Beer Filtration

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Clarity can be accomplished with

- Time
- Finings
- Separation
Time, Stokes Law

- \( u_g \) = the terminal settling velocity
- \( d \) = the diameter of the particle
- \( \partial_v \) = the density of the particle
  \[ 1.1-1.33 \text{ g/cm}^3 \]
- \( \partial_i \) = the density of the liquid
  Beer is \( 1.007 \text{ g/cm}^3 \)
- \( g \) = acceleration due to gravity
  \[ 9.8 \text{ m/s}^2 \quad 32 \text{ f/s}^2 \]
- \( \mu \) = the viscosity of the liquid
  Beer is 1.8 centistokes

\[
u_g = \frac{d^2 (\partial_v - \partial_i) g}{9 \mu}\]
• Stoke’s law predicts that large dense particles will settle faster than small light ones, and any particle will settle best in a low density and low viscosity liquid.
Finings

• Kettle finings

• Isingglass
  • Cask
Separation

• Filter
  • Depth Filters
    – Powder Filters
      • Pressure Leaf Filters
      • Candle Filters
      • Plate and Frame Filters
    – Sheet Filters
    – Module
    – Deep Bed Filters
  • Surface Filters
    – Membrane Filters
  • Cross Flow Filters

• Centrifuge
Darcy's law

- Darcy's law is a phenomenologically derived equation that describes the flow of a fluid through a porous medium.

- Henry Darcy based the results on experiments on the flow of water through beds of sand.
Darcy's law

\[ Q = \frac{K\Delta PA}{L\mu} \]
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- \( Q \) = quantity of filtrate collected per unit time
- \( K \) = permeability coefficient of the bed
- \( \Delta P \) = pressure across the filter bed
- \( A \) = area of the filter bed
- \( L \) = depth of the bed
- \( \mu \) = viscosity of the bed
Darcy's law

\[ Q = \frac{K\Delta PA}{L\mu} \]
What do you want out of your beer?
Yeast

• Kunze describes Yeast as Oval to round with a length of 8-10μm and a width of 5-7μm.

• Negative Charge
Bacteria

• Bergey’s Manual of Determinative Bacteriology describes Bacteria size ranging from 0.2-10.0μm in the smallest dimension.

• Negative Charge

Lactobacillus brevis 0.5 x 2.0μm
Haze

- Colloidal particles approximately .5-1μm in diameter, appear to play a principal role in haze formation, called point particles, settle very slowly because of their low density.

- To get chill haze to filter out you need to chill the beer down to 29-30 degrees for several day and keep it cold while filtering.
Filter Terms

- Nominal
- Absolute
- Beta Ratio
- Zeta Potential
- Depth filter
- Surface filter
- Hydrophilic
- Hydrophobic
- Bubble Point
Nominal Filters

• Nominal filter ratings are an arbitrary value, indicating a particulate size range at which the filter manufacturer claims the filter removes some percentage. Nominal ratings vary from manufacturer to manufacturer and cannot be used to compare filters among manufacturers. Processing conditions such as operating pressure and concentration of contaminant have a significant effect on the retention efficiency of the nominally-rated filters.

• DE filters and Sheet filters and nominal rated filters.
**Absolute Filters**

- **Absolute** filter ratings are a value associated with a filter that represents the size of the smallest particle completely retained. Complete retention is within the experimental uncertainty of a standard test method consistent with the intended filter usage. Among the test conditions that must be specified are test organism (or particle size), challenge pressure, concentration, and detection method used to identify the contaminant.

- Absolute filters are typically membrane filters
Beta Ratio

- Multi-pass testing uses a specified contaminate, of known size, added regularly in measured quantities to the fluid which is pumped continuously through the filter. Measured samples of fluid are then taken at timed intervals from both the downstream and upstream of the filter simultaneously, particles are measured and counted by particle counters.

- Beta (#) = Number of particles (x) upstream / Number of particles (x) downstream
  [Where x = particle size in microns]

- Beta 5000 = 99.98% removal
- Beta 1000 = 99.90% removal
- Beta 100  = 99.00% removal
Zeta Potential

• Zeta potential is the electrical potential that exists at the sheer plane of a particle.

• Zeta-Potential allows for the retention of charged particles smaller than the rated pore size of the filter media. This can help with very fine particles.
Depth Filter

• As particles make their way through the thick filter media there are several ways it can become entrapped.

