P&I Diagrams
Process Control
Vapor Compression cycle

4/16/15

Paris!

EIL
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Ticket/seat reservation for Mark McCready

EUROSTAR

Date	Time	Train	Depart		Arrive	Time	Date	Class	Coach	Seat
04/07	07:55	9008	LONDON ST-PANCRAS	→	PARIS NORD	11:17	04/07	Standard	17	83

Additional information
Check in at least 30 min before departure time
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You are booked in a duo seat
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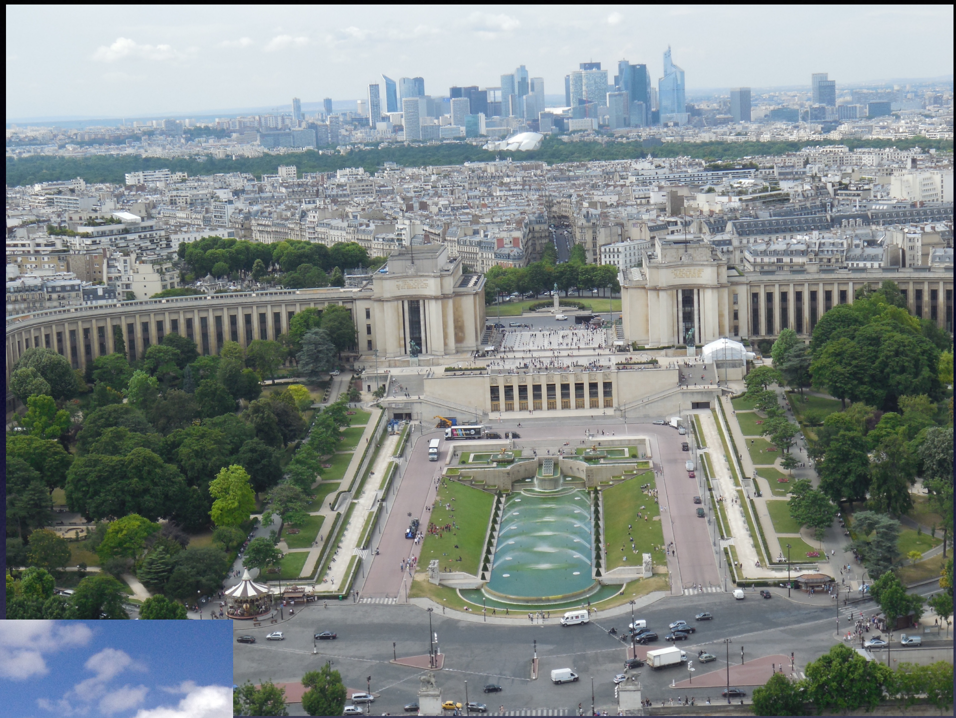
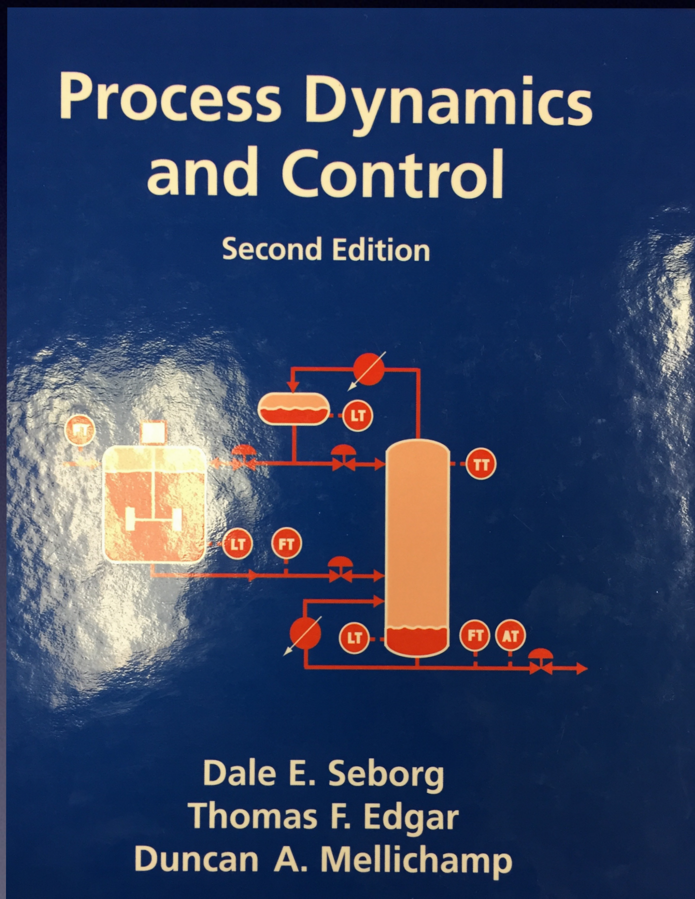
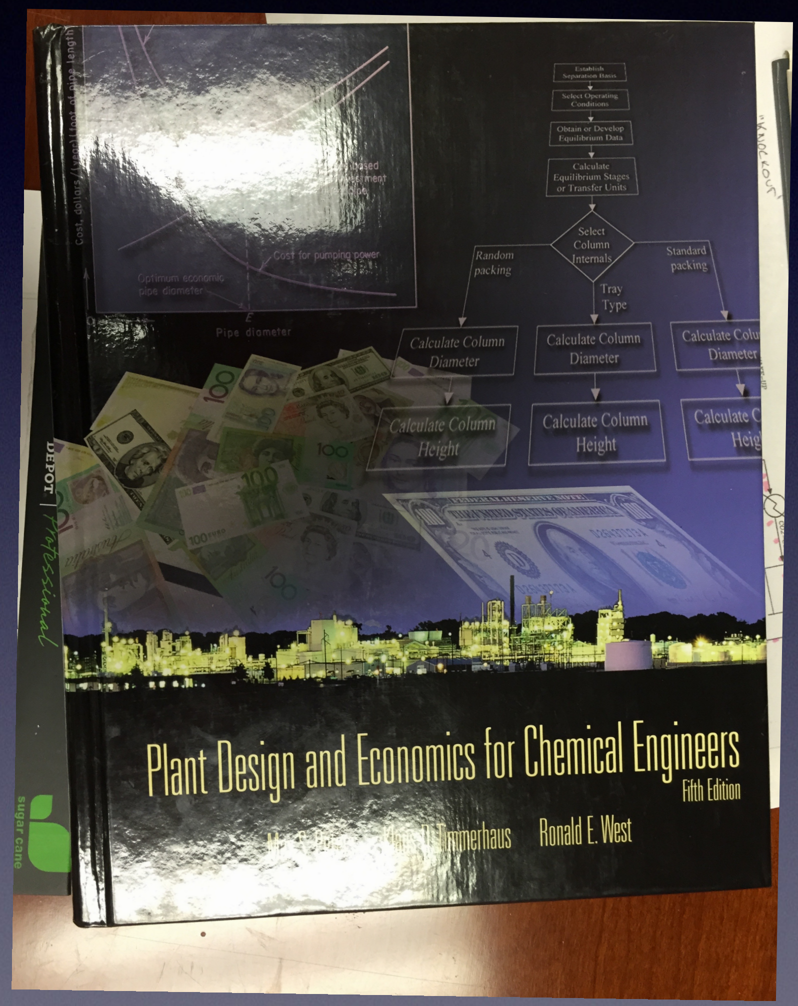
Paris



Partial references for today





Piping and instrumentation diagrams

- Intended to show the details of <u>all</u> pipes, valves, sensors/transducers of the process.
- If it were "your" process, you would want to know everything.
- There may be bypasses, multiple pumps, extra valves, heat exchangers in series, backup thermocouples, …
  - that are not shown on the process flow diagram but might be important in an emergency or just for maintenance
- The Imperial Instructors take this knowledge of the hardware very seriously so you will get a lot of time to trace every connection in the plant

