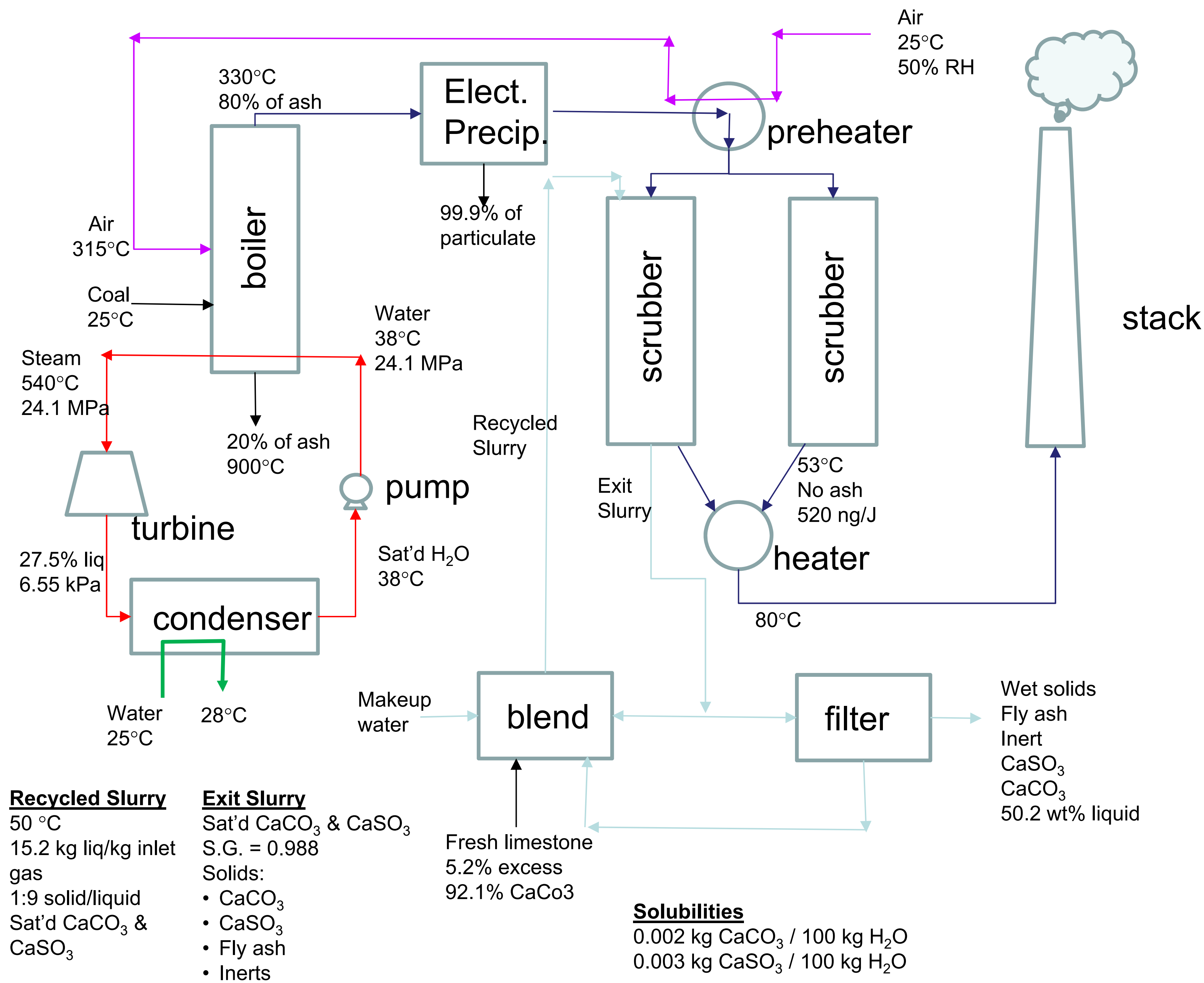