• It can be caught on the surface, entrapped in the tortuous path or it can be absorbed
Depth Filter

- Thick Porous Matrix
- Depth Straining
- Settling Zones
- "Tortuous Path" Pore
- Surface Retention
- Direction of Flow
Surface Filter

• Surface filters typically traps contaminants larger than the pore size on the surface.

• Contaminants smaller than the rated size may pass through or may be captured within the membrane by other mechanisms.

• Membrane are surface filters and are typically used for critical applications such as sterilizing and final filtration.
Surface Filters
Hydrophilic filters are easily wet with water. Hydrophilic filters can be wetted with virtually any liquid, and are the preferred filters for aqueous solutions, as appropriate by compatibility. Note that in the filtration industry, “hydrophilic” is used somewhat differently than in some other fields, where it refers to a material to which water clings.

Once wetted, hydrophilic filters do not allow the free passage of gases until the applied pressure exceeds the bubble point and the liquid is expelled from the pores of the membrane.
Hydrophobic

• **Hydrophobic** filters will not wet in water but will wet in low surface tension liquids, for example, organic solvents such as alcohols. Once a hydrophobic filter has been wetted, aqueous solutions also will pass through.

• Hydrophobic filters are best suited for gas filtration, low surface tension solvents, and venting. In certain applications, hydrophobic filters are used to filter aqueous solutions because of compatibility requirements.
Bubble Point

- Bubble Point testing is a non-destructive integrity test which correlated to bacterial challenge testing.
Types of Filters
Types of Filters

• Depth Filters
  – Powder Filters
    • Pressure Leaf Filters
    • Candle Filters
    • Plate and Frame Filters
  – Sheet Filters
  – Module
  – Deep Bed Filters

• Surface Filters
  – Membrane Filters

• Cross Flow Filters
Powder Filters

• Pressure Leaf Filter
  – Vertical or Horizontal

• Candle Filters

• Plate and Frame
All powder filters work on the same principles. They have a fine screen or other fine pore sized marial that has is larger than the sizes of the powder used.

A course base or pre-coat layer is applied that bridges the gaps in the screens.

A second coat of the body feed grade powder is applied over the top of the pre-coat.

Now beer is brought in and body feed is dosed inline to continually add fresh DE and prevent the surface from blinding.

Powder filters are use primarily for rough filtration.
Pressure Leaf Filters, Vertical or Horizontal

- Vertical and horizontal pressure leaf filters utilize a pressure vessel in which fine mesh screened covered hollow plates have been installed.

- Unfiltered beer enters the pressure vessel passes thought the pre-established DE layers on the leaf and exits through a manifold connecting the leaves.
Vertical Vs. Horizontal

- Vertical leaf filters are less expensive but may not permit dry cake discharge. You may need to use water to remove the cake and some towns waste water systems don’t like it (DE has a very high BOD requirement).

- Horizontal types are more expensive and cost more to maintain do to the seals and drive unit that a required for spinning the plates.
Canldle Filters

• Candle filters use a series of candle type structures made up of a central fluted pipe with notched rings stack on it. Unlike leaf filters they can easily be back-washed.

• Pressure drop across the bed is slower to rise with candle filters. This is do to the increases in surface area as the DE cake gets thicker. As the DE cake increases to ½” on a 2” candle your surface area increases from 75 sq” to 113 sq” for every 12” of length.
Plate and Frame

• Plate and frame filters have the appearance of sheet filters.

• The difference is the addition of the sludge frame. It gives the space required for the DE cake that builds during pre-coat and filtering.

• Removing sludge is difficult.
Types of Powders

- Diatomaceous Earth
- Cellulose
- Perlite
- PVPP
Diatomaceous Earth

• DE is the remains of microscopic plants called diatoms. They are algae that have the unique ability to extract silica from water to produce skeleton type structures.

• There are more than 15,000 types in the seas today, and have existed for millions of years

• During cretin periods they have been in such quantities that their fossils covered the bottom in thick layers
• Today it is mined from huge chalk-like deposits, ground to a powder, sterilized and calcined at 800-900 C. Then air classified into various grades.

• It is virtually inert filter aid. Predominantly pure silica. Use only low iron types.

