



Scientific & Technical Report

Specifying Porous Metal Backwash Filter Assemblies For Catalyst Removal From FCC Slurry Oil

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Introduction

Process Description

Fluid Catalytic Cracking (FCC) produces high octane gasoline, C₃/C₄ olefins and isobutane by the catalytic cracking of heavy gas oils in a fluid bed reactor. The primary product separation is carried out in a fractionator which produces gas as the overhead products, gasoline and heavier gas oils as side draw-off products and heavy cycle gas oil as the bottoms product. This bottoms stream contains the catalyst fines, and is sometimes referred to as slurry oil.

Catalyst as Contaminant

The solids concentration of slurry oil typically exceeds 1500 ppm, which must be lowered substantially before the oil can be sold. Typically, slurry oil is disposed one of three ways:

1. It is most commonly blended into the No. 6 fuel oil pool, also known as bunker C fuel. The typical alumina concentration permitted in No. 6 fuel oil is 250 ppm, which originates solely from the catalyst in the slurry oil component. To meet this specification, refineries often add lighter, solids-free saleable products to dilute the slurry oil. This limits the total revenue capability of the refinery since No. 6 fuel oil is a relatively low price product.

2. It can be used as a feedstock to a coker unit or a hydrocracker. This converts a portion of the slurry oil to lighter, higher value products, but it does not remove the catalyst from the system.

3. It can be sold as a feedstock to carbon black manufacturers. Slurry oil with a maximum solids content of 100 ppm can yield a selling price of \$1-2/barrel higher than fuel oil.

The particle size distribution of the catalyst is highly variable depending on the FCC unit and fractionator throughput and operating conditions. The following is a typical size distribution:

Diameter (µm) (actual particle count)	% by number
1-5	30
5-15	55
15-25	10
25-50	5
>50	<0.3

Every refinery with an FCC unit has this need to highly concentrate solids into a small volume for easy recycle, while maximizing the recovery of saleable clarified oil. The backwash waste stream contains approximately 30% by weight catalyst, allowing easy recycle to the riser of the FCC unit. The clarified oil from the backwash filter has a sufficiently low solids and alumina content to be sold at a \$1-2/barrel premium as carbon black feedstock. Alternately, it can be blended into the No. 6 fuel oil pool without exceeding the alumina specification for No. 6 fuel oil, maximizing the total revenue of the refinery. In refineries where slurry oil is used as feedstock to a coker, hydrocracker or visbreaker unit, filtration of the slurry oil prior to the unit will minimize operating problems caused by the presence of high solids concentrations in the feeds to these units. The clarified oil can be used as a boiler fuel without causing fuel nozzle erosion.

In each application, the appropriate filter grade will be selected for the required solids removal. The filter sizing and operation can be tailored to satisfy the specific requirements of the refinery. Automated control of multi-vessel backwash filtration units provides reliable, continuous operation. Selecting the proper filtration system for slurry oil is not a trivial task. In order to help the user select the right filter for his/her slurry oil, the following specification has been provided and should be used as a guideline.

1.0 Intended Use

The porous metal backwash filter system is used in slurry oil to remove catalyst solids for improved product quality and reduced operating costs.

1.1 The system consists of a number of equally sized pressure vessels each containing an equal area of Rigimesh®* medium arranged in multi-cylindrical form. The vessels operate in parallel, each vessel in turn performs the specific functions of filtration, *in-situ* reverse flow, gas assisted discharge of collected catalyst and when required, an *in-situ* soak to dissolve retained asphaltenes.

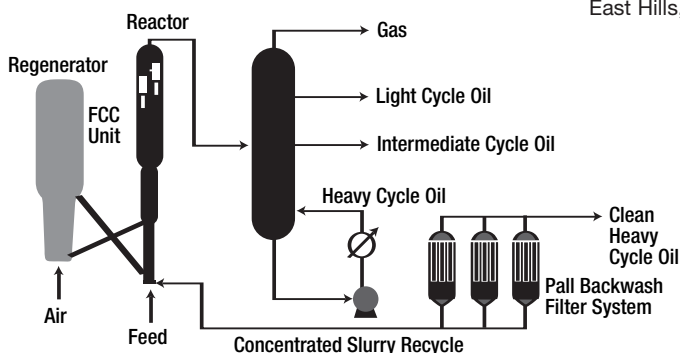
1.2 The mechanism of filtration is a direct interception of catalyst particles on the surface of the Rigimesh filter. This initial capture starts and enhances the capture of all other particles 1 micrometer and larger. This ongoing formation of a surface cake continues to build-up to a depth of 3 mm or greater.

