American Filtration & Separation Society
Spring Conference

Liquid Filtration Equipment

Dr. Wu Chen
Dr. Biplab Mukherjee
The Dow Chemical Company

April 28, 2015
Charlotte, NC
Filtration = Filter Media ???

Filter Media

Filtration

- Filter medium is a crucial part in liquid filtration but it alone does not make the filtration work.
- The equipment to hold media and make the filtration work is equally important, sometimes much more important than the media.
- Filtration is not the only way to separate particles from a fluid steam.
- Depending on the separation mechanism, there are sub-categories in liquid filtration or separation.
- The discussion of liquid filtration equipment will follow the filtration mechanism.
Liquid Filtration Mechanisms

- Straining
- Cake Filtration
- Depth Filtration
- Cross Flow Filtration
We will briefly introduce the most frequently used liquid filtration equipment based on the filtration mechanisms.

**Straining Equipment**

- This types of filters use straining (direct sieving) as their primary filtration mechanism.
- There are more straining equipment (in terms of numbers) than any other liquid filtration equipment combined. All process/plants use them.
Types of Straining Equipment

- Screens
  - Fixed Screens
  - Moving Screens
- In-line Strainers
  - Manual Strainers
  - Automatic Strainers
    - scraper
    - backwash
    - disc
    - spring
- Bag Filters
  - Bags
- Cartridge Filters
  - String Wound
  - Melt Blown
  - Pleated

Common Filter Media
- metal screen
- synthetic woven
- synthetic non-woven
- metal screen
- synthetic woven
- synthetic non-woven
- synthetic non-woven
- synthetic woven
- metal
In-line Strainers

Manual Strainers

Basket Strainers

courtesy of Plenty

Y Strainers

Automatic Strainers

Scraper Type

courtesy of Spirax Sarco

Disc Type

courtesy of Eaton
Bag Filters

- Media are made into a bag and the influent flows inside out of the bag and the particles are retained by the bag.
- Bags are disposable and made of synthetic fibers.
- Low cost in vessel and media is the key advantage.
- Bags have smaller surface areas compared to cartridge filters so bags are used for low solids loading or easy-draining solids.
- Important to change the filter at the recommended pressure drop or the bag will be totally plugged and blow down of liquid becomes impossible.
Cartridge Filters

String Wound Cartridges

- Fiber yarn is wound around a mandrel to form a depth medium. This type of cartridge is less expensive than the pleated type and is frequently used to remove larger particles (> 30 μm) or as a prefilter upstream of a pleated cartridge.

Pleated Cartridges

- Media sheets are pleated to provide additional surface area.
- Surface area is always larger than that provided by its wound counterpart and therefore higher solid loading.

Melt Blown Cartridges

- Filtering fabrics are built onto the cartridge by the melt blown technology which allows precision control of fiber density in the fiber matrix.
- The surface area is limited to the cylindrical surface.
More Varieties of Cartridges

Resin Bonded

Metal

Pleated Tubular

Courtesy of Park Process Filtration

Courtesy of Pall Filtration
Cake Filtration Equipment (Cake Filters)

• This type of filters use cake filtration as the primary filtration mechanism.
• Handling (build, discharge and cleaning) of filter cake is the main concern for the design and operation of this type of filters.
• This type of filters have the most variety in equipment design.
• They can be categorized by the filtration driving force (gravity, vacuum, pressure, compression and centrifugal)
Types of Cake Filters

Cake Filters

Gravity
- Batch
  - nutsche
  - belt
  - tipping pan
- Continuous
  - leaf
  - flat bed
  - drum
  - disc
  - table
  - belt
  - tipping pan

Vacuum
- Batch
  - nutsche
- Continuous
  - leaf
  - flat bed
  - drum
  - disc
  - table

Pressure
- Tank
  - nutsche
  - leaf
  - tray
  - candle
  - Filter Press
  - plate and frame
  - chamber
  - Semi-continuous
    - flat bed
    - tower
  - Continuous
    - drum
    - disc
    - special

Compression
- Batch
  - diaphragm
  - horizontal diaphragm
  - tubular
  - Continuous
    - belt press
    - screw press

Centrifugal
- Batch
  - vertical basket
  - peeler
  - inverting
- Continuous
  - pusher
  - worm screen
  - vibratory screen
  - screen bowl

Common Filter Media
- synthetic woven
- synthetic nonwoven
- metal mesh
Gravity Cake Filters

- They use very low driving force (<0.5 psi, <3.5 KPa)
- They are used for large (>1000 µm) and very fast draining solids (average cake permeability $K_{av}>10^{-9}$ m$^2$)

Examples of Gravity Filters

Batch (Gravity Nutsch)