• Lompoc, California is considered the largest and purest deposit in the world.
Safety Issues

• Considered cancer causing

• While DE is not an immediate hazard to your health it can cause problem with long term exposure. Silicosis

• Need to control dust in and around filter areas and storage areas.
Potential Health Effects

• **Inhalation:**
  Causes dryness and irritation to the respiratory tract. Symptoms may include coughing, sore throat, breathing difficulty (dyspnea), and wheezing. Excessive inhalation may cause decreased pulmonary function, lung damage and silicosis. Acute silicosis is manifested by dyspnea, fever, cough and weight loss. Severe respiratory symptoms may lead to death.
Cellulose

- Harmless to health
- pH-stable in the range pH 2 to 11
- Non-abrasive
- can be disposed of without harming the environment
- Better life cycle assessment compared to mineral filter aids
Cellulose
Perlite

• Perlite is a material of volcanic origin and consists principally of aluminum silicate.

• It has relatively high bounded water content so that when the raw ore is heated it softens and the water trapped in the structure expanse.

• This basically creates glass foam that can be milled to form a very light loose powder which weighs 20-40% less than DE.
PERLITE

TYPICAL PERLITE FILTER AID
Brewing Issues

• According to (Technology Brewing and Malting 2nd Edition, Kunze), at low pH values perlite releases chalk and iron. Consequently it should only be used for wort filtration.
Safety Issues

• According to the FDA, Perlite is classified the same as household flower (nuisance dust) and does not pose any health risks.

• Perlite does not have any stringent disposal criteria and may be suitable for discharge into sanitary sewers.
PVPP

• POLYVINYL POLYPYRROLIDONE can be used as a secondary filtration process to improve stability.

• The set up is much the same as with any powder filter except that the pvpp can be regenerated with caustic washing
Sheet Filters

• Sheet filters look similar to plate and frame minus the sludge frame.

• A cellulose and DE sheet 3-5mm thick is sandwiched between two plates. They can range in sizes from 20cm to 120cm.

• Beer passes from the inlet side of one plate through the sheet and is collected on the outlet side of the other plate.
• Sheet filters are very simple to use, pressure shocking less likely to affect outlet turbidity but may allow passage of microorganisms.

• As pressure drop increases it is possible to back flush the sheets.

• The norel plastic plates can deform if overheated, and the stainless plates are very expensive but can be steam sterilized.
• Some of the drawbacks are that they leak.

• The sheets can not be regenerated indefinitely and the plates require manual cleaning.

• They can occupy a large space due to the small load capacity vs. surface area.
Module Filters

• Module filters are round rigid filter elements up to 16” or 40 cm in diameter. They look like a cross between a horizontal leaf filter and a sheet filter. The module is a plastic frame with a DE impregnated cellulose sheet on both side attached to a central column.

• The module can be stacked up to 4 high in one housing. The modules are expensive compared to sheet.
Deep Bed Filters

- Deep-bed filters are unique filter pads made out of cellulose and diatomaceous earth. Due to the layered pad design, proceeding in stages from coarse inlet side to a very fine outlet side and a pad thickness of 24 mm they have a few advantages.
- They are able to withstand pressure shock well.
- Securely separate yeast and bacteria with no premature blocking of the sterile layers
Surface/Membrane Filters

• Cartridge membrane filters are generally much smaller in surface area and serve mostly as sterile filters as the beer is on its way to packaging.

• Membranes are made from several different materials like polysulfone and polypropylene.

• Housing can range from a single 10” to a 50+ 40” Cartridges.

• They are the only filters that you can verify before and after each run to ensure integrity.
<table>
<thead>
<tr>
<th>Type</th>
<th>Top Cap</th>
<th>Bottom Cap</th>
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<tbody>
<tr>
<td>DOE with gasket</td>
<td><img src="image1.png" alt="Flat Gasket" /></td>
<td><img src="image2.png" alt="Flat Gasket" /></td>
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<tr>
<td>Flat Cap/2 x 222 &quot;O&quot; Ring</td>
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<tr>
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<td><img src="image9.png" alt="Fin" /></td>
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Membrane Materials

- Cellulose acetate (CA),
- Polyvinylidene fluoride (PVDF),
- Polyacrylonitrile (PAN),
- Polypropylene (PP),
- Polysulfone (PS),
- Polyethersulfone (PES),
Cellulose acetate (CA),

- Composed of Cellulose di- and triacetate
- Low static charge
- May be sterilized repeatedly without loss of integrity or change in bubble point
Polyvinylidene Fluoride (PVDF)

- PVDF
  - Extremely low protein binding
  - Compatible with wide range of chemicals and acids
  - Repeatedly steam sterilizable
Polyacrylonitrile (PAN)

• Polysulfone membranes exhibit excellent resistance to pressure, temperature and aggressive cleaning regimes.

