Goal: Want to generate 1000 MW ($1x10^6$ kJ/s) of Electricity.

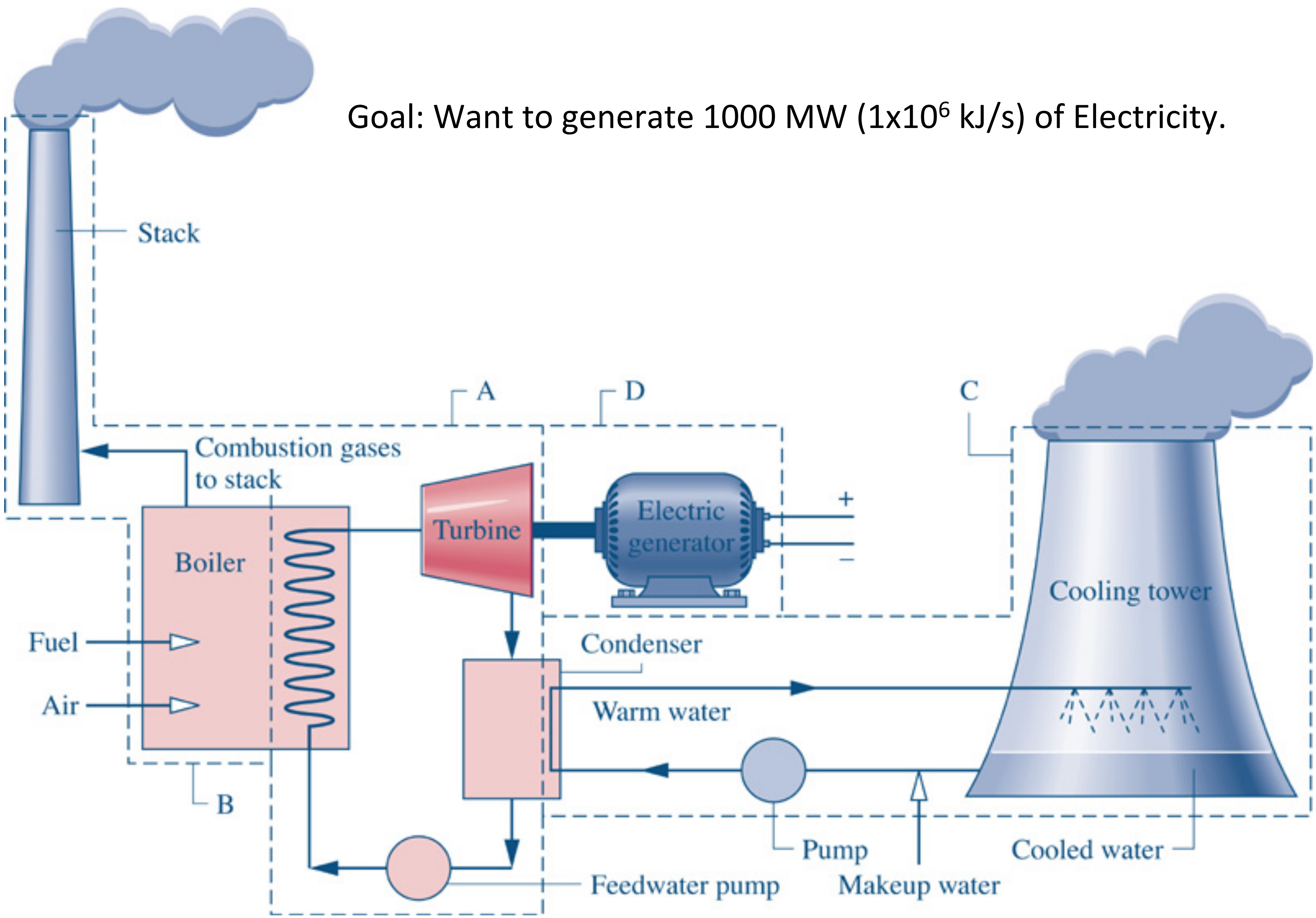
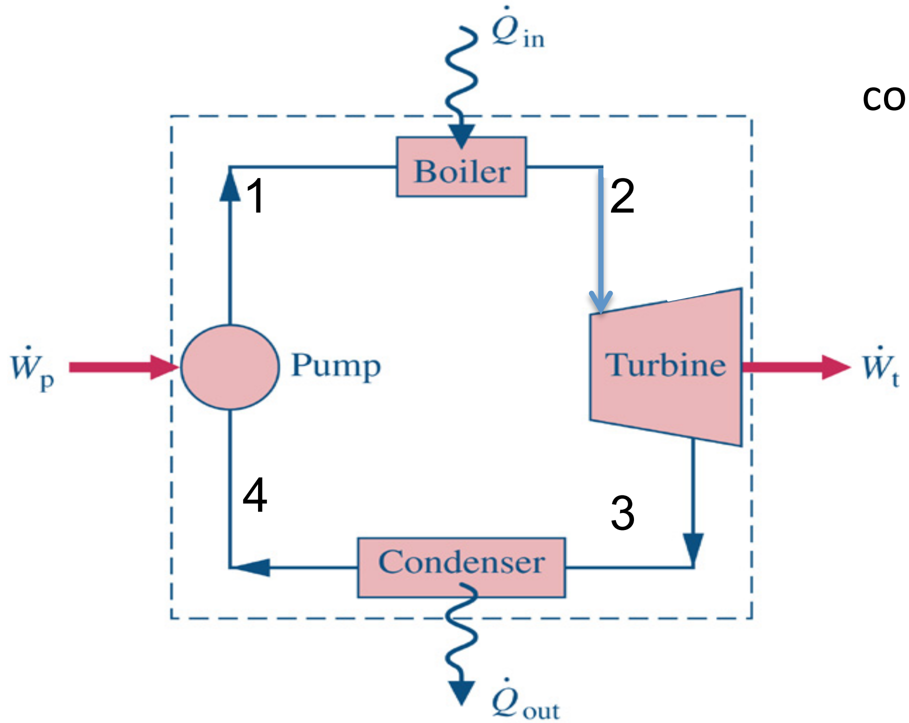