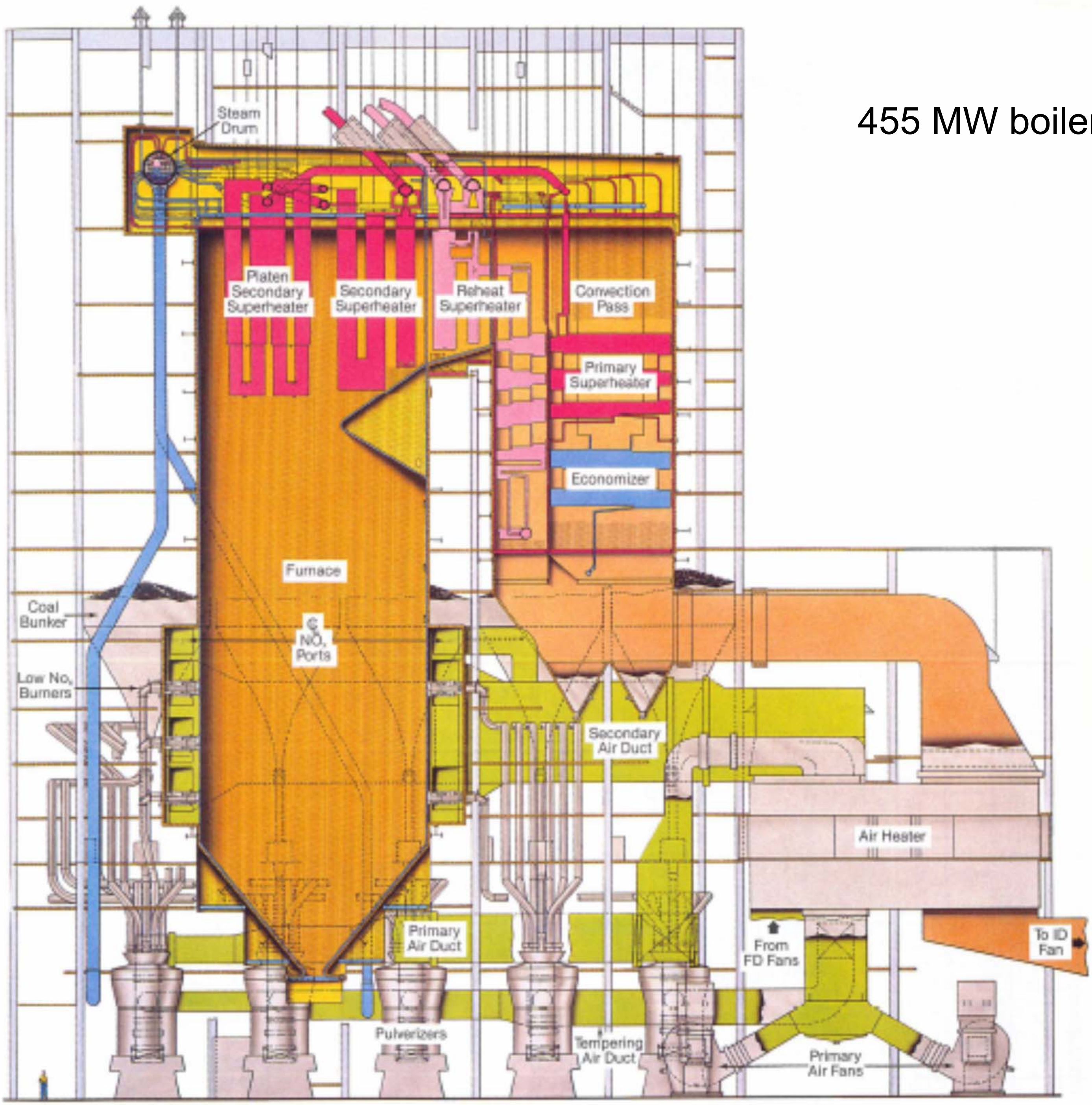

