

# Modelling Double-Riser Fluid Catalytic Cracking Units

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## Background

Fluid Catalytic Cracking (FCC) is a key process in refineries as it cracks high molecular weight hydrocarbons in the presence of a catalyst and heat, producing gasoline and lighter, higher-value fluids. To add to the importance of this unit, recent forecasts for gasoline and other fuels indicate that the FCC will remain one of the most important heavy oil conversion units in the refining industry [1].

On the oil availability and quality side, unconventional oil has been playing an increasingly important role in world oil supply. This translates to a gradual quality decrease in the feed to the different units in a refinery [2]. To answer these changes, FCC technologies are constantly pushing the boundaries, developing more efficient and flexible units such as the RFCC (Residue FCC) and more recently a “Two riser FCC” configuration. This last process was developed to be flexible enough to be operated in different modes depending on market demands. [3]

## Summary

The Symmetry\* Process Software platform allows for fully rigorous double riser configuration (see Figure 1) for both FCC and Residue FCC (RFCC) configurations, allowing you to:

- Predict the reactivity of feeds & blends
- Save time and resources on simulation
- Optimize the reactor’s operating conditions considering:
  - Catalyst deactivation
  - Mechanical considerations
  - Chemical additive interactions
  - Pretreatment unit performance

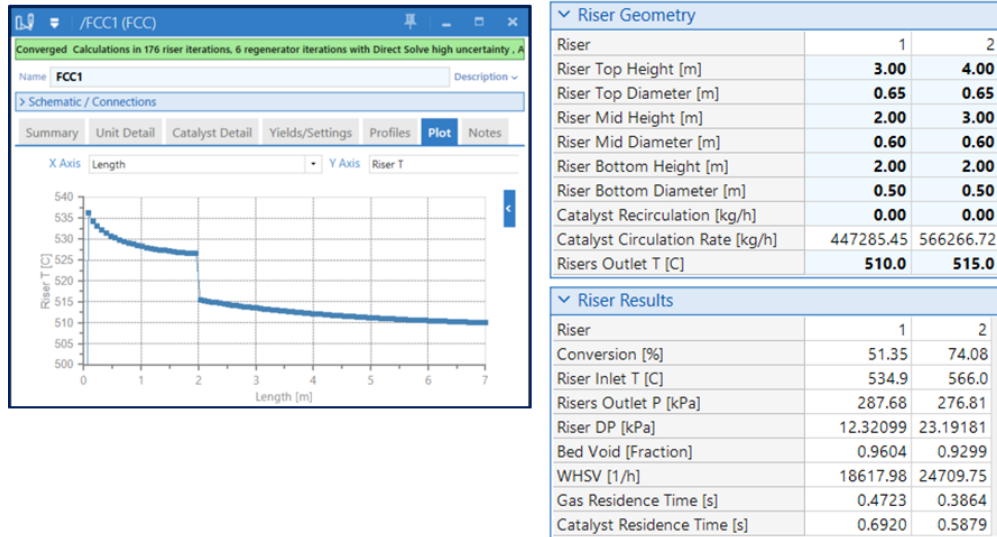


Figure 1. Symmetry's Double Riser FCC

## Double-Riser FCC in Symmetry

Symmetry's FCC unit previously only supported a "One riser" conventional FCC with both single and two-stage regeneration available (see Figure 2).

However, in order to keep up with constantly changing technologies, an effort to develop a double-riser feature for the FCC was completed in 2020.

This new additional configuration allows the user to model two independent risers, where effluents are stripped off the catalyst on a common stripping section similar to that reported by Wang et.al.[4] (see Figure 3). The catalyst is subsequently regenerated in either a single or a two-stage regenerator (see Figure 2).

