DIPLEGS & VALVES

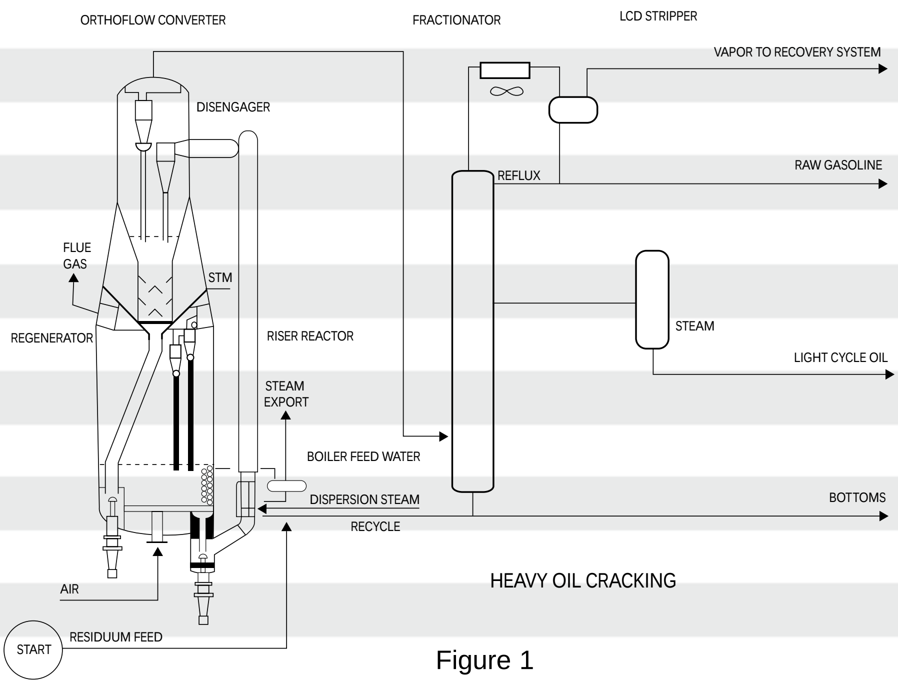

Figure 1

In each of the two fluid catalytic cracker vessels, diplegs are the means used to return the catalyst particles collected in the cyclones to the fluidized catalyst bed. This can be seen on Figure 1, which shows an outline drawing of a Heavy Oil Fluid Catalytic Cracker. In the regenerator vessel there are two stages of cyclones, and in the disengager (reactor) vessel there is one stage of riser cyclones and one stage of upper cyclones. No termination device is shown on any dipleg, but in an operating unit almost every dipleg would either discharge onto a splash plate or through a valve.

Basic Cyclone Operation

Before proceeding further with our discussion of diplegs and valves, it seems appropriate to take a brief look at a cyclone and describe how its operation interfaces with the dipleg. Figure 2 shows both a vertical section view through a cyclone and a three-dimensional sketch of a cyclone with a portion of the shell removed. In the section view, the three gas flow patterns in a cyclone are depicted. The entering gases spiral downward along the cyclone wall. The exiting gases rise up the center of the cyclone and leave through the clean gas outlet. The third gas flow pattern is the transfer of gases from the downward gas stream to upward gas stream all along the interface between these two streams. The completion of the reversal of the gas flow takes place below the cone outlet.

