Technical Information Paper

DAHLMAN

(R)FCC Slurry Oil Filtration

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1. Introduction

The elegant FCC process was developed in the late 1930's to process and convert vacuum distillates (VGO - Vacuum Gas Oil) to lighter components, using a fluidized cracking catalyst. Typical operating temperatures in the regenerator are approx. 720 ºC and in the reactor approx. 500 ºC. The feedstock to the FCC unit is typically VGO but can include many other heavy streams.

The FCC reactor contains a fluidized bed of catalyst whose equilibrium size distribution ranges between 20 and 150 microns. In the reactor, coke forms on the catalyst as a result of condensation reactions and deactivates the catalyst. To prevent the build-up of coke and provide energy to drive the endothermic cracking reactions, the catalyst is continuously (re)cycled between the reactor and the regenerator to burn off coke. Reaction products leave the reactor in a gaseous state after passing through cyclones which, when functioning properly, remove the majority of entrained equilibrium sized catalyst particles and smaller catalyst fines.

The catalyst fines are erosion products caused by the collision of catalyst particles with each other and with the walls of the unit. These fines have a greater chance, than the equilibrium sized catalyst, of escaping capture in the reactor cyclones since the removal efficiency of cyclones, for particles of uniform density, decreases with decreasing particle size.

Catalyst or fines escaping capture in the reactor cyclones are fed along with the products to the main fractionator of the FCC separation system and leave the fractionator with the bottom product. Since the fines content of the SO can interfere with its use as a product, there is a need to remove them. Removing fines from the SO upstream of tankage will eliminate the need to settle fines in tankage and eliminate the generation of the majority of the tank bottom sludge. The slurry oil process requires the filter to withstand rigorous service conditions and the benefits of an all-metal filter are obvious.

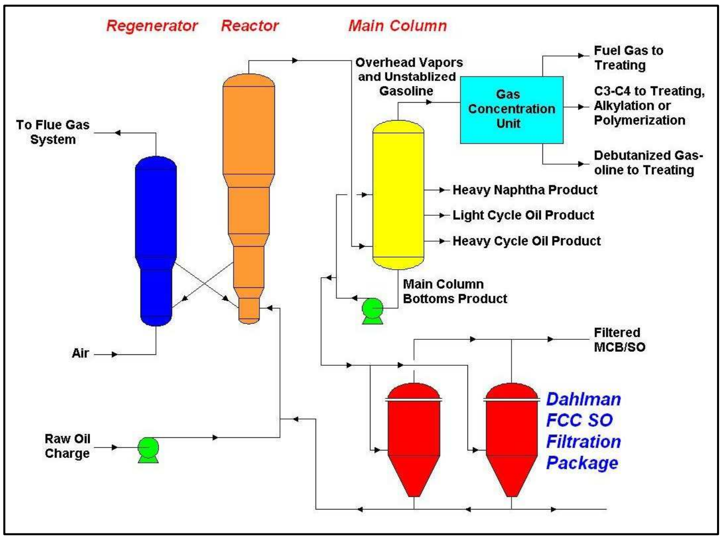


Figure 1 – Typical FCCU with integrated Dahlman FCC SO Filtration Package

1.1 Removing catalyst particles

A key goal for removing the catalyst particulate is upgrading of product fuel oils or upgrading to provide feedstock for production of carbon black or other products. Removing the catalyst fines also reduces the wear of downstream components due to the abrasive nature of the particles. More recently, there has been added emphasis on removing the catalyst fines to prevent settling and sludge formation in slurry oil storage tanks in addition to concerns over the hazardous waste classification of catalyst-containing tank sediments.

Fuel oil vendors for years have used storage tanks, barges, and chemical agents to settle catalyst material from oil products. This leaves behind large volumes of toxic sludge in the containment which eventually needs to be cleaned the waste discharged in an environmentally safe manner. Today these practices are closely monitored by government officials and accordingly waste treatment of this sludge has become expensive and should be minimized. Filtration of the slurry oil at the refinery can significantly reduce these costs by returning the catalyst fines back to the reactor.