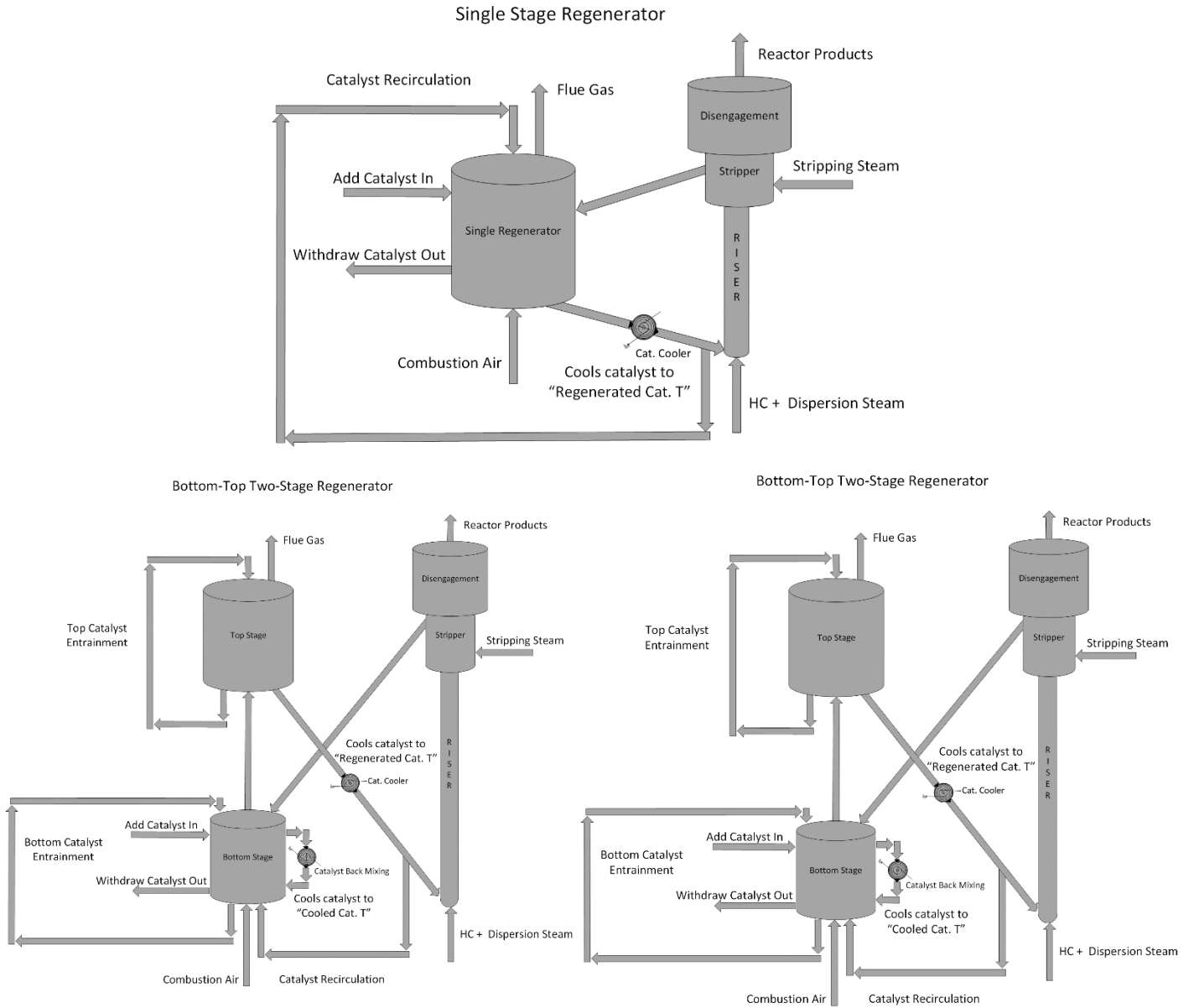


Figure 2. FCC Possible Configurations

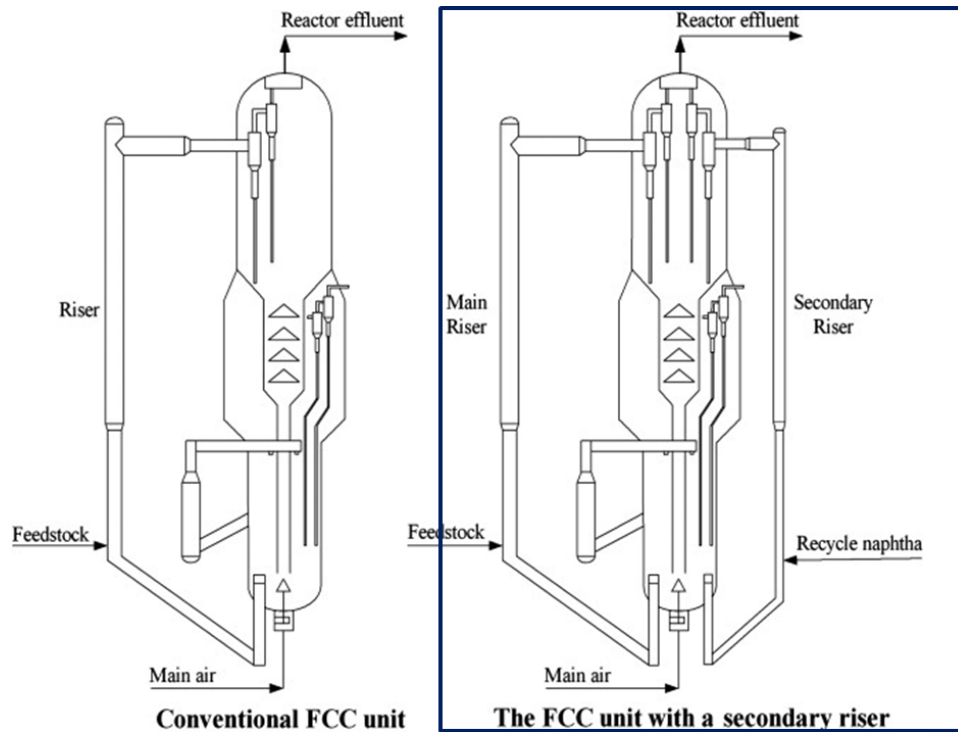


Figure 3. Double riser schematic [4]

## Double Riser Features

When selecting the double riser option, a series of features and differences between single and double riser FCC units can be noted.

Mainly, this option allows the user to specify two different riser sections with different feeds, dispersion steam and quench:

- Single Diameter
  - Additional Feed port
  - Additional Dispersion port
- Multi-Diameter
  - Additional Feed port
  - Additional Dispersion port
  - Additional Quench port

In the Summary tab, the “Additional Riser Results” is now going to reflect the two different catalyst to oil ratios, one for each riser (see Figure 4):

▼ Additional Riser Results		
Riser	1	2
Catalyst/Oil wt		

Figure 4. Additional riser results

Specifying the RON/MON is still possible. The FCC unit operation will find the catalyst circulation rate (thus riser temperature) in order to achieve this specification. The only difference between single and double riser FCC is that when in double riser mode, the overall catalyst circulation rate (and thus outlet temperature) is going to increase/decrease in order to find the desired RON/MON, all while keeping the risers outlet temperatures (ROT) ratio constant. For example:

	Scenario 1	Scenario 2
Spec RON	No	Yes
RON	91	93
ROT1 (Riser 1)	515	520
ROT2 (Riser 2)	518	523.03
ROT1/ROT2	0.9904	0.9904

When working with a double riser FCC, the geometry for each riser can then be specified, including the possibility of multi-diameter risers (see Figure 5):