Fig08_01

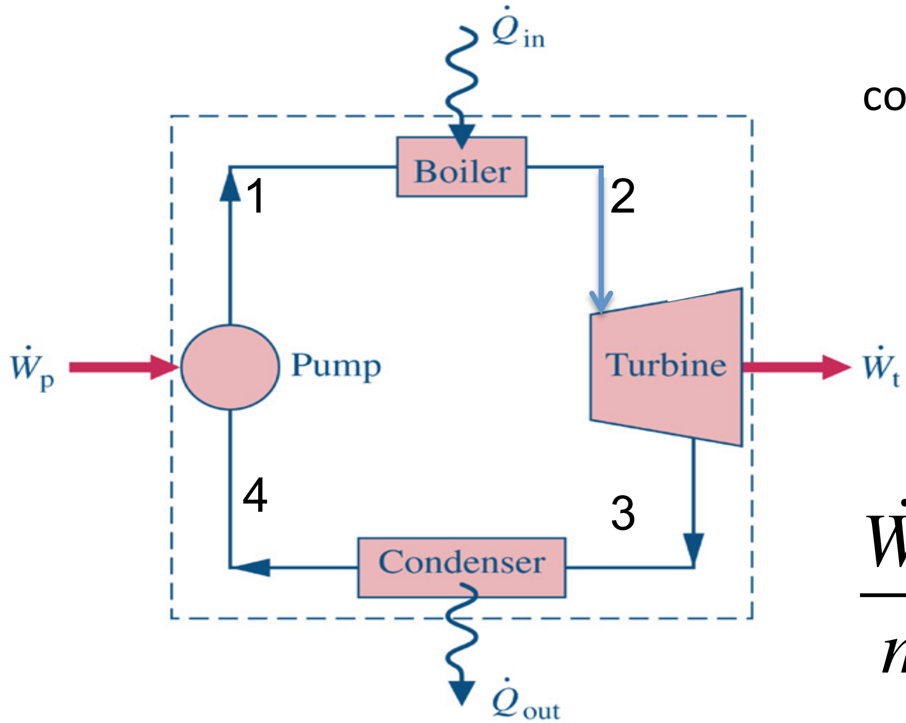



Consider a system similar to what the components that we've just analyzed in class.