Air
25°C
50% RH
330°C
80% of ash
Elect.
Precip.
preheater
stack
Air
315°C
boiler
99.9% of
particulate
scrubber
scrubber
Coal
25°C
Water
38°C
24.1 MPa
Steam
540°C
24.1 MPa
Recycled
Slurry
20% of ash
900°C
pump
Exit
Slurry
53°C
No ash
520 ng/J
turbine
heater
Sat'd H_2O
38°C
27.5% liq
6.55 kPa
condenser
80°C
Water
25°C
28°C
Makeup
water
blend
filter
Wet solids
Fly ash
Inert
$CaSO_3$
$CaCO_3$
50.2 wt% liquid
Recycled Slurry
50 °C
15.2 kg liq/kg inlet gas
1:9 solid/liquid
Sat'd $CaCO_3$ & $CaSO_3$
Exit Slurry
Sat'd $CaCO_3$ & $CaSO_3$
S.G. = 0.988
Solids:
• $CaCO_3$
• $CaSO_3$
• Fly ash
• Inerts
Fresh limestone
5.2% excess
92.1% CaCo3
Solubilities
0.002 kg $CaCO_3$ / 100 kg H_2O
0.003 kg $CaSO_3$ / 100 kg H_2O

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

455 MW boiler



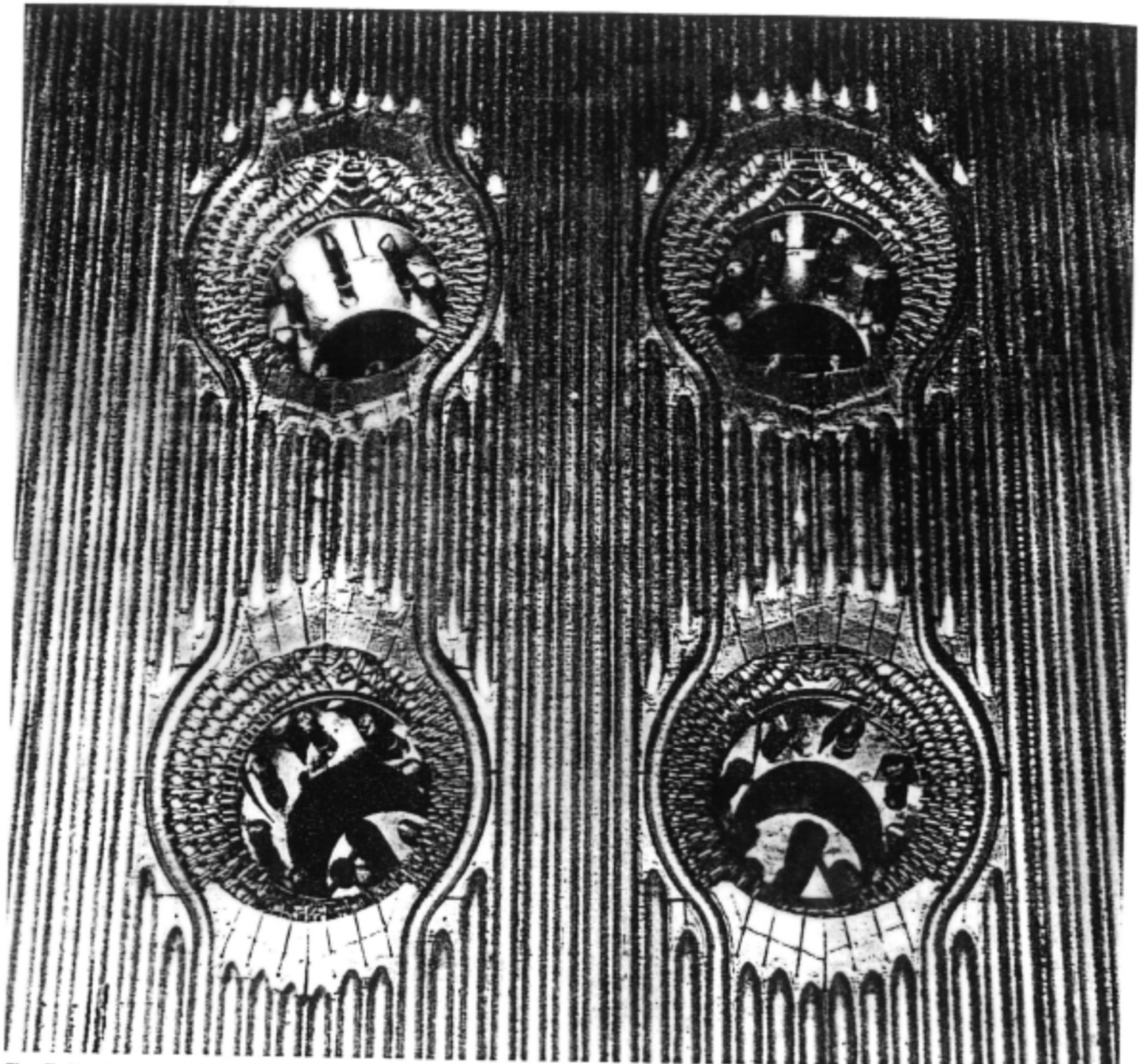


Fig. 7 Membrane-wall construction applied to a burner wall.

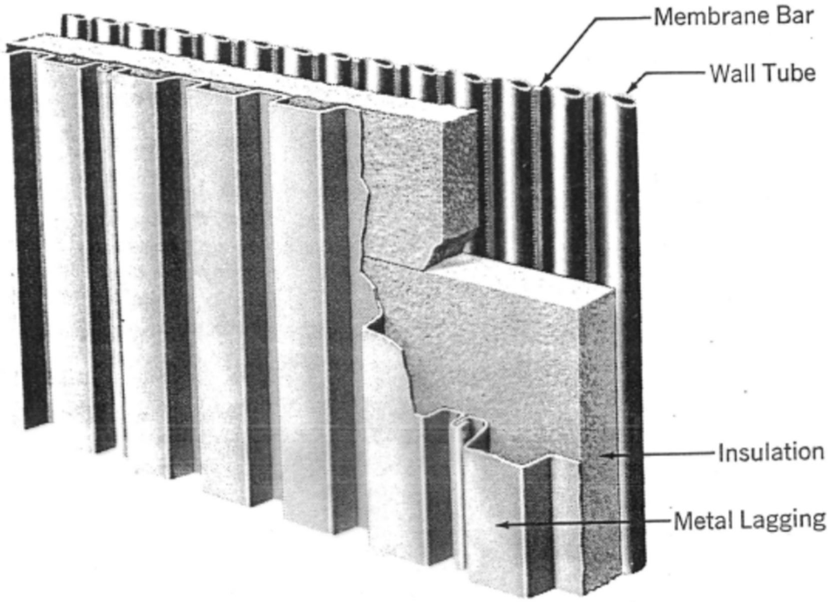


Fig. 2 Membrane wall construction.

