TITAN'S EXPERIENCE IN PHYSICAL SEPARATION DEVICES

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ABSTRACT

As a naphtha cracker, Titan is used to several types of separators especially in the quench and hot fractionation section. This paper will zoom into the separation process involving immiscible fluid phase with different densities for separation to occur. Three principles used to achieve physical separation of gas, liquids or solids are momentum, gravity settling, and coalescing. Seperators may employ one or more of these principles.

There are four types of physical separation devices currently being applied in Titan crackers, i.e., liquid-liquid separation, 3-phase separation, gas-liquid separation, and particulate removal (filtration).

Two types of liquid-liquid separation device used here, the first is using chevron baffle in water quench tower to separate Raw Pyrolysis Gasoline from quench water. This operation is based on "gravity separation". The second type applies "coalescing separation" in the oil-water coalescer to separate dissolved hydrocarbon in quench water or to remove water from Raw Pyrolysis Gasoline.

3-phase separation applied when we have water, liquid hydrocarbon and hydrocarbon gases in the inlet stream. Two types of vessel used here, i.e. the vertical and the horizontal type. Vertical vessel is mainly applied when the ratio of gas-liquid is high. Horizontal vessels are most efficient where large volumes of total fluid and large amounts of dissolved gas are present with the liquid. An example for vertical vessels is the compressor suction drums while good representative of horizontal vessel is the spent caustic deoiling drum.

The commonly used gas-liquid separator here is the flash drum. It normally used to separate the gas evolved from liquid flash from a higher pressure to a lower pressure, for example the hydrogen drum separating hydrogen from methane. Besides, steam drums are used to separate saturated steam from water.

Particulate removal is most common in both crackers. Majority of it is pipe strainer or filter using metal perforations with wire mesh lining. The design of filter can be T-type, Y-type, basket types or duplex basket depends on piping routing, flow capacity, pressure drop or cleaning frequency. Besides that, we have also cartridge filter made of fiber. The important parameter for particulate removal is monitoring of pressure drop. The clogged cartridge needed change out or strainer need cleaning when pressure drop increases. This job is easy and requires less manpower, however if it is not carried out, a clogged filter might trip the compressor and subsequently shut down the whole plant.

LIQUID-LIQUID SEPARATOR

Liquid-liquid separation may be divided into two broad categories of operation. The first is defined as "gravity separation" where the two immiscible liquid phases separate within the vessel by the differences in density of the liquids. Sufficient retention time must be provided in the separator to allow for the gravity separation to take place. The settling of Raw Pyrolysis Gasoline in our Quench Water Tower in the most representative "gravity separation" process. The cracked gas from furnace must be cooled down as fast as possible to avoid over cracking. This happens in three steps, the Selective Linear Exchanger (SLE), the quench oil tower and the quench water tower. In the quench water tower, cracked gas is cooled by direct contact with circulating quench water where gas temperature will be brought down to 40°C. Some hydrocarbon will condensed and needed to be separated with water in the bottom of the tower. The bottom of quench water tower contains a series of chevron-type plate baffles for the settling out of water and hydrocarbon phase. Figure 1 shows the physical outlook of chevron plate baffle. The V-shape baffles provided sufficient retention time to allow gravity settling of oil-water mixture in the tower. Water will then be collected in the bottom of conical portion while oil will float and collected inside the solid plate. This internal separator is efficient and less maintenance needed. The tower will only be opened up for cleaning during plant shut down every 3 years.

