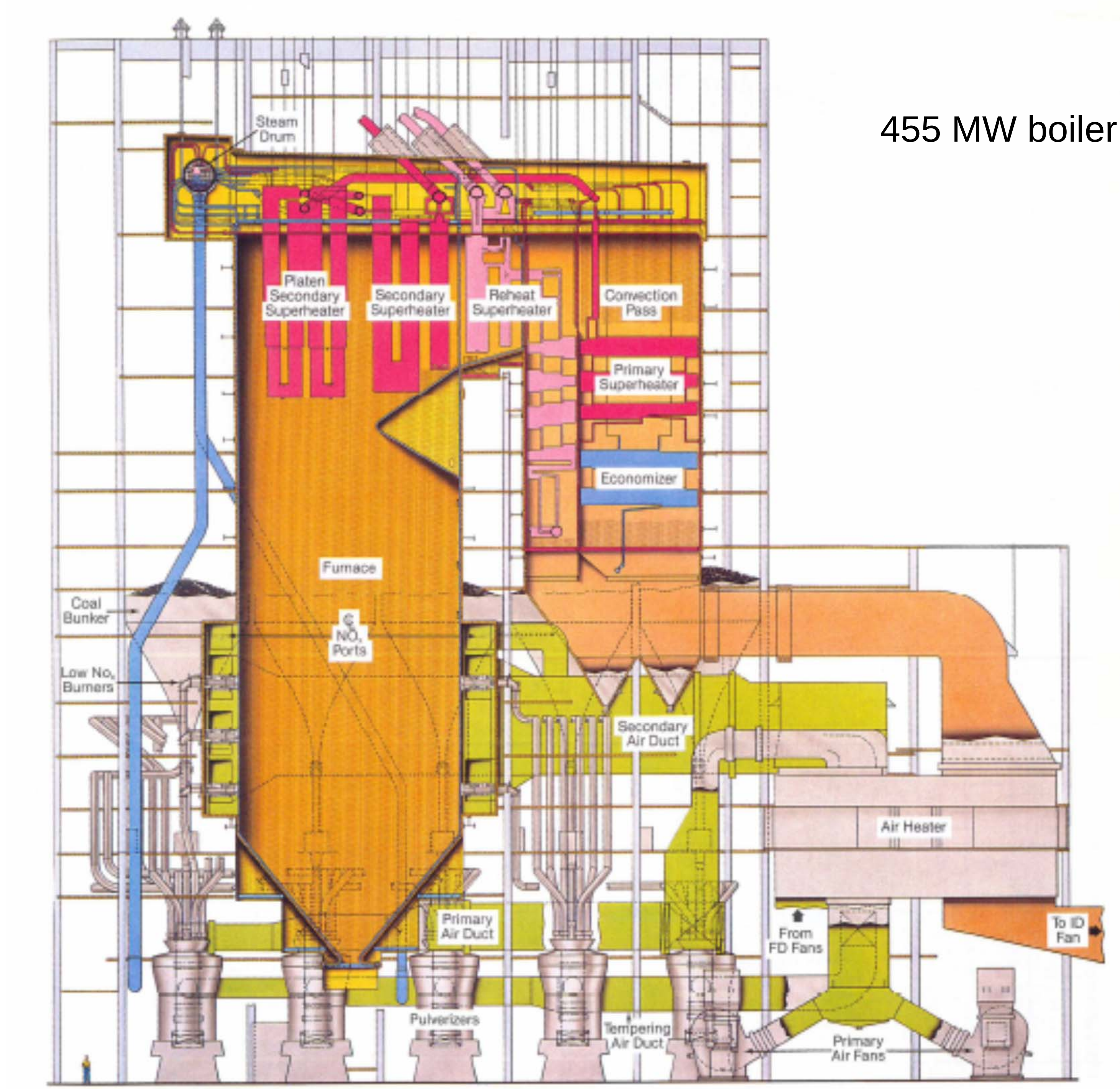