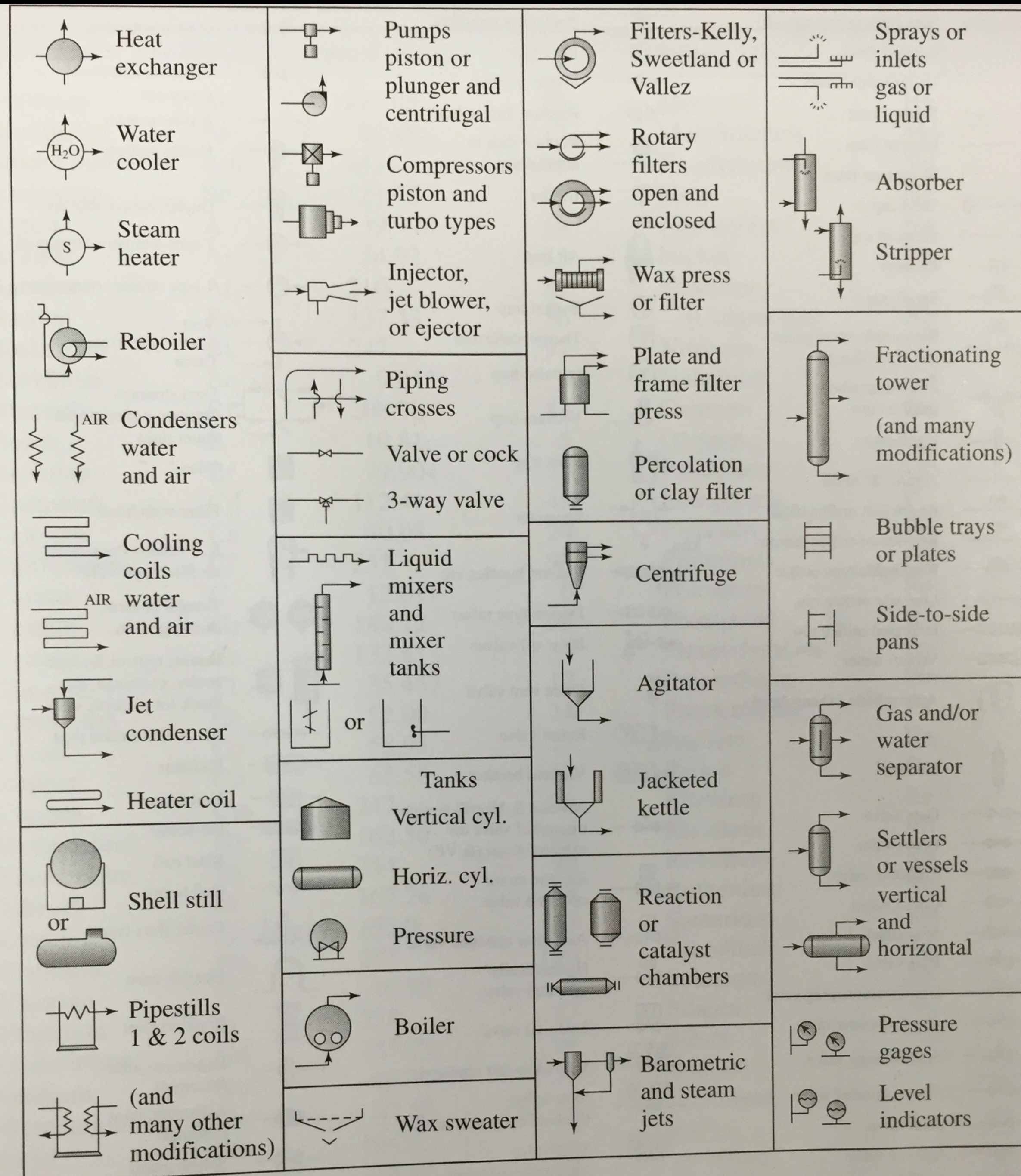


Figure D-5
Equipment symbols

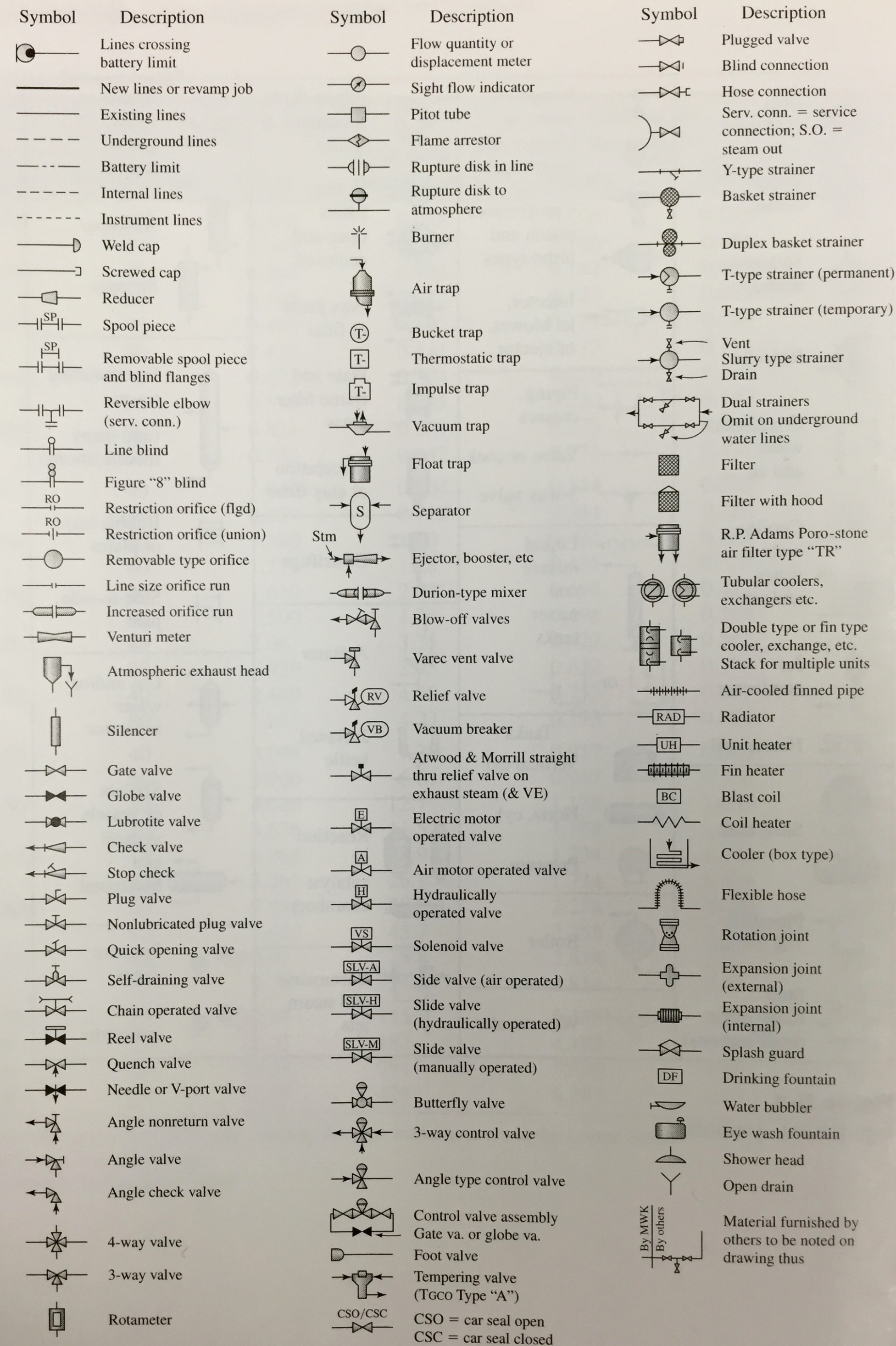


Figure D-6

Flowsheet symbols, particularly for detailed equipment flowsheets. *(Courtesy of the*

