FRAMEWORK FOR SELECTING THIN-CAKE CANDLE FILTER TECHNOLOGY FOR REMOVING SOLID CONTAMINANT FINES FROM RECIRCULATING ACID GAS SCRUBBING FLUID STREAMS

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ABSTRACT

The need for filtration systems in scrubbing units has been well documented. Filtration provides the benefits of reduced hot spots in the regenerator reboiler, reduced heat exchanger fouling and reduction of foaming in the absorbers. This paper discusses thin-cake candle filter technology that is used to remove trace amounts of solid contaminant fines from the recirculating fluid stream. These contaminants originate from various sources and are generally less than 3 - 5 microns in size, which makes their removal very difficult. Candle filter technology and the process of thin-cake building, is a new approach that is employed for high-efficiency and cost-effective fines removal.

KEYWORDS

Automatic Filter, Cake Filtration, Candle Filter, Catalyst, Catalytic Cracking, Diatomaceous Earth, Filter Cake, Filter Cake Discharge, Filter Cake Wash, Fine Particle, Precoat Filtration

1. INTRODUCTION

Sulfur dioxide (SO_2) removal systems are in many types of applications such as fluid catalytic cracking (FCC) and Coker units at refineries, acid plant tail gas, spent acid recovery plants, smelters, pulp mills, natural gas, power generation, cogeneration, chemical process plants as well as process vent streams in sulfur plants. While the plant location and type of removal process may vary, there is a need to remove fine particulate matter from the recirculating liquid streams for efficient scrubbing operation and to protect absorbers, condensers and reboilers, heat exchangers, pumps, downstream purification systems, etc. The particulate matter can be catalyst fines and other contaminants in the feedstock. It is difficult or impossible to remove particles of this size in settling tanks, hydrocyclones or centrifuges, so the particles must be removed by filtration. The use of thin-cake candle filter technology has been proven to be a cost-effective and reliable approach to removing the contaminants, recovering the scrubbing liquids and drying the cake for easy landfill disposal.

2. PROBLEM DEFINITION

Various catalyst and carbonized particles are carried into the gas and are captured by the scrubbing fluid. The flow rate of the scrubbing can be as high as 150 m^3/hr so the fluid must be regenerated and reused to make the process economical. The fine particles are less than 3 to 5 microns and they will accumulate in the scrubbing system unless they are removed from the scrubbing fluid. These particles cause fouling in heat exchangers and foaming in the trays of the scrubbers, so the particles must be removed from the scrubbing fluid before it can be reused. The scrubbing fluid can fluid can be water, an amine salt fluid (e.g. CanSolv®) or some other proprietary fluid (e.g. the LabSorb® phosphate salt system). This paper discusses specifically the removal of fines from an amine fluid, but the theoretical basis and the technology can be used for other scrubbing fluids.

3. THEORETICAL BASIS

The following equation is the basic equation that relates the flow rate through a filter for constant pressure filtration. Various forms of this equation are used to evaluate the lab data gathered and then to scale up the lab data to the required production system.

$$\frac{dV}{A\,dt} = \frac{\Delta P}{\mu(\alpha'(\Delta P)^s\,\{V[\rho c/(1-mc)]\,/A\} + r)} = \frac{\text{Driving Force}}{\text{Total Resistance}} \qquad \text{Equation 1; Ref. 1}$$

where: V = slurry volume
A = filtration area
t = time
ΔP = pressure drop across the filter cake and filter media
μ = filtrate viscosity
r = resistance of the filter media
α' = resistance of the filter cake
s = a compressibility constant and it is 0 for an incompressible cake and it is 1.0 for very compressible cake.
ρ = filtrate density
c = the mass fraction of the solids in the slurry
m = mass ratio of the wet cake to the dry cake

Equation 1 is integrated and rearranged to determine the amount of time required to filter a known quantity of material at a given pressure. The results of the integration are shown in Equation 2.

$$t = \frac{\mu\alpha'(\Delta P)^s\,[\rho c/(1-mc)]}{2\Delta P}\frac{V^2}{A^2} + \frac{r\,\mu}{\Delta P}\frac{V}{A} \qquad \text{Equation 2}$$