2.0 Operation

2.1 The backwash system should provide efficient separation of fine particles from a fluid stream by collecting the particles on the surface of a composite stainless steel, sintered metal filter. The filters are then cleaned, *in-situ*, by backwashing in the reverse direction, dislodging the solids from the filter and flushing the filter vessel. The filter system should function with no loss in collection efficiency or suffer from physical degradation at the temperatures

* Rigimesh is a registered trademark of Pall Corporation, East Hills, New York.

Figure 1
FCC Slurry Oil



typically found in the fractionator outlet (600-700°F). No heat exchanger should be needed to protect the filter system unless coking is present at the temperature of the slurry oil.

3.0 Sizing and Process Requirements

- 3.1 The amount of surface area required for the optimum backwash filter depends on the flow rate, the type, size, and concentration of FCC catalyst.
- 3.2 Guidelines for a typical slurry oil backwash application operations are flow densities of 0.5 to 0.6 GPM slurry oil per square foot of filter area, operational differential pressures of 20 to 25 PSID, temperature between 400-700°F, and catalyst concentrations up to 6000 ppm.
- 3.3 On-line backwash cleaning should be accomplished with the filtered process fluid using a gas assist. Periodic on-line solvent soaking with Light Cycle Gas Oil (LCGO) should be used to dissolve asphaltenes which, if not dissolved, can blind the filter.
- 3.4 If there is a minimum/maximum or frequency of backwash (cycle time), this should be specified. A one (1) hour cycle time should be considered a practical minimum.

4.0 Mechanical Requirements

- 4.1 The filter should be constructed of a fixed pore surface medium. A felted or non-fixed pore filter that migrates media and unloads solids with fluctuations in flow and pressure is not acceptable.

A medium which captures catalyst within its depth is also unacceptable since FCC catalyst mechanically breaks down into ever smaller particles the longer it remains in service. No matter how fine one's sintered powder or felt metal filters are, some catalyst will become smaller than the surface pore sizes.

Since powdered sintered metal and felt metal have depth to them, these small catalyst particles will pass through the surface pores and become lodged within the depth of the sintered powder metal where they cannot be dislodged by simply reversing the flow of liquid. Powdered metal or felt metal filters are not acceptable for this application.

- 4.1.1 What is required is a surface filter medium with no depth in which to capture and lodge catalyst particles. Rigimesh sintered woven wire mesh membrane is a surface filter manufactured by starting with fine woven wire mesh and sintering it in a high temperature vacuum furnace. This bonds all wires at their points of contact and results in a thin, fixed pore structure of extremely uniform shape and size distribution. This pore structure remains constant, unchanging even at the maximum differential pressure, be it in the forward or reverse flow direction.

The filter mesh must be sintered to fix the filter pore size by bonding every wire to one another. This increases strength, improves filter life, and maintains the filter's efficiency. Unsintered mesh is unacceptable.

There is no depth or tortuosity to Rigimesh medium. Either the particles are captured on the surface of the mesh or passed through it, making it most resistant to fouling.

- 4.1.2 The filter medium must provide enough support to withstand a minimum of 100 PSID in forward flow differential and 70 PSID in reverse direction when formed into an element.

4.2 Filter Elements

- 4.2.1 Material of construction should be 304L SST Rigimesh (sintered wire mesh membrane) filter medium. Solid hardware is 304 SST.

4.2.2 Elements should be of an all welded construction.

4.2.2.1 Element sections must be joined by welding solid joiner rings to the porous metal. For strength and durability, porous to porous circumferential welds are not permitted.

4.2.2.2 After all welding, the filter element must be hydrogen annealed to stress relieve and provide maximum corrosion resistance.

4.2.3 The differential pressure requirement of the filter element should be 100 PSID in forward flow and 70 PSID in reverse direction.

4.2.4 The filter should be designed to withstand the temperature typically found in the fractionator outlet stream (600-700°F) without physical degradation or loss of filter integrity.

4.2.5 Filter element fittings should provide a positive seal within the housing between the filter elements and tubesheet, using 321 SST O-rings to withstand temperatures up to 700°F.