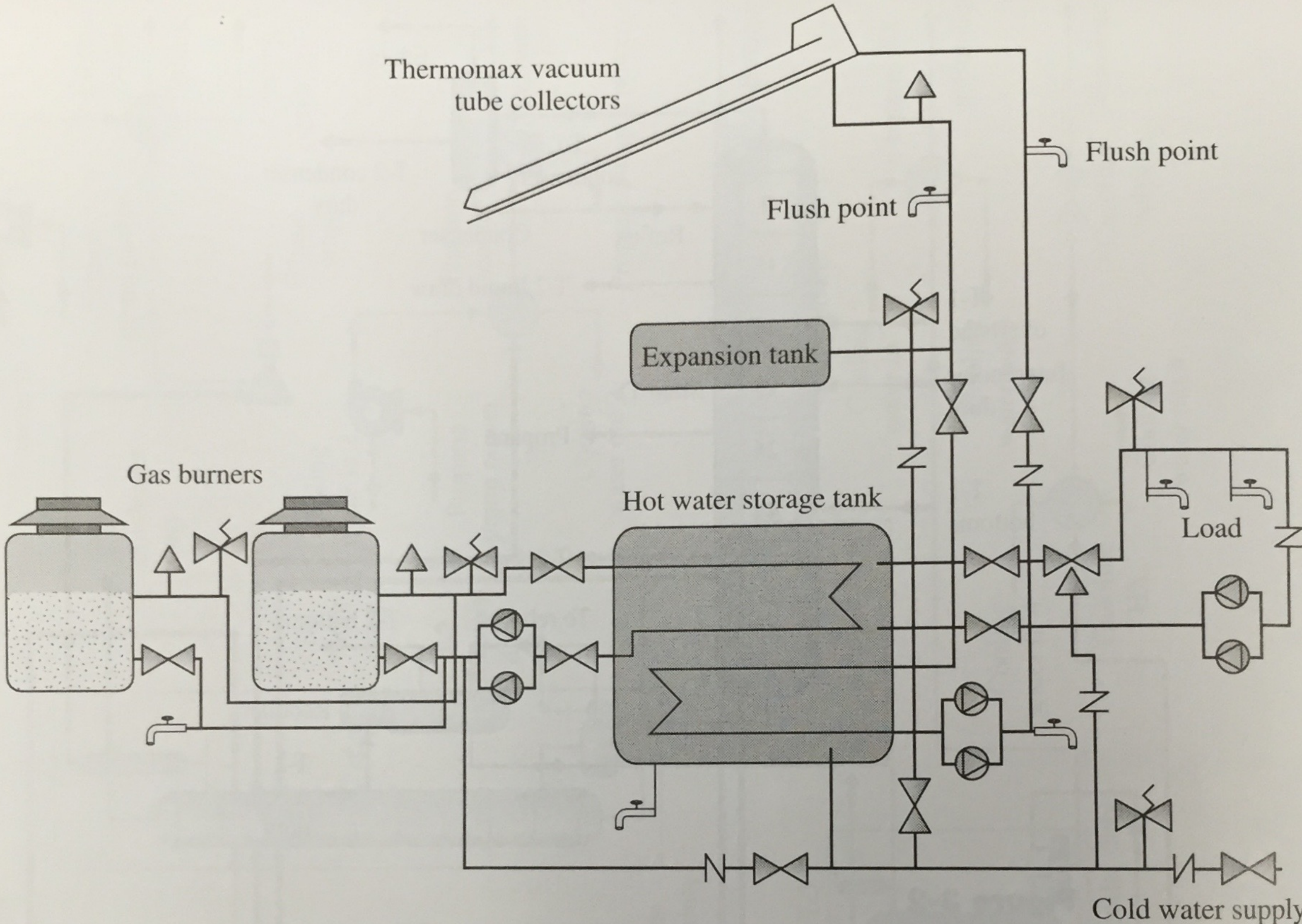
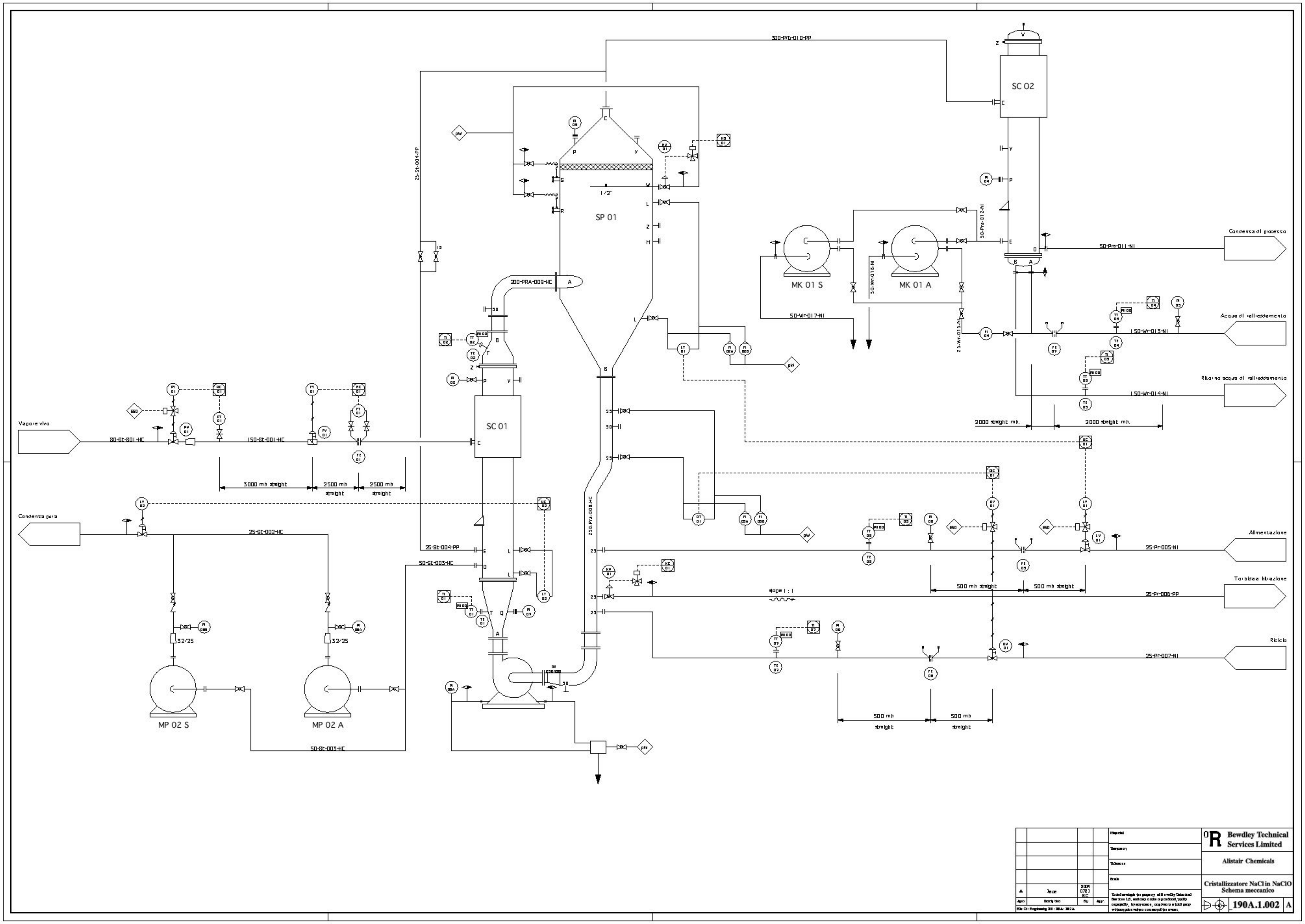


Figure 3-3
Piping and instrumentation diagram for a commercial integrated solar water heating system


500-Prb-010-PP
SC 02
SP 01
SC 01
MK 01 S
MK 01 A
MP 02 S
MP 02 A
Vapore vivo
80-St-001-HC
150-St-001-HC
3000 mh straight
2500 mh straight
2500 mh straight
Condensa pura
25-St-002-HC
25-St-004-PP
50-St-003-HC
200-PRA-009-HC
250-PRA-008-HC
50-Wr-017-NI
Condensa di processo
50-Pra-011-NI
Acqua di raffreddamento
150-Wr-013-NI
Ritorno acqua di raffreddamento
150-Wr-014-NI
2000 straight mh.
2000 straight mh.
Alimentazione
25-Pr-005-NI
Torbida a filtrazione
25-Pr-006-PP
Riciclo
25-Pr-007-NI
500 mh straight
500 mh straight
Bewdley Technical
Services Limited
Alistair Chemicals
Cristallizzatore NaCl in NaClO
Schema meccanico
190A.1.002
A
Issue
2004
By
Appr.