Equation 2 can be further simplified when the cake is incompressible and when the resistance of the filter media is negligible. Equation 2 then reduces to the following:

$t = (b' / \Delta P) * (V/A)^2$, Equation 3

where $b' = \mu\alpha'[\rho c/(1-mc)] / 2$

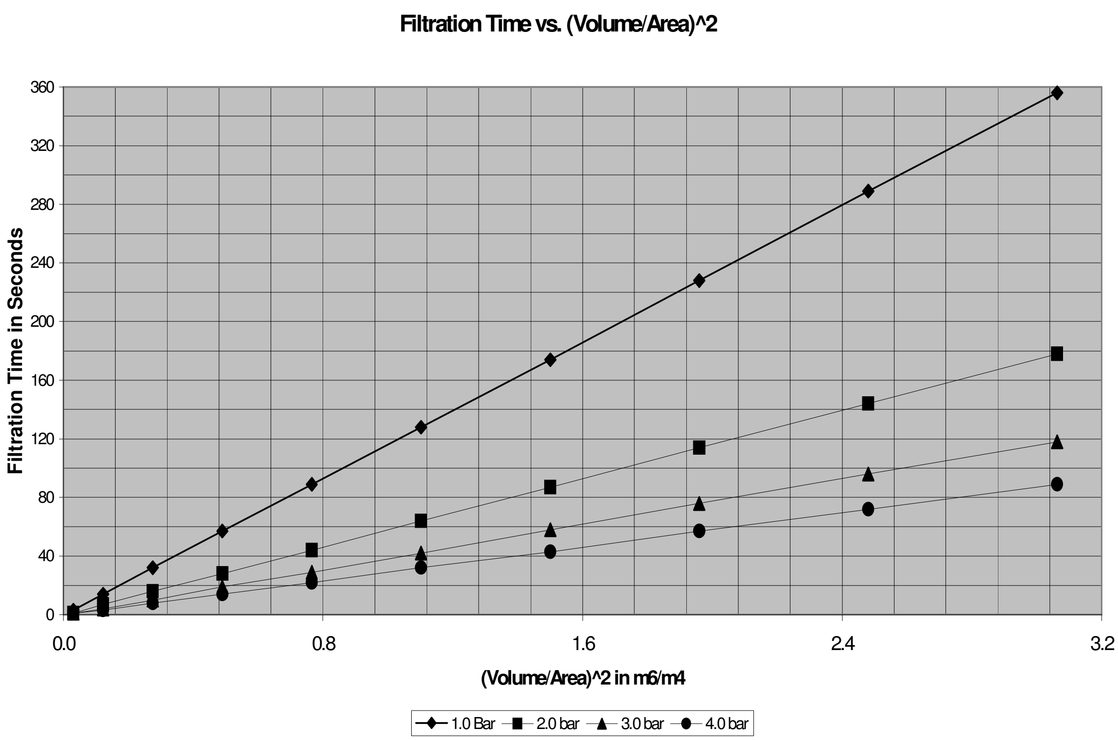
Equation 3 is the final equation that was used to evaluate the lab data.

4. LABORATORY TESTS

4.1 Filtration Tests

All filtration and washing tests were conducted in a 400 ml Pocket Leaf Filter that had a filtration area of 20 cm^2 and a fill volume of 400 ml. The filter media for all of the tests was a woven, specially designed media for the scrubbing application; the cloth was precoated with a known amount of Hyflo Super Cell. Filtration tests were conducted at ambient temperature and at 1.0 bar, 2.0 bar, 3.0 bar and 4.0 bar. The filtration data is shown in Figure 1.

Figure 1 – Filtration Time vs. (Filtrate Volume / Filter Area)^2



A Least Squares Regression was performed on the lab data to determine b' for Equation 3. The regression had a correlation of fit R2 = 0.99 and determined that b' = 32.38 X 10^{-3} bar * hr * m^6/m^4. The excellent fit of the data to Equation 3 confirms that the assumptions of a negligible media and precoat resistance, and an incompressible cake are correct.