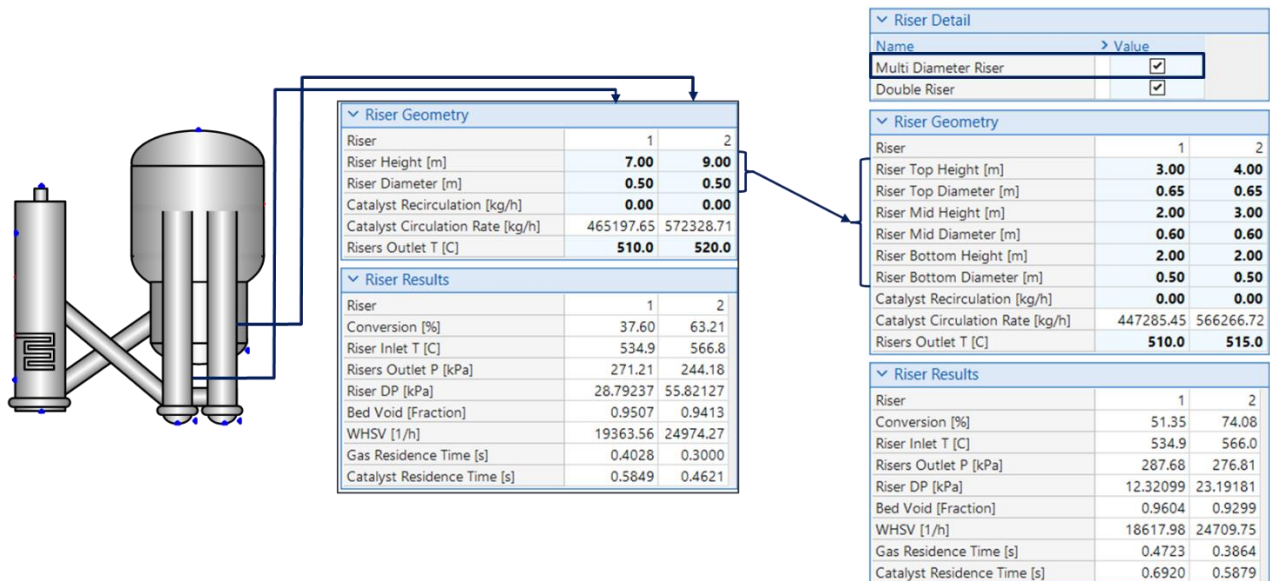


Figure 5. Double-Riser Geometry inputs

Additionally, profiles for each riser are available in both table & plot format (see Figure 6):

Converged Calculations in 176 riser iterations, 6 regenerator iterations with Direct Solve High uncertainty. All regenerator sulfur/nitrogen oxidized

Name: FCC1 (FCC) Description: -

Schematic / Connections

Summary Unit Detail Catalyst Detail Yields/Settings Profiles Plot Notes

Riser 2

Unit Profiles	Length [m]	Riser [C]	Catalyst T [C]	Pressure [kPa]	Process Velocity [m/s]	Process Veloc. [m/s]	Void Fraction [Fraction]	Solid Void Fraction [Fraction]	Conversion [%]
0	0.00	314.7	700.0	300.00	5.95	0.9541	0.3891	0.6109	0.00
1	0.10044	557.8	557.8	296.73	14.89	11.29	0.872	0.1228	6.86
2	0.20087	554.6	554.6	297.51	16.11	12.50	0.8789	0.1211	10.89
3	0.30131	552.6	552.6	296.10	17.20	13.46	0.8876	0.1124	15.70
4	0.40174	551.0	551.0	294.76	18.14	14.27	0.8940	0.1060	20.21
5	0.50218	549.7	549.7	293.48	18.99	14.99	0.8991	0.1009	24.22
6	0.60261	548.6	548.6	292.26	19.78	15.65	0.9033	0.0967	22.03
7	0.70305	547.7	547.7	291.10	20.51	16.24	0.9068	0.0932	22.38
8	0.80349	546.9	546.9	290.00	21.19	16.79	0.9099	0.0901	23.47
9	0.90392	546.2	546.2	288.93	21.83	17.31	0.9126	0.0874	26.94
10	1.00436	545.6	545.6	287.91	22.45	17.79	0.9150	0.0850	29.13
11	1.10479	545.0	545.0	286.91	23.04	18.26	0.9171	0.0829	29.86
12	1.20523	544.5	544.5	285.94	23.61	18.70	0.9191	0.0809	30.78
13	1.30566	544.0	544.0	285.00	24.16	19.12	0.9209	0.0791	31.80
14	1.4061	543.6	543.6	284.09	24.69	19.53	0.9225	0.0775	33.97
15	1.50654	543.2	543.2	283.20	25.20	19.92	0.9240	0.0760	36.17
16	1.60697	542.8	542.8	282.33	25.70	20.30	0.9254	0.0746	36.84
17	1.70741	542.5	542.5	281.48	26.18	20.66	0.9268	0.0732	37.74
18	1.80784	542.2	542.2	280.64	26.65	21.01	0.9280	0.0720	38.85
19	1.90828	541.9	541.9	279.83	27.11	21.35	0.9291	0.0709	39.38
20	2.00871	541.6	541.6	279.05	27.61	21.68	0.9301	0.0700	39.85
21	2.10915	541.3	541.3	278.29	28.10	22.00	0.9311	0.0692	40.16
22	2.20958	541.0	541.0	277.55	28.58	22.31	0.9320	0.0685	40.64
23	2.31002	540.7	540.7	276.83	29.05	22.61	0.9329	0.0679	41.29
24	2.41045	540.4	540.4	276.13	29.52	22.90	0.9337	0.0674	41.29
25	2.51089	540.1	540.1	275.44	30.00	23.19	0.9345	0.0670	41.54
26	2.59794	539.8	539.8	274.77	30.48	23.48	0.9353	0.0667	41.94

