Process Engineering: Equations to Situations

Last few weeks have been hectic due to extra work pressure in view of Corona lock down. Working on 3 projects simultaneously with all clients wanting to finish major work before lock down kept me and team very busy. Now is the time to recuperate and be ready for post-Corona realities and challenges. I am sure there would be risks but opportunities as well.

This lock down has highlighted importance of "work-from-home" and "Online Learning". We at Probite had realized that sooner or later it would come to this and had launched our online training course on 16-March. It is going well at the moment.

I have received enquiries from many just-passed out engineers for online training. This fresh talent is full of energy, but is unsure if what they learnt in college is what industry demands?

Few years into the industry and most of your colleagues would tell you how college education is of no use in industry. They do not teach us in college anything that we use here.

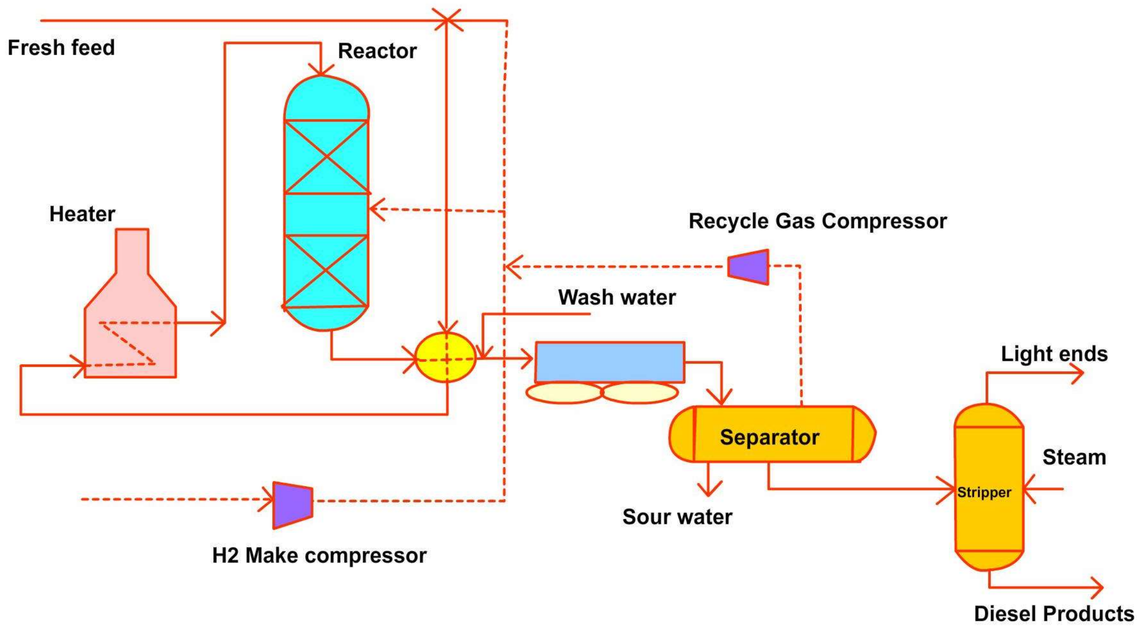
This is far from true.

I will share few design situations wherein I felt: "Ohh! We could apply that concept from Chemical Engineering Syllabus here".