4.3 Filter Design

4.3.1 The filter will capture particles on the outer surface of the cylindrical elements.

4.3.2 Filters which capture material on the inside of the cylindrical are not acceptable.

Technical Note: In the case of the former (outside capture), as the cake increases on the surface of the filter, the filter area increases. This tends to allow the flow

through the filter to remain constant. However, when capturing particulate on the inside of the filter, as the cake thickness increases, the filter area decreases. The flow then decreases as the resistance to flow has substantially increased due to an increase in fluid velocity.

4.4 Filter Housing

4.4.1 The housing should be designed for:

- a) the specified pressure at the temperature typically found in the fractionator outlet stream (i.e. 600-700°F),
- b) even flow distribution,
- c) specified element spacing for cake build up (i.e. 1/2" - 1" between elements), and
- d) easy access for changeout (i.e. a solids sump area for catalyst capture).

4.4.2 The filter housing should be constructed of carbon steel.

4.4.3 Nozzles for inlet, outlet, drain, backwash fluid, vent, and pressure taps should be provided in a specified connection size and type to allow for proper operation.

4.4.4 The initial clean pressure drop across the filter elements and housing should be specified (typically 5 PSID or less).

4.4.5 All major pressure vessels (i.e. 6" diameter and greater) should be designed, fabricated, and stamped in accordance with the ASME Boiler Pressure Vessel Code, Section VIII, Division 1.

4.4.6 Special requirements for jackets, closures, or davits should be specified as required.

- 4.4.7 Special requirements for non-destructive testing like radiography, liquid penetrant inspection, magnetic particle inspection, leak testing, etc. should be specified as required.

4.5 Filter System

- 4.5.1 The system should consist of two or more filter housings specified above. Each housing should contain multiples of the filter elements specified above to provide for continuous flow.
- 4.5.2 The system should allow for an additional standby filter vessel which can be utilized during system repair or maintenance, while operating at full capacity.
- 4.5.3 The system manufacturer should have technical factory start-up service available and a detailed technical operating/maintenance manual should be provided.

4.6 Electrical Requirements

- 4.6.1 All electrical equipment should be designed for Class 1, Groups C&D, Division 2 outdoor service, unless otherwise specified.
- 4.6.2 Field connections for power should terminate in a junction box on the edge of the skid.

4.7 Structural

- 4.7.1 The filter housing(s), receiver, piping manifolds, and control panel should be mounted on a common skid.
- 4.7.2 The equipment should be arranged on the skid for easy access during maintenance and operation.
- 4.7.3 Lifting lugs should be provided for off loading and setting on foundation.

Anchor bolt holes should be provided on the skid base.

4.8 Painting

- 4.8.1 All exposed carbon steel surfaces should be cleaned and coated with 1-2 mil finish coat per PTM Spec P40 or equal.
- 4.8.2 Special surface preparation or painting should be specified as required.

5.0 Instrumentation Requirements

5.1 General

- 5.1.1 Instrumentation should be provided to automatically backwash one or more filters on differential pressure initiation. The set point for Delta P should be programmable.
- 5.1.2 Indicators should be provided to indicate operation and backwash sequence. A pushbutton/selector switch should be provided for manual initiation of the backwash step.

5.2 Control Panel

- 5.2.1 Panel should be suitable for the installation environment.
- 5.2.2 The prewired control panel will be locally and permanently mounted on the skid, unless specified otherwise.
- 5.2.3 Options such as a backwash alarm, low backwash pressure alarm, limit switches, time or override, etc., should be specified separately as required.

5.3 Instrument Quality

- 5.3.1 Pushbuttons, pilot lights, selector switches, etc., should be Allen Bradley or equal.
- 5.3.2 Process valves should be Mogas or similar ball valves.

5.3.3 Pressure and temperature instrumentation should be Rosemount or equal.

5.3.4 Level indicators should be capacitance type Robert Shaw or equal.

5.3.5 Programmable controllers should be Allen Bradley SLC500 or PLC 5.

5.4 Auxiliary equipment such as pumps, flowmeters, heat tracing, flow controllers should be specified separately as required.

6.0 Testing

6.1 The entire filter system should be hydrostatically tested in accordance with ASME Code, Section VIII, Division 1.

6.2 The control system should be cycled manually to assure proper valve sequencing.

6.3 A filter element integrity test should be performed on all filter elements prior to shipment using a nondestructive "Bubble Point Test" that has been correlated to a destructive challenge with test contaminant to certify it meets the rated efficiency.

