CH402 Capstone Design Problem
Fluid Catalytic Cracking of Crude Oil

1. Objectives.
2. Background.
3. General Tasks in the Design Project.
4. Requirements and Guidance on Design Problems for IPR-1.
5. Submission for IPR 1.
6. Grading
7. Simulator Instructions

Overall Project Objectives

1) Enhanced understanding of unit and process operations.
2) Understanding IT infrastructure in a process plant.
3) Understanding basic controller configurations in a process plant.
4) Understanding and appreciation of piping and instrumentation diagrams (P&IDs).
5) Enhanced understanding of process economics.
6) Enhanced understanding of ChemCAD.
7) Development of communication ability.
8) Enhanced understanding of safety issues confronting process engineers.

Background

Simulation Solutions, Inc. is a company located in Shrewsbury, NJ, that makes process simulators. A process simulator is a virtual chemical plant designed to assist companies in training plant operators, engineers, and supervisors. The software interface is a representation of the actual control room that allows changes in control variables and shows a readout of the response. The result is a “live” simulation of the plant. The latest beta test version of the software is a virtual petroleum refinery. The program contains control room and outside operator views of the plant. Some additional information about Simulation Solutions, Inc. can be found at: http://www.simulation-solutions.com.

The particular refinery that was modeled is located in Bakersfield, CA. Bakersfield is located at the southern end of the San Joaquin Valley in South Central California. Kern County is home to 18 giant oil fields that have produced more than 100 million barrels of oil each, including four “super giants” that have produced over one billion barrels of oil. According to the San Joaquin Geological Survey, approximately 31,000 oil wells have been drilled in the county and 10% of U.S. oil production comes from this region. The refinery is one of 14 in California that can make the gasoline and diesel that meet the state’s environmental regulations, particularly for low sulfur diesel. The refinery previously experienced a series of accidents that led to an overhaul of the safety procedures and to an intensive revamping of the safety protocols in the plant, including training protocols using the Simulation Solutions plant simulators. The

Bakersfield refinery was formerly owned by Kern Oil & Refining, and was sold in 2008 to Flying J. The refinery is currently scheduled for a series of upgrades and expansions that will essentially double its production. You can visit the refinery website and view live webcam images at: http://www.bigwestca.com/bigwest/appmanager/bwoc/home?_nfpb=true&_pageLabel=flyingjPortal_portal_page_18

The simulated plant you will be operating is very new, and you will be conducting a "full" start up and shakedown. This includes a revision of the start-up procedures. The experiences you will go through are very similar to the issues that engineers and operators face when they start up a real plant. You will be faced with unknown technical questions, as well as incomplete procedures and diagrams. Your mission in this assignment is to develop a safe working start up procedure that will be used by operator and engineer trainees in the field. You will be provided with old help menus as well as a preliminary start up procedure, but will need to make modifications as you work your way through the plant.

The time requirements for this project are extensive, but you will have 13 lessons as well as the intervening time to complete it. For example, a minimum of 4-5 hours of simulator time is required for one complete pass through the simulator, which translates to 10-15 hours of actual time for your first run. You will need to run the simulation multiple times to develop and improve your procedure, but the actual time should decrease substantially as you figure out what you are doing.

You will also have access to a demo FCC unit in Bartlett Hall Room 415 to assist you in visualizing the process. You will need to look at this and study it in order to understand the FCCU simulator. You are also encouraged to make liberal use of the internet in researching the process. There are many good websites with detailed descriptions.

General Tasks in the Design Project (To be completed by the end of the project):

1) Research hydrocarbon cracking chemistry and be able to provide an informed discussion.
2) Research the cracking process and know the basic functions of all units in the process.
3) Familiarize yourself with the simulation software operating under design conditions. Explore each of the controllers and understand how each controller responds to disturbances. You will be asked to provide an I/O and a functions diagram of the process.
4) Modify the cold start procedure (provided) so that it is updated and current with the new simulation software.
5) Provide inspection protocols, including a mapping and log sheets, for all sensor, valve, and switch locations for the outside operator.

6) Provide a detailed design of the fractionator column using ChemCAD, and be prepared to offer the Flying J Oil Company a price quote for a new fractionator column for the expansion, including all support equipment, piping, pumps, and heat exchangers.
7) In lessons 38 and 39, you will be giving a powerpoint presentation to the class.
8) In lesson 40, you will also be required to submit a written, updated procedure that works. This will comprise the formal report portion of your grade. As part of this grade, you will also be required to submit an electronic copy of your working start-up log file.