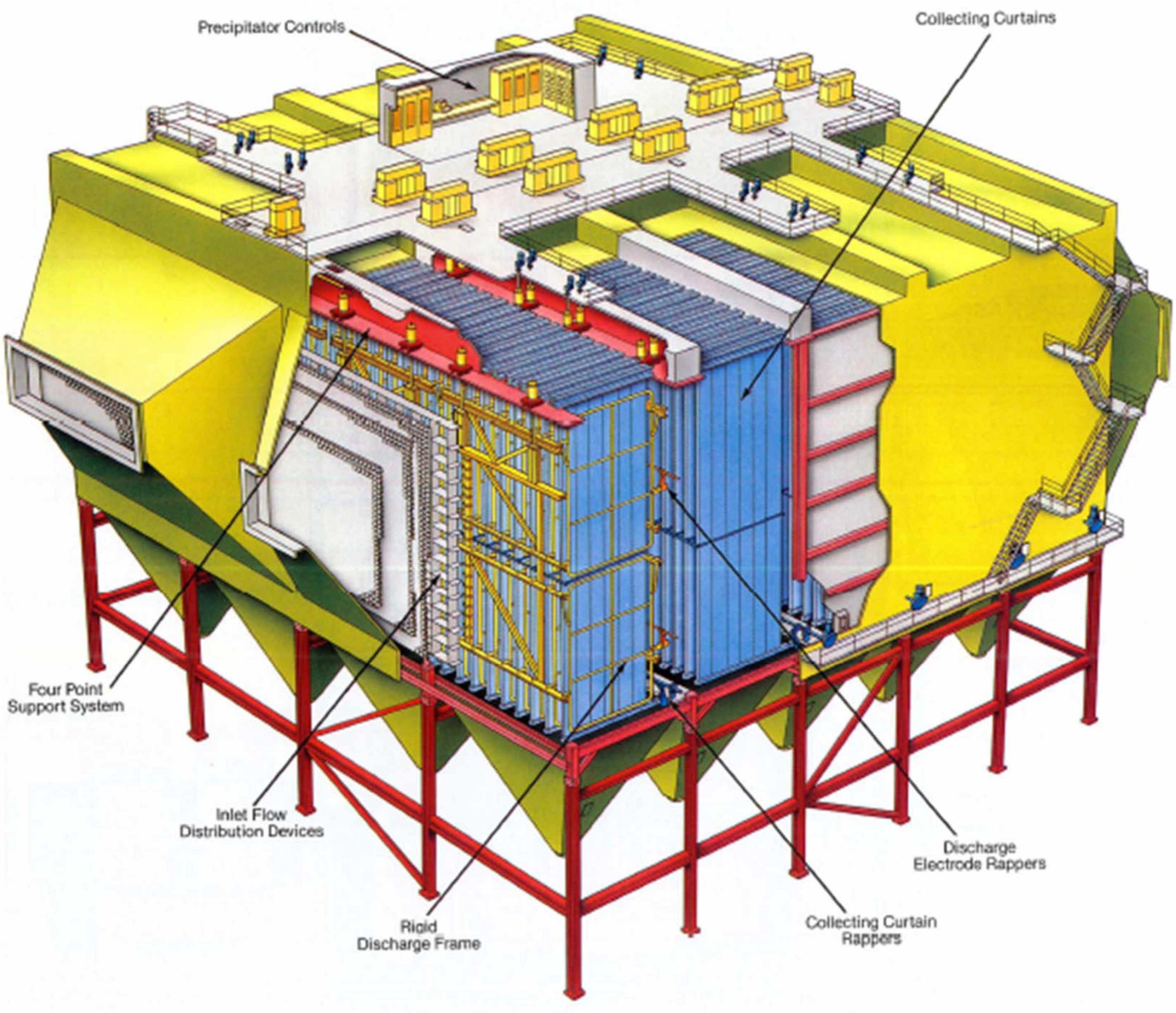
455 MW boiler