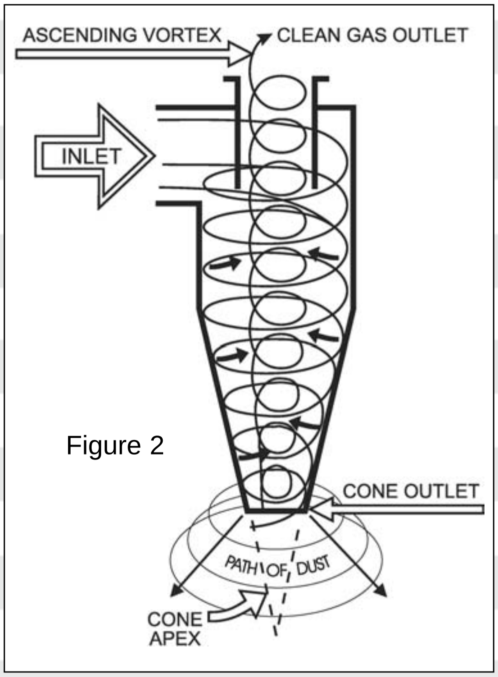

Figure 2

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The flow of the collected catalyst in the lower portion of a cyclone is indicated on Figure 3. After centrifugal force concentrates the catalyst against the upper wall of the cyclone, the downward spiraling gases move the particles down the cyclone wall and through the cone outlet. Notice that both gases and catalyst must pass through the cyclone cone outlet. If the flow rate of collected catalyst is too high, there will be insufficient space for passage of the two gas streams. When this occurs, some of the collected particles are re-entrained in the rising gas stream and carried out of the cyclone. We have found that when the weight rate of catalyst particles entering a cyclone divided by the cross sectional area of the cone outlet exceeds 80 lb/ft^2-s (390 kg/m^2-s), re-entrainment of particles starts to occur. This flow rate is about one half of the maximum flow rate, 150 lb/ft^2-s (735 kg/m^2-s), we recommended in a dipleg. The reason is that in a properly designed cyclone the cyclone gas streams do not enter the dipleg. You may have read published articles in which the author noted that he had measured mass flows in excess of 200 lb/ft^2-s (975 kg/m^2-s) through large diameter diplegs during laboratory testing. We agree that under controlled conditions such flow rates are possible. However, in an operating catalytic cracker the catalyst loading entering a cyclone is not constant. Based on data from many operating units, we have found that our maximum recommended mass flow rate compensates for these fluctuations. When, because of increased through put or because of an error in the initial system design, the required catalyst mass flow through the cone outlet of a first stage cyclone or a riser cyclone exceeds 80 lb/ft^2-s (390 kg/m^2-s), one can reduce the problem by truncating the cone at a higher elevation as shown on Figure 4. The effectiveness of this procedure has been demonstrated in several operating units.

Mass Flow Limits

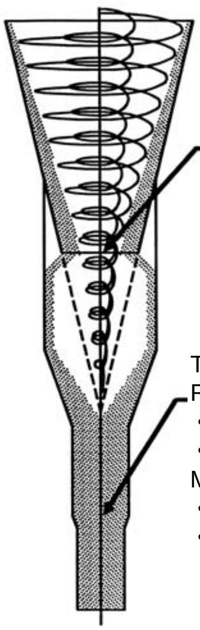


Figure 3

Modification for existing first stage cyclones to reduce mass flow through the cyclone cone outlet

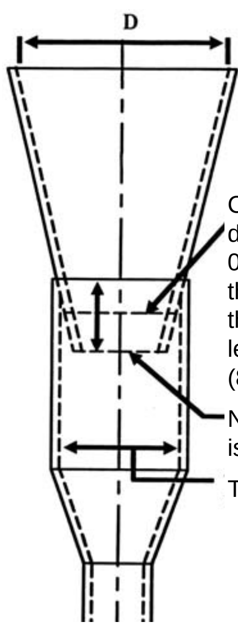


Figure 4

The Reasons for Cyclone Diplegs

Earlier it was noted that a cyclone dipleg is the means used to return collected catalyst to the fluidized bed at the bottom of the vessel. A dipleg is also the means used to provide a barometric type seal that prevents or minimizes gas leakage into the cyclone solids outlet. Leakage through the solids outlet will re-entrain some of the collected catalyst particles and carry them out of the cyclone with the exiting gases. The three basic formulas used to calculate the intermediate pressure drops through a cyclone system are shown on Figure 5. These formulas are used to calculate:

- the pressure drop due to acceleration at the first stage cyclone inlet
- the pressure drop from a cyclone inlet to the cyclone gas outlet
- the pressure drop from a cyclone inlet to the top of the cyclone dipleg

Figure 5
Cyclone Pressure Drop and Hopper or Dipleg Suction

Inlet Bell
Δ Pb = V^2 (Dg + Ds) Hb

Cyclone Pressure Drop
Δ Pc = V^2 Dg Hc

Δ P = Pressure Drop
V = Inlet Velocity
D = Density
H = Velocity heads corrected for dimensional units used