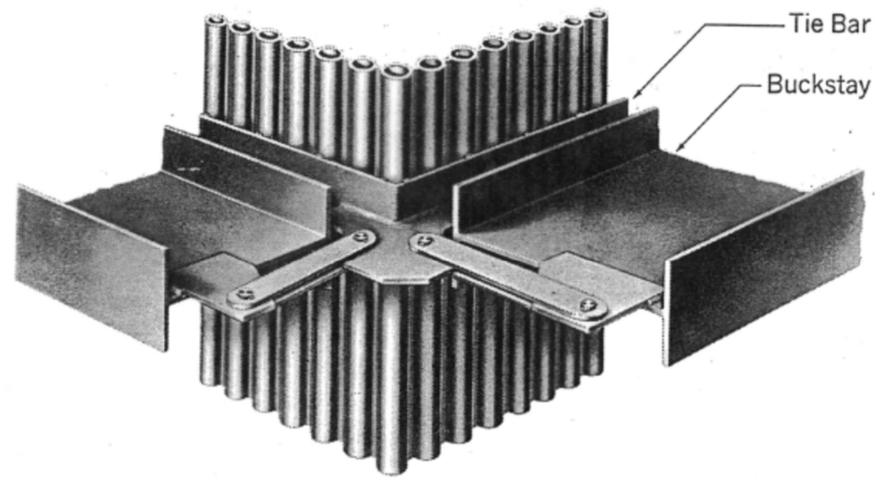


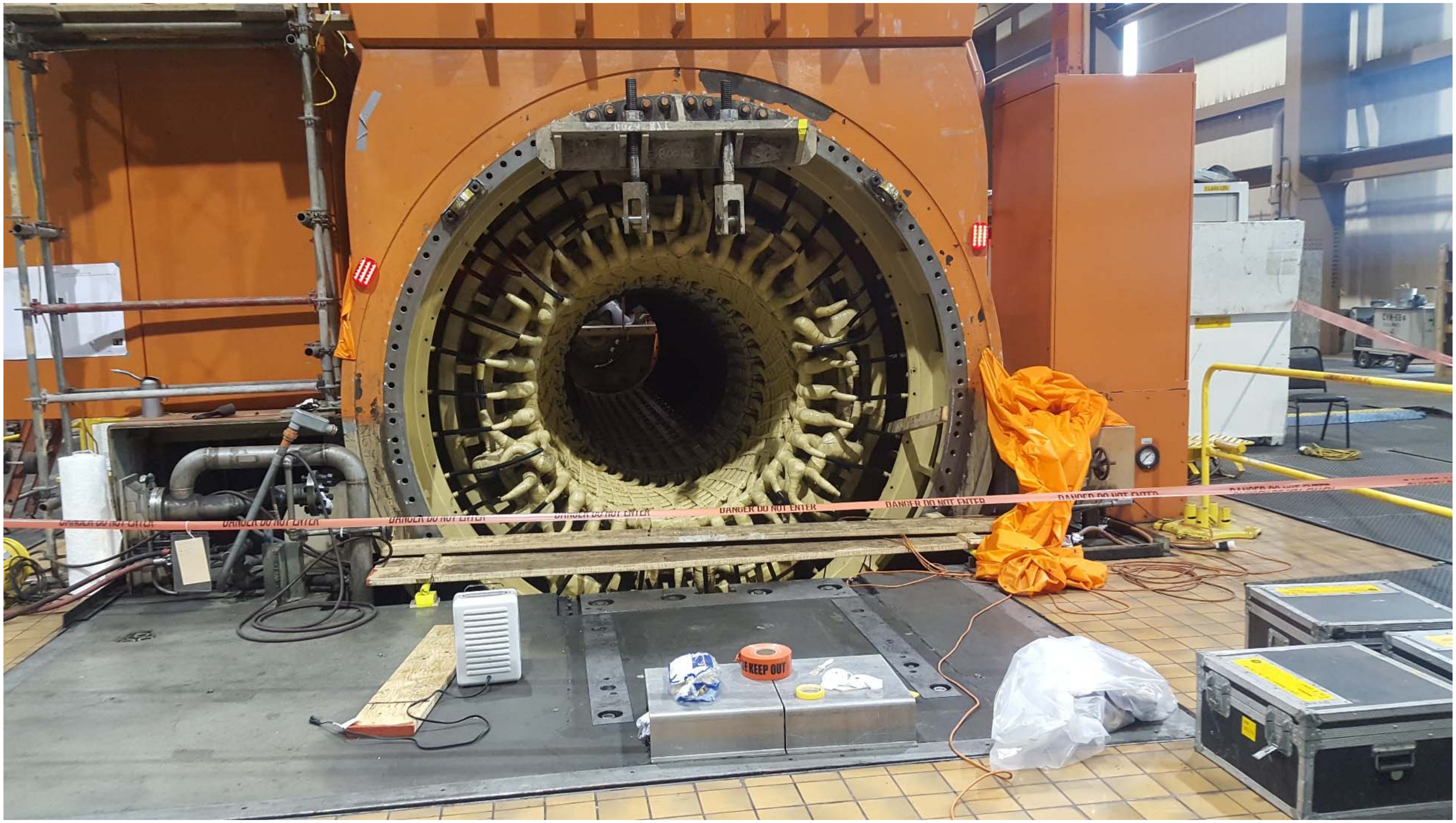
Fig. 6 Tie bar and buckstay arrangement at corner of furnace.