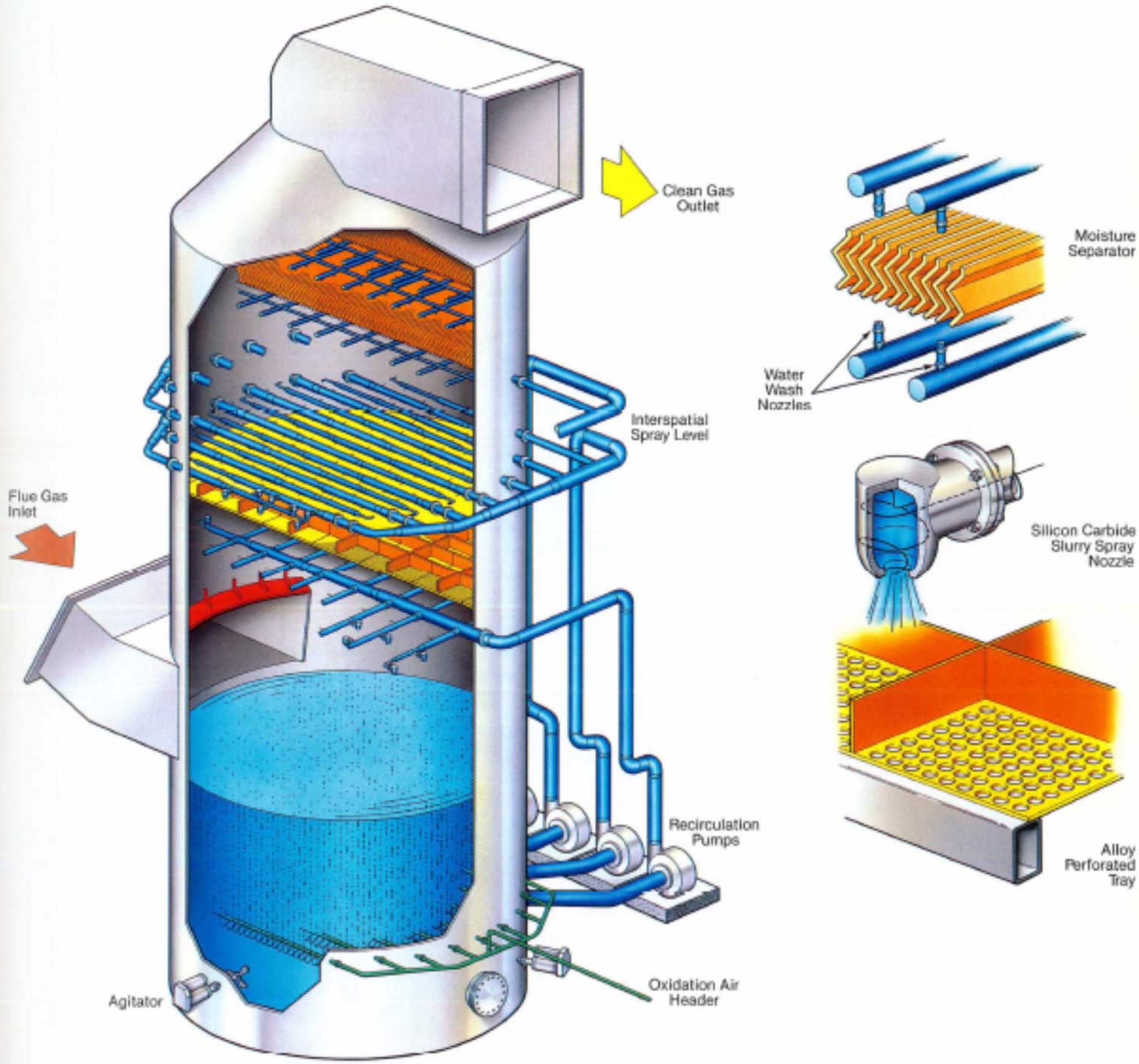
From Steam, Babcock & Wilcox, 1992, Plate 1.