Continuous (Gravity Belt)
Vacuum Cake Filters

- Vacuum is the driving force (<10 psi=20 in Hg=500 mm Hg) for filtration.  
- They are used for suspensions which allow fast cake builds up which can be contributed by one or more of the following factors
  * relative coarse (> 30 μm) particles
  * fast draining solids (average cake permeability $10^{-9} > K_{av} > 10^{-13}$ m²)
  * suspensions with high solid concentrations
- The continuous vacuum filters can handle large quantity of slurries.
- They are not suitable for operating at high temperatures close to boiling point of the liquid.

```
Vacuum Filters
   /       \
Batch Filters  Semi-Continuous  Continuous Filters
   /           /          \
Drum Filters  Disc Filters  Table Filters
           /          \        
        Belt Filters Tipping Pan Filters
```
Examples of Vacuum Filters

Batch (Vacuum Leaf)

Vacuum Belt Filter

Continuous (Vacuum Disc Filter)

Continuous (Vacuum Drum Filter)
Pressure Cake Filters

- They use hydraulic pressure up to 100 psi (700 KPa).
- They are useful for fine (1-70 µm) and slow draining solids (average cake permeability $10^{-11} \leq K_{av} \leq 10^{-15} \text{ m}^2$).
- They are suitable for high temperature operation.
- Most of the pressure filters are operated in batch.
- Some continuous pressure filters are available.

```
Pressure Filters
   Batch
   Nutsches
   Tanks
   Semi-Continuous
   Continuous
   Presses
```
Examples of Pressure Filters

- **Nutsches**
- **Tanks (Vertical Leaf Filter)**
- **Tanks (Candle Filter)**
- **Presses**
- **Semi-Continuous Filter**
- **Continuous Filter**
Compression Cake Filters

This type of filters use mechanical compression rather than pump pressure for cake compression.

- Low to high mechanical pressures (up to 2000 psi, 14000 KPa).
- Compared to pressure filters, drier cakes can be produced for compressible cakes.
- The capacity is normally small for high pressure units.
Examples of Compression Filters

Batch (Diaphragm Press)

Continuous (Belt Press)

Batch (Tube Press)
Centrifugal Cake Filters

- They use centrifugal force for filtration (250-2000 g-force).
- Filtering centrifuges can be enclosed during filtration and cake discharge so they are good for handling hazardous materials.
- The total filtration area in each unit is limited.
- Temperature control is not as good as pressure filters.
Examples of Centrifugal Filters

Batch (Vertical Basket)

Batch (Horizontal Basket)

Continuous (Pusher)  Continuous (Worm Screen)  Continuous (Screen Bowl)

Courtesy of Siebtechnik

Courtesy of Westfalia
Depth Filtration Equipment (Deep Bed Filters)

• This type of filters are used for clarification of liquid with low solids (<200 mg/l) content.
• Key equipment used for depth filtration are granular filters (sand filters) and deep bed cartridge filters.
• The common media used are silica sand, anthracite coal, garnet, granular activated carbon and crashed walnut shell.
• Single or multiple media can be used in a filter.
Types of Depth Filters

Deep Bed Filters

Granular
- Gravity
  - trough
  - traveling bridge
  - valveless
- Pressure
  - high rate
  - conventional
- Continuous
  - up-flow
  - down-flow

Cartridge
- String Wound
  - Fabrics
  - Nonwoven
    - melt blown
    - Sintered metals
    - powder
    - fiber

Others
- Disc
  - metal fiber

Commonly used media
1. granular – sand
2. synthetic nonwoven
3. metal fibers
Examples of Depth Filters

Depth Filters

Gravity

Pressure

Continuous

Inlet Distributor

Inlet

Drain Down

Bottom Distributor

Filtrate Outlet & Backwash Inlet

Water

Sand

Underdrain

Concrete Basin

Anthracite Fine Garnet

Coarse Garnet

Courtesy of Ashbrook
Cross Flow Filtration Equipment (Membrane Filters)

- The traditional filtration media are used to remove particles with sizes down to around 1 \( \mu \text{m} \). The progress of material technology in the past three decades had made membranes with pore sizes down to a few Å (10\(^{-10}\) m) available. This development had allowed a new arena of filtration technology which is generally called membrane filtration.
There are no clear-cut boundaries among different types of membrane filtration. Above chart shows the general classifications.
Geometry of Membranes

Flat Sheet

Tubular

Spiral

Hollow fiber

Courtesy of Dow Chemical

Courtesy of Pall Filtration

Courtesy of APV
Types of Membrane Filters

Membrane Filters

Microfiltration
- Flat Sheet
  - Plate and frame
  - cassette
- Spiral
- Tubular
- Rotating Disc
- Vibrating Disc

Ultrafiltration
- Flat Sheet
  - Plate and frame
  - cassette
- Spiral
- Tubular
- Hollow fiber

Nanofiltration
- Spiral
- Tubular
- Hollow fiber

Reverse Osmosis
- Spiral
- Hollow fiber

Common Filter Media
- synthetic organic membrane
- inorganic membrane
Summary

• There are a wide variety of equipment for liquid filtration
• There are complexities in designs and operations of these equipment
• Equipment design and media both play important roles for a successful filtration.
• A user needs to know what options are available.
• A supplier need to know the limit of its own products and aware of competing technologies.