Heat Exchanger (6 ft diameter)

High Pressure Heat exchanger

Turbine

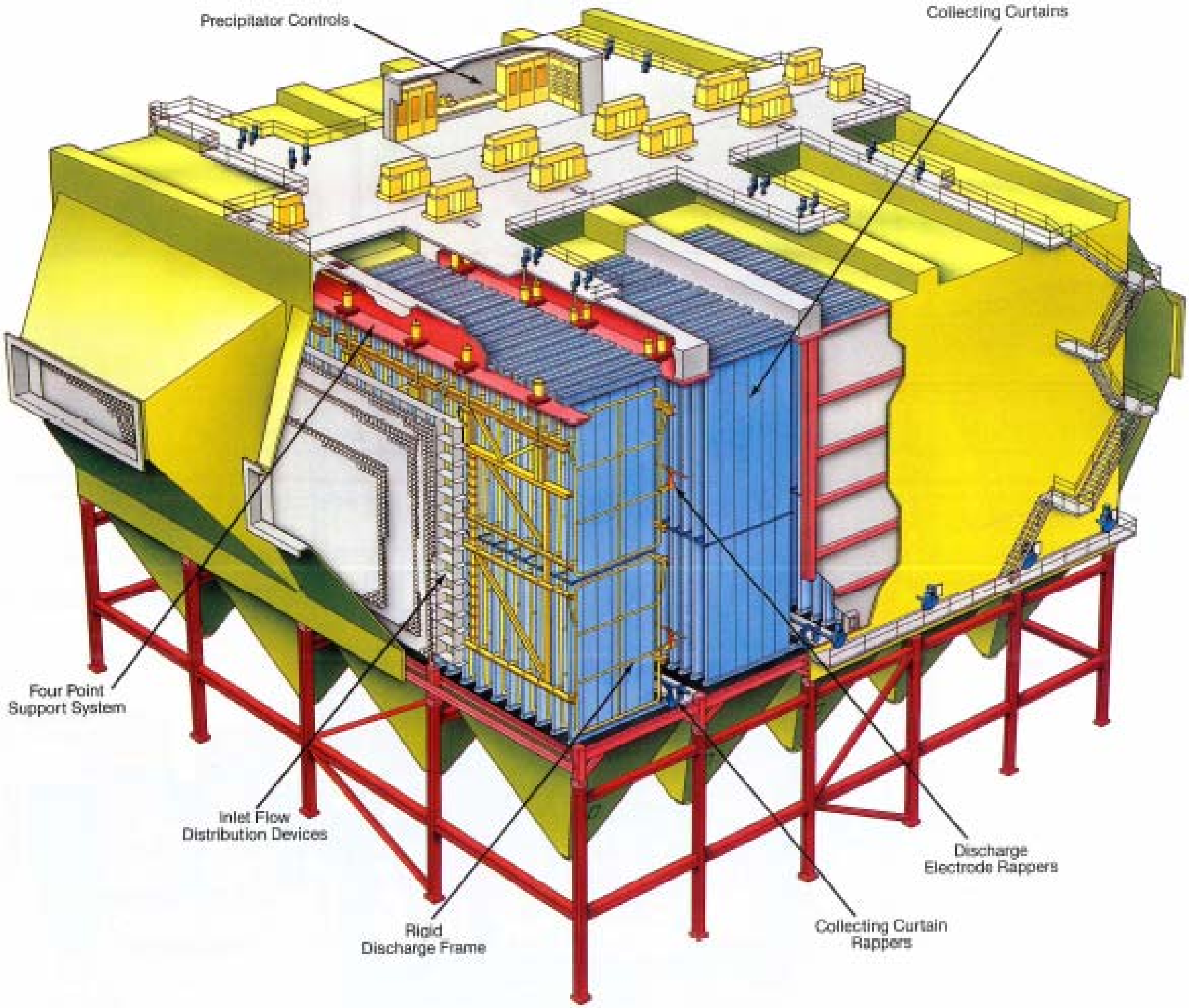
Generator



Spinning Part of Generator

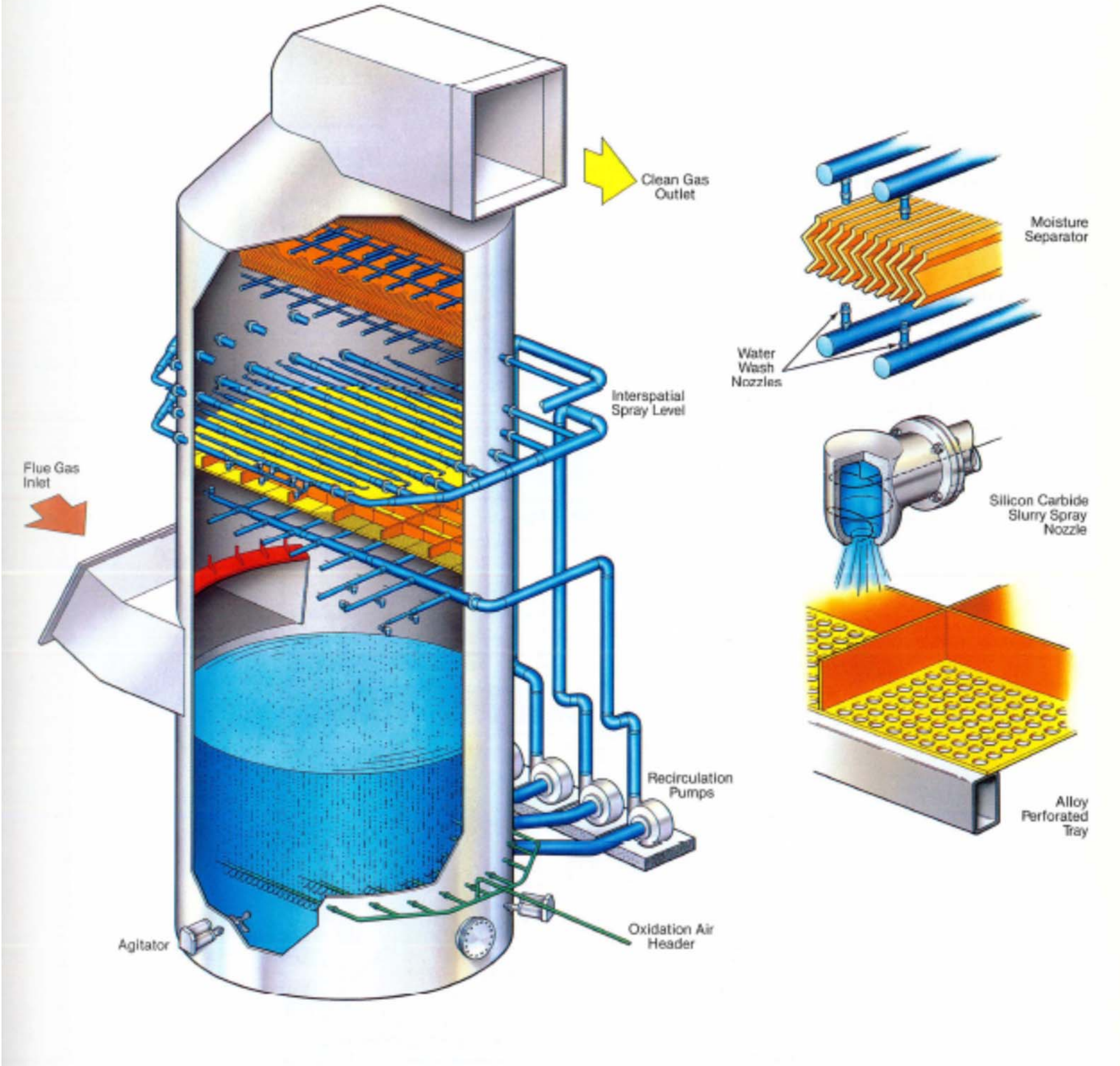
Water Pipe to Cooling Towers 350,000 gal/min!!!

Electrostatic Precipitator



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

Wet flue gas desulfurization scrubber