The second category is defined as "coalescing separation". This is where small particles of one liquid phase must be separated or removed from a large quantity of another liquid phase. The application is common in the quench section, compression section and hot fractionation section. The separator applying "coalescing separation" is as below:

i. Horizontal coalescer with cartridge element at water stripper feed to reduce the hydrocarbon content in dispersed phase from 2.5 volume % to less than 30ppm. This coalescer is important to ensure oil-free water to be fed to steam generator.

ii. Horizontal coalescer with cartridge element to remove water from a continuos hydrocarbon phase containing a disperse phase of water droplets. This unit is located up-stream of a liquid hydrocarbon dehydrator. It will ensure no free-water being carried over which will damage the molecular sieve in the dehydrator.

iii. Horizontal vessel with wire mesh coalescer pad to remove water from a continuos hydrocarbon phase containing a disperse phase of water droplets. This unit is located up-stream of RPG Hydrogenation Reactor. The vessel is slanting at about 2° to ensure water flow into the collecting boot.

Horizontal vessels have advantage over vertical once due to the larger interface area available in the horizontal style, and the shorter distance particles must travel to coalesce. Figure 2 shows the cartridge element used for coalescing.

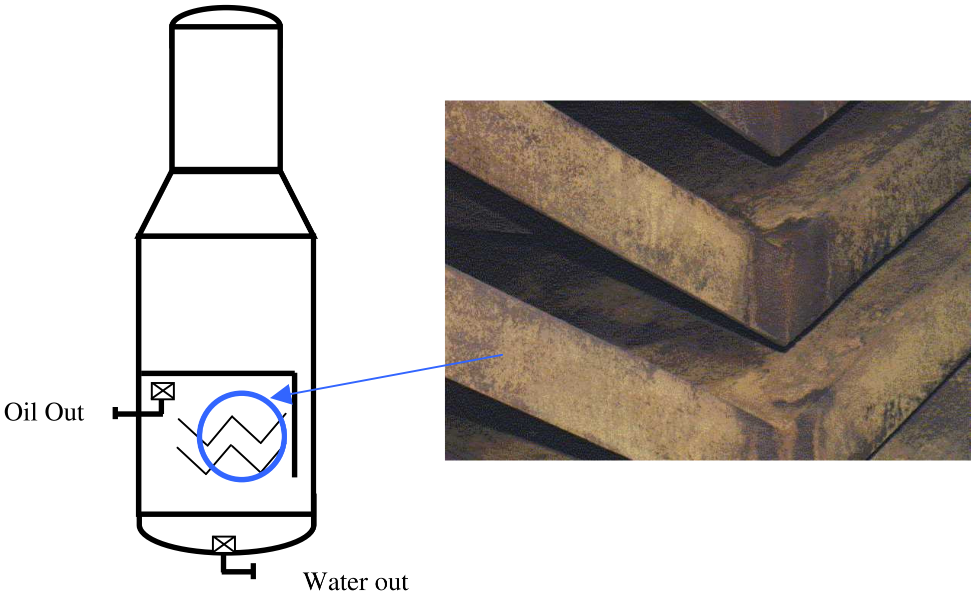


Figure 1 : Chevron-type Plate Baffles

Figure 2 : Used Cartridge Elements

3-PHASE SEPARATOR

This apply when we have water, liquid hydrocarbon and hydrocarbon gases in the stream. The separators are usually characterized as vertical or horizontal. Regardless of shape, the separation vessel contains four major sections as listed below:

i. The primary separation section used to separate the main portion of free liquid in the inlet stream
ii. The secondary or gravity section designed to utilize the force of gravity to enhance separation of entrained droplets.
iii. The coalescing section utilizes a coalescer or mist extractor. Our normal application is using a knitted wire mesh pad on top of vessel.
iv. The sump or liquid collection section acts as receiver for all liquid removed from gas in the primary, secondary, and coalescing section.

In this section we are going to go through the 3-phase separator as a knockout drum for cracker gas compressor. We have a five stages cracked gas compressor to provide adequate feed forward flow to down stream fractionation units. In between each stage there is knockout drum. The function is to knockout condensed hydrocarbon and water. These separators are important to ensure liquid free gas feed to compressor. The knockout drum for the second stage is a 3-phase separator. It is a vertical vessel, having 2 compartment at the bottom portion and a mist eliminator on top of the vessel as shown in Figure 3.