1.2 Creating value

The slurry oil has to be clarified in order to maximize the value of this stream. Such clarification involves the use of metal filters (due to high temperature) with in-situ regeneration i.e. backwash filters. The removal efficiency of such a backwash filter is greatly affected by the filter cake formed, on the surface of the filter medium, during the filtration cycle.

A filter system has the potential to:

- Convert a traditional FCC main column waste into a valuable commodity
- Expand the refiners market for FCC bottoms
- Unlock an on-site energy source
- Significantly reduce storage tank cleaning costs
- Provide an environmentally friendly process improvement that can pay for itself in less than one year
- Convert a toxic waste sludge into an environmentally safe process discharge

The intent is to remove particulate matter from liquid streams. To accomplish this, a porous metal filter medium with sufficiently small pores and sized at an appropriate flow rate per unit of filter area, effectively retains solids at or near the filter's outer surface. This results in the formation of a permeable cake of solids which can be dislodged either at: a predetermined pressure drop, or a certain predetermined time interval. The filter elements are automatically cleaned in the reverse flow direction utilizing a method known as gas assist. By initiating this reverse flow, dislodged solids are purged from the filter system where they may be returned directly to the process for reuse or removed from the process stream and sent to a storage or collection unit.

Slurry oil / MCB, after removal of solids, is typically used for:

- Carbon black manufacturing
- Needle cokes manufacturing
- Fuel oil (no. 6 fuel oil or bunker C fuel)
- (Resid) Hydrocracker / hydrogenation feedstock (see information below)

Typical customer fluid specification targets are:

• Needle coke feedstock	25-100 ppm
• Hydrotreater / residue hydrocracker feedstock	10-50 ppm
• Coker feedstock	50-150 ppm
• Anodic or needle grade coke feedstock	25-100 ppm
• Carbon black feedstock	50-500 ppm, typically 100 ppm
• Carbon fibre production	5-10 ppm
• Boiler or Furnace oil	50-150 ppm
• Industrial and electric utility fuel	50-100 ppm
• No. 6 or Bunker C. fuel oil	50-150 ppm
• Marine fuel	50-150 ppm
• Pitch feedstock	25-100 ppm

2. Automatic Gas Assisted Backwash Filtration

The Dahlman automatic gas assisted backwash technique is excellent for FCC Slurry Oil filtration. This technology has been proven for many years and on different applications and especially for heavy oil filtration.

2.1 Filter Principles

The filter package consists of 2 or more filter vessels (e.g. 2 x 100%, 3 x 50%), one backwash receiver vessel and a gas accumulator vessel and includes all necessary pumps, controls, valves, instruments and piping.

High quality sintered metal powder filter elements, are utilized, which are installed in a vessel such that solids are retained on the inner surface of the element, while clean filtrate is passed through the solids "cake" and element and flows out at the top of the vessel. Solids are removed from the vessel periodically by a gas assisted backwash procedure.

In this procedure, inlet and outlet valves are closed and a gas pressure is built on top of the liquid at the clean side of the filter. A quick opening bottom valve causes the solids to dislodge from the element inner surface and to be carried out of the vessel. The filters are then being brought back on-line, and the cycle is repeated.