Electrostatic Precipitator



From Steam, Babcock & Wilcox, 1992, Plate 6.

Wet flue gas desulfurization scrubber

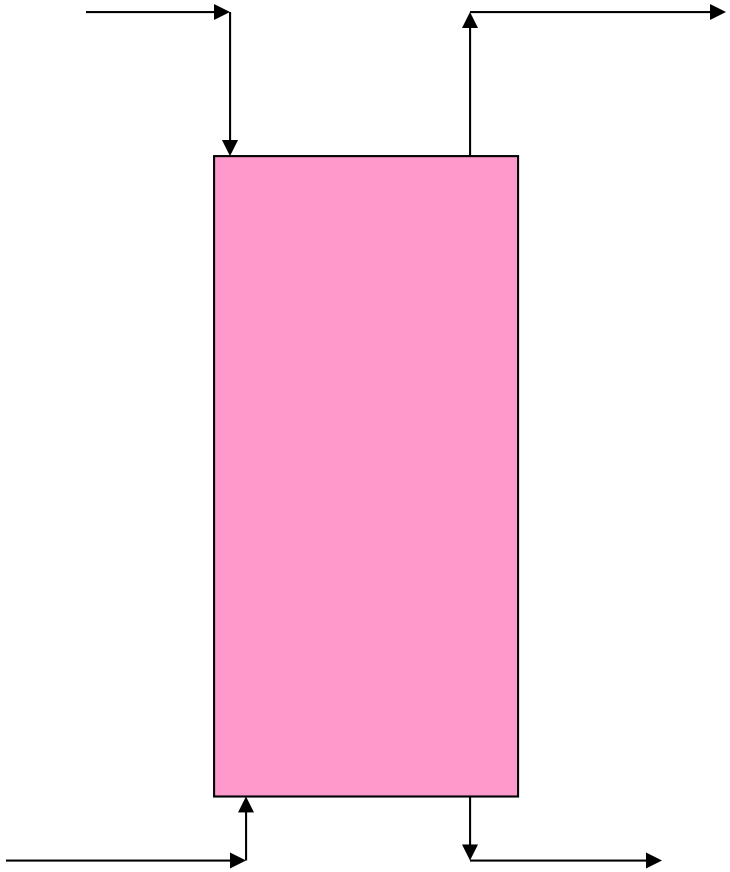


From Steam, Babcock & Wilcox, 1992, Plate 7.

Homework Hints from Web Page

- 14-6. Wow- This was a hard problem. The author's answer key had lots of mistakes. The solubilities are not in the book, but are listed in Perry's Chemical Engineering Handbook. To be consistent, let's use the following solubilities:
  0.002 kg $CaCO_3$/100 kg liquid H_2O
  0.003 kg $CaSO_3$/100 kg liquid H_2O
  I found that sometimes drawing a unit separately, with the inlet and outlet streams, along with the different phases, helped me to sort through this problem. See the TA's to check answers.
  On 14.6e, the second part of this problem is somewhat ambiguous. What is really wanted is the mass fraction of each component in the wet solids.
- 14-7. I found it a lot easier to do this problem if I calculated the heat of formation of coal. The high heating value of the coal is given, which is the negative of the heat of combustion assuming that the hydrogen goes to liquid water. All reactants and products are 25 C for this value of the heat of combustion. Since the heat of combustion is the total enthalpy of the products minus the total enthalpy of the reactants, and the total enthalpies at 25 C are merely the weighted sums of the heats of formation, the only unknown in this equation is the heat of formation of coal. Assume a basis of 100 kg of dry coal, calculate the products, and then calculate the weighted sum of enthalpies, and finally determine the heat of formation of the coal.
- 14-10. The only way that this problem makes sense is if the heat input to the boiler is really the heating value of the coal going into the boiler. This is the way that the regulations are written.
- 14-14c. From the flow rate of methane, multiply the flow rate by the heat of combustion (i.e., the high heating value). This is an approximate heat addition rate. Then divide by the high heating value of the coal.