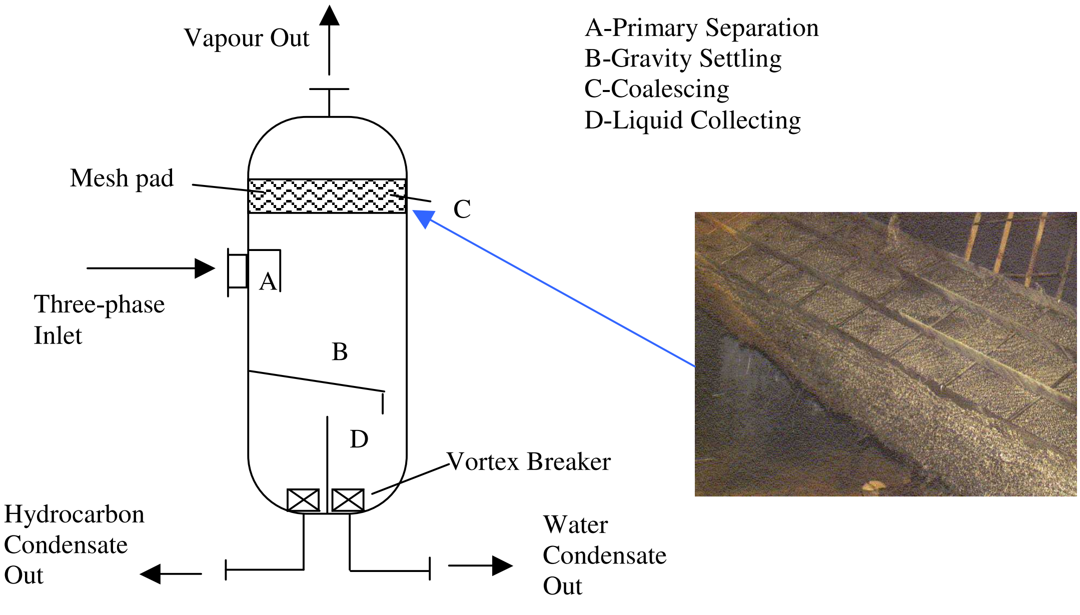


Figure 3 : Compressor Second Stage Suction Drum

Vertical vessel selected here because the gas-liquid ratio is high. The cracked gas from 1st stage compressor enters the vessel striking a diverting baffle which initiate primary separation. Liquid removed by the inlet baffle falls to the bottom of the vessel. Hydrocarbon condensate, which is lower density, will over flow to the left compartment. The gas moved upward, passing through the mesh pad to remove suspended mist, and then the "dry" gas flow out. Liquid removed by the demister is coalesced into larger droplets, which will then fall through the gas to the liquid reservoir in the bottom. The mist eliminator removes the very small droplets of liquid from the gas by impingement on a surface where they coalesce. A typical liquid carryover from the mist eliminator is less than 0.013 ml per m^3. The demister pad must be removable through manway or manhole for cleaning and repair. The small picture is the close view of one portion of demister pad.

Horizontal type 3-phase separator is the spent caustic deoiling drum (Figure 4). The vessel is used to separate spent caustic from caustic scrubber with hydrocarbon gas and liquid hydrocarbon. The major sections are similar to vertical vessel except for the mist extractor. The greater liquid surface area in this configuration provides optimum condition for releasing entrapped gas. The liquid which, has been separated from the gas moves along the bottom of the vessel to the liquid outlet. The gas and liquid occupy their proportionate shares of shell cross-section. In this case, the denser caustic settles to the bottom compartment and lower density hydrocarbon liquid will overflow to the other part of the bottom compartment.

