No.	Description	APC	Complex Control
16	Can control loop continue operation if a control loop element is “Disconnected” from master command (APC or “Complex control”) ? Sometimes this is described as: • In AUTO mode, or • In MANUAL mode, by Console Operator command	Yes/No **(4)**	Yes/No **(4)**
17	Can control loop continue operation if one(1) manipulated variable is “Disconnected” from the control loop command ? Sometimes this is described as: • In AUTO mode, or • In MANUAL mode, by Console Operator command	Yes	Maybe **(6)**
18	Can control loop continue operation when several manipulated variables are “Disconnected” from the control loop command ?	Yes (Advisor mode)	Maybe **(7)**
	Response time		
19	Minimum Sample time (or Maximum execution frequency)	Every 30 min	Every 100 msec **(2)**
20	Can all control loop elements operate at different execution frequencies (different sample times in the same control loop ?	Normally **NO**	Yes
21	Faster control loop time response to plant upsets ?	No	Yes
22	Can keep stable plant operation against plant upsets ?	No	Yes
23	Can control loop smooth change operation condition, or switch to other operation modes ? In other words, Does control loop promote harmonized operation of controlled variables ?	Yes	Yes
	Engage / Disengage with plant operation		
24	Can control loop be IN SERVICE at startup, just after safeguarding is in NORMAL state (Healthy) ?	No	Yes
25	Can control loop be IN SERVICE even when the plant is starting up?	No Automatic disconnection	Maybe **(7)**
26	Plant is tarting up, BUT it is at a minimum feed flow condition, Can control loop be IN SERVICE?	Yes	Maybe **(7)**
27	Can control loop be IN SERVICE even while process constraints are not satisfied, or Unstable condition?	Yes	Yes

No.	Description	APC	Complex Control
28	Can control loop be IN SERVICE when plant is starting up, but plant is within process constraints ? In other words, Can control loop be IN SERVICE when all required process constraints are satisfied ?	Yes	Yes
29	Is integration with safeguarding required on plant shutdown ?	No, just disconnection	No, just disconnection
30	Is integration with safeguarding required to facilitate plant smooth startup after shutdown ?	No **(5)**	Yes
31	Smooth changes in the manipulated variables is achieved by:	Maximum "Speed of Change" limitation in command signals	Application of smooth controller tuning to controllers in control loop, "Speed of Change", or both

NOTE 1 "Manipulated variables" are commanded through "Complex Control", "Supervisory Control", "Basic/Regulatory control" or "Sequence Control".

NOTE 2 Normal sample time uses to be every 1 second.

NOTE 3 If functionality was implemented, APC can continue in case of malfunction of an instrument that provides one measured/controlled variable. Last good value will be used.

NOTE 4 Alternative control modes shall be provided.

NOTE 5 APC is monitoring plant operation and should indicate when it can be activated. Upon activation APC shall start to control plant from current plant operation condition.

NOTE 6 "Complex Control" can operate with one(1) manipulated variable in MANUAL mode, ONLY if this consideration was included in the control loop design.

NOTE 7 Depending on process plant, it can be allowed or not to use "Complex Control" with one(1) or more manipulated variable in MANUAL mode. ONLY if provision was included in the control loop design.