Individual Scrubber



Slurry in
$CaCO_3$(s)
Inert(s)
Sat'd $CaCO_3$(aq)
Sat'd $CaSO_3$(aq)
H_2O (liq)
$CaSO_3 \cdot \frac{1}{2}H_2O$(s)

Air Out
O_2
N_2
10% of SO_2 gas in
H_2O (sat'd vapor)
CO_2 + Extra CO_2

Air In
O_2
N_2
H_2O (gas)
CO_2
SO_2 gas

Slurry Out
$CaCO_3$(s)
Inert(s)
Sat'd $CaCO_3$(aq)
Sat'd $CaSO_3$(aq)
H_2O (liq)
$CaSO_3 \cdot \frac{1}{2}H_2O$(s)

SO_2 Reaction

$$CaCO_3 + SO_2 + \frac{1}{2}H_2O$$
$$\rightarrow CaSO_3 \cdot \frac{1}{2}H_2O + CO_2$$

$$\dot{n}_{SO_2,removed} = \dot{n}_{SO_2,in} - \dot{n}_{SO_2,out}$$

$$\dot{n}_{CO_2,formed} = \dot{n}_{SO_2,removed}$$

$$\dot{n}_{CaCO_3,consumed} = \dot{n}_{SO_2,removed}$$

$$\dot{n}_{CaSO_3-hydrate,formed} = \dot{n}_{SO_2,removed}$$

$$\dot{n}_{H_2O,consumed} = \frac{1}{2}\dot{n}_{SO_2,removed}$$

H_2O Balance on a Scrubber

$$\dot{n}_{H_2O(g),in} + \dot{n}_{H_2O(liq),in} + 0.5\dot{n}_{CaSO_3-hydrate,in}$$

From boiler exhaust

From recycled slurry

From recycled slurry

$$= \dot{n}_{H_2O(g),out} + \dot{n}_{H_2O(liq),out} + 0.5\dot{n}_{CaSO_3-hydrate,out}$$

To stack

In slurry

In slurry

Values in green are unknown, but-----

$$\dot{n}_{CaSO_{3-hydrate},formed} = 0.5\dot{n}_{CaSO_3-hydrate,out} - 0.5\dot{n}_{CaSO_3-hydrate,in}$$

Since the amount formed is known, the water balance now has only one unknown: $\dot{n}_{H_2O(liq),out}$