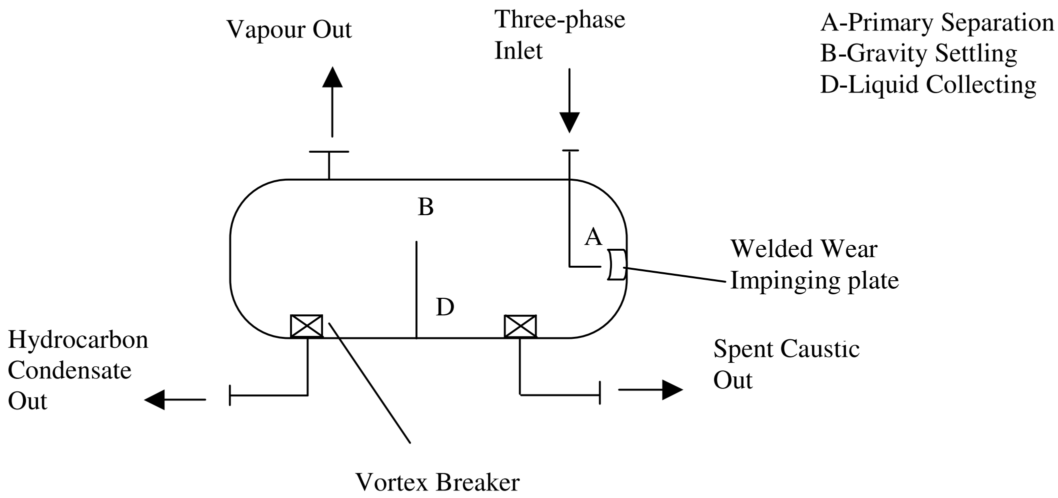


Figure 4 : Spent Caustic Deoiling Drum

GAS-LIQUID SEPARATOR

Generally the gas-liquid separator can be high gas-liquid ratio where the structure is similar to 3-phase separator except for the bottom portion where only one compartment needed. It is widely applied in a cracker. For example steam drums and all kinds of reflux drum. Certain application involved flashing effect where used to separate the gas evolved from liquid flash from a higher pressure to lower pressure. The most common application is in the cold fractionation section and the Hydrogen recovery system. There are 8 drums in the process flow diagram starting from the depropanizer and ending at Hydrogen recovery section. The usage of flash drums provided rough separation helps to separate gas and liquid hydrocarbon generated from flashing effect and reducing the load to distillation column.

Some compressor suction drums only have one liquid compartment. These drums also act as gas-liquid separator to knock down any condensate from gas.

FILTRATION

Filtration or particulate removal is most common in both crackers. It applies to the separation of solid particles from a fluid by passage through a porous medium. In Titan, three types of filter normally apply, i.e. the metal perforations with wire mesh lining strainer, the metal basket with fabric socks, and the cartridge filter.

Strainers are used in piping system to protect equipment sensitive to dirt and other particles that may carried by the fluid. During system start-up and flushing, strainers may be placed upstream of pumps to protect them from construction debris that may have been left in the pipe. A typical start-up strainer (Figure 5) is normally in conical shape and to be install temporary in between flanges. It will be removed after line flushing. Line flushing is an important job before plant start-up to ensure all equipment and piping is clear of any debris. Titan’s second cracker was forced to shut down for a few days barely two months after initial start-up due to pluggage of plate-fin exchanger inlet strainer.

Permanent strainers may be installed upstream of pumps, plate-fin exchanger, control valves, traps, and instruments to protect them from corrosion products that may become dislodged and carried throughout the piping. Process area widely installed strainer are quench oil and quench water circulation pumps, caustic tower circulating pump and plate-fin exchanger at cold section.

Strainers are available in a variety of styles, including “Y”, “T”, and basket. The Y-strainer (Figure 6) is generally used upstream of traps, control valves, and instruments. The Y-strainer resembles a lateral branch fitting with the strainer element installed in the branch. The end of the lateral branch is removable to permit servicing of the strainer. Also, a blow-off connection, which we call “bleeder” may be provided in the end cap to flush the strainer.