2.2 Precision Filter Media

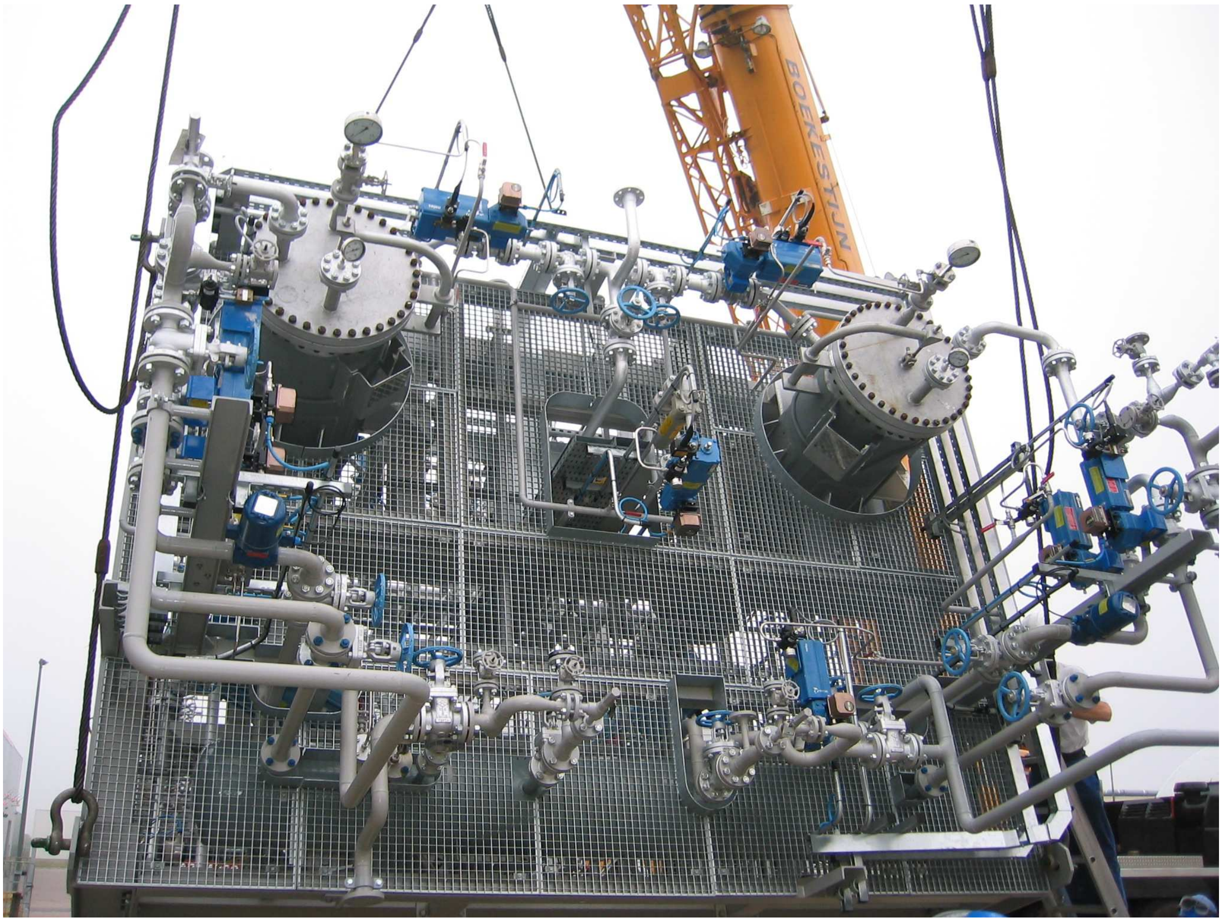
There are many types of backwashable filters in the commercial marketplace in a variety of mechanical configurations. What truly distinguishes one from the other is the filter media used in the filter. Media selection is the key parameter for achieving the desired separation and for ensuring long operation life. Precision porous metal filter media have controlled porosity and pore size that maximises efficiency. For backwash filters to be successful over time, the media must provide the particle retention efficiency cycle after cycle. The rapid gas assisted backwash that Dahlman utilizes, eliminates channeling and incomplete cleaning, which occur with other type elements.

Clean pressure drop over the filters, i.e. pressure drop seen directly after a backwash, is very stable, usually under 0.2 bar, indicating that the Dahlman filter media are cleaned very effectively by the special backwash cleaning procedures. The dirty pressure drop is program adjustable up to the design limit of the elements or process requirements. This value for starting the backwash cleaning cycle usually can be preset up to 3 bars enabling high cake thicknesses and resulting in long cycle times.
Several of our filters in slurry oil service have been operating with their originals, contributing to low operating costs.