9. APC example

Figure 2 – Typical FCC reactor-regenerator arrangement

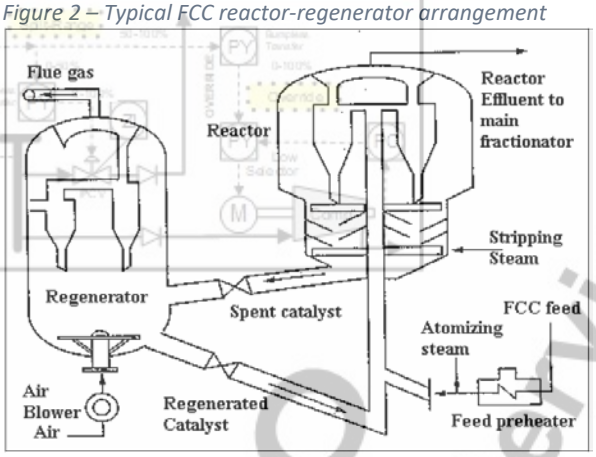


Figure 3 – Typical FCC main fractionator configuration

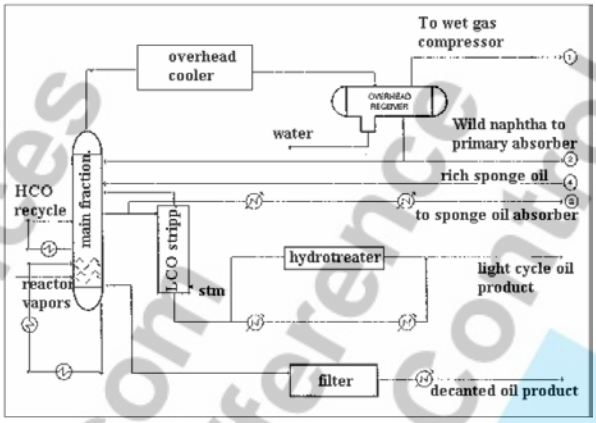
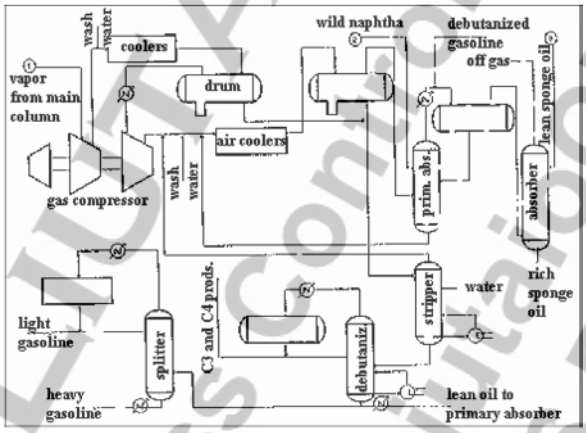


Figure 4 – Typical FCC gas concentration (GASCON) plant configuration



The Fluidized Cracking Catalytic Unit (FCCU) is one of the most important plants of a modern high-conversion refinery. It produces the bulk of high quality naphtha blending components from low quality feeds. Even small improvements in the operation of such units' impact on the overall refinery economics. See reference [3].

APC technology was applied to an FCCU, including the gas concentration plant. Figure 2, Figure 3 and Figure 4 shows general schematics of a typical FCCU.

The APC control structure of the plant consists in three(3) MPC covering the number of manipulated, feedforward and controlled variables that are shown in Table 2.

Table 2 – Number of manipulated, feedforward and controlled variables for a typical MPC implementation in a FCCU

#	Description	Number Manipulated variables	Number Feedforward variables	Number Constraint variables
1	Reactor, Regenerator, Main fractionator	24	14	62
2	Gas Concentration	8	8	19
3	Depropanizer column	4	3	10

From a personal experience in a FCCU like the described above, I want to mention that once the FCCU were in the "Ready To Load" condition (it means all unit within operation constraints):

a) To feed up the unit from ZERO(0.0) to normal operation feed rate, the manual procedure used to take 36-40 hours.
b) The APC implementation allowed to feed up the unit in 8 hours.
c) APC implementation sample time was every 30 min.

10. "Complex Control" example

A single centrifugal compressor is used to rise the pressure from one plant output, before it is fed to another plant.

The single compressor "Complex Control" loop structure consists of:

- Anti-Surge control loop.
- Compressor Load control.
- Integrated compressor Load-Anti-Surge control.

The constraint variables are clearly indicated in compressor sketch in "APPENDIX A".

For this "Complex control" loop implementation, the Compressor's "Startup Sequence" starts and prepares the compressor for operation up to the "Ready To Load" condition (it means all unit within operation constraints), next the Compressor's "Complex Control" loop rises the compressor load up to the required gas discharge pressure.

A separate control loop at the inlet of the downstream plant control the feed flow to that plant.

For this compressor control implementation:

a) Anti-Surge control is executed every 100 msec.
b) The rest of the "Complex Control" loop is executed every 1.0 sec.

Table 3 – Number of manipulated, feedforward and controlled variables for a typical single compressor "Complex Control" loop

#	Description	Number Manipulated variables	Number Feedforward variables	Number Constraint variables
1	Single compressor	2		7

APPENDIX A – Single compressor "Complex Control" loop sketch