UOP
A Honeywell Company

FCC Vortex Separation™ Technology: The VDS™ Design and VSS™ Design

Refining

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UOP's Vortex Separation technology is the latest in a long line of fluid catalytic cracking (FCC) riser termination improvements for more effective separation of the catalyst and hydrocarbon phases in the FCC reactor. UOP offers two options: the Vortex Disengager Stripper™ (VDS) design and the Vortex Separation System™ (VSS) design.

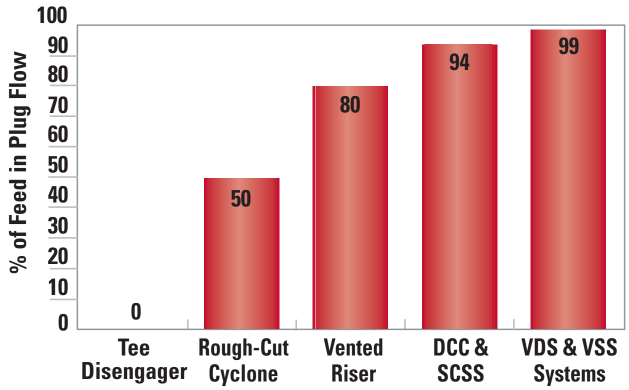
Background

No riser termination device contains 100% of the hydrocarbon vapors flowing to it. Containment refers to the amount of hydrocarbon vapor that exits the primary separation device without spending time in the reactor vessel. In all systems, the catalyst flows into a primary separation device, either cyclonic or inertial. Most of the captured vapors quickly pass out of the device and into downstream, secondary cyclones.

As a rule, fluidizing gas must be entrained in the catalyst stream exiting the primary separation device. These vapors escape into the reactor-stripper vessel. In the dilute phase of the reactor, the hydrocarbon vapors spend an extended period in the presence of catalyst and high temperature. Overcracking of this hydrocarbon vapor leads to higher dry gas production and loss of selectivity.

UOP's Vortex Separation technology minimizes the vapor passing into the reactor vessel to provide the greatest reaction selectivities. Said another way, UOP's Vortex Separation technology maximizes hydrocarbon containment. Vortex Separation technology achieves more than 99% hydrocarbon containment (see Figure 1).

Figure 1 ■ **Hydrocarbon Containment**



In addition to achieving rapid separation and high containment, UOP's Vortex Separation technology also provides a termination device that is flexible to operational changes and forgiving in upset conditions.

Prestripping requirements

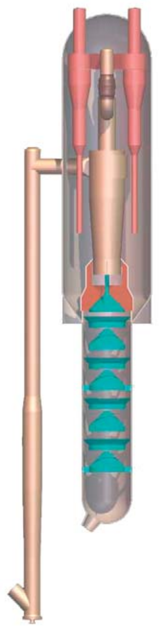
In direct-connected cyclones and other cyclonic separation systems, considerable hydrocarbon vapors escape the cyclone environment and enter the reactor vessel. The gas that keeps the catalyst fluidized travels down the cyclone diplegs with the catalyst. Because almost the entire catalyst circulation travels through the primary cyclone diplegs, the gas phase carried with it can be 5 to 6 wt-% of the feed. As a result, a cyclonic system without prestripping can achieve only 94 to 95% hydrocarbon containment at best. When released into the stripper or reactor vessel, this remaining hydrocarbon can spend 30 seconds or more in direct contact with hot, active catalyst. A substantial amount of this material eventually leaves the reactor as light ends, condensed ring aromatics and coke on the catalyst.

To capture and recover the useful products in this hydrocarbon stream and prevent overcracking, some form of prestripping of catalyst is needed before it discharges into the reactor. To strip flowing catalyst effectively, the downward velocity of catalyst must be less than the bubble rise velocity within the fluidized catalyst phase. The velocity difference is necessary so that the hydrocarbon gas phase can rise out of the catalyst phase and be quickly removed from the system. To minimize the stripping diluent (which in most cases is steam), a dense phase of catalyst is desirable. A dense catalyst phase also reduces interstitial volume by effectively "squeezing" gas from the catalyst. UOP's efforts focused on converting the catalyst stream flowing down the dipleg into a slower moving dense phase so that the prestripping step could be accomplished. This effort resulted in the Vortex Separation technology.

The VDS design

The first commercial application of Vortex Separation technology was for smaller stacked reactor systems that are easily revamped to an external riser. This design is known as the Vortex Disengager Stripper (VDS) design (see Figure 2). A single VDS system is fitted at the end of an external side-entry riser.

Figure 2
The VDS Design



Although the VDS system uses the same principles of centrifugal separation as a cyclone, it functions somewhat differently and has a special section at the base to slow catalyst flow and form a dense phase. Stripping steam is injected at the base of this chamber below the dense phase of catalyst. The stripped hydrocarbons rise up into the disengager and exit through the gas tube with the rest of the vapor phase. A set of secondary cyclones is connected to the vapor outlet to complete the catalyst separation.