1. <u>Flow over a flat plate - finite / infinite / semi-infinite</u>

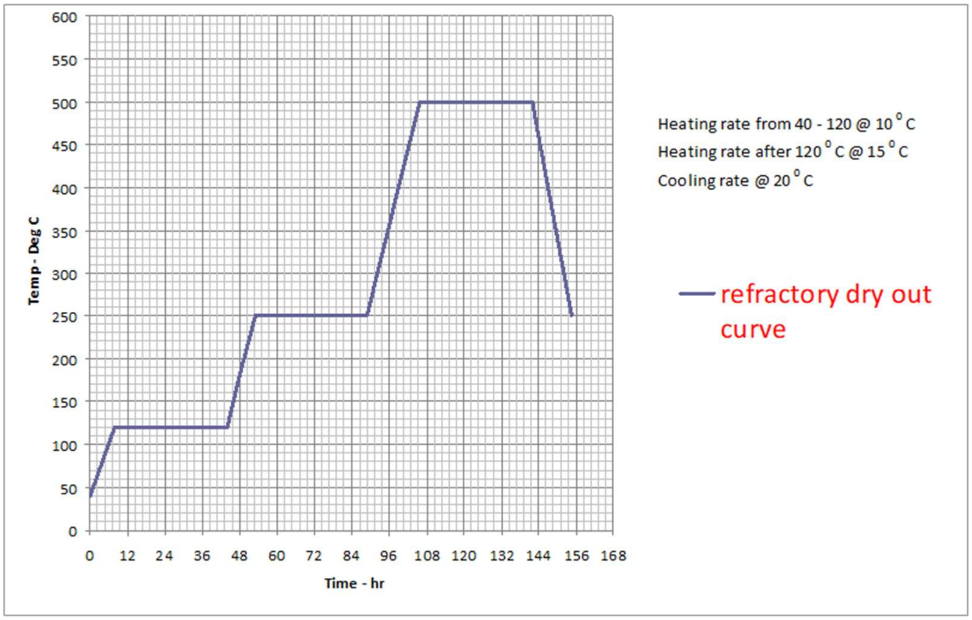
Background

Before catalyst is loaded, Hydroprocessing reactor needs to be dried to avoid catalyst forming muck. Sketch below shows Hydroprocessing reactor scheme (from here)



For reaction system drying, reactor loop is pressurized with Nitrogen using reciprocating make-up compressor. Centrifugal compressor circulates Nitrogen in closed loop. Nitrogen is heated in reactor feed fired heater, picks up moisture in the loop, is cooled in reactor effluent air cooler, deposits moisture in separator and goes back to circulation compressor.

Fired heaters have a carbon steel shell and coated with refractory which shields it from high temperature in firebox (like tandoor). This refractory needs to be dried in a temperature versus time graph that looks like below. Often reactor and refractory dry-out proceeds parallelly.



Planning this dry-out operation was an excellent experience for me wherein I had to advise loop pressurization level using reciprocating compressor, circulation compressor speed, fired heater burner firing sequence in sync with heating rate as per refractory dry-out profile etc.

Situation

Everyone is happy that commissioning has started and years of efforts are about to culminate in a good project delivery.

Evening time.

Temperature of loop has been kept at 120 ^{o}C and is to be increased to next plateau at 250 ^{o}C. Additional burners are fired by commissioning team. Few hours later piping engineer comes running stating that springs of supports have not been unlocked. These spring supports are critical to ensure pipe is supported as temperature increases. These are locked at low temperatures and needed to be unlocked before pipe temperature reaches 200 ^{o}C. It is winter time and already dark. These springs are in inaccessible areas and it is risky to try and unlock them in dark.

Project manager turns to process engineer and asks him to check how much time before temperature of the loop would increase to 200 ^{o}C?

Process engineer remembered all the flow over a flat plate and temperature profile in semi-infinite / infinite slabs problems from

Chemical Engineering Mathematics course. Alas, he would have paid more attention if he would have known applications.

But he was smart enough to have planned entire dry-out operation using finite difference calculation beforehand and could assure project manager that it would not be before next afternoon that pipe loop temperature would reach 200 ^{o}C.

Springs were unlocked first thing next morning. Temperature in pipe loop did not reach 200 ^{o}C until next evening and a major situation was averted.

2. Hypochlorite Dosing Skid

During our last year, we had messed up our hostel lobby during one festival of colour celebration.

Hostel warden who happened to be our Chemical Reaction Engineering teacher, had asked us to estimate how much time it would take for colour drums emptied in the river to reach boys swimming downstream! Sweet revenge for the professor.

Fast forward few years.

Seawater is used as cooling water in many coastal sites. Huge pumps are employed for the purpose. Seawater intake channels are dug and screens are installed to capture trash before seawater is pumped to headers.

Seaweed is major problem that chokes these screens. Hypochlorite is dosed in these channels to kill seaweed. Space is at a premium as you want to minimize cost of intake channel Number and size of nozzles need to be optimized to kill seaweed before it can reach screen.