2.3 Gas assisted backwashing

To ensure the availability of gas for the backwash procedure at any time Dahlman includes for a gas accumulator vessel. Nitrogen or fuel gas is stored at a pre-determined pressure level of about 6-8 bar above operating pressure. At the end of the filter cycle, when the pressure drop has reached its programmed maximum, the inlet is ramped down while the other vessel is progressively taken into operation. When the other filter is fully operational, both the filtrate (outlet) valve is closed and the (feed) inlet valve of the vessel are closed.

Subsequently the connection between the gas accumulator vessel is opened and a pressure of gas is built on top of the liquid in the clean side of the filter, after which the quick-opening outlet (drain)valve is being actuated. This causes the gas to expand while pushing the liquid through the filter elements. Consequently, the filter cake on the inside of the filter elements dislodges along the entire length of the filter tube. Filtered liquid is then forced back by the expanding gas, carrying the accumulated solids and liquid to the backwash receiver vessel, in a matter of seconds. The rapid gas assisted backwash, eliminates channeling and incomplete cleaning.



3. Critical design parameters

For the design of a FCC Slurry Oil Filtration unit there are a few critical parameters which will be discussed in the next few paragraphs.

3.1 Operating temperature

One of the most critical parameters for a good design of a Slurry Oil Filtration Package is the operating temperature. MCB (Main Column Bottoms also called Slurry Oil) leaves the bottom of the main column at a temperature above 290°C. Because this stream does contain the most heavy molecules it is evident that the cracking process is continuing . The heavy components in MCB are mostly aromatic type molecules including the typical condensed benzene ring which crack very slowly. When these aromatics do crack, a substantial part of their conversion represents coke. The coke produced by catalytic cracking typically comprise molecules with very low hydrogen-to-carbon ratios rather than being elemental carbon (C). If MCB feed temperature to a filtration system is above 290°C it is obvious that plugging of the filter by coke forming is a serious threat.

The present very large aromatic molecules, usually called asphaltenes have the feature of precipitation when the hydrocarbon liquid is cooled down below about 230°C. Because of their sticky nature these components can grow together and form a layer on the filter element surface.

Based on the comments as stated above you will understand that there is a strong preference to have a temperature in the operating window (230°C - 290°C) as described above in order to prevent plugging by cokes or asphaltenes. In case plugging becomes present the cycle time will rapidly decrease and the lifetime of the filter elements will decrease too. A soaking step can be added to remove eventual precipitated asphaltenes dissolving it with for example LCO (Light Cycle Oil).

3.2 Sludge discharge

By filtering the slurry oil the solids remain on the element surface. The elements will be cleaned periodically with a gas assisted backwash procedure. The dirt is gathered in the backwash receiver vessel (BWRV). From this vessel the sludge can be directed to the riser, which is very common, or anywhere else.

Directing the sludge to the riser a few aspects have to be taken into account as settling, flow rate and solids content. To prevent particle settling in the backwash receiver vessel we have optimized the vessel layout including the inlet of carrier medium. However due to the relatively high specific density of the catalyst particles in combination with heavy hydrocarbons there is an increased risk on settling and agglomeration of particles. The longer the time needed for emptying the backwash receiver vessel, the higher the risk on settling will be.

From our experience we know that a continuous flow to the riser is very important in order to prevent any disturbances in the operation of the FCCU. Fluctuations in flow and solids content has to be avoided for as much as possible. From our cooperation with FCCU licensors we understand that the impact of flow is more significant than the impact of solids content. In fact there are two options to direct the sludge to the riser. The first one is the use of pumps (one in operation, one standby).

In our design the pumps are used for both mixing purposes and for continuously directing the BWRV content to the riser. The mixing effect is obtained by redirecting the flow from the Backwash Receiver Vessel (BWRV), through the pumps back to the BWRV. In order to provide a minimum level in the BWRV a carrier medium is added, for example heavy cycle oil (HCO), which also has a dilutive effect.

It is obvious that the use of pumps guarantees a constant flow minimizing fluctuations in the solids content and preventing eventual settling.