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

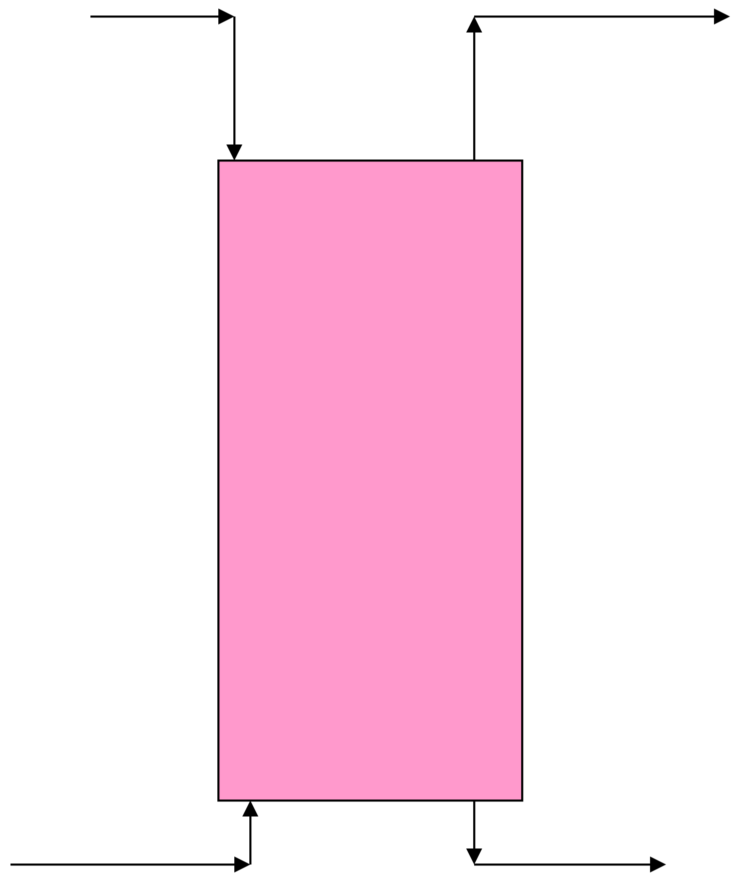
Homework Hints from Web Page

- 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
Fly ash

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)
Fly ash

SO_2 Reaction

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

$$\dot{n}_{SO_2,removed} = \dot{n}_{SO_2,in} - \dot{n}_{SO_2,out} \;\; (= \;\dot{\xi})$$