4.2 Washing Tests

Cake samples were washed with tap water in a single pass in the Pocket Leaf Filter to determine the amount of washing required to remove the amine salts from the cake. It was determined that a washing was efficient enough to wash virtually all of the amine salts from the cake. Counter-current washing was not tested during these trials.

4.3 Drying Tests and Cake Density Measurement

Five of the washed cake samples were pulse dried in the Pocket Leaf Filter with ambient temperature air. The drying was accomplished by pressurizing the Pocket Leaf Filter and then releasing the pressure through the filtrate valve. Each sample was dried by pulse drying. The moisture of the cake was low enough after drying for easy landfill. The cake density was measured after drying in the Pocket Leaf Filter and found to be 1800 kg / m^3.

5. SCALE-UP FOR A PRODUCTION FILTER

An existing Scrubbing System had an amine flow rate of 50 m3/hr with an average concentration of fines of 600 ppm. It was desirable to remove the fines by filtration at a constant flow rate. The filter cake was to be washed before the drying to recover the amine salts from the cake. A candle filter was selected for this application and was operated using the following processing steps:

- Step 1 = Filling the Filter With Slurry
- Step 2 = Precoating the Filter
- Step 3 = Filtration
- Step 4 = Cake Washing
- Step 5 = Draining the Filter
- Step 6 = Drying the Cake
- Step 7 = Discharging the Cake

Each Step requires a certain amount of time and the sum of these times is the total cycle time. The minimum size for the filter occurs when the time for the Filtration step is equal to the sum of the other steps, but it is also desirable for most operating plants to load the precoat into the system no more than one time per day. Therefore, the starting point for sizing the system was to determine what size filter would be required to process the required flow rate using a 24 hour Filtration Step. The time required for the other steps was then calculated based on the selected filter.

5.1 Required Filtration Area Calculations

Equation 3 was rearranged to solve for the required filtration area assuming a filtration time of 24 hours and an average filtration pressure of 1 bar.

$A = V * [b' /(t * \Delta P)]^{0.5}$ Eqn. 4

Where, V = Flowrate X Filtration Time = 50 m^3/hr X 24 hours = 1200 m^3

b' = 32.38 X 10^{-3} bar * hr * m^6/m^4

t = 24 hours

ΔP = 1.0 bar

$A = 1200$ m3 * [32.38 X 10^{-3} bar * hr * m^6/m^4 /(24 hours * 1.0 bar)]$^{0.5}$ = 44.1 m^2

A BHS-Filtration Candle Filter Type KT-91/46 has 91 candles and a filtration area of 46.3 m^2. Two KT-91/46 filters were used in series for this application so that one filter would be in the Filtration Step while the other filter would be in the Washing, Draining, Drying, Discharge, Filling, and Precoating Steps.

5.2 Cake Mass, Volume and Height Predictions

The cake consists of the precoat, the fines that are collected and the residual moisture in the cake. The KT-91/46 has an area of 46.3 m^2 and the lab tests determined that the precoat loading was adequate for this application. The fines collected in the Filtration Step can be calculated by the fines concentration in the feed, the feed rate, and the filtration time. The fines collected were 600 kg Fines / 10^6 kg Feed X 50 m^3/hr Feed X 1,089 kg/m^3 Feed X 24 hours = 784 kg Fines. The total mass of cake (precoat, fines and moisture) per cycle results in a cake thickness of 14 mm.

5.3 Filling Step

The Type KT-91/46 candle filter has a fill volume of 11.0 m^3 and was filled at 50 m^3/hr, so the time for the filling step was predicted to be 11.0 m^3 / 50 m^3/hr = 0.22 hours.

5.4 Precoating Step and Required Amount of Precoat

The precoat was pumped through the filter and allowed to recirculate to the precoat tank for 0.75 hours.

5.5 Cake Washing

The lab tests determined that the residual amine salts can be removed from the cake. The washing time was = 0.44 hours.

5.6 Draining and Drying

The heel liquid in the filter was drained by pressurizing the filter with 1.0 bar air while draining the heel through a heel drain valve near the bottom of the filter. The heel drain required 0.45 hours. The cake was pulse dried in the filter by pressurizing the filter with plant air and then releasing the pressure through the filtrate valves. The drying time required is 0.25 hours.