Recommended Regression...  Activate Reduced Order Model  Ignored



Figure 6. Double Riser Profiles & Plots

## How to Add a Double-Riser FCC

The FCC double riser feature can be accessed in two ways:

1. By dragging and dropping the new “FCC 2R” stencil directly into the flowsheet (see Figure 7):

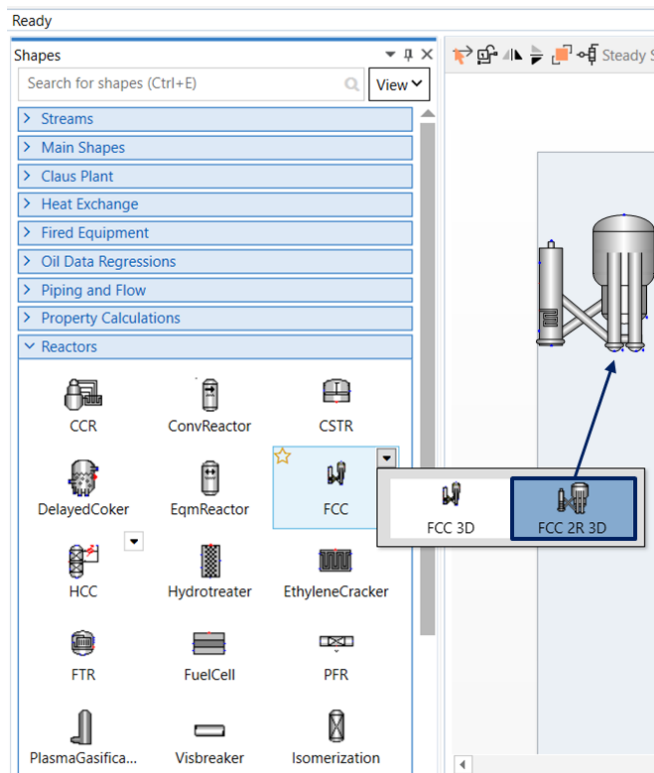


Figure 7. Adding an FCC 2R unit

- By clicking on the "Double Riser" checkbox located in the Unit Detail Tab (see Figure 8):

The screenshot shows the Symmetry Process Software Platform interface for unit FCC1. The 'Unit Detail' tab is active, displaying parameters for the riser and stripper. The 'Double Riser' checkbox is checked, and the 'Riser Height' is 7.00 m. The 'Stripper Detail' section shows parameters such as Disengagement Volume, Stripper Height, Stripper Diameter, Stripper Steam Rate, Stripper Steam T, and Stripper Steam P.

Riser Detail		Stripper Detail	
Name	Value	Name	Value
Multi Diameter Riser	<input type="checkbox"/>	Disengagement Volume [m3]	0.000
<b>Double Riser</b>	<input checked="" type="checkbox"/>	Stripper Height [m]	6.00
Symmetrical Riser Units	1	Stripper Diameter [m]	1.80
Riser Geometry		Stripper Steam Rate [kg/h]	3194.00
Riser Height [m]	7.00	Stripper Steam T [C]	526.7
		Stripper Steam P [kPa]	308.00

Figure 8. Switching between single and double riser

## References

- [1] Shan, Hong-hong, et al. "Experimental study of two-stage riser FCC reactions." *Fuel* 80.8 (2001): 1179-1185.
- [2] WEO, IEA. "International Energy Agency, World Energy Outlook 2012." Paris Google Scholar (2012).
- [3] Zhang, Jinhong, et al. "Multifunctional two-stage riser fluid catalytic cracking process." *Applied petrochemical research* 4.4 (2014): 395-400.
- [4] Wang, Gang, Chunming Xu, and Jinsen Gao. "Study of cracking FCC naphtha in a secondary riser of the FCC unit for maximum propylene production." *Fuel Processing Technology* 89.9 (2008): 864-873.

To learn more about the Symmetry Process Software Platform please contact your local Schlumberger office.

\*Mark of Schlumberger