Assume ideal conditions initially

Look up state 2 properties

| | P (bar) | T (deg. C) | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/(kgK) | x |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | 40 | 478 | | | | | |
| 3 | .6 | | | | | | .92 |
| 4 | | | | | | | |



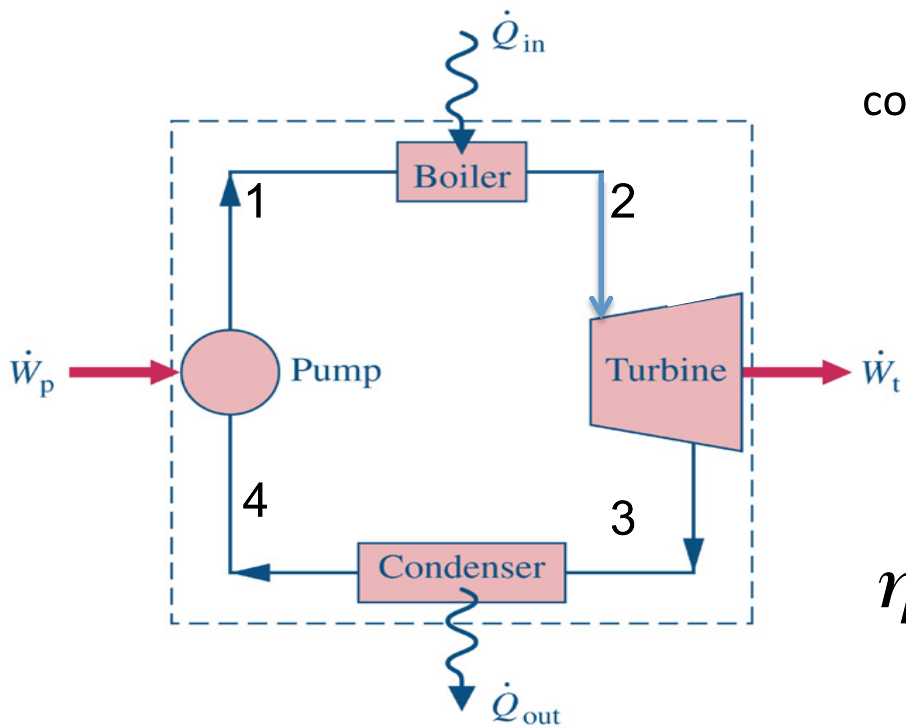

Consider a system similar to what the components that we've just analyzed in class.

Assume ideal conditions initially

Look up state properties

$$\frac{\dot{W}_P}{\dot{m}} = v(P_1 - P_4) \text{ Work Added}$$

| | P (bar) | T (deg. C) | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/(kgK) | x |
|---|---|---|---|---|---|---|---|
| 1 | 40 | 86.91 | .0010338 | 355.84 | 363.93 | 1.1565 | Liq |
| 2 | 40 | 478 | .083603 | 3060.16 | 3394.63 | 7.0219 | SH |
| 3 | .6 | 85.94 | 2.51352 | 2319.22 | 2469.97 | 7.0211 | .92 |
| 4 | .6 | 85.94 | .0010331 | 359.79 | 359.86 | 1.1453 | 0 |




Consider a system similar to what the components that we've just analyzed in class.

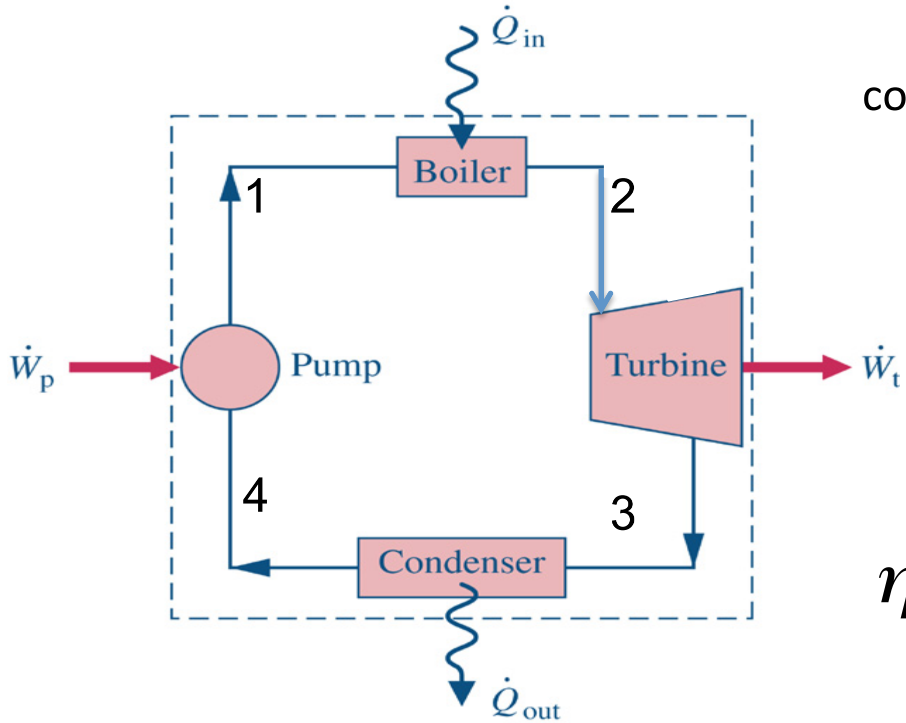
How to address actual conditions?