Imperial Flowsheet

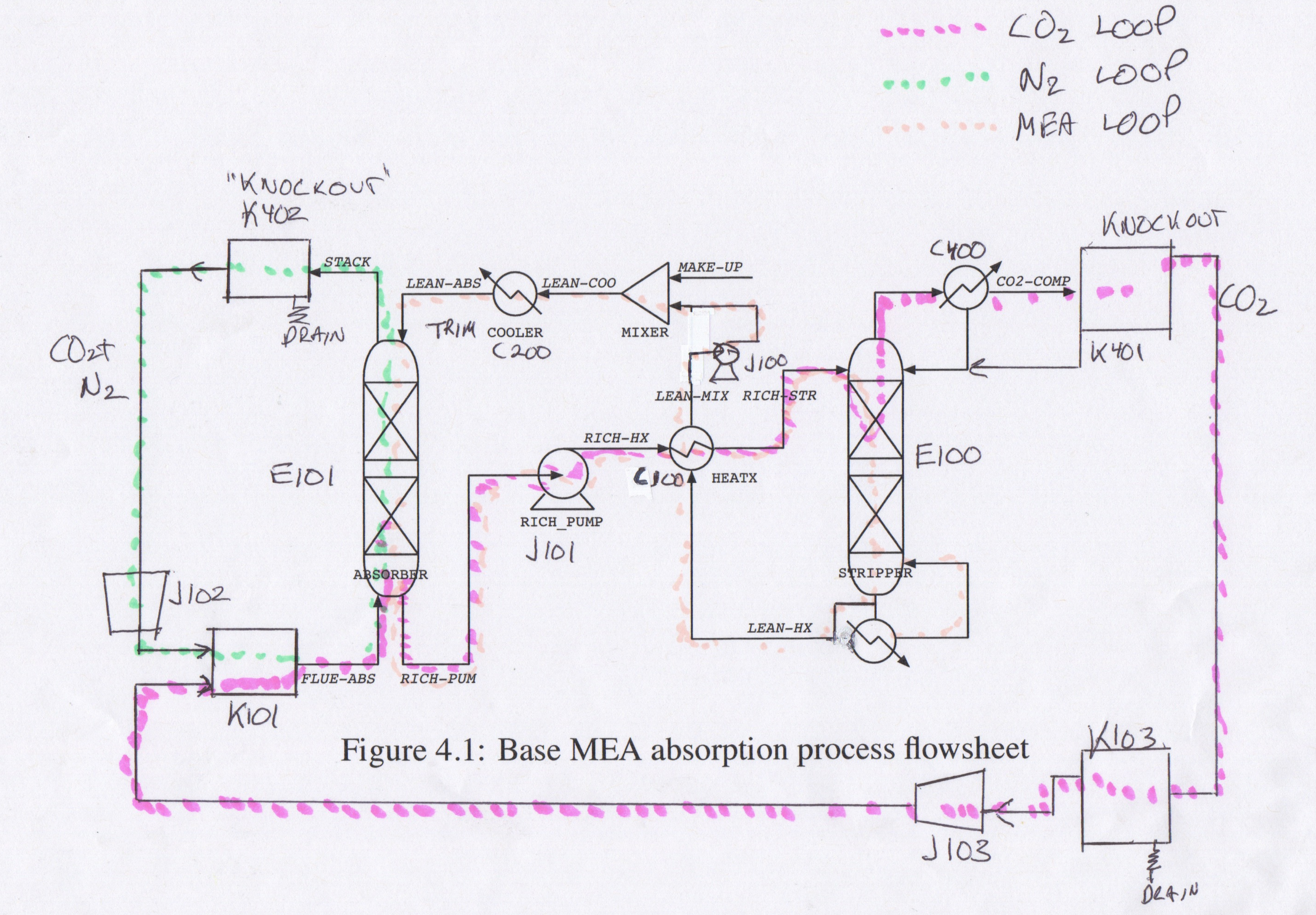
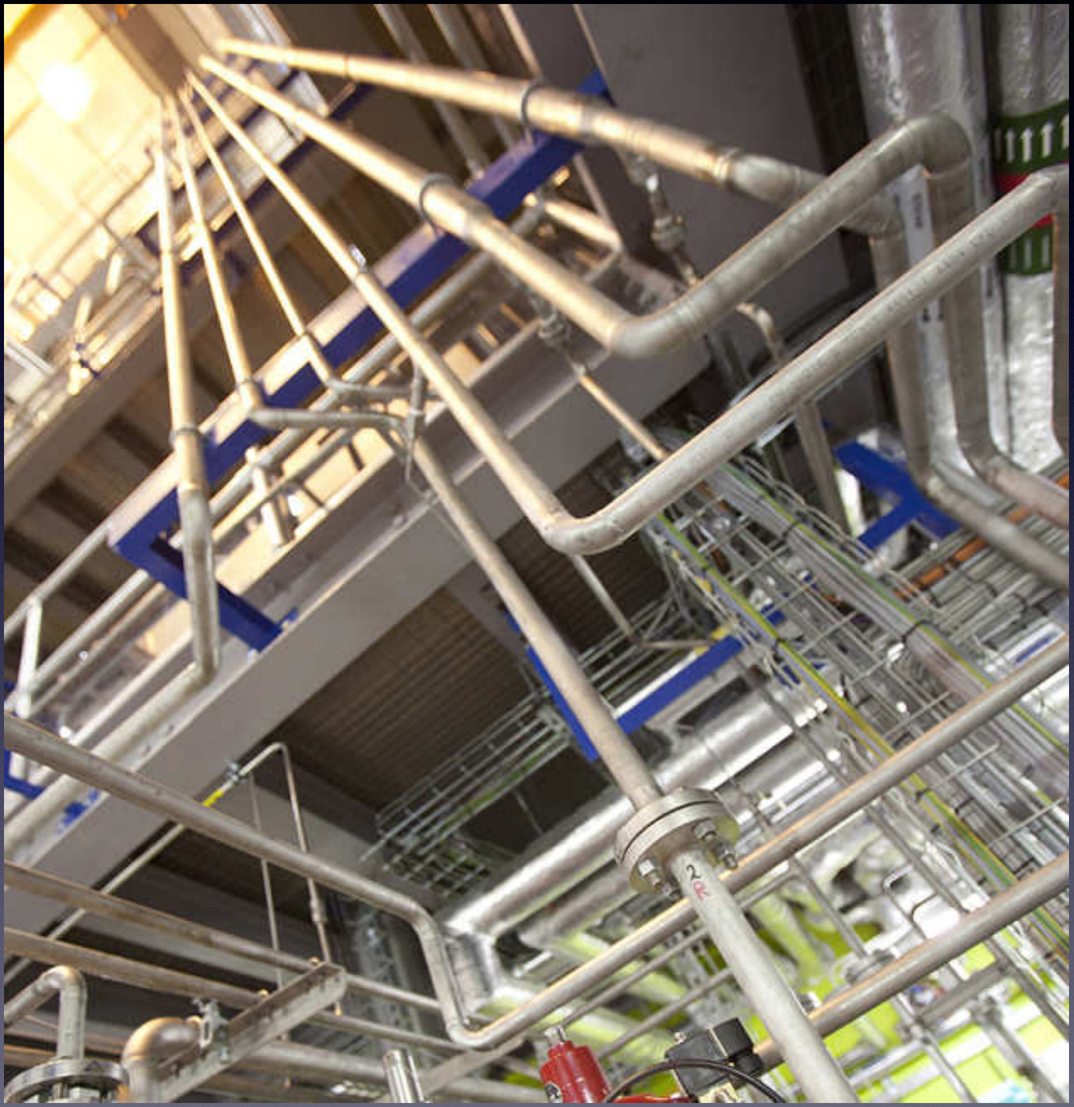


Figure 4.1: Base MEA absorption process flowsheet

Pipes!



Cables, transducers, thermocouples

Infra-red Spectroscopy

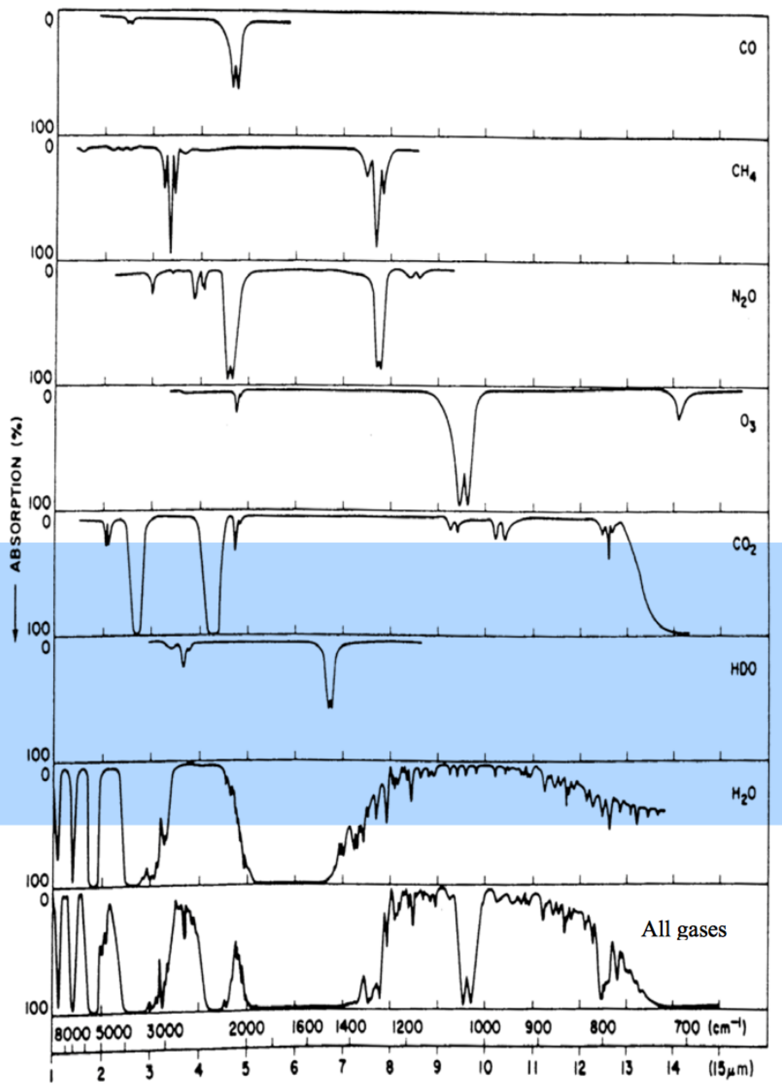


Figure 6.2 ***Low-resolution*** infrared absorption spectra of the major atmospheric gases. (compare to Figure 6.3 that shows transmission with higher spectral resolution)

Control: driving a car

- If we just stick the basic situation…
  - You are driving a car on a "test track" with no other cars.
  - The goal is to drive a preferred "line" at constant speed.
  - How could this be accomplished?

Driving car

- *Feedback* control
    - You could be watching or listening to see/hear if you are “on” the track (or preferred “line”)
        - Yes: do nothing, No: correct back (on/off)
        - Pretty crude and might not get you back *on* in time
    - You could have in mind a range of paths that are more or less desirable. As you get away from a more desirable position, you correct or correct harder
    - The second might work, but you could be *surprised* if the path changes

Driving Car

- *Feedforward* Control
  - You look at the road ahead and turn the wheel according to a specified set of rules or equations that are presumed to be adequate to keep the car on track. In the simplest idealization you are not looking at where you are on the road, only what is coming up.
    - The ability to anticipate is certainly a benefit and if all goes will could get the car almost exactly on track
    - If something goes wrong, e.g., the road has bumps or some slope, then the specified turning won't work perfectly.

Driving a car

- We could also mention: Sensitivity/stability
  - Let's not..
    - or just say you will have to drive different vehicles differently!
- So what you really use is a combination of feedback and feedforward control
  - With feedback you use a complex algorithm that includes thinking of how fast the car is returning to the path.

