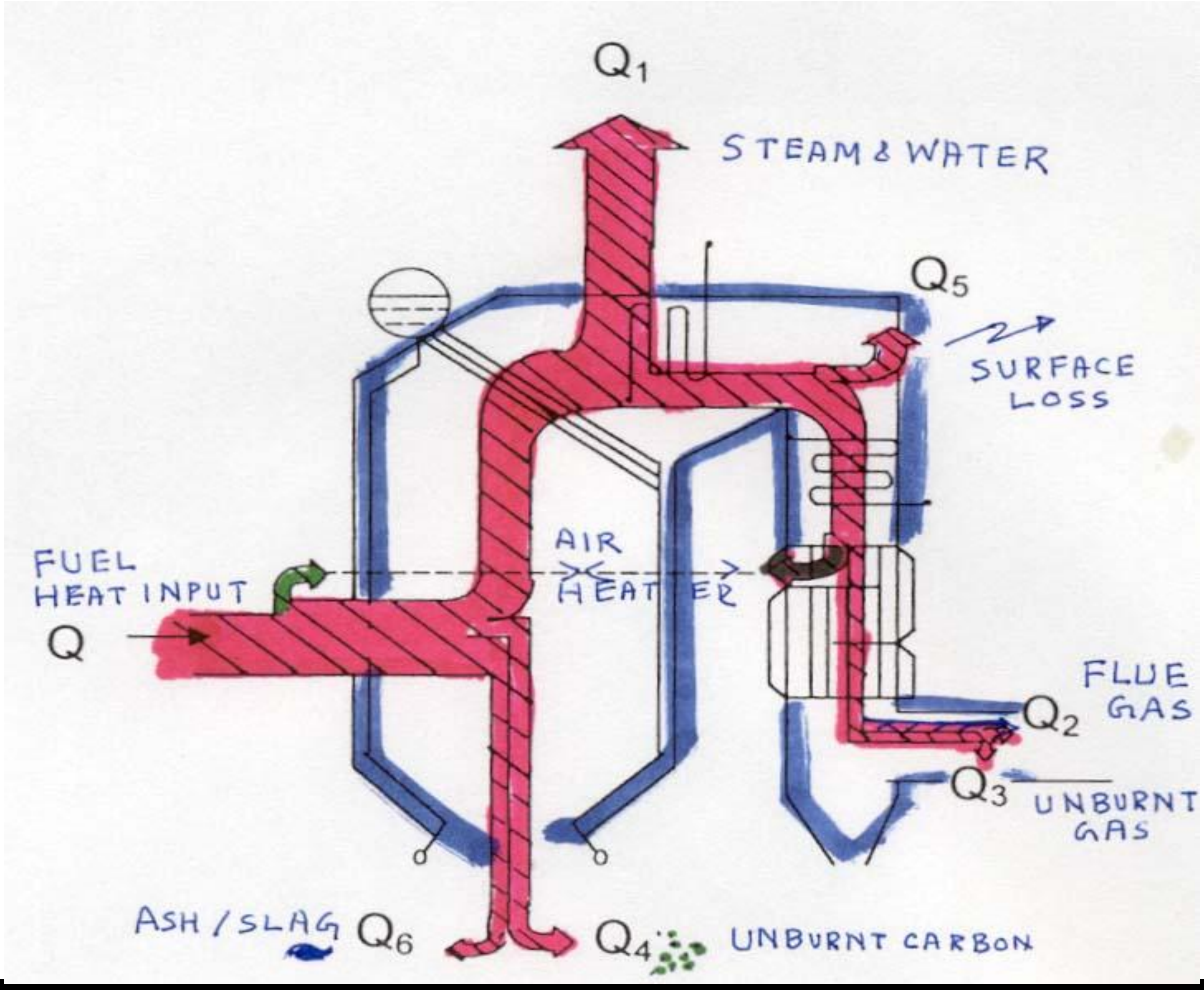
$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = 1 - \frac{\text{Heat losses}}{\text{fuel heat input} + \text{heat credits}}$$

Heat distribution in a power plant



HEAT FLOW IN A BOILER



Heat given to steam in a boiler

- Heat delivered to water = $m\ (H_{steam} - H_{feed})$

  where

H_{steam} = Enthalpy of superheated steam (kJ/kg)

H_{feed} = Enthalpy of feed water (kJ/kg)

m = amount of water produced from all sources

HEAT BALANCE

- HEAT INPUT = HEAT UTILIZATION +LOSSES
- $Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$
- Q = Available heat of fuel
- Q_1= Heat utilized by steam and water
- Q_2 = heat lost through stack gas
- Q_3= Incomplete combustion (CO, CH_4 H_2)
- Q_4 = Unburned carbon
- Q_5 = Loss from boiler surfaces
- Q_6 = sensible heat in ash