6.4 To assure proper sizing and selection, laboratory and/or field tests should be conducted when possible for filterability studies, particle count, and backwash feasibility by a Scientific Laboratory Service Group (Ref. Scientific and Laboratory Services (SLS), Pall Corporation, Port Washington, New York).

7.0 Shipping

7.1 Each piece of equipment should be tagged with the ASME Code plate and the manufacturer's nameplate with model number, serial number, and date of manufacture.

7.2 The system should be thoroughly dried and all openings should be covered for protection from the elements.

7.3 The system should be packaged to maximize protection during normal transportation.

8.0 Spare Parts

8.1 A complete listing of spare parts required for the first year of operation of the slurry oil system should be provided.

Equipment Specifications (Typical)

Item	Number	Description
1	2 or 3	<p>Backwash filter vessels fabricated from carbon steel or an alloy suitable for the service temperature and pressure in accordance with ASME VIII, as Division 1 code. Vessel to be complete with body option flanges as to support removal tubesheet option assembly and all necessary liquid inlet and outlet, as inlet and vent, and solids outlet connections with Class 300 flanges. Additional nozzles for level instrumentation and differential pressure switches are provided as required. Solids discharge via bottom outlet cone.</p> <p>Vessel Diameter: Determined by flowrate with the extra vessel option allowing for system maintenance while running at full capacity.</p> <p>Corrosion Allowance: 125"</p> <p>Design Pressure: 170 PSIG @ 650°F</p> <p>NDT: 100% Radiography All Butt Welds</p> <p>Closure Flanges: 300# Class</p> <p>Gaskets: Spiral Wound S.S.</p> <p>The above vessels are to be mounted on a carbon steel supporting skid. Skid fabricated from channels with perimeter support.</p>
2	1 per vessel	<p>Tubesheet fabricated from AISI 304 Stainless Steel to ASME VIII Division 1.</p> <p>Design Pressure: 4.22kg/cm² (60 PSID)</p> <p>Design Temperature: 650°F</p>
3	1 per vessel of filters w/ spare as option	<p>Rigimesh® K filter elements fabricated from sintered 304L composite.</p> <p>Length: 1524 mm</p> <p>Diameter: 25 mm</p> <p>Pressure Rating: 4 bar</p> <p>Sealing: Metal O-ring</p> <p>Number per Vessel: Determined by Flow Rate</p> <p>Design Pressure: 100 PSID Forward Flow</p> <p>Removal Rating: 50 PPM Catalyst in Effluent Slurry Oil (recommend no-charge SLS testing)</p>
4	1 set	<p>Interconnecting pipework fabricated from carbon steel or an alloy suitable for service, temperature and pressure. Principally comprised of:</p> <ul style="list-style-type: none"> • 300# RFWN Flanges Inlet/Outlet Feed Lines • 300# RFWN Flange Slurry Discharge Line • Air Vent, Blowback Gas Header Lines • LCGO Flush/Soak Line
5	1 set	<p>Automatic control valves to direct the process flow and filter cleaning. These are Mogas Valves specified by refineries in the U.S. because of their durability in this service.</p> <p>Manual block and bypass valves to isolate individual housings are included with the system with the extra vessel option allowing for system maintenance while running at full capacity.</p> <p>An automatic bypass Mogas or similar valve is supplied in the event of an upset condition that would generate more catalyst than the system was designed to handle.</p>
6	1	<p>Instrumentation with the following description:</p> <p>The operator's control panel is designed to be locally mounted on the filter skid in a Division 2 non-hazardous area. The enclosure is rated NEMA 7 and contains the main operator interface. The control system requires 120 volt, 50/60 Hz single</p>
7	1 lot	<p>The control system provides both automatic and manual modes of operation for the filter system. In automatic mode, all valve sequencing and operations are handled by the control system based on a minimum of operator inputs. To accommodate unusual operational or maintenance requirements, a manual mode of operation is provided. When operating the system in manual mode, the operator has full control of all valve sequencing and operation from the main control panel. All filter system process variables are available to the operator on the control panel.</p> <p>The control system is designed around a programmable controller. The controller is equipped with sufficient 120 volt and analog I/O to monitor and control the entire filter system. The controller supports the Allen Bradley Data Highway, plus an automation network which allows peer to peer communications to other PLCs.</p>



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