Subscripts:
B - Inlet Bell
C - Cyclone
D - Dipleg
G - Gas
S - Solids Load

Two things should be noted at this point. First, no entrance acceleration loss is calculated for cyclones that receive gases and catalyst directly from a riser. Second, the pressure drop from the cyclone inlet to the clean gas outlet and the pressure drop from the cyclone inlet to the top of the dipleg are seldom the same. Further, any cyclone modifications, such as a change in the diameter of the cyclone gas outlet tube, will not have the same effect on the two pressure drops. The calculations used to determine the catalyst level in a dipleg are shown on Figure 6. Once the hopper suction has been calculated, the only other data needed to determine the catalyst level in a dipleg are the length of dipleg submerged in the bed, the density of the fluidized catalyst in the bed, and the density of the fluidized catalyst in the dipleg. Most fluidized beds have densities between 25 and 35 lb/ft³ (400 and 560 kg/m³). Because of the high mass flow in a first stage dipleg, one may use a dipleg density of 30 lb/ft³ (480 kg/m³) or the bed density, whichever is greater. When the first stage dipleg is not submerged in a bed, it is suggested that a density of 25 lb/ft³ (400 kg/m³) be used. For a second stage dipleg, we normally use a density of 20 to 22 lb/ft³ (320 to 350 kg/m³) when designing a new cyclone system and a density of 25 lb/ft³ (400 kg/m³) when calculating the ability of an existing system to operate at a higher through put. In extreme cases, we have found it necessary to use a second stage dipleg density of 25 lb/ft³ (400 kg/m³) in the design of a replacement cyclone system.

Figure 6
Dipleg Level Calculation

Level due to dipleg submergence
$L_1 = L_s * D_b / D_d$

Level due to hopper suction
$L_1 = (\triangle P_b + \triangle P_{c1} \ldots + \triangle P_{cn} + \triangle P_{d(n+1)}) * 6.24 / D_d$

Catalyst level in dipleg above bed (above valve when dipleg not submerged)
$L = L_1 - L_s + L_2$

- L_1 - Level above bottom of dipleg due to submergence
- L_2 - Level due to hopper Suction
- L_s - Dipleg length submerged in bed (dense phase)
- D_b - Density of bed
- D_d - Density in dipleg
- $\triangle P$ - Pressure drop across inlet transition (bell)
- $\triangle P_c$ - Pressure drop from cyclone inlet to gas outlet
- $\triangle P_d$ - Pressure drop from cyclone inlet to top of dipleg

Subscripts 1, n, n+1 - Cyclone stage

The catalyst level above the bed in a dipleg that is submerged in the bed is the sum of:

- Any differential in level resulting from different bed and dipleg densities
- The pressure drop from the vessel to the top of the dipleg corrected for the difference between the density of water and dipleg density

When a dipleg is not submerged in a catalyst bed, the catalyst level in the dipleg above the valve outlet is only the pressure drop from the vessel to the top of the dipleg corrected for the difference between the density of water and the dipleg density.

A Reactor Cyclone System

A generic reactor (disengager) vessel with a riser that discharges downward and a two stage set of cyclones, each with a dipleg that discharges a through counterweighted valve located above the bed is shown in Figure 7. Between 75 and 85 percent of the catalyst will separate from the gases at the riser