The other option is the use of gas to pressurize the backwash receiver vessel (BWRV). After the BWRV is emptied, another utility, for example heavy cycle oil (HCO) will be fed to the riser in order to maintain a continuous flow rate at all time, in- or excluding discharged slurry from the receiver vessel. After emptying a filter vessel into the BWRV, the complete inventory of the BWRV is directed to the riser within a short period of time in order to prevent solids settling. Though this alternative configuration also ensures a continuous flow rate to the riser, flow rates as well as solids concentrations of this flow to the riser tend to be somewhat higher. The main benefit of a "pumpless" slurry oil filtration system is the exclusion of the advanced, and therefore very expensive pump systems.

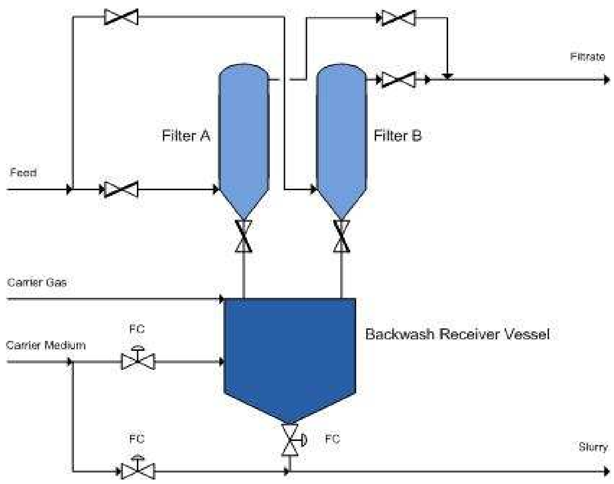


Figure 2 - Slurry Oil Filtration System without recirculation pumps

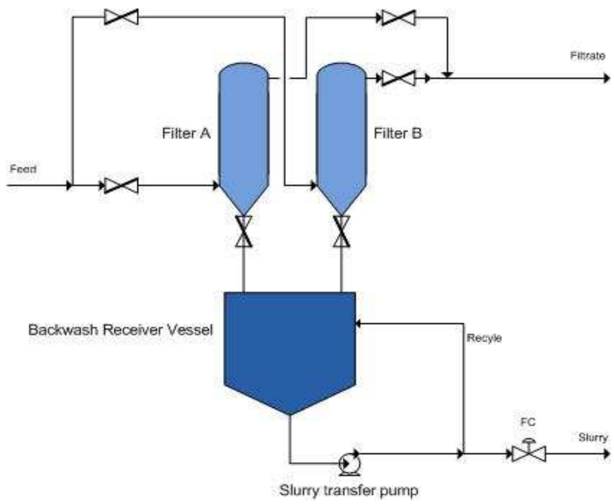


Figure 3 - Slurry Oil Filtration System with recirculation pumps

4. Performance

The automatic gas assisted backwash technology has proven itself in many projects. In this chapter results are shown from one of the Dahlman Slurry Oil Filtration units that we have supplied in the past and which is still successfully in operation.

4.1 Differential Pressure

In order to determine the performance of the filter unit the differential pressure is one of the most appropriate parameters. The process of pressure build-up shows how the elements deal with the solids. The cycle time, which can be retrieved from the same graph, indicates for the actual dirt holding capacity. Also the cleaning efficiency becomes clear from the differential pressure measured directly after a cleaning cycle.