Back to reading dispersion analysis chapters of Reaction Engineering books by Levenspiel and Fogler!

3. Storage Tank Heat Gain

Background

Diesel tank is a standard feature of most of the Oil and Gas Central Processing Facilities (CPF). Diesel is fed to Essential Diesel Generator which provides electricity back-up at remote locations.

Diesel is stored in fixed roof tanks with vent open to atmosphere. Diesel usually has flash point above maximum ambient temperature and hence this is usually not a problem.

Situation

As is usually the case, not everything runs to a script. Client indicated that due to scarcity, availability, procedures, Operators tend to use any hydrocarbon source in diesel range that they can lay their hands on. So, flash point could be less than ambient temperature!

Client suggested that we give shade to diesel tank to avoid increasing temperature above flash point.

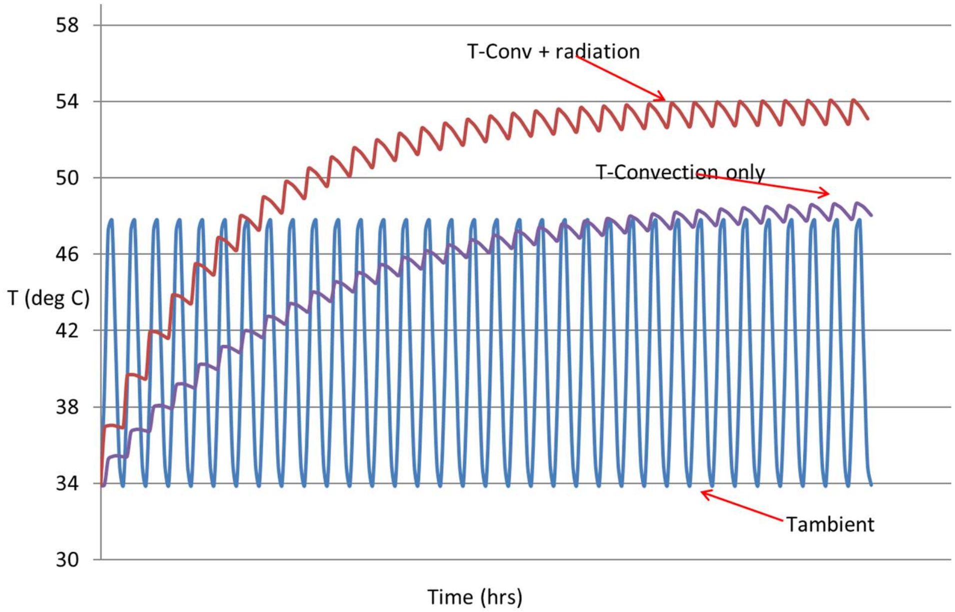
So, process engineer starts calculating heat gain by diesel from ambient temperature. Most of the heat loss / gain calculations are based on very good article "Predict Storage Tank Heat Transfer Precisely" by Kumanna and Kothari. We showed that even with heat gain from ambient, diesel temperature still did not increase above lowered flash point.

Client did not agree as in Middle East region, black body temperature is around 90 ^{o}C so any calculation with only ambient air temperature (shade temperature) was deemed insufficient.

Fortunately for process engineer, daily ambient temperature record of 3-4 years was available. A plot of air temperature versus days is a sine wave. Frame a differential equation of tank content temperature with periodic boundary condition and voila you have temperature profile of tank contents and answer to client question.

Only missing link was how to combine solar radiation with air temperature to get periodic boundary condition. Process engineer did not find answer to this at that time but stumbled upon term sol-air temperature term used in HVAC and wrote a paper on it. Not best of my works, but that is story for some other day!

Project does not offer luxury to do research and hence finite difference technique was employed with black body temperature assumed as tank surface temperature for 12 hours of the day and ambient air temperature for balance 12 hours. During day time, diesel gains heat and during night time loses the heat.



Net result is there is an incremental gain of temperature by tank contents every day during summer. Similarly, during winter, tank contents lose heat only incrementally. This lead-lag behaviour of storage systems is well explained in Kern.