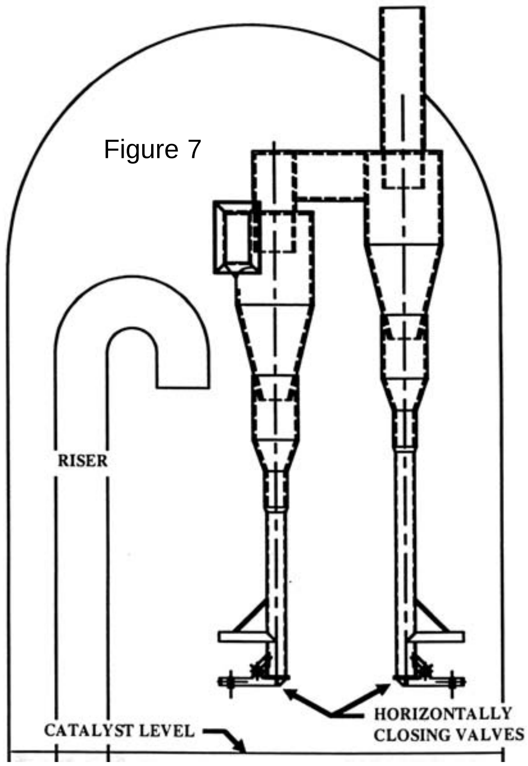


Figure 7

discharge. The first stage cyclone will collect 99.9+ percent of the entering catalyst. This leaves a very small quantity of catalyst in the gases going to the second stage cyclone. However, the pressure drop from the vessel to the top of the second stage dipleg will be about 55 inches (1.40 m) water gauge, primarily due to the high density of the hydrocarbon vapors.

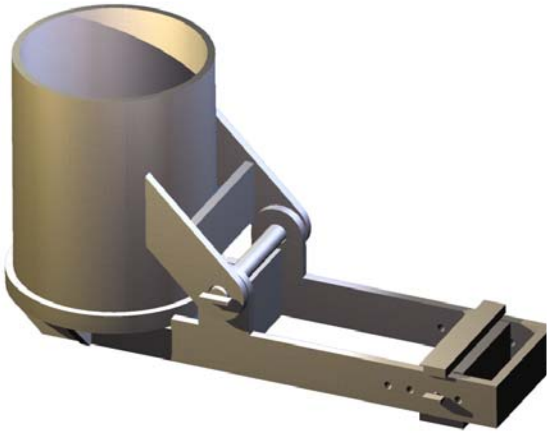
Reactor cyclone systems of this type have generally not performed as well as expected. The chief reason for this appears to be gas leakage through the second stage dipleg valves. This leakage not only re-entrains some of the collected catalyst, but it also brings in catalyst from the vessel. When check (trickle) valves were used instead of counterweighted valves, the gas leakage increased. When the diplegs with check (trickle) valves were extended so that they were submerged in the fluidized bed above the stripper, the gas leakage decreased to a level similar to the leakage through unsubmerged counterweighted valves.

Counterweighted Dipleg Valves

Drawing L-2043 shows details and dimensions of counterweighted dipleg valves. Counterweighted valves are the only valves on which it is standard practice to line the closure plates with hex mesh and refractory. These valves are recommended when the diplegs will infrequently or never be submerged in the catalyst bed. They have been used on diplegs that were normally submerged in a catalyst bed but not always successfully. The major reason for using counter weighted valves when the diplegs are not submerged in the horizontal valve seat. Catalyst tends to completely cover the closure plate and to some extent discharge around the entire 36° perimeter of the valve seal. This outward flow of catalyst tends to resist the inward leakage of gases.

In Figure 7, shrouds are shown above the valve counterweight arms. Any time that the catalyst enters the vessel above the counterweighted valves, the counter weight arms should be shrouded to prevent falling catalyst from interfering with the operation of the valves.

Drawing L-2043



NOTES:
1. All Material will be type 304h s.s., except pipe will be the same material as the dipleg.
2. Surface of closure plate is lined with ¾" hexmesh and refractory.

A	B	C
6	7 5/8"	2'– 3 3/16"
8	9 5/8"	2'– 4 13/16"
10	11 ¾"	2'– 6 ¼"
12	1'– 1 ¾"	2'– 10 7/8"
14	1'– 3"	3'– 2 5/8"
16	1'– 5"	3'– 2 5/8"
18	1'– 7"	3'– 4 7/8"
20	1'– 9"	4'– 1 1/8"
22	1'– 11"	4'– 3 3/8"
24	2'– 1"	4'– 4 5/8"