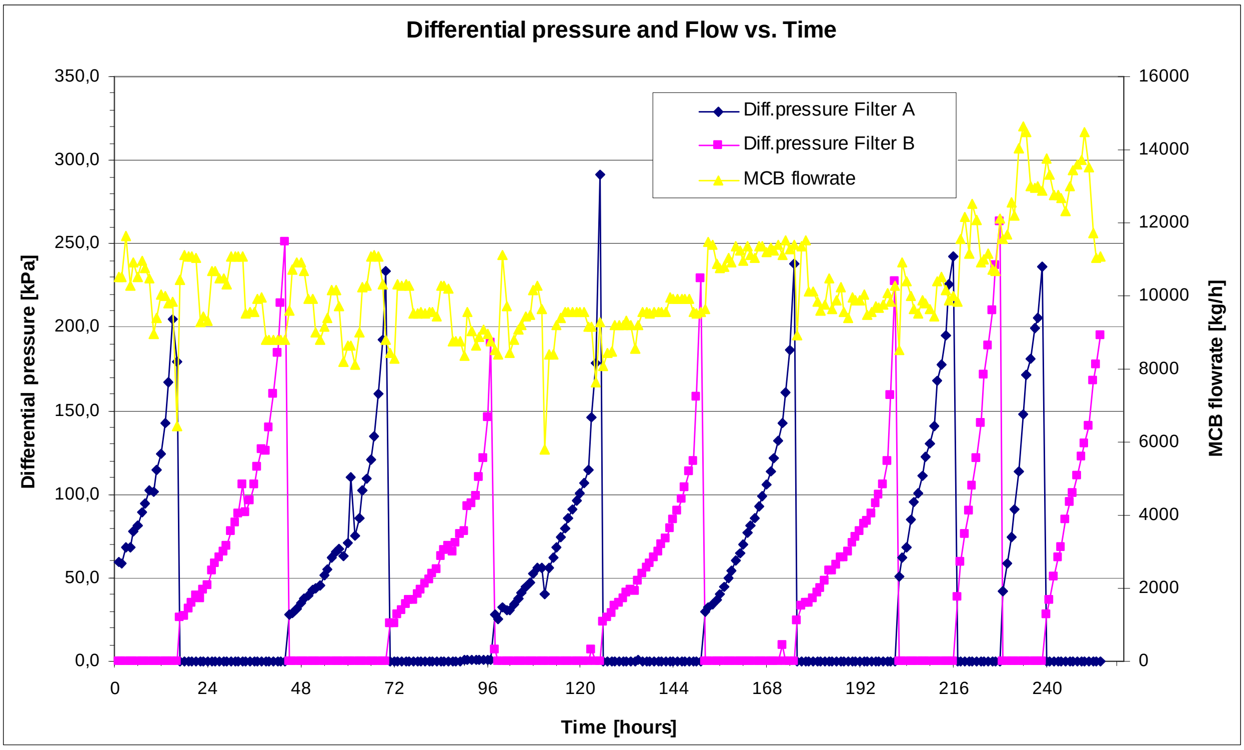


Figure 4 – Operational characteristics of Dahlman Slurry Oil Filtration System

The graph above shows the differential pressure and slurry oil flow rate. The pressure build-up is quite regular and repeatedly decreased to its initial value after backwashing of the filter elements. This expresses the effectiveness of the Dahlman gas assisted backwash cleaning technology as well as the stability of the cake forming process.

4.2 Filter efficiency

Obviously the most important parameter indicating the successful operation of the slurry oil filtration package is the filter efficiency. It clearly shows if the slurry oil is filtered in accordance with the specifications and it the clarified slurry oil can be used accordingly in the downstream processing.

Dahlman usually guarantees the removal of the solids (Ash, coke, catalyst) in the FCC slurry oil down to a concentration which is equal or less than 80 ppm. However levels of 50 ppm down to 20 ppm are achieved in practice.

Reference data of delivered Dahlman Slurry Oil Filtration Packages:

	Reference 1	**Reference 2**
Feed type	Hydroprocessed atmospheric residue, upgraded to VGO by LC Fining; deep HDN, HDS, HDM	Hydroprocessed VGO (HDS; moderate HDN, HDS, HDM)
Inlet concentration	Typically 800 ppm	Typically 6000 ppm
Cycle time	Every 24 - 37 hours regenerated based on dP (2,8 barg)	Every 4 - 5 hours regenerated based on dP (2,5 barg)
Outlet concentration	< 10 - 30 ppm based on Ash content (ASTM D482-95)	< 100 ppm based on Ash content (ASTM D482-95)
Efficiency	~ 99 %	~ 99 %

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