Y-strainer is normally used in small line, for bigger pipeline T-strainer is preferred. There is more than 87% T-strainer applied in our plant. The advantages of T-strainer compared to Y-strainer are larger flow capacity, applied to larger pipe size, and lower pressure drops

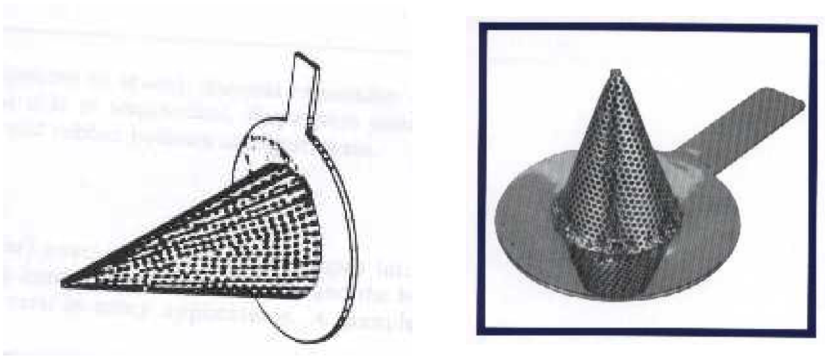


Figure 5 : Temporary Conical Strainer

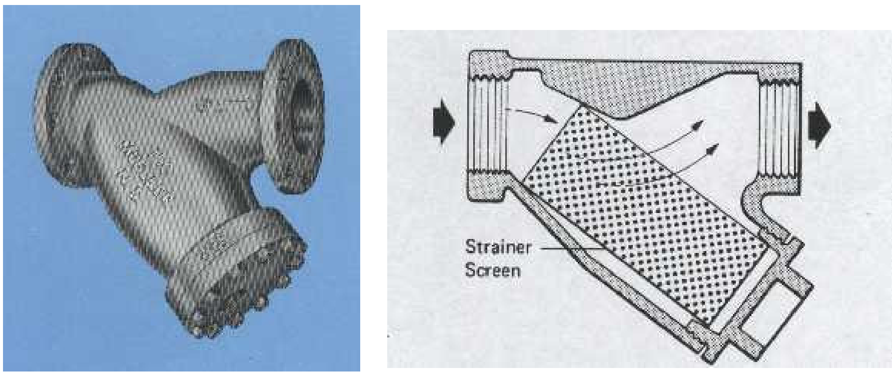
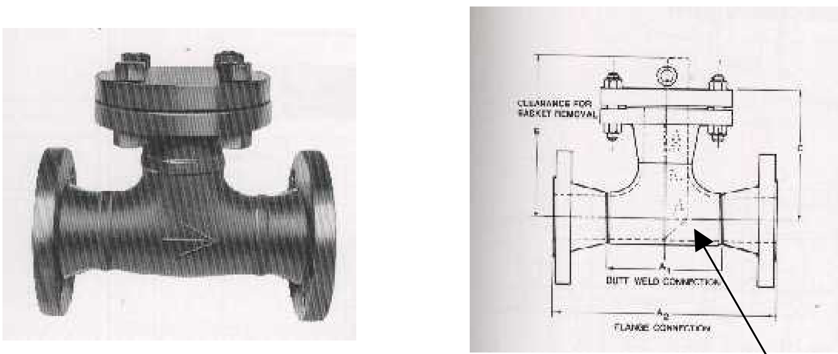


Figure 6 : Typical Y-strainer

Figure 7 is the typical T-strainer. There are several shape of T-strainer used, i.e. the W-shape, the V-shape and hollow cylindrical shape (Figure 8). The W and V shape is applied at plate-fin exchanger inlet line, while the cylindrical shape is normally used at compressor inlet piping where it is installed at the elbow. Basically, the shape of strainer screen is designed to provide more surface area with less pressure drops.