A) Measure/observe any two independent state properties and look up the rest.

B) Use reasonable efficiency estimates for each device

$$\eta_P = \frac{\dot{W}_{\text{P-Ideal}}}{\dot{W}_{\text{P-Actual}}} \qquad \eta_T = \frac{\dot{W}_{T\text{-Actual}}}{\dot{W}_{\text{T-Ideal}}}$$

| | **P (bar)** | **T (deg. C)** | **v $m^3$/kg** | **u kJ/kg** | **h kJ/kg** | **s kJ/(kgK)** | **x** |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | 40 | 478 | | | | | |
| 3 | .6 | | | | | ? | ? |
| 4 | | | | | | | |




Consider a system similar to what the components that we've just analyzed in class.

How to address actual conditions?

A) Measure/observe any two independent state properties and look up the rest.

B) Use reasonable efficiency estimates for each device

$$\eta_P = \frac{\dot{W}_{\text{P-Ideal}}}{\dot{W}_{\text{P-Actual}}} \qquad \eta_T = \frac{\dot{W}_{T\text{-Actual}}}{\dot{W}_{\text{T-Ideal}}}$$

$$\eta_T = 0.90$$

$$\eta_P = 0.95$$

| | P (bar) | T (deg. C) | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/(kgK) | x |
|---|---|---|---|---|---|---|---|
| 1 | 40 | 87.5 | | | 364.15 | | |
| 2 | 40 | 478 | .083603 | 3060.16 | 3394.63 | 7.0219 | SH |
| 3 | .6 | 85.94 | 2.6228 | 2404.41 | 2562.44 | 7.27653 | .96 |
| 4 | .6 | 85.94 | .0010331 | 359.79 | 359.86 | 1.1453 | 0 |

# Performance ?

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \qquad \eta_{Ideal} = \frac{(3394.63 - 2469.97) - (363.93 - 359.86)}{(3394.63 - 363.93)} = \frac{920.6}{3030.7} = 30.38\%$$

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \qquad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

$$\eta_{Max} = 1 - \frac{T_C}{T_H} = 1 - \frac{87.5 + 273.15}{478 + 273.15} = 1 - .48 = 52\%$$

Goal: Want to generate 1000 MW ($1x10^6$ kJ/s) of Electricity.