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

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

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

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

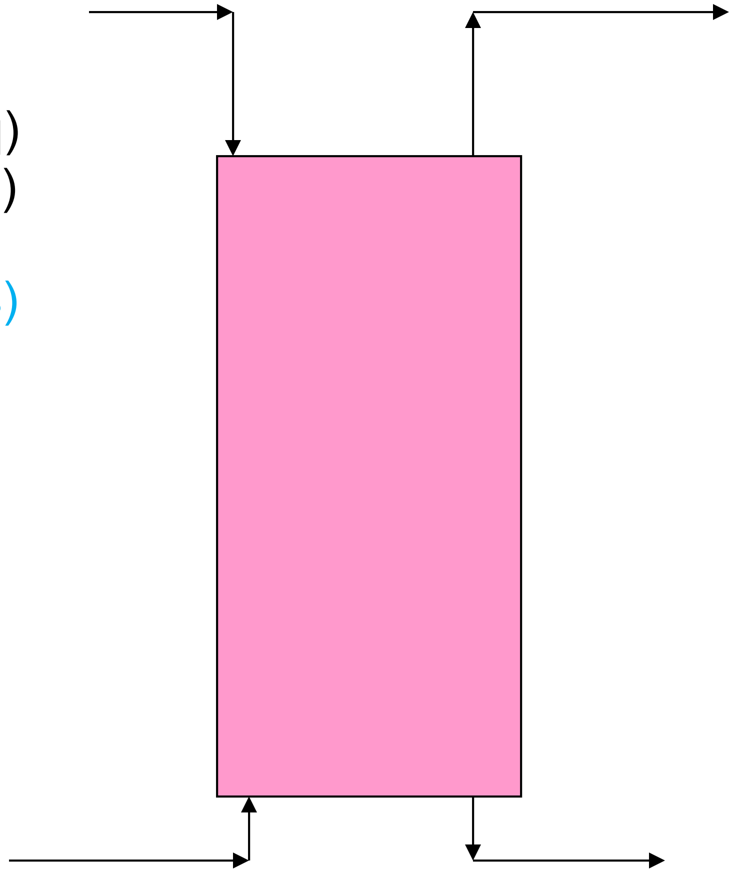
H_2O Balance on Individual Scrubber

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
Fly ash

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)
Fly ash

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 and blue are unknown, but -----

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

Since $\dot{n}_{CaSO_{3-hydrate},formed}$ is known (previous slide), the water balance now has only one unknown:

$$\dot{n}_{H_2O(liq),out}$$

A note on treating the mass of liquid with solubilities

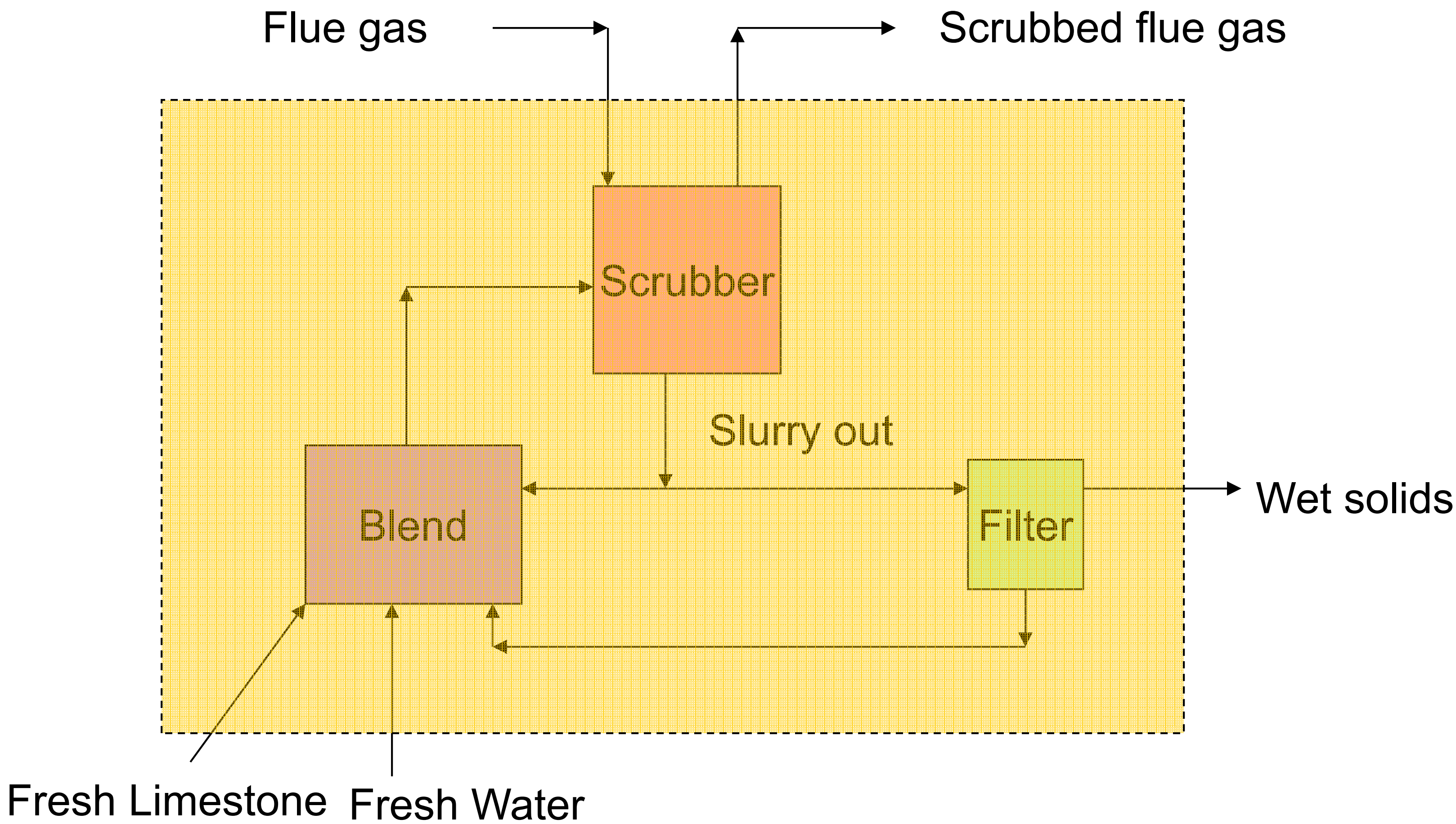
$$\dot{m}_{liq} = \dot{m}_{H_2O,liq} + \dot{m}_{CaCO_3,aq} + \dot{m}_{CaSO_3,aq}$$