A note on treating the mass of liquid with solubilities

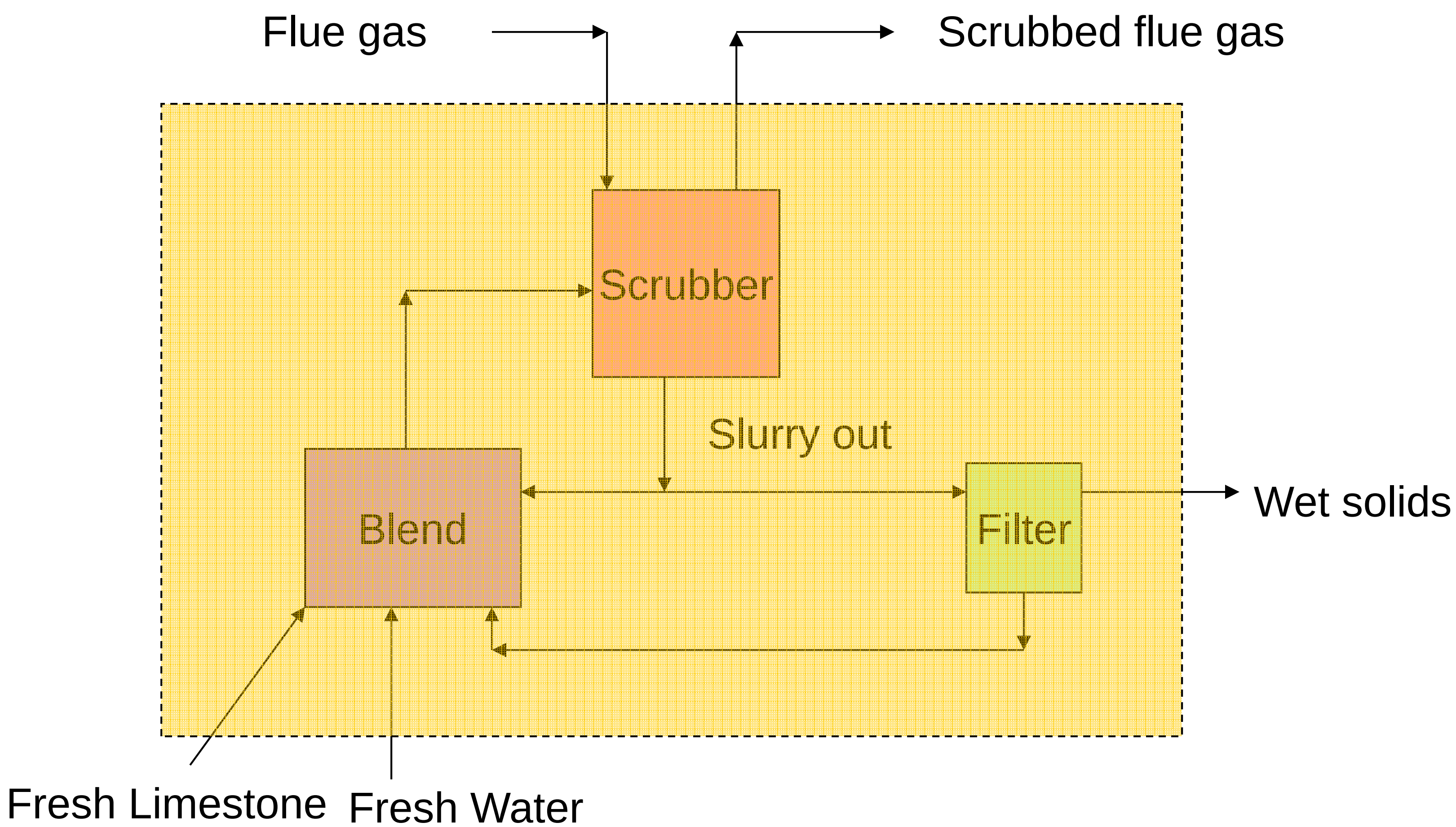
$$\dot{m}_{liq} = \dot{m}_{H_2O,liq} + \dot{m}_{CaCO_3,aq} + \dot{m}_{CaSO_3,aq}$$

$$\dot{m}_{CaCO_3,aq} = \frac{0.002}{100}\dot{m}_{H_2O}$$

$$\dot{m}_{CaSO_3,aq} = \frac{0.003}{100}\dot{m}_{H_2O}$$

$$\dot{m}_{liq} = \left(1 + \frac{0.002}{100} + \frac{0.003}{100}\right)\dot{m}_{H_2O}$$

14.6 (e)



Flue gas
Scrubbed flue gas
Scrubber
Slurry out
Blend
Filter
Wet solids
Fresh Limestone
Fresh Water