Requirements and Guidance on Design Problems for IPR-1:

IPRs are meant to ensure that you are making satisfactory progress toward the completion of the main tasks outlined above. IPRs are by appointment with me and will not be conducted during normal class hours. Class time is reserved for informal group meetings and for FE exam prep. You are required to do 4 IPRs at approximately one-week intervals. IPRs are informal desk-side briefings, but there are submission requirements. You will receive written guidance for each. Failure to schedule and execute an IPR will result in a grade of zero for that portion of the grade. There are no re-dos allowed on IPRs.

VERY IMPORTANT: You will use the results of each IPR to perform the next one. They are cumulative in nature. Save your requirements on files on your share drive so that I can inspect your progress independently. Bottom line: If you meet the requirements of the IPRs, your report performance and preparation will be dramatically improved, and your life will be considerably easier at the end of the semester.

Submission for IPR 1:

1) Develop chemistry background, including 1 finished powerpoint slide of the cracking reaction and mechanism. Use reputable literature references. Google and Wikipedia are considered a minimum level of performance (think rubric). Read and discuss the process economics as a group. Use this information to define your problem.
2) Develop process engineering background. You will be required to submit 1 finished slide of the I/O diagram for the process and 1 finished slide of the functions diagram. Use Example 4-2 in the text as a guide. Meet as a group and discuss this. Recall that I/O diagrams must include feed, product, and utility costs!
3) Required definitions: light-cycle oil, heavy cycle oil, crude oil, naptha, fluid catalytic cracking, atmospheric distillation, vacuum distillation. Provide these definitions in a finished powerpoint slide.
4) Develop general economic background for the problem. Again use reputable literature references. Read and discuss the process economics as a group. Use this information to define your problem. SRI and Kirk-Othmer are considered authoritative.

5) Present evidence to your instructor that you have made some progress on the start-up procedure. Remember that I am looking for multiple iterations.

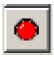
Grading:

The design project is worth 400 points out of 1700 in the course, or approximately 23.5% of your grade. The written report is due on lesson 38 and is worth 200 points. The oral reports will be during lessons 39 and 40, and will be worth 100 points. You are also responsible for four (4) weekly IPRs, each worth 25 points.

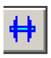
Simulator Instructions

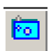
Important Buttons in the Simulator:

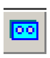
Run Process - starts the simulator; do this at the beginning of your work and after any time you press stop and then want to continue.

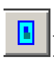
Freeze Process - stops the simulator; this is useful for taking notes in your written log without affecting your score.

 Load Store Initial Condition – allows user to load exercises, snapshots, backtrack, and initial conditions

 Exercises – allows user to load previously stored exercises.

 Snapshot

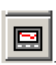
 Backtrack

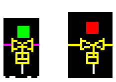
Pumps, valves, and switches

Audible alarm – disables the audio alarm so that you cannot hear it, but red process variable indicators will still flash.

 Acknowledge Alarm – turns off the alarm. The process variable will remain "red" until it moves within the alarm range.

 Alarm Silence – Silences alarm without deactivating it.

Advanced Trending – shows the time response of each process variable.

 Switches – little red or green boxes that allow you to switch a device on or off. The color of the switch indicates its current state. Red is off and green is on.

Process control variables – moving your mouse over the blue number and clicking it allows you to manipulate the variable.

Note: Process variables that can be manipulated are under control. That is, they have a "C" in their names, such as FIC201, LIC201, etc. Access the controls by moving the mouse over the numeric readout and clicking it. For example, FIC201 appears as above. This variable can be set either manually or automatically.

Cold-start Procedure (Provided by Simulation Solutions and to be modified by your group):

1) Commission FIC-136(6) to prevent Compressor from surging when started.Set at about 14.2 KNM3/H and place in automatic.

2) Start air compressor, C-101, using HS-132(13). (Note: In actual practice, it will be necessary to follow the manufacturer's procedures to bring this item on line.)

3) Open FIC-131(1,6) manually about 20% to start air flow through the air preheater and to the regenerator.

4) Place PIC-117(1) in operation and set at 2.28 KG/CM2.

5) Increase FIC-131(1,6) gradually to about 23.7 KNM3/H.