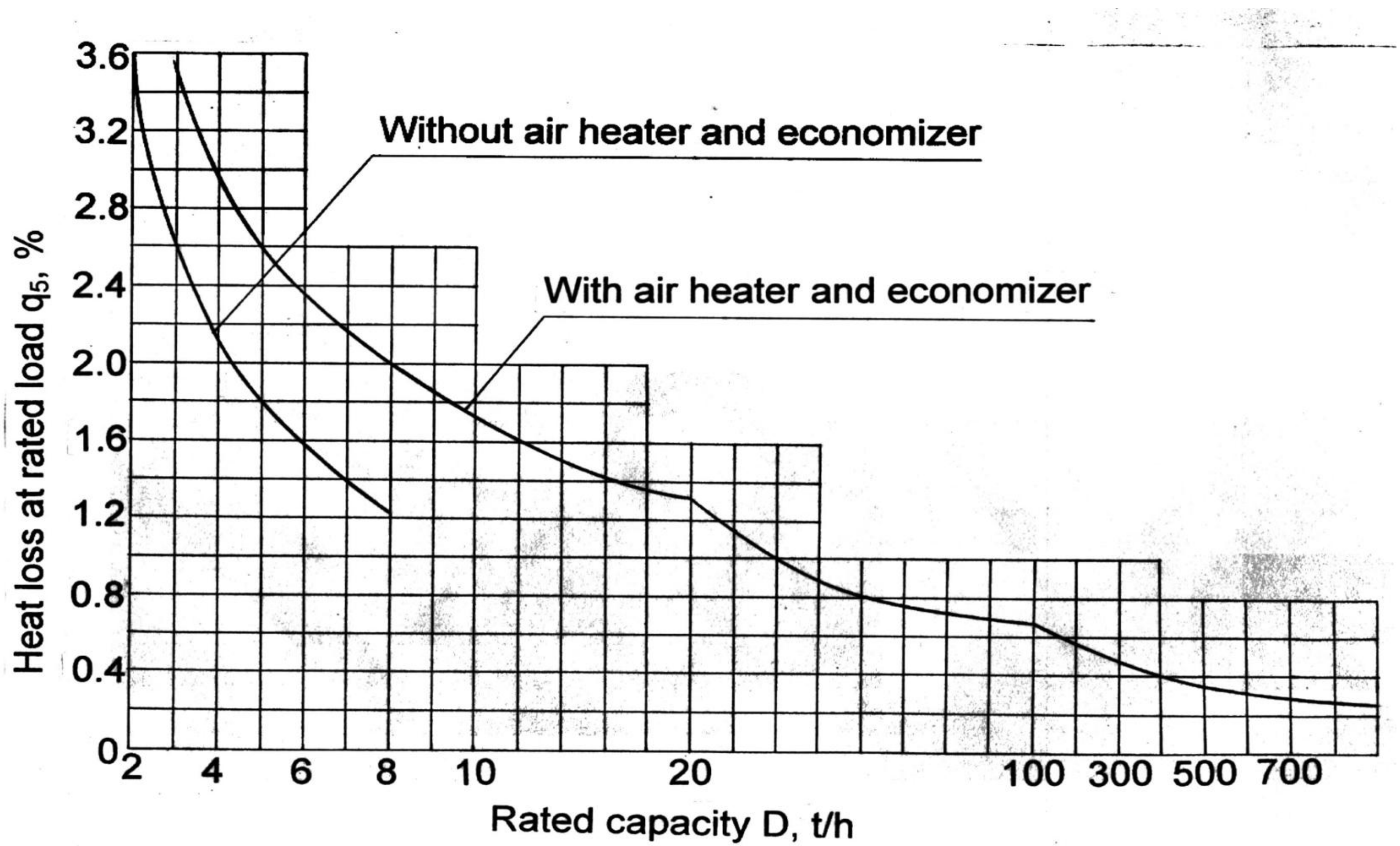
Components of Heat Input, Q

- Lower heating value (LHV)
- Sensible heat of fuel ($C_f T_f$)
- Sensible heat of air [$\alpha(H_b - H_a)$]
- Heat of fuel atomizing steam [$G_{as}(H_{as}$-2500)]

HEAT LOSS COMPONENTS

- Flue gas loss, $Q_2 = [(I_g - \alpha I_\alpha)(1 - Q_4/Q)]$
- Incomplete combustion of gas, $Q_3 = [V_g(126\,CO + 108H_2 + 358CH_4) x (1 - Q_4/Q)]$
- Heat loss due to unburned carbon, $Q_4 = 32866(G'_{ba}C_{ba} + G'_{fa}C_{fa})$
- Heat loss due to surface radiation & convection, $Q_5 = \sum F_s(h_c + h_r)(T_{sb} - T_0)$

CONVECTION-RADIATION LOSS (Q_5)