Process control

- These same principles apply to chemical processes.
  - Feedback to make sure you are on track
  - Feedforward to anticipate "upsets" — say from fluctuations in the feed concentration or temperature
- For either driving or a chemical process, you need specifications (e.g., concentration) from which you create "setpoints".

Simple process example

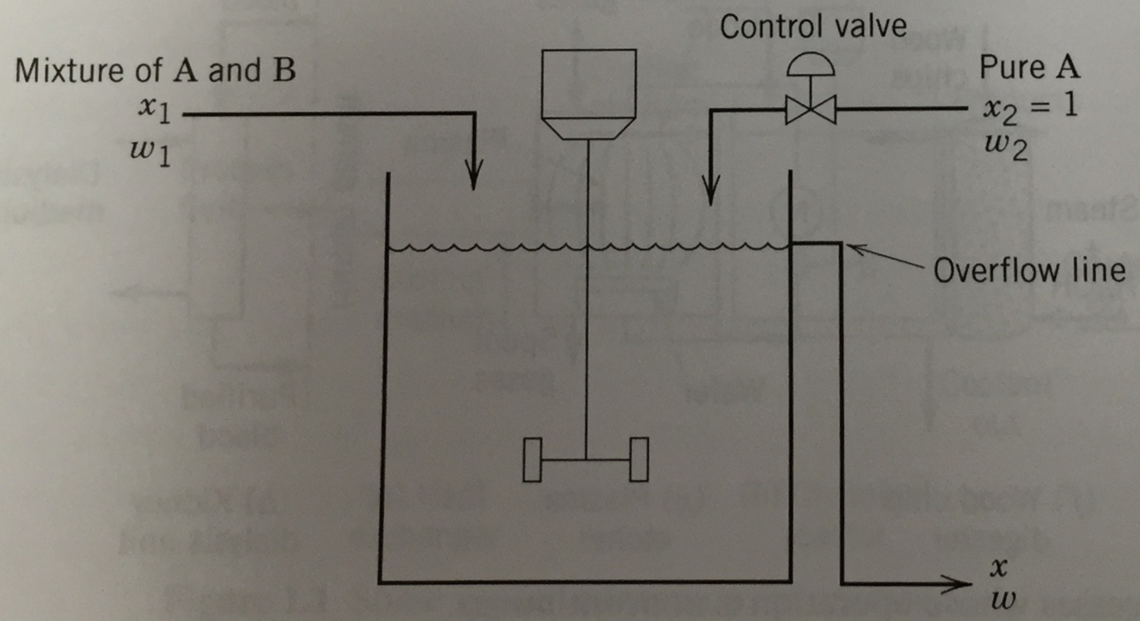
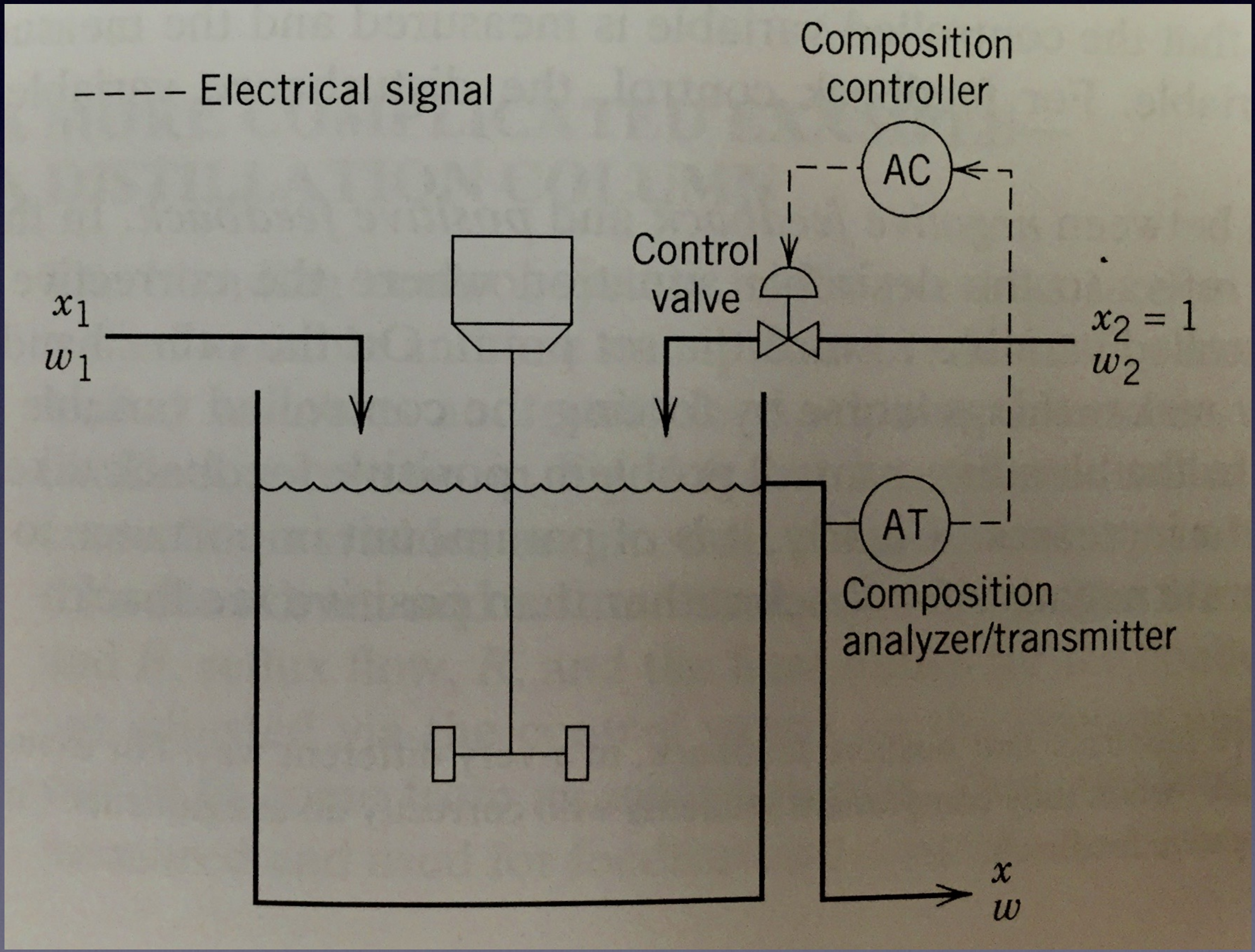


Figure 1.3 Stirred-tank blending system.

Feedback: Measure output, adjust input



Feedforward

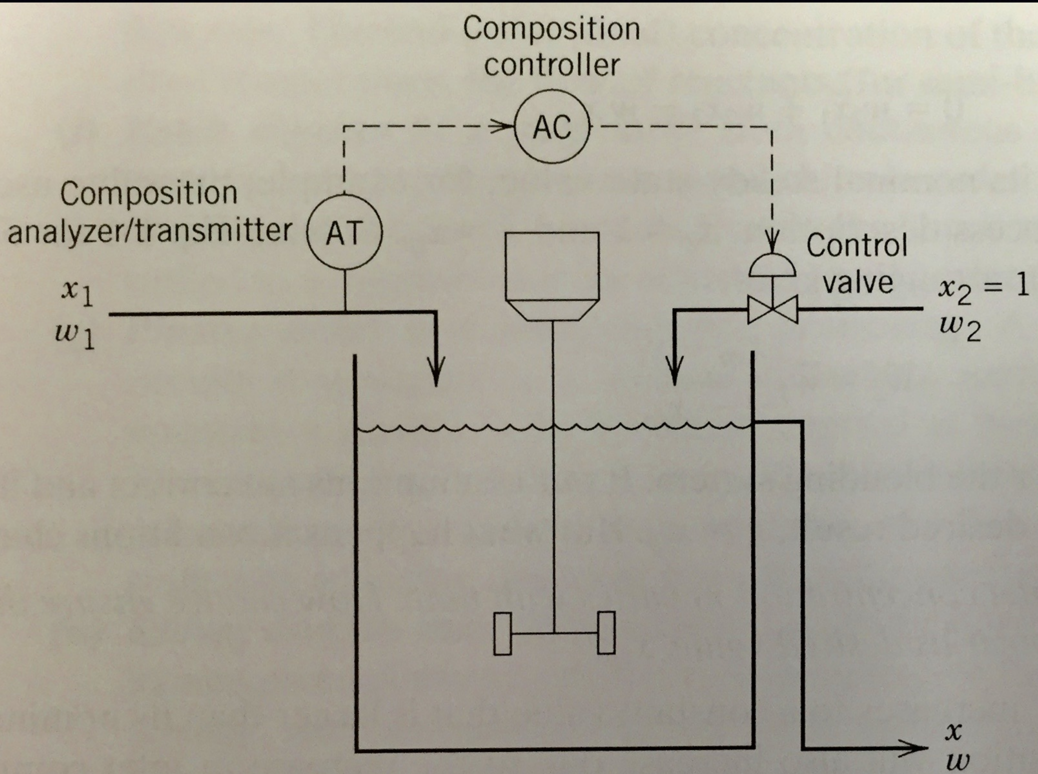


Figure 1.5 Blending system and Control Method 2.