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Size	A	B	C	D	E	F
6"	8"	11 15/16"	8 5/16"	2'– 4 ¼"	1'– 2 13/16"	11 5/8"
8"	8"	1'– 2 1/16"	10 11/16"	2'– 8 ¾	1'– 5 ½"	1'– 1 5/8"
10"	8"	1'– 4 ¼"	1'– 1 3/16"	3'– 1 7/16"	1'– 7 9/16"	1'– 3 ¾"
12"	8"	1'– 6 3/8"	1'– 3 ½"	3'– 7 7/8"	1'– 10 1/8"	1'– 5 ¾"
14"	8"	1'– 7 11/16"	1' – 5"	3'– 8 11/16"	1'– 11 ½"	1'– 7"
16"	8"	1'– 9 ¾"	1'7 3/8"	4'– 1 1/8"	2'– 2 1/16"	1'– 9"
18"	8"	1'– 11 13/16"	1'– 9 ¾"	4'5 9/16"	2'– 4 3/16"	1'– 11"
20"	8"	2'– 1 15/16"	2'– 0 1/16"	4'– 10"	2'– 6 9/16"	2'– 1"
22"	8"	2'– 4"	2'– 2 7/16"	5'2 7/16"	2'– 9 3/16"	2'– 3"
24"	8"	2'– 6 1/8"	2'– 4 ¾"	5'– 6 7/8"	2'– 11 ½"	2'– 5"
26"	8"	2'– 8 3/16"	2'– 7 1/8"	5'– 11 5/16"	3'– 1 7/8"	2'– 7"

Drawing 3L-3823

Unshrouded Dipleg Check Valves

If one prefers that the reactor cyclone diplegs be submerged in the catalyst bed above the stripper, then unshrouded check (trickle) valves should be used on the diplegs. These valves are shown on *Drawing 3L-3823.* Because the gas velocities in the fluidized bed above the stripper are low, usually less than 1 ft/s (0.30 m/s), no shrouding is needed to protect the valves from turbulences in the bed. The major concern when submerging reactor cyclone diplegs in the bed above the stripper is that the bed is sufficiently fluidized so that the valves will operate and catalyst will flow out of the diplegs.

When the reactor cyclone system is similar to the system shown on Figure 7, then the top half of each second stage valve seat should be closed off with a plate that is flush with or recessed slightly below the lip of the seat.

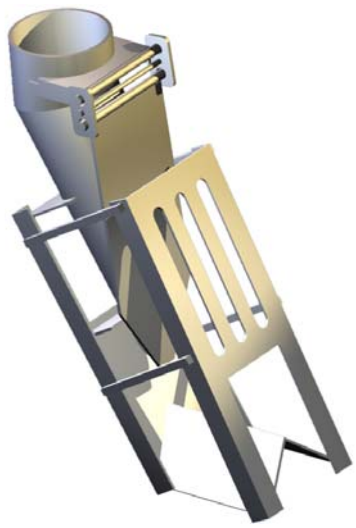
Other diplegs on which unshrouded valves are sometimes used are first stage regenerator cyclone diplegs. The use of valves on these diplegs helps to reduce catalyst losses during start-up and shutdown when the first stage diplegs are not submerged in the bed. During normal unit operation, there is no reason to prefer a dipleg valve in place of the more common first stage dipleg termination device, a splash plate.

Splash Plates

One type of splash plate is shown on Drawing L-2394. Two other types of splash plates that are frequently used are a flat, horizontal plate and a conical plate (sometimes called a "coolie hat"). Each of these plates is supported from the dipleg by 3 or 4 straps. The inclined splash plate allows one to encourage horizontal circulation in the bed. Otherwise, any of the above splash plate designs accomplish the basic purpose of a splash plate, the deflection of any large gas bubbles away from the dipleg outlet. Inclined splash plates are also used on some riser cyclone diplegs to direct the catalyst discharge into the stripper.

Size	A	B	C	D	E	F
6”	8”	11 15/16”	1’ – 6 ¼”	3’ – 2 3/16”	1’ – 10 ¾”	1’ – 0 5/8”
8”	8”	1’ – 2 1/16”	1’ – 9 ½”	3’ – 7 9/16”	2’ – 2 5/16”	1’ – 2 5/8”
10”	8”	1’ – 4 ¼”	2’ – 0 7/8”	4’ – 1 1/8”	2’ – 6 1/8”	1’ – 4 ¾”
12”	8”	1’ – 6 3/8”	2’ – 4 1/16”	4’ – 6 7/16”	2’ – 9 ¾”	1’ – 6 ¾”
14”	8”	1’ – 7 11/16”	2’ – 6 1/16”	4’ – 9 ¾”	3’	1’ – 8”
16”	8”	1’ – 9 ¾”	2’ – 9 ¼”	5’-3”	3’ – 3 9/16”	1’ – 10”
18”	8”	1’ – 11 13/16”	3’ – 0 7/16”	5’ – 8 ¼”	3’ – 7 1/8”	2’
20”	8”	2’ – 1 15/16”	3’ – 3 5/8”	6’ – 1 9/16”	3’ – 10 ¾”	2’ – 2”
22”	8”	2’ – 4”	3’ – 6 13/16”	6’ – 6 13/16”	4’ – 2 5/16”	2’ – 4”
24”	8”	2’ – 6 1/8”	3’ – 10 1/16”	7’ – 0 3/16”	4’ – 5 15/16”	2’ – 6”
26“	8”	2’ – 8 3/16”	4’ – 1 ¼”	7’ – 5 7/16”	4’ – 9 ¼”	2’ – 8”