6) Open catalyst slide valves LICV-102(3) and TICV-101(3) to allow air flow into the reactor.

7) Make sure the reactor vent valve(12) is open, and the vapor to fractionator valve(12) is closed.

8) Start steam to the fractionator using "bottom steam valve(13).

9) Open PIC-210(7) fully in manual, fractionator controller to flare, to purge the fractionator for about ten minutes.

10) Start air preheater to heat the regenerator and reactor, using TIC-134(6) in manual to admit fuel gas to the preheater. Increase temperatures at a rate of about 40.6-46.1 deg c. per hour and until a temperature of 204.4 deg f. shows on TI-108(3). NOTE: To minimize heat up time, use group 18 switch "SPEED REG HEATING". Turn off when temperature reaches 204.4 deg c..

11) Close both slide valves between the reactor and regenerator, and start steam to the reactor by opening HS-122(12) and setting FIC-104 about 35% open.

12) Continue to heat up the regenerator to 426.7 deg c., using TIC-134(6).

Monitor TI-112(1) and TI-113(1). NOTE: Once again "SPEED REG HEATING(18)", can be used to rapidly bring the temperature to 426.7 deg c..

13) Start loading catalyst to the regenerator using HIC-118(2).
14) Monitor LI-111(1). When the catalyst level is sufficient (about 30%) to seal the cyclone dip legs, stop the catalyst loading.

15) Maintain the regenerator temperature above 354.4 deg c.. Again, in order to save start up time, use "SPEED REG HEATING(18)", if needed.

16) Start Torch oil flow by opening HS-121(12) and setting FIC-115(1) at about 15%. Temperature will climb when torch oil lights.

17) Restart catalyst loading making sure temperature does not fall below 354.4 deg c.. Increase air and torch oil flows to maintain this temperature.

18) Gradually reduce the load on the air preheater as the torch oil provides the heat.

19) Continue to load catalyst until LI-111(1) reads 50%, and heating the bed to 632.2 deg c., TI-112(1)). We are now ready to start catalyst circulation.

20) Open emergency reactor steam valve HIC-123(4) about 50% and allow steam to purge to the atmosphere for about 5 minutes.

21) Set PIC-201(7) about 0.14 to 0.18 KG/CM2 above reactor pressure shown on PI-103(3). Place PIC-201(7) in automatic. It should be set at about 0.9 KG/CM2.

22) Open vapor to fractionator valve(12) and close reactor vent to atmosphere valve(12). Steam is now going from the reactor to the fractionator to purge the line between the reactor and fractionator.

NOTE: In the plant it will be necessary to monitor all drains and low points in the fractionator to draw off condensate as it forms.

23) Start catalyst circulation by slowly opening the regenerated catalyst slide valve, TICV-101(3) about 10% with the controller in manual.

24) Trend and monitor PDIC-116(3), the pressure differential across the slide valve.

25) When a pressure differential shows on PDIC-107(3), slowly open the spent catalyst slide valve, LICV-102(3) manually to return catalyst to the regenerator.

26) When PDIC-107(3) decreases to 0.035 KG/CM2, close the slide valve.

27) Repeat this procedure of dumping catalyst from the reactor to the regenerator 4 or 5 times. Trend and monitor TI-108(3), reactor stripper temperature, and LIC-102(3), stripper level.

28) Continue to load catalyst using HIC-118(2) while establishing normal levels in the reactor and regenerator.

29) When operating levels are established, cease loading catalyst, and raise the regenerator bed to 704.4 deg c. using TIC-134(1).

30) Fill the feed surge drum to 50% using LICV-142(5) in manual. When drum is 50% full place LIC-142(5) in automatic.

31) When it is certain that catalyst circulation has been established and the reactor temperature as shown in TIC-101(3) is above 537.8 deg c., start the fresh feed pump, P-101A(13), and set FIC-121(5) at about 9.9 M3/H. Place FIC-121(5) in automatic.

32) Light off the feed preheater by opening TICV-127(4) about 10% in manual.

33) Adjust the feed preheater outlet temperature, TIC-127(4) to 197.2 deg c., and place the instrument in automatic.

34) Increase the fresh feed rate,FIC-121(5) in steps of 3.3 M3/H every 10 minutes, until the flow rate is at its design condition of 45.8 M3/H.