Method 2. *Measure x_1, adjust w_2.* As an alternative to Method 1, we could measure disturbance variable x_1 and adjust w_2 accordingly. Thus, if $x_1 > \overline{x}_1$, we would decrease w_2 so that $w_2 < \overline{w}_2$. If $x_1 < \overline{x}_1$, we would increase w_2. A control law based on Method 2 can be derived from Eq. 1-3 by replacing $\overline{x}_1$ with $x_1(t)$ and $\overline{w}_2$ with $w_2(t)$:

Our Process

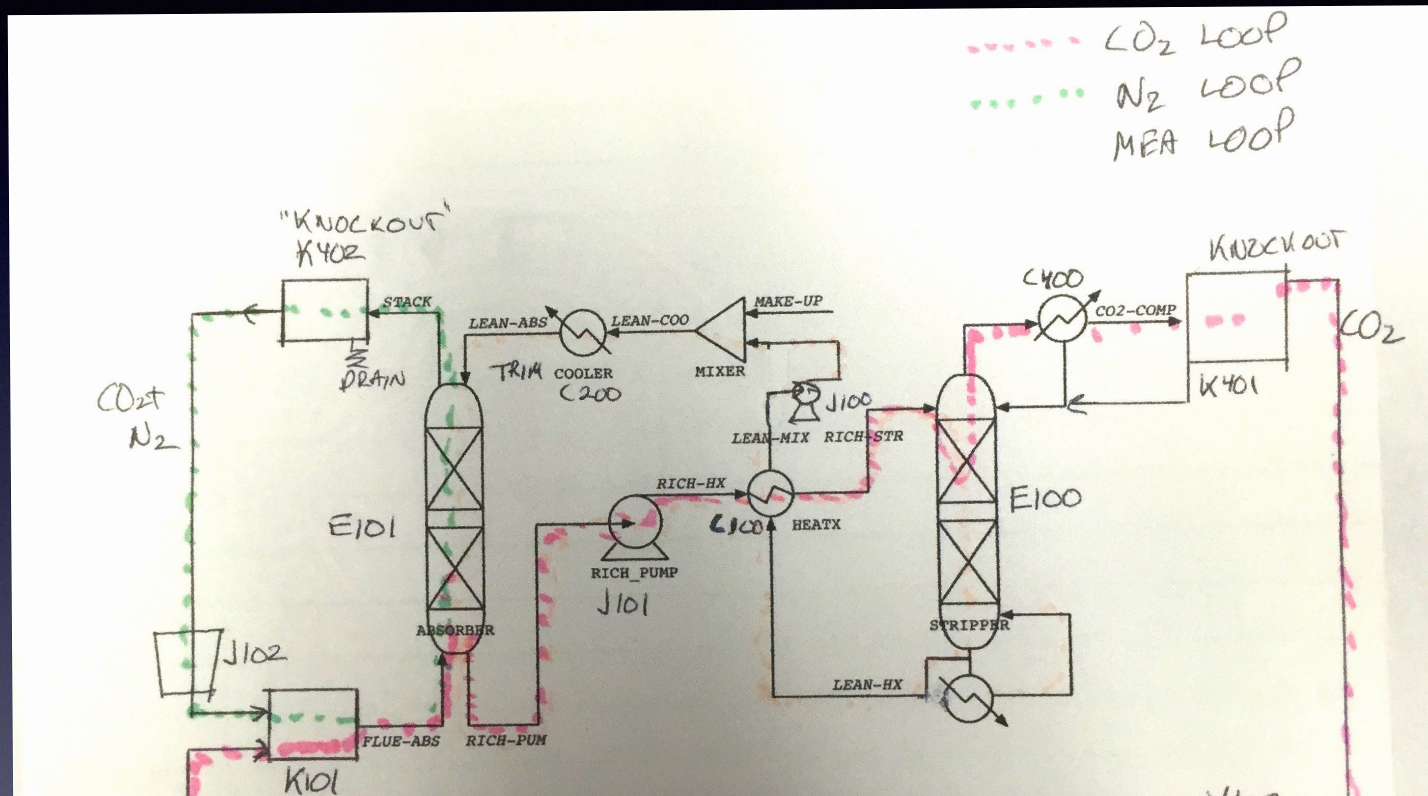
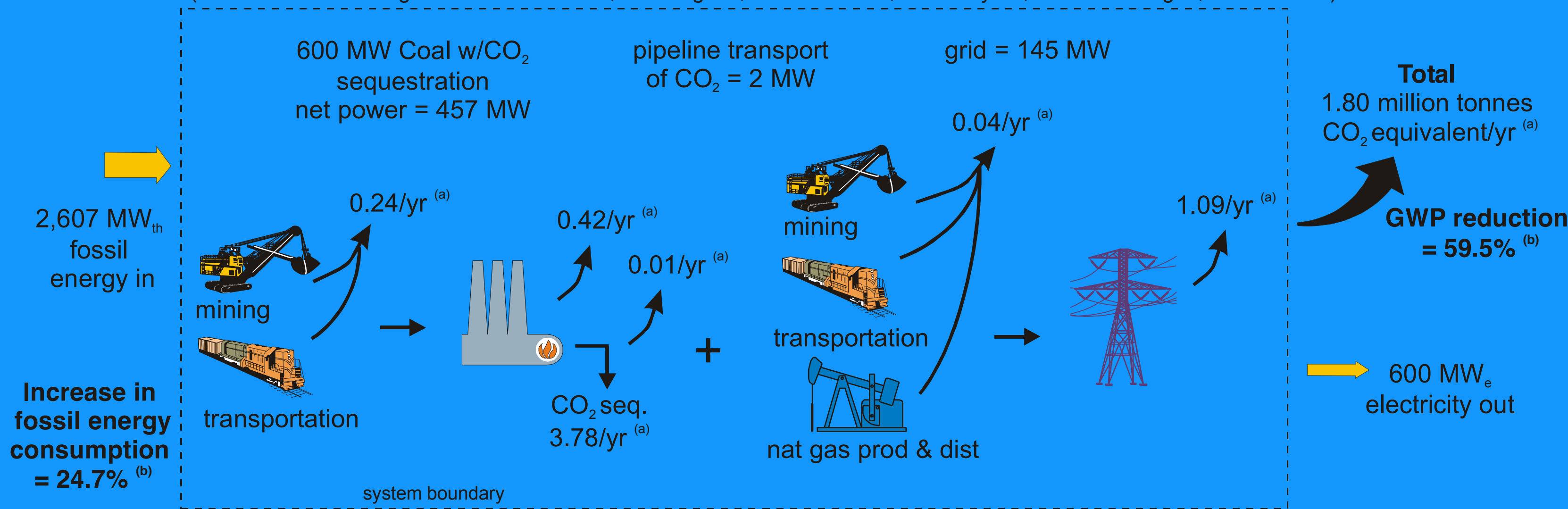


Figure 4.1: Base MEA absorption process flowsheet

Coal/w sequestration (+NG)

Figure 3: Coal-fired Power Plant with CO_2 Sequestration and 145 MW of Grid Capacity Added to Maintain 600 MW

(U.S. mid-continental grid mix is 64.7% coal, 5.1% lignite, 18.4% nuclear, 10.3% hydro, 1.4% natural gas, and 0.1% oil)



Notes: (a) GHGs (CO_2, CH_4, and N_2O) expressed in million tonnes CO_2-equivalents/yr at 100% capacity; (b) Change in GWP and change in fossil energy consumption compared to reference

Expected “specs”

- CO_2 concentration in Absorber exit is below ~1% or 5%
- Either because the other gas needs a specified purity or because you are required to remove a certain fraction of the CO_2
    - adjust temperature of input MEA stream (easy)
    - adjust flowrate of input MEA stream (easy, but propagates back through the process and changes concentration only in certain ranges)
    - remove more CO_2 from MEA in stripper

For dilute systems:

$$z = H_{OG} N_{OG} = H_{OG} \int_{y_2}^{y_1} \frac{dy}{y - y^*}$$

$$H_{OG} = \frac{V}{K'_y a S} = \frac{V}{K_y a (1 - y)_{*M} S}$$

- *V* is the gas flow rate in moles/time
- K'_y is the appropriate mass transfer coefficient
- *a* is the area of gas-liquid contact per volume of packed bed
- *S* is the cross sectional area of the column
- *y* is the mole fraction of the component in the gas
- y^* is the equilibrium value of the transferring gas component in the liquid.