Drawing 3L-3822



Partially Shrouded Dipleg Check Valves

Up to this point we have not discussed the valves used on second stage cyclone diplegs in a regenerator. These are normally partially shrouded check (trickle) valves. There are two partially shrouded check (trickle) valve designs, one where the bottom shroud is cantilevered and one where the bottom shroud is supported at both ends. With the cantilevered design the bottom shroud may either be a flat or angle plate as shown on Figure 8. The design with the plate supported on both ends is shown on *Drawing 3L-3822.* This design was developed when some of the cantilevered shroud plates were found curled up against the closure plates, thus preventing operation of the valves. Further, it was found that on a number of cantilever design valves, the cages over the closure plates fell off during operation. Upon examination, it was found that these failures occurred in the heat-affected zones at welds that went completely around the rods supporting the cages.

Because of this, the valve with the shroud plate supported on both ends was designed to exclude any circumferential welds. Except for these two problems, partially shrouded check (trickle) valves have proven to effectively prevent rising gas bubbles and normal horizontal bed circulation from interfering with the discharge of catalyst from the second stage diplegs. Partially shrouded check valves have also been used on some first stage diplegs in regenerators and on some reactor cyclone diplegs instead of unshrouded check valves.

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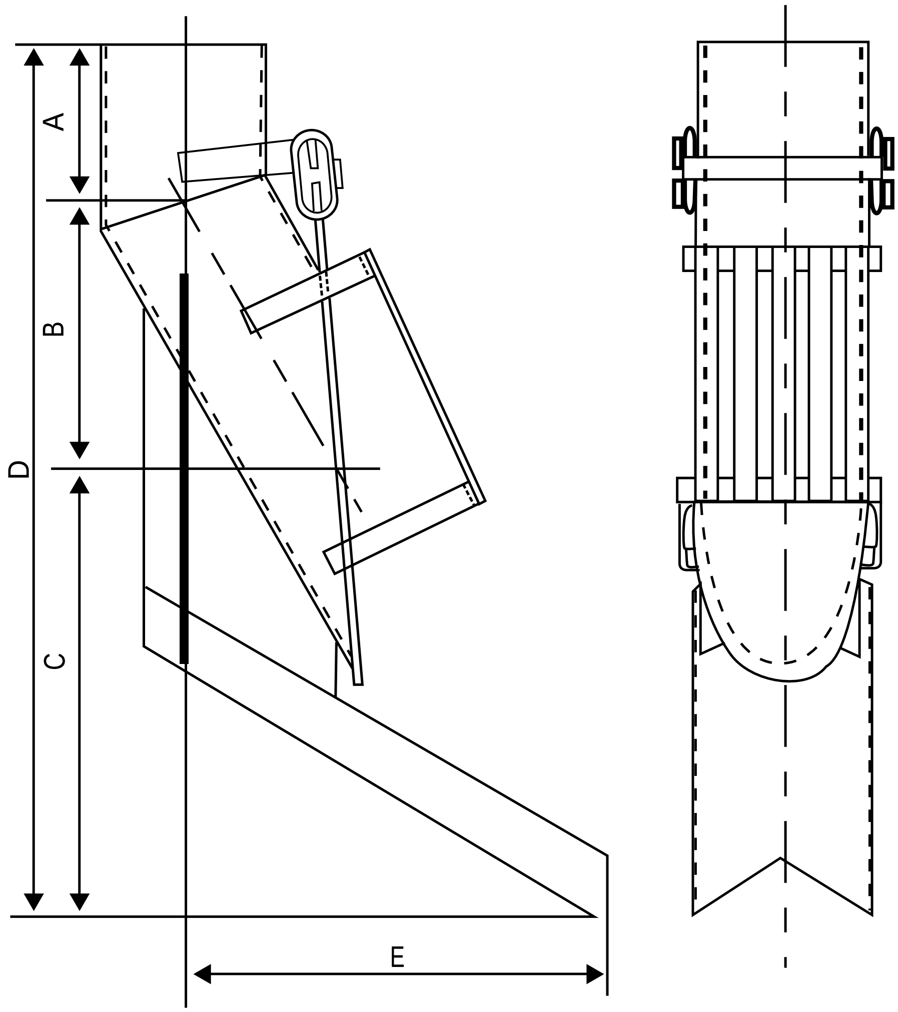