Strainer element can be different shape

Figure 7 : Typical T-strainer

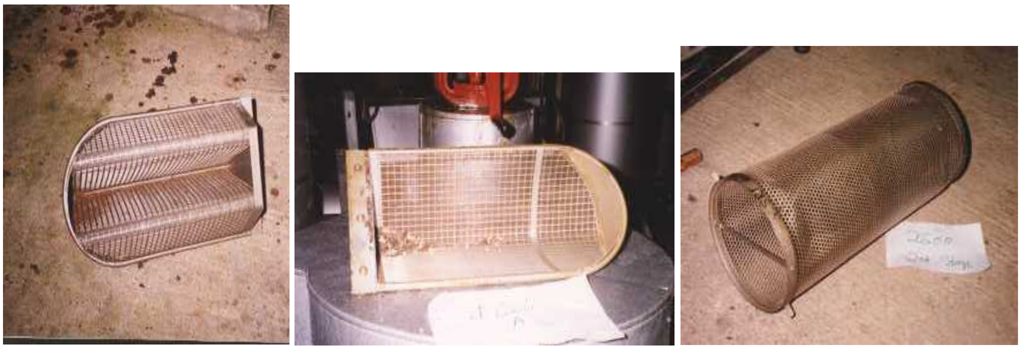


Figure 8 : W-shape, V-shape and Cylindrical T-strainer

Basket strainers (Figure 9) are generally used where high flow capacity is required. It has large filtration area resulting lower pressure drops. The basket strainer is serviced by removing the cover, which yields access to the basket. Only 4% strainer in plant is basket type because the cost is higher comparing to T or Y type. Basket strainers are also available in a duplex style (Figure 10) which consists of two parallel basket and diverting valves which permit diversion of the flow through one of the strainer elements while the other element is being serviced – an essential feature where flow cannot be interrupted. Furthermore, duplex strainer with automatic back wash facility had been introduced. It will start the switching and back flush automatically by sensing the pressure across strainer. This feature will definitely save manpower for strainer cleaning, however, the cost is consider high compared to normal simplex basket strainer. Economic justification was made based on strainer cleaning frequency and no down time due to uninterrupted flow.