Expected spec

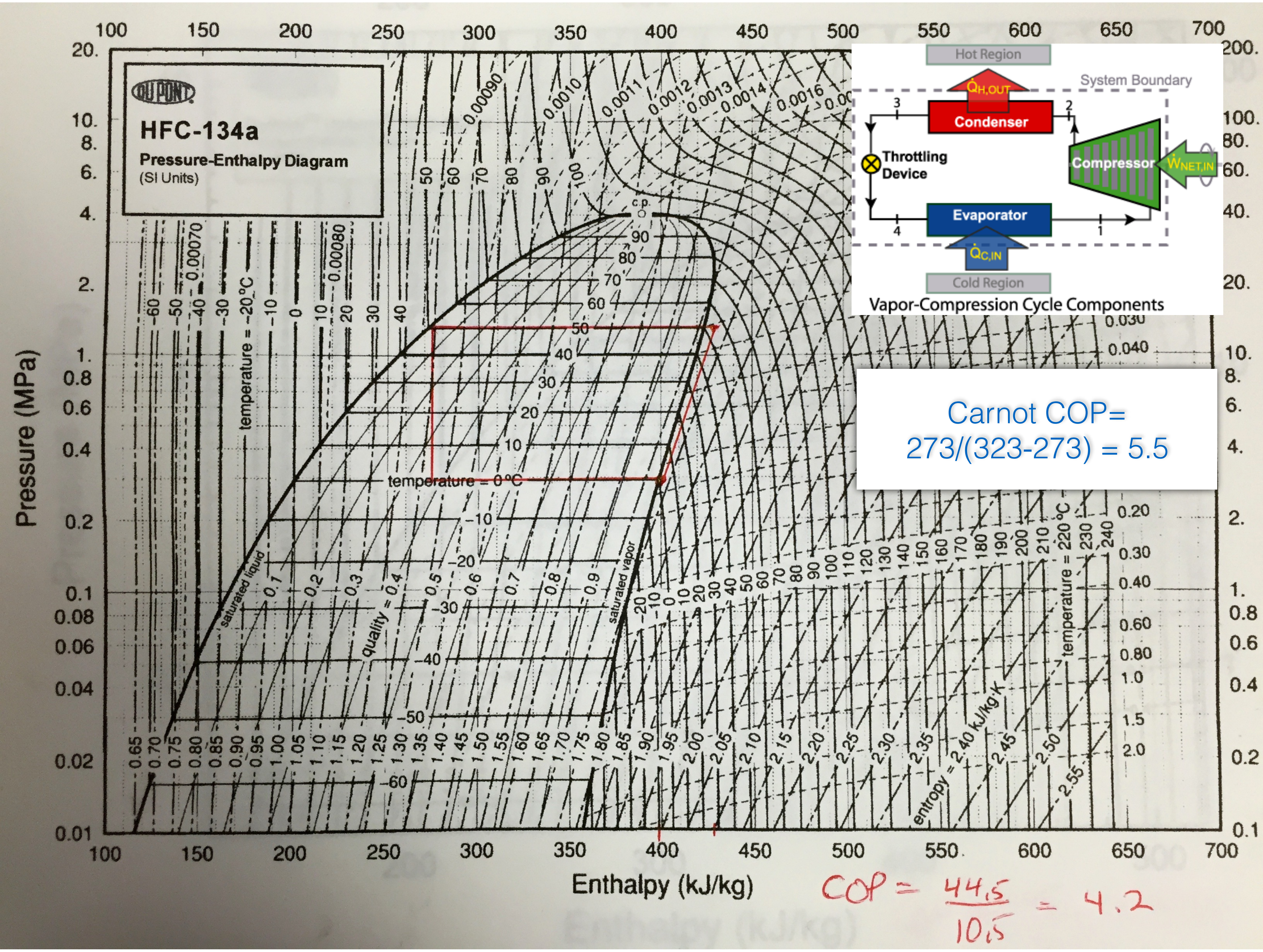
- Nitrogen in exit CO_2 stream
  - Change temperature in absorber
- Water vapor in exit MEA stream
  - More/colder water in condenser

Propagated effect

- If you change the MEA flowrate or want to change the concentration of CO2 in the MEA feed, the reboiler steam rate will have to be adjusted

Vapor Compression Refrigeration

- Very common process for creating cold or liquifying a gas
  - Can be used to “pump heat”
- The Carnot efficiency can be greater than 1 since you are just pumping heat, not turning heat into work
- Usually you have a temperature requirement on the cold side (evaporator) because this what you want to cool.
- You also have a temperature range for being able to successfully expel the heat (outside your car or refrigerator)
  - The pressures are adjusted to match these temps.
  - Flowrate of refrigerant provides require cooling capacity



Carnot COP=
273/(323-273) = 5.5

Experimental device

Figure 4.1: Photograph of the *PA-Hilton R633* Refrigeration Cycle Demonstration Unit.

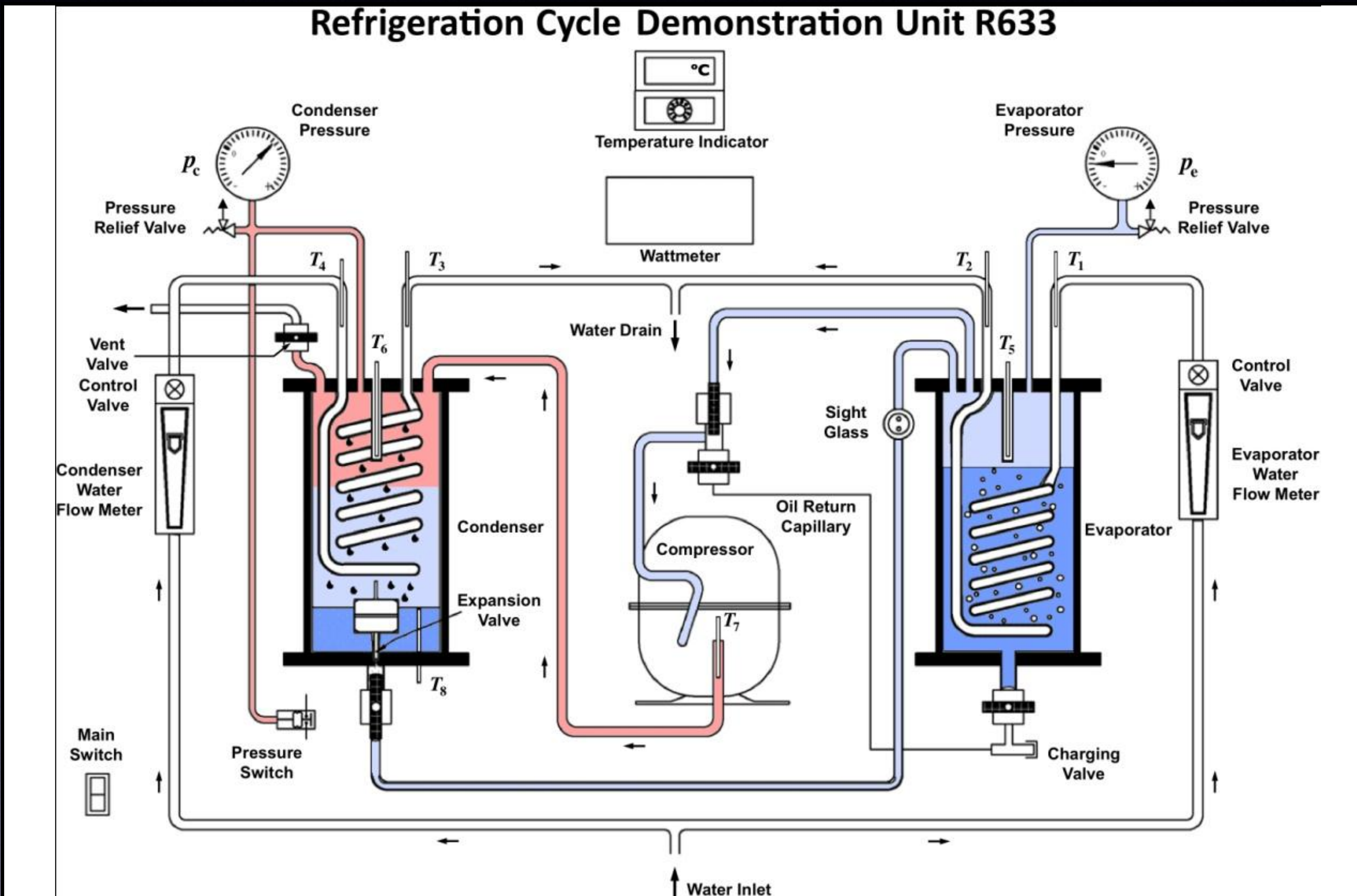
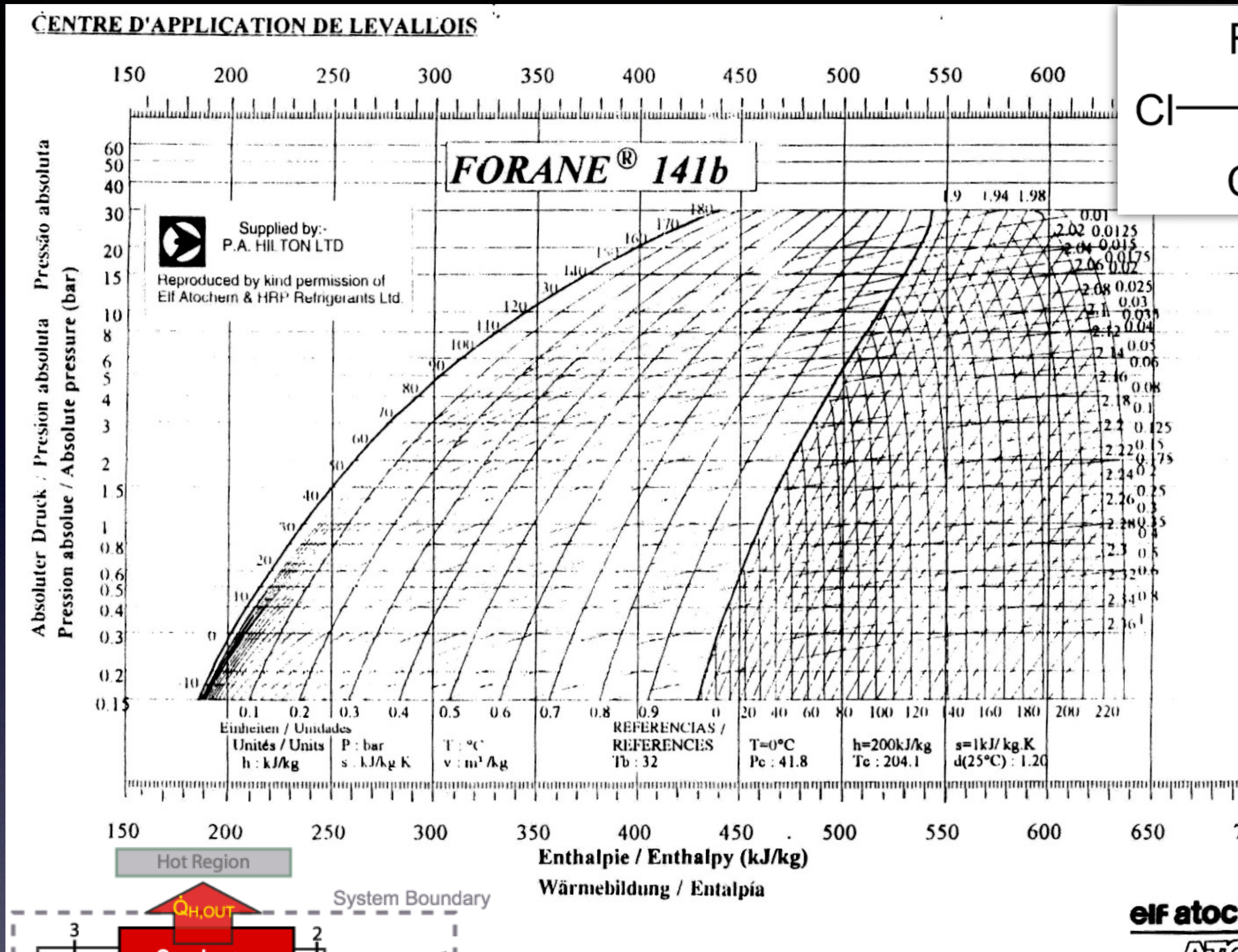
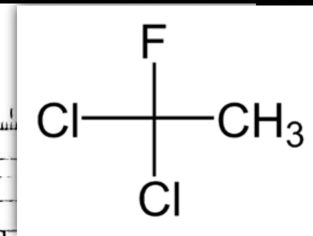
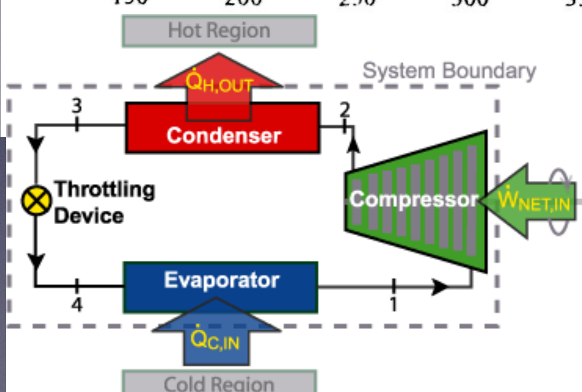