Figure 8

Size	A	B	C	D	E
2 ½”	2 ½”	4 5/16”	7 ½”	1’ – 2 5/16”	5 11/16”
4”	4”	6 15/16”	1’	1’ – 10 15/16”	9 7/8”
6”	6”	10 3/8”	1’ – 6”	2’-10 3/8”	1’ – 3 13/16”
8”	8”	1’ – 1 7/8”	2’	3’ – 9 7/8”	1’ – 9 ¾”
10”	10”	1’ – 5 5/16”	2’ -6”	4’ – 9 5/16”	2’ – 3 5/8”
12”	12”	1’ – 8 ¾”	3’	5’ – 8 13/16”	2’ – 9 ½”
14”	14”	2’ – 0 ¼”	3’ – 6”	6’ – 8 ¼”	3’ – 3 ½”
16”	16”	2’ – 3 11/6”	4’	7’ 7 11/16”	3’ – 9 3/8”
18”	18”	2’ – 7 3/16”	4’ – 6”	8’ – 7 3/16”	4’- 3 5/16”
20”	20”	2’ – 10 5/8”	5’	9’ – 6 5/8”	4’- 9 ¼”
22”	22”	3’ – 2 1/8”	5’ – 6”	10’ – 6 1/8”	5’ – 3 1/8”

DIPLEGS & VALVES

Fully Shrouded Dipleg Check Valves

The last type of dipleg valve offered by most cyclone suppliers is the fully shrouded check (trickle) valve shown on *Drawing 3L-4388*. The shroud which is either round or rectangular fully surrounds the valve except for the lower portion of the closure plate. This type of valve is seldom used, but it has been the only effective solution when catalyst from a spent catalyst return line or catalyst from a riser directly impinged on a dipleg valve.

Drawing 3L-4388

Size	A	B	C	D	E	F
6"	11"	11 15/16"	1' – 3 3/8"	3' – 2 5/16"	1'-2"	1'-6"
8"	11"	1' – 2 1/16"	1' – 9 ½"	3' – 10 9/16"	1'-5"	1'-8"
10"	1'	1' – 4 ¼"	2' – 0 7/8"	4' – 5 1/8"	1'-8"	1'-10"
12"	1'	1' – 6 3/8"	2' – 4 1/16"	4' – 10 7/16"	1'-11"	2'
14"	1'-1"	1' – 7 11/16"	2' – 6 1/6"	5' – 2 ¾"	2'-1"	2'-1"
16"	1-1"	1' – 9 ¾"	2' – 9 ¼"	5' – 8"	2'-3"	2'-3"
18"	1'-2"	1' – 11 13/16"	3' – 0 7/16"	6' – 2 ¼"	2'-6"	2'-5"
20"	1'-2"	2' – 1 15/16"	3' – 3 5/8"	6' – 7 9/16"	2'-9"	2'-7"
22"	1'-3"	2' – 4"	3' – 6 13/16"	7' – 1 13/16"	3'	2'-9"
24"	1'-3"	2' – 6 1/8"	3' – 10 1/16"	7' – 7 3/16"	3'-3"	2'-11"
26	1'-4"	2' – 8 3/16"	4' – 1 ¼"	8' – 1 7/16"	3'-6"	3'-1"

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