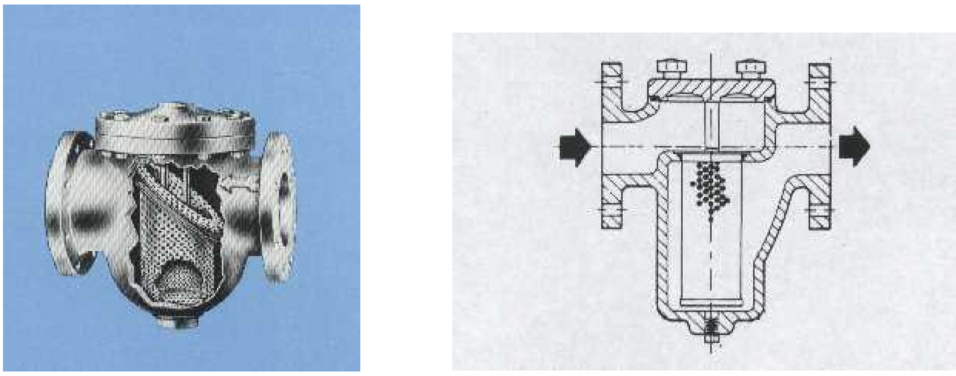


Figure 9 : Typical Basket Strainer

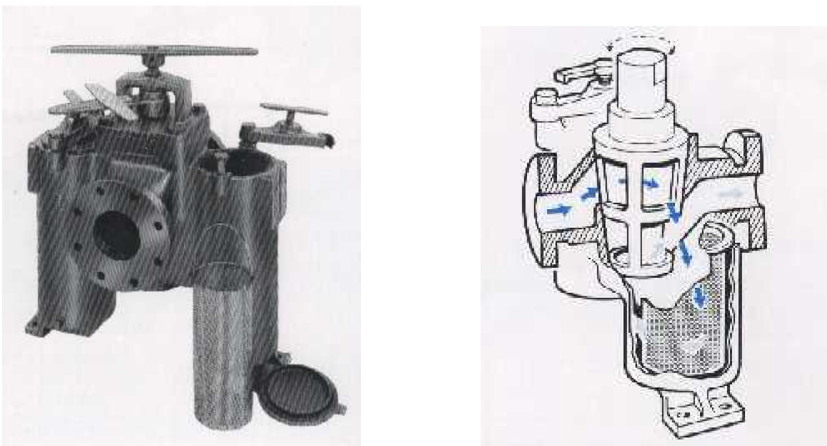


Figure 10 : Duplex Basket Strainer

Filter with screen basket and socks is applied at cracker-1 quench water filter. This unit is a vertical vessel consists 4 basket strainers, wearing a nylon socks, designed to remove solid materials 20 microns in diameter and larger. Design allowable pressure drop is 1 bar. There is a pressure drop indicator on-site to show the pressure drop across on-line filter. We normally switch the filter when pressure drop is above 0.5 bar.

Filter with cartridge type element is used in cracker-2 quench water filter and Pyrolysis Gasoline feed filter. The earlier is design to remove 20 microns or larger, the later used to remove 5 microns or larger solid particles from inlet stream. Both unit using disposable cartridge type element made of cotton or nylon.

Filter selection is mostly based on pressure drop allowable, cleaning frequency, particle sizes to be removed, flow capacity, pipe size, and cost. Screen type filter can be easily removed, clean, and reuse. However, if we required removal of solid material up to few microns, the wire mesh is not suitable. Refer to U.S. Sieve Series and Tyler Equivalents (ASTM – E-11-61), to remove particles 37 micron and larger, we need to have 400 mesh strainer. This will impact the cost and the reliability of the strainer. Common strainer mesh size in process side is 10 to 60 mesh only. For removal of solid particle up to 5 microns, cartridge element is the best. Cleaning frequency is one of the considerations for strainer selection. The fuel oil pump and the distillate stripper pump suction strainer need to be cleaned up to 5 times a day due to pluggage by coke particles. In order to save manpower and to avoid shutting down the pump too frequently, we modified the Y-strainer to duplex basket type. This allowed on-line strainer cleaning, more capacity, more open area and easier strainer cleaning. The total saving from maintenance can pay out the strainer cost easily.

Here is the example we change the fuel oil pump suction strainer from 2" Y-strainer to 2" duplex basket strainer, thus increases screen free area from 3.41 sq. in. to 30.7 sq. in., in other words increases the flow capacity by 9 times. Besides, the cleaning frequency reduces from 6 hours a day to less than half an hours a day because the duplex strainer has more surface area and easier to clean. With this, we save the maintenance or manpower cost and avoids shutting down the pump during cleaning. This modification is easily pay back by 3 months period.

CONCLUSION

The application of separators in a cracker is mandatory. The benefits from the installation can be summarized as follow:

i. providing an initial rough separation of component before feed into distillation column as the application of flash drums
ii. to avoid liquid carry over to compressor or to turbine
iii. to separate oil from water to avoid fouling
iv. to separate water from hydrocarbon to protect catalyst from deactivation and to avoid hydrate formation in distillation column
v. to protect downstream equipment from erosion by removing solid particles

The separators are simple, but play an important rule to ensure any plant runs smoothly.

REFERENCES

1. M.L. Nayyar (ed.), **Piping Handbook (6th ed.)**, A.108-A.109 (1992)
2. Gas Processors Suppliers Association, **Engineering data Book Vol. 1,** 7, 15-16 (1998)
3. Perry, Robert H. (ed.) **Perry's Chemical Engineers' Handbook (6th ed.)**, 21, 15 (1984)
4. Hayward Strainers Catalogue
5. Mueller Steam Specialty Product Guide