Solids Out in Filter Cake

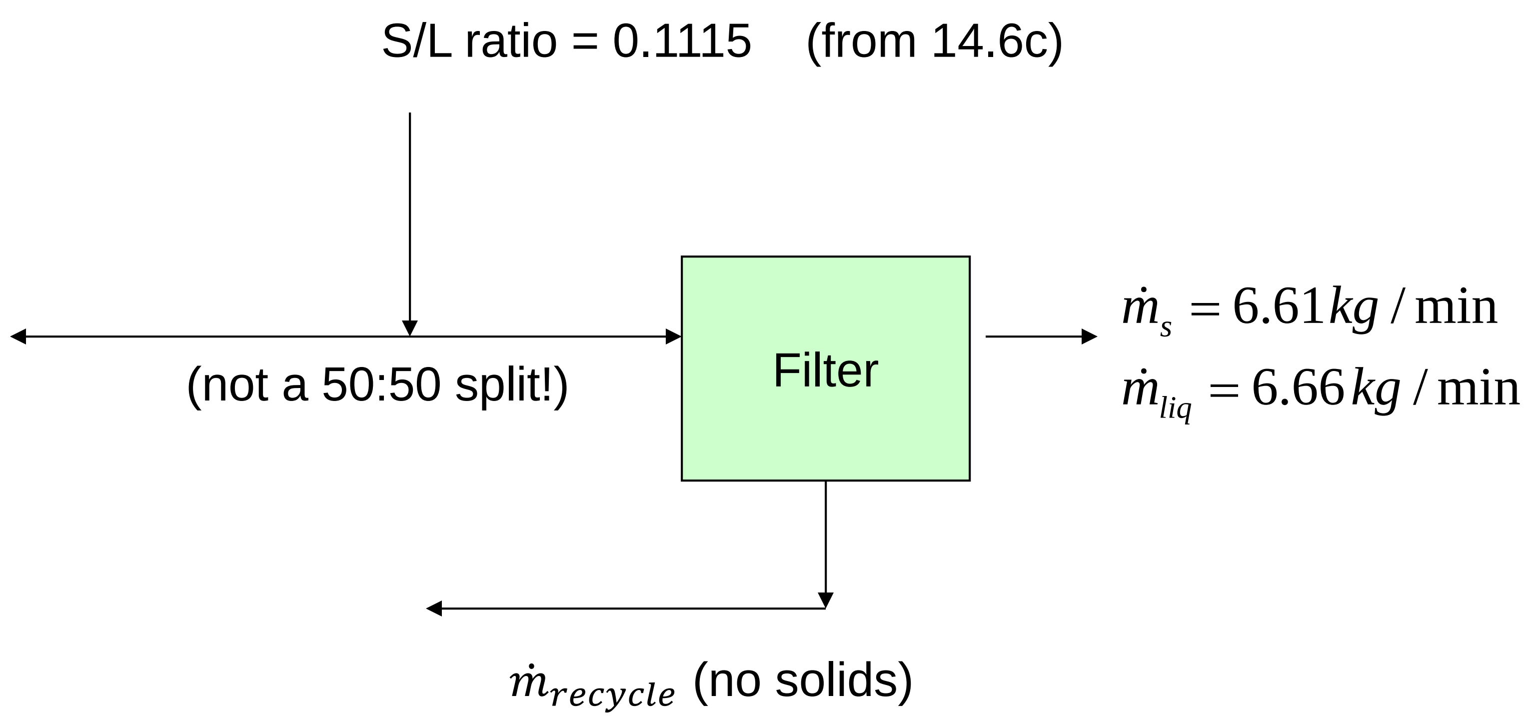
- All inerts (solid) from limestone $\rightarrow$ inerts in solid in filter cake
- All unreacted $CaCO_3$ in with fresh limestone $\rightarrow$ wet filter cake
- All $CaSO_3$ removed $\rightarrow$ wet filter cake ($CaSO_3$ hydrate)
- All flyash in with flue gas $\rightarrow$ filter cake

- Sum of all of above = $\dot{m}_{solids}$
  + small amount of aqueous $CaSO_3$ hydrate

- Need to guess $\dot{m}_{H_2O,liq}$ and use solver to ensure that

$$\frac{Total\ mass\ of\ liquid\ out}{Total\ mass\ out} = 0.502$$

14.6 (f)



So $$\frac{\dot{m}_s}{\dot{m}_{liq} + \dot{m}_{recycle}} = 0.1115$$ (combination of outputs from filter has same S/L ratio as the inlet)

Rearranging,

$$\dot{m}_{recycle} = \frac{\dot{m}_s}{0.1115} - \dot{m}_{liq}$$