• Very low affinity and adsorption characteristics results in high product recoveries, and long service life.
Polypropylene (PP, N66)

- Thermal resistance
- Wide pH tolerance
- Homogeneous pore structure
- Dimensional stability
- Highly hydrophobic (needs to be treated)
Polyethersulfone (PS)

- PES
  - High thermal resistance
  - High degree of dimensional stability
  - Good chemical resistance
  - Low protein binding
Polyethersulfone (PES)

- Low protein binding
- Acid and base resistant
- Low protein adsorption
Membrane Integrity Testing

• One of the most important aspects of the use of filters is to have a non-destructive integrity test. Bubble point testing.

• During production of sterile product, the filter should be subjected to such an integrity test before and after filtration.

• This is done to ensure that the filter meets specification, is properly installed and intact during filtration, and to confirm the rating of the filter.
Bubble Point Test

• The test is designed to determine the pressure at which a continuous stream of bubbles is seen downstream of a wetted filter nitrogen gas pressure

• To perform a Bubble Point Test, gas is applied to one side of a wetted filter, with the tubing downstream of the filter submerged in a bucket of water.
Crossflow

• In crossflow filtration the beer is pumped tangential to the membrane filtering medium and particles are swept away with the flow.
Crossflow

• The key aspect is that the use of DE is no longer necessary.

• Fully automated crossflow systems are less labor intensive to operate than are DE filters.

• The high capital cost and low throughput has been preventing it from gaining acceptance, but they are gaining ground.
Centrifuge
• https://www.youtube.com/watch?v=dxTT_bP6lwI
Filtering

• How to set up a basic DE filtration
  – Fill system with plant water and sanitize.
  – Drain and rinse system.
  – Fill system with DA water
    • Our DA water limit is 50 ppb
  – Load dosage tank with pre-coat and de-aerate
    • Hyflo Super-Cel 1 lbs./m²
  – Coat the screens.
Filtering

– Load dosing tank with basecoat and de-aerate
  • Standard Super-Cel 2 lbs / m2
– Coat the screens
– Load dosing tank with body feed
  • For a 250 bbl filter run we use 50-75 lbs. of Body Feed
Filtering

– Run 400 gallons of DA water to the floor and bring beer on line.

– Thing we monitor throughout the run.
  • Flow Rate
  • Pressure Drop
  • Temperature
  • DO
  • CO2

– End of run chase beer with DA water
1. Inlet Valve
2. Discharge Valve
3. Recycling Valve
4. Flow Regulation Valve
5. Mixing Tank Suction Valve
6. Mixing Tank Return Valve
7. Total Exhaust Valve
8. Housing Return Valve
9. Mixing Pump Suction Valve
10. Mixing Pump Priming Valve
11. Wash System Valve
12. Sample Valve
13. Water Inlet
14. Air Purge Valve
15. Spray Arm
16. Dose Control
17. Deaeration Stone
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Microbiological stability can be accomplished with

• Separation

• Heat
Objective of Pasteurization

- Reduce the chance that microorganisms survive in beer and remain at the required low level.
Factor Effecting Pasteurization

- Number and Kind of Microbes
- Size of package
- Level of comfort
Pasteurization Units (PU)

- One PU is defined as 1 minute at 60C (140F)

- 5.6 PU’s is the minimum safe heat treatment for beer.

- Brewers typically operate in the range of 5-15 PU’s
Tunnel Pasteurizers

- High capital
- Large foot print
- High energy load
- Reliable and Effective
Flash Pasteurizers

- Minimize off flavors usually associated with heating
- Lower capital and operating costs
- Space saving
- Low maintenance cost
- Lower energy consumption
Filling Aseptically

Sources of Contamination

1. Beverage itself
2. Plumbing
3. Containers
4. Conveyors
5. Auxiliary fluids
6. Filler bowl
7. Filler heads
8. Closures and Conveyors
9. Hopper
10. Jaws and Closure equipment
11. People
12. Atmosphere