35) While increasing the feed to the reactor, gradually reduce the emergency steam to the reactor, HIC-123(4) to zero. Adjust the reactor stripping steam, FIC-104(4) to the design rate of 4037 KG/H.

36) Gradually reduce the torch oil flow through FIC-115(1) to zero, and block off using HS-121(12).

37) 37) Increase catalyst circulation rate to keep TI-108(3) about 535 deg c..38) As the reactor effluent starts to go to the fractionator, the fractionator will start to warm up. Turn off the fractionator "bottom steam valve(13)".

38) Open cooling water to the condenser, E-209, by opening HIC-300(8) about 50%.

39) When a level,LIC-224(11) appears in the bottom of the fractionator, start circulation of bottoms back to the feed preheater inlet. Set HS-202(13) in the "A" position. Start P-207(14). Monitor LIC-224(11) to be sure a level is maintained in the bottom of the fractionator.

40) When a hydrocarbon level appears in the overhead receiver, D-203, place the condensate draw controller, LIC-207(7) in service, set at 50% and in automatic.

41) Start the reflux to the tower by opening FIC-206(8) about 15% in manual. Start the reflux pump, P-202(14).

42) Adjust the flow of reflux to maintain a top tower temperature of 129.4 deg c. as shown on TIC-205(8).

43) When the top tower temperature is about 129.4 deg c., place TIC-205(8) in automatic set at 129.4 deg c., and place FIC-206(8) in cascade.

44) Open FIC-204(7) about 15% manually. Start P-201(13).

45) Place LIC-203 in automatic and set at 50%. Place FIC-204(7) in cascade.

46) There should now be a level in the LCO draw pan. Open LIC-214(9) manually about 10% to admit LCO to the stripper. Open FIC-215(9) manually to obtain a steam flow of about 363 KG/H. Place FIC-215(9) in automatic and set at 391 KG/H.

47) 48)When a level appears in the bottom of the stripper, open FIC-218(9) about 15% and start P-204(14). Adjust FIC-218(9) manually to maintain a stripper bottoms level of about 50%

48) As feed rate to the fractionator increases, increase the draw rate to the LCO stripper using LIC-214(9) in manual.

49) Open FIC-211(9) manually about 15%, and start pump P-203(14) to initiate upper pumparound reflux. Open HIC-310(10) manually to maintain an LCO return temperature of 137.8 deg c. as shown on TI-212(10).

50) As feed rate increases, gradually increase LCO circulation rate, and increase HIC-310(10) to hold the return temperature of 137.8 deg c.. Place FIC-211(9) in automatic when flow rate is high enough for control.

51) A level should now be showing on tray 15, LIC-219(9). Open FIC-220(9) manually about 15%, and start pump P-205(14).

52) Start a small flow of Recycle back to the riser. Open FIC-221(9) about 15% manually.

53) Open HIC-320(10) to 50%. Open FIC-216(9) about 15%, and monitor TI-217(10). Place FIC-216(9) in automatic and adjust flow through FIC-216(9) to maintain TI-217(10) at about 185 deg c.. It may be necessary to adjust HIC-320(10) to hold this temperature.

54) Adjust FIC-221(9) to maintain a flow rate of about 10% of the fresh feed rate.

55) Open FIC-227(11) about 15% manually. Place TIC-226(11) in Service and set at 371.1 deg c.. to control tower bottoms temperature. Switch HS-202(13) to the "B" valve position.

56) Open FIC-223(11), decant oil product, about 15%, and start P-206(14). Place FIC-223(11) and LIC-224(11) in automatic. Then switch FIC-223(11) to cascade.

57) The compressor should now be started. Open FICV-209(7) 100% manually.Open PICV-202(7) about 15% manually to warm up the compressor turbine and give it a slow roll.

58) Open PICV-202(7) manually to about 60%. When compressor is up to speed, place PIC-202(7) in automatic and set at 0.9 KG/CM2.

59) Place FIC-209(7) in automatic and set at 1607 NM3/H.

60) Raise the set pressure of PIC-201(7) to 1.26 KG/CM2.

61) All sections of the plant are now operating although not at design conditions. As conditions permit, place controllers in automatic and cascade where appropriate. Gradually adjust conditions to the design conditions shown in Appendix 5. It is best to make changes in a stepwise fashion, allowing the unit to line out at each new condition before making another change.

CONGRATULATIONS! You have now succeeded in bringing on line this major process unit.