Other losses

- Moisture in sorbents = $L_q X_m H_g$ kJ/kg
- Calcination losses = $L_q X_{caco3} 1183$ kJ/kg
- Moisture loss in fuels = $m_f H_g$ kJ/kg
- Moisture loss in air = $A_f X_{air} H_g$ kJ/kg
- Loss in hydrogen burning = $9H H_g$ kJ/kg
- Sulfation credit = 15141 $\eta_{so2} S$ kJ/kg
- Unburnt carbon loss in ash = 32790 $X_c W_a$
- Dry flue gas = $W_g H_g$

HEAT BALANCE (PC & CFB) - I

ITEM	PC	CFB	CFB
	%	% GOOD	% WORST
Moisture in limestone		0.06	0.1
Calcination		1.02	1.69
Sulfation		-1.6	-1.69
Unburnt C	0.25	0.5	2
Dry flue gas	5.28	5.57	5.6
Fuel H_2O	1.03	1.03	1.03
H_2O from H_2	4.16	4.19	4.19

HEAT BALANCE (PC & CFB)-ii

ITEM	PC	CFB	CFB
Surface loss	0.03	0.3	0.8
H_2O in air	0.13	0.14	0.14
Ash sensible heat	0.03	0.09	0.76
Bottom ash	0.05		
Fan & Mill credit	-.45	-.075	-0.40
TOTAL LOSS	10.81	10.55	14.31

LOSSES FROM A CFB BOILER

Component	Loss (kW)	Area (m2)	Surface temp.(C)
Cyclone loop seal	482	1241	89
Combustor	394	1804	43
Drum & piping	173	1355	67
PA Duct	134	1610	56
Air heater	111	1408	51
Conv. Pass & SA duct	47	537	58

Heat losses (from CFB Boiler-Basu)

- Calcination loss
  $CaCO_3$ $$= \frac{Feed\ rate\ of\ CaCO_3 \times 1830 \times 100}{Fuel\ \ feed\ rate \times\ \ HHV} \quad (6.2)$$
- $MgCO_3$ $$= \frac{Feed\ rate\ of\ MgCO_3 \times 1183 \times 100}{Fuel\ \ feed\ rate \times HHV} \quad (6.3)$$
- Sulfation credit $$= \frac{\mathrm{E}_{sor} S\ 15141 \times 100}{HHV} \quad (6.5)$$
- Unburnt carbon loss $$\frac{\mathrm{X}_c \times W_a \times 32790 \times 100}{HHV}, \quad (6.6)$$
- Dry flue gas loss = $$M_a \frac{(\mathrm{H}_f) \times 100}{HHV}, \quad (6.7)$$

H_f is difference in enthalpy of steam at flue gas temperature and that of water at ambient condition

Losses

- Moisture loss from fuel = $(M_f\ H_f\ 100)/HHV$

  H_f is difference in enthalpy of steam at flue gas temperature and that of water at ambient condn
- From air = $(M_a\ X_m\ H_f\ 100)/HHV$
- From hydrogen burning = $9HxH_f\ x100/HHV$
- FD fan credit = - (Power consumed)/(M_c HHV)
- Sensible heat in ash =
  - $[Ash]\ x_b(\ T_{ba}-T_0)+(1-x_b)(T_{fa}-T_0)$

Problem

- A boiler fires 250 kg pure Methane per hour using dry air with 20% excess air. Higher heating value is 54865 kJ/kg

- Find the volumetric capacity of the combustion air fan and induced draft fan for the boiler if the air handled by these fans are at 27 C and 127 C respectively
- Find the efficiency of the boiler assuming complete combustion neglecting air preheating, surface heat loss 1%

Problem II

- Nova Scotia Power Corporation is considering co-firing in their Trenton plant (150 Mwe) which fires coal. The co-firing unit is an external hot gas generator capable of generating 3 MWth heat. This hot gas will be fed into the boiler. This unit will have surface heat loss as per the worst case scenario in a CFB boiler. Using required data from sources
- Find the reduction in CO2 emission
- Savings in fuel cost
- Effect on thermal efficiency of the main boiler

Fuel

Fuel	Unit	Coal	Waste wood
HHV (Dry basis)	MJ/kg	24.65	20.14
Moisture	Wt%	7	14.2
Volatiles	-	66	79.1
C	Wt% DAF	56.59	49
H	-	4.21	5.9
O	-	5.69	40.7
N	-	0.9	2.5
S	-	4.99	0.05
Cl	-	0.4	0.03
Ash	-	20.6	1.9

Price (C$ per ton wet fuel)

- Waste wood - $7/ton +$10/ton/100 km
- Whole tree chip - $45/ ton delivered
- Moisture = 45-55%
- Heating value 8200-8500 BTU/dry lb fuel
- Price of imported coal in Point Tupper $35-$65 (av.$50/ton)
- Heat rate: 7400 kJ/kWh
- Ca/S ratio = 2.0 for 90% capture