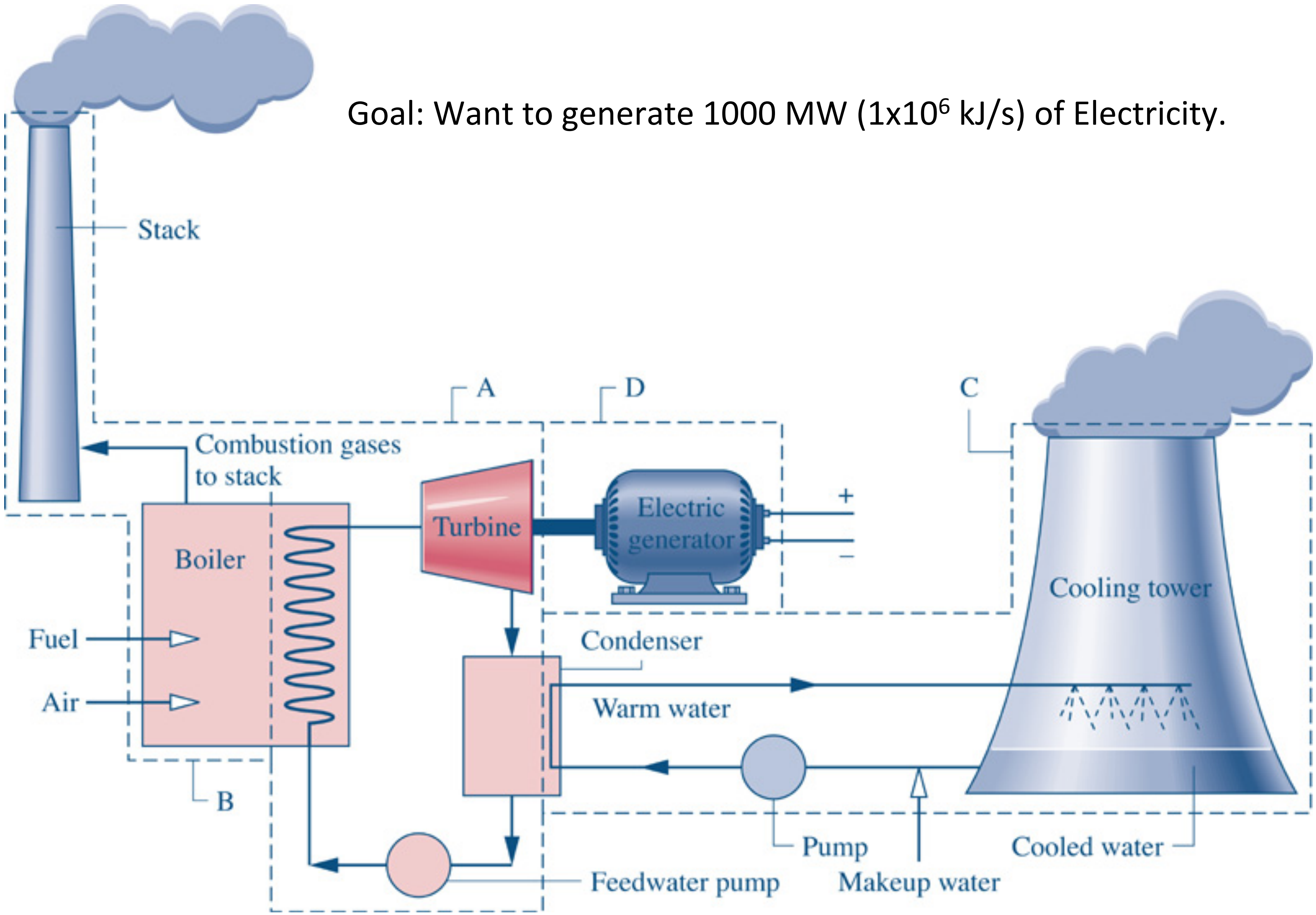



**Fig08_01**

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances

Performance ?

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \quad \eta_{Ideal} = \frac{(3394.63 - 2469.97) - (363.93 - 359.86)}{(3394.63 - 363.93)} = \frac{920.6}{3030.7} = 30.38\%$$

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \quad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

$$\eta_{Max} = 1 - \frac{T_C}{T_H} = 1 - \frac{87.5 + 273.15}{478 + 273.15} = 1 - .48 = 52\%$$

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \qquad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

$$\dot{W}_{Net-Actual} = (3394.63 - 2562.44) - (364.15 - 359.86)\frac{kJ}{kg} = 827.9\frac{kJ}{kg}$$

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\mathrm{In}}} = \frac{\dot{Q}_{\mathrm{In}} - \dot{Q}_{out}}{\dot{Q}_{\mathrm{In}}} \qquad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

$$\dot{W}_{Net-Actual} = (3394.63 - 2562.44) - (364.15 - 359.86)\frac{kJ}{kg} = 827.9\frac{kJ}{kg}$$

$$\dot{W}_{1000\,MW} = \dot{m}\frac{kg}{s} w\frac{kJ}{kg} = \dot{m}\frac{kg}{s} 827.9\frac{kJ}{kg}$$

$$\frac{\dot{W}_{1000\,MW}\ \frac{kJ}{s}}{w\frac{kJ}{kg}} = \dot{m}\frac{kg}{s} = \frac{1x10^6\ \frac{kJ}{s}}{827.9\frac{kJ}{kg}} = 1{,}208\frac{kg}{s}$$

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation
3.) Determine Boiler fuel requirements

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \qquad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation
3.) Determine Boiler fuel requirements

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \qquad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

$$\dot{Q}_{\text{In-Total}} = \dot{m}\frac{kg}{s}\dot{Q}_{\text{In}}\frac{kJ}{kg} = 1{,}208\frac{kg}{s}\ 3030.5\frac{kJ}{kg} = 3.661x10^6\, kJ\ Energy$$