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

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

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

14.6 (e)



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

Solids Out in Filter Cake

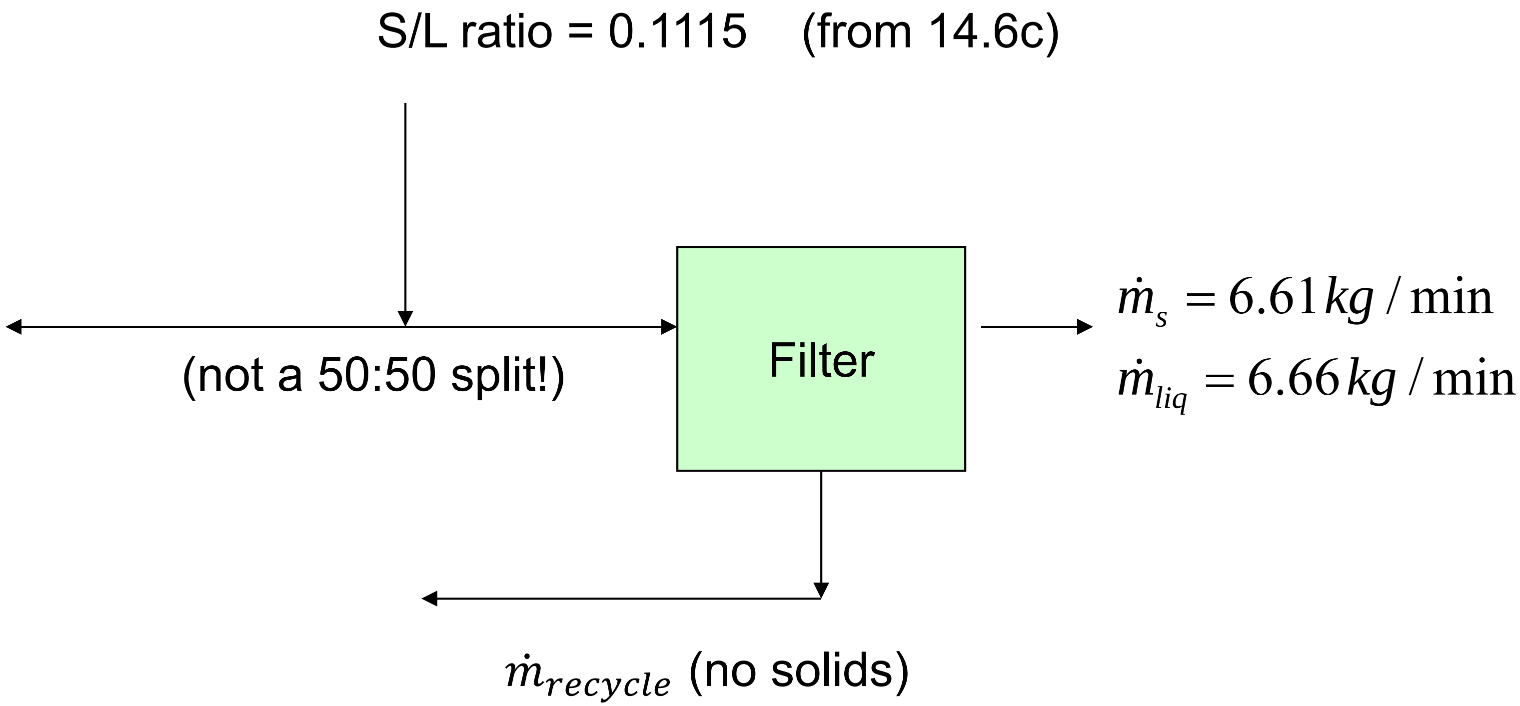
- All inerts (solid) from limestone $\rightarrow$ inerts in solid in filter cake
- All unreacted $CaCO_3$ in with fresh limestone $\rightarrow$ wet filter cake
- All SO_2 removed $\rightarrow$ wet filter cake ($CaSO_3$ hydrate)
- All flyash in with flue gas $\rightarrow$ filter cake

- 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,

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