5.7 Cake Discharge

The cake is discharged from the candles by pulsing air back through the candles while the bottom valve is open. The total discharge time is 0.08 hours

5.8 Actual Production Filter Results vs. Predicted Results

The actual cycle time for the production filters was recorded and found to be within 2% of the predicted cycle time. The residual salts in the filter cake were undetectable and the residual moisture in the filter cake was suitable for sending to a landfill.

6. SUMMARY

Various fine particles must be removed from scrubbing fluids to ensure proper operation of the scrubber, heat exchangers, etc. Laboratory tests were conducted on an amine and the results of the laboratory tests were used to scale-up to a production candle filter that would remove 600 ppm of solids from a 50 m^3/hr amine stream. The results in the production filter matched the predictions and demonstrated that candle filter technology is well suited to remove fines from scrubbing fluids.

Reference 1 - Transport Processes and Unit Operations, Second Edition by Christie J. Geankopolis, 1983, pp 750 – 758

Barry A. Perlmutter is currently President and Managing Director of BHS-Filtration Inc., a subsidiary of BHS-Sonthofen GmbH. BHS is a manufacturer of thin-cake filtration, washing and drying technologies. Barry has over 25 years of technical engineering and business marketing experience in the field of solid-liquid separation including filtration and centrifugation and process drying. He has published and lectured extensively worldwide on the theory and applications for the chemical, pharmaceutical and energy / environmental industries and has been responsible for introducing and creating growth for many European companies and technologies into the marketplace. Barry began his career with the US Environmental Protection Agency. He received a BS degree in Chemistry from Albany State (NY) University, MS degree from the School of Engineering at Washington University, St. Louis and an MBA from the University of Illinois. Barry served on the Board of Directors of the American Filtration and Separations Society (AFS). He is currently a member of several organizations including, AFS, International Society of Pharmaceutical Engineers (ISPE), American Chemical Society and the North Carolina World Trade Association.

BHS FILTRATION

BHS Thin-Cake Pressure and Vacuum Filtration Technologies
For Batch/Continuous Operations
From High Solids to Clarification Applications

BHS-Sonthofen GmbH, founded in 1563, is a leader in technology and innovation. BHS specializes in thin-cake (3 mm - 180 mm) filtration, cake washing and drying technologies.

BHS serves three major market segments as follows:

- Chemical: Fine, Specialty, Agricultural, and Others
- Pharmaceutical: Bulk and Final Products
- Energy / Environmental: Refinery, Power Plants, Wastewater and Others

Specialized Applications & Centers of Excellence:

BHS is organized both locally and globally. BHS-Filtration Inc., a subsidiary of BHS-Sonthofen GmbH is responsible for North America and Mexico.

For specialized applications, BHS is organized globally with centers of excellence. For example, for terephthalic acid, power plant and the dewatering and drying of gypsum applications, this expertise resides at BHS-Sonthofen GmbH. For refinery and bio-energy applications, the expertise for process engineering, etc. resides at BHS-Filtration Inc.

Product Technologies & Capabilities

The BHS technologies and expertise are thin-cake (3 mm – 180 mm) filtration, cake washing and drying. The five-patented BHS technologies are as follows:

- Rotary Pressure Filter
- Continuous-Indexing Vacuum Belt Filter
- Candle Filter
- Pressure Plate Filters
- Autopress, an Automated/Contained Specialized Filter Press

These technologies are installed for pressure or vacuum filtration, for batch or continuous operations from high solids slurries (up to 60% solids) to clarification applications with solids to less than 1% and trace amounts.

Process Lab Testing & On-Site Pilot Testing

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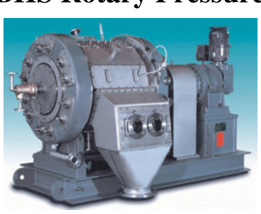
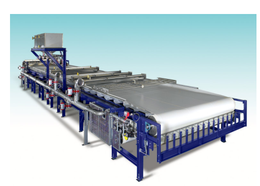
BHS Rotary Pressure Filter



BHS Duplex Candle Filter

BHS Vacuum Belt Filter



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