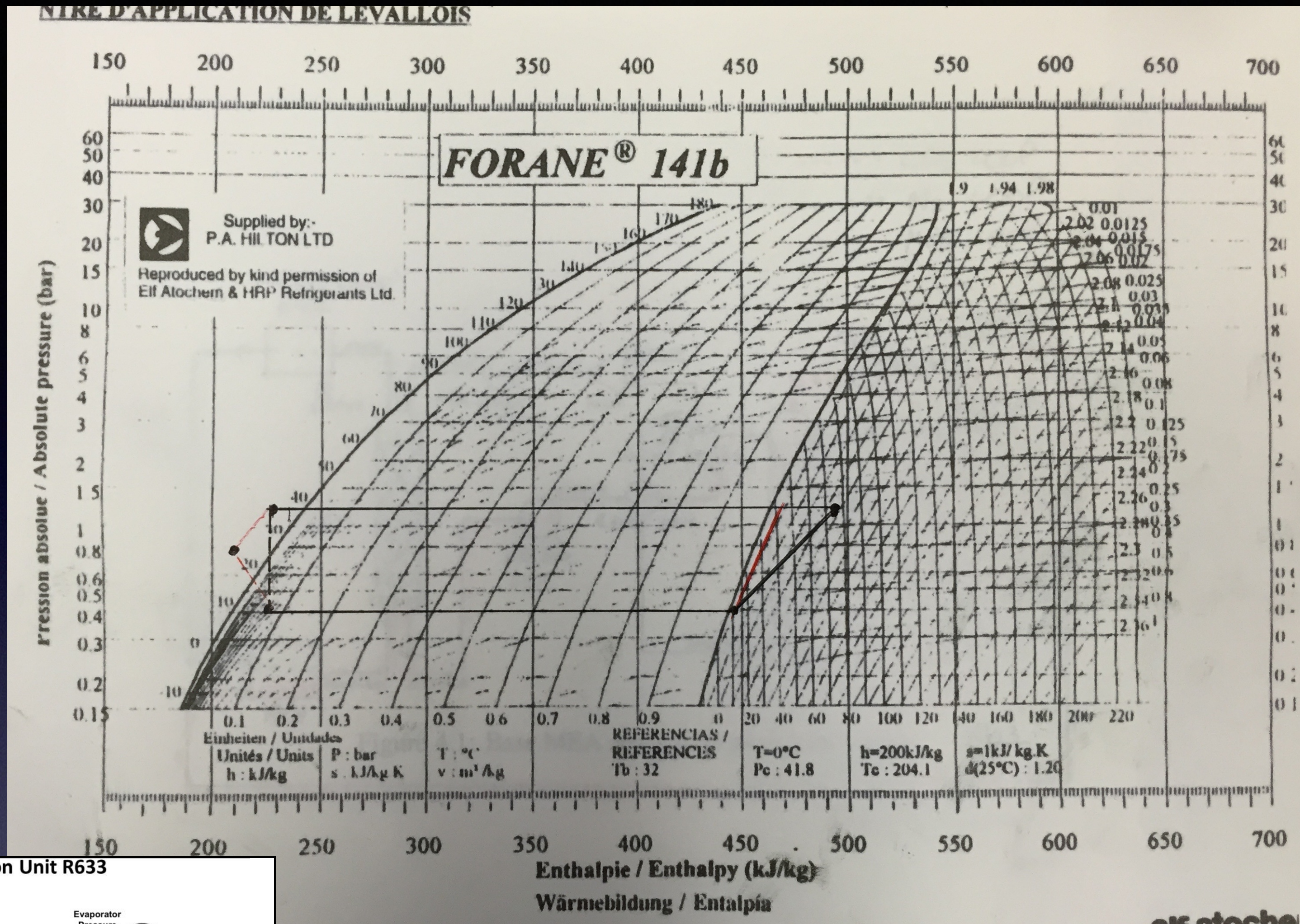
Figure 4.2: A schematic of the *PA-Hilton R633* Refrigeration Cycle Demonstration Unit.

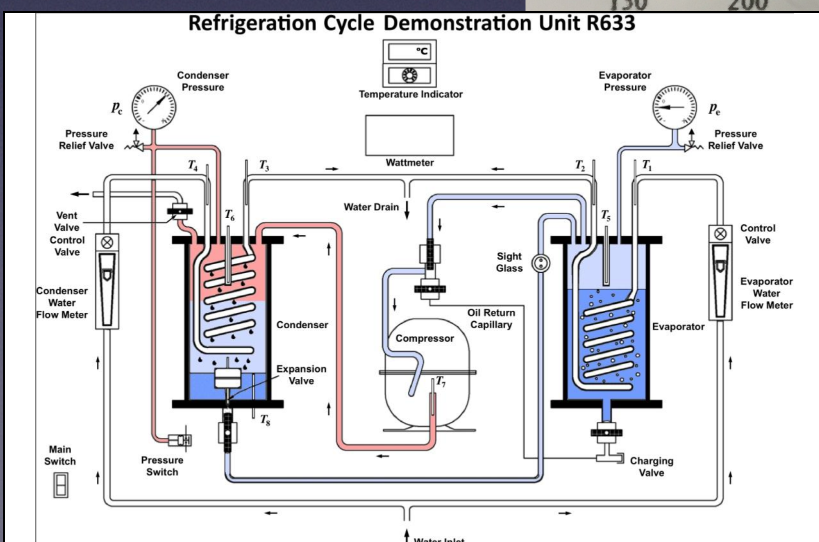






Vapor-Compression Cycle Components





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