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation
3.) Determine Boiler fuel requirements

$$\eta = \frac{\dot{W}_{Net}}{\dot{Q}_{\text{In}}} = \frac{\dot{Q}_{\text{In}} - \dot{Q}_{out}}{\dot{Q}_{\text{In}}} \qquad \eta_{Actual} = \frac{(3394.63 - 2562.44) - (364.15 - 359.86)}{(3394.63 - 364.15)} = \frac{827.9}{3030.5} = 27.32\%$$

$$\dot{Q}_{\text{In-Total}} = \dot{m}\frac{kg}{s}\dot{Q}_{\text{In}}\frac{kJ}{kg} = 1{,}208\frac{kg}{s}\ 3030.5\frac{kJ}{kg} = 3.661x10^{6}\ {kJ}/{s}\ \ Energy$$

What about Boiler efficiency? Say 85% efficient implies:

$$\dot{Q}_{\text{In-Fuel}} = \frac{\dot{Q}_{\text{In-Total}}}{Efficiency} = \frac{3.661x10^{6}}{.85}\ {kJ}/{s} = 4.306x10^{6}\ {kJ}/{s}\ \ Fuel\ Energy$$

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation
3.) Determine Boiler fuel requirements
4.) Determine chemical balance

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation
3.) Determine Boiler fuel requirements
4.) Determine chemical balance

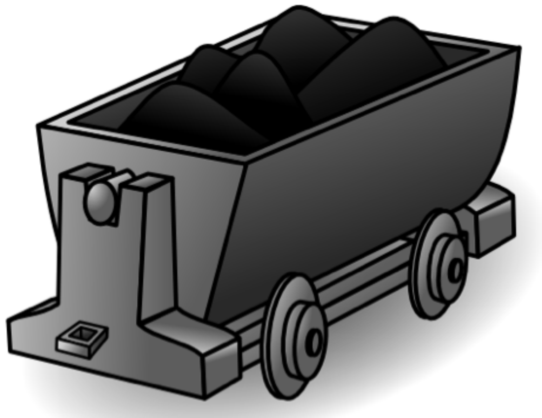
Assume Coal (the dominant fuel source) is used with a heating value of 5,500 kJ/kg coal.

How much fuel is required to run a 1000 MW power plant?
What are the C02 and other emissions?

1.) Given state variables, determine Ideal and Actual performances
2.) Determine the mass flow rate for 1000 MW generation
3.) Determine Boiler fuel requirements
4.) Determine chemical balance

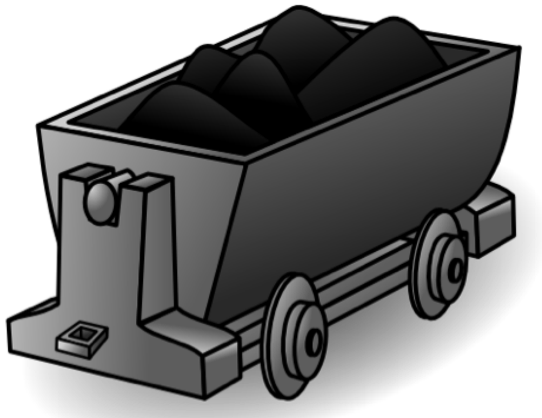
Assume Coal (the dominant fuel source) is used with a heating value of 5,500 kJ/kg coal.

$$\dot{m}_{Coal} = \dot{Q}_{\text{In-Fuel}} = \frac{4.306x10^6\, {}^{kJ}\!/_{s}\ Fuel\, Energy}{5{,}500\,\frac{kJ}{kg}} = 783\, {}^{kg}\!/_{s}\ Fuel = 67.65x10^6\,\frac{kg}{day}$$



A coal train car has a carry capacity of Approximately 100,000 kg/car

$$train\ cars = \dot{Q}_{\text{In-Fuel}} = \frac{\dot{m}_{Coal\ per\ day}}{m_{Coal\ per\ car}} = \frac{67.65x10^{6}\ \dfrac{kg}{day}}{100{,}000\ \dfrac{kg}{car}} = 677\,\frac{train\,cars}{day}$$



A coal train car has a carry capacity of Approximately 100,000 kg/car

$$train\ cars = \dot{Q}_{\text{In-Fuel}} = \frac{\dot{m}_{Coal\ per\ day}}{m_{Coal\ per\ car}} = \frac{67.65x10^6\ \dfrac{kg}{day}}{100{,}000\ \dfrac{kg}{car}} = 677\,\frac{train\,cars}{day}$$

In 1999 the average train could pull 70 coal cars. Consequently, about 10 train deliveries per day are required to run the power plant!