The VSS design

For larger units and for units with internal risers, the VDS design has some mechanical drawbacks. For these layouts UOP developed the Vortex Separation System (VSS) design (see Figure 3).

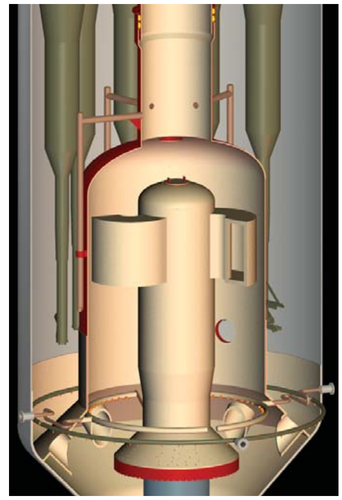
Figure 3
The VSS Design

The VSS design

- Retains hydrocarbon containment and prestripping characteristics of the VDS system
- Is compact to fit into the widest possible range of reactor styles and sizes
- Has a lower investment cost than the VDS system

In the VSS design, the catalyst-vapor mixture travels up the reactor riser through the center of the chamber and exits through special disengaging arms. These arms generate a centrifugal flow pattern that separates the catalyst from the vapor inside the chamber

Figure 4 ■ **Vortex Chamber**



(Figure 4). The flow mechanism is similar to that of traditional cyclone inlet horns. The catalyst falls and forms a dense phase at the base of the chamber, where it is prestripped prior to flowing into the reactor stripper. The stripped hydrocarbon vapors are fully contained in the chamber and exit with the rest of the riser effluent vapors to the secondary cyclones. The only hydrocarbon lost to the reactor vessel is that which accompanies the small amount of catalyst disengaged by the cyclones.

In both the VSS and VDS systems, hydrocarbon rising from the stripper vessel is captured in the chamber and is prevented from spending excessive time in the surrounding reactor space. The overall hydrocarbon containment for this system exceeds 99%.

Compared to other riser termination systems offered today, the VSS and VDS systems reduce the potential for nonselective post-riser cracking. The calculated post-riser residence time of the hydrocarbon phase within the chamber is less than one second. By creating a dense phase of catalyst, and stripping it within the primary separation device, the hydrocarbon “leaking” into the reactor vessel is minimized. In comparison, the dilute phase stripping of other systems is flawed because the interstitial volume is difficult to displace (the catalyst downward velocity exceeds the stripping bubble rise velocity). UOP’s Vortex Separation technology has successfully overcome the shortcomings of earlier systems while maintaining operating flexibility.

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Experience

The VDS system was first commercialized in 1991 and has been commissioned for operation in five units. Table 1 shows comparative data before and after one of the revamps.

Table 1 ■ **VDS Commercial Data**

	Tee	VDS
Feed Rate, BPSD	Base	1.1 x Base
Feed API	24.8	25.4
Reactor Temp., °F	966	976
Conversion, vol-%	74.0	76.0
Gasoline, vol-%	54.8	59.3
C_2^-, wt-%	3.3	2.8
Coke, wt-%	Base	0.84 x Base

The VSS design was first commercialized in 1995. As of October 2003, the VSS design has been commissioned for operation in nearly 30 units and all are still in service. This extensive experience in such a short time frame is a testament to the yield, selectivity and operational excellence that VSS technology delivers to the refining industry.

Table 2 shows comparative data before and after one of the many revamps. In this particular performance test, the post-revamp unit was operated in a "constant conversion" mode and then in a "constant coke yield" mode as compared to the pre-revamp performance test.

Table 2 ■ **VSS Commercial Data**

	Pre-Revamp	Same Conversion	Same Coke Yield
Feed Rate, BPD	Base	Base	Base
Feed, Sp. Gr.	0.916	0.918	0.918
UOP K	11.68	11.7	11.69
Feed Temp., °F	380	430	420
Reactor Temp., °F	975	950	990
Yields			
C_2^-, wt-%	2.32	1.82	2.63
$C_3 + C_4$, vol-%	27.2	24.6	29.7
Gasoline, vol-%	57.2	60.7	59.6
Light Cycle Oil, vol-%	17.1	17.4	15.1
Clarified Oil, vol-%	8.9	8.4	6.9
Coke, wt-%	Base	0.91xBase	Base
Conversion, vol-%	74.0	74.2	78.0

These types of yield improvements make UOP's Vortex Separation technology a popular and profitable revamp project.

For more information

For more information, contact your local UOP representative or our Des Plaines sales office:

e-mail: info@uop.com
fax: +1-847-391-2253
phone: +1-847-391-2000

UOP LLC
25 East Algonquin Road
Des Plaines, IL 60017-5017
U.S.A.
www.uop.com

UOP 4523-44 1107