FILTER BACKWASHING

I. Introduction
A. Backwashing: a unit operation used for the removal of particulates from the filter media.
B. As particulates build up in and on the filter media, the pressure drop builds up to a level that exceeds the available head. The filter is then taken out of service and backwashed or regenerated.
C. Particles are dislodged from the filter medium by reversing the flow of water and causing the bed to fluidize and then expand, thereby allowing the particles to be released.
D. Backwashing is performed on one of the following basis.
   1. When the headloss through the filter reaches some predetermined level, e.g. 8 to 10 feet.
   2. When turbidity levels in the effluent reach some set level, e.g. 0.05 NTU.
   3. Some municipalities’ backwash their filters on a time schedule, such as every 24 to 48 hours.
E. Types of particles that may be found in backwash water are:
   1. Algae
   2. Humic colloidal compounds
   3. Viruses
   4. Asbestos fibers
   5. Clay particles
F. Backwashing is sometime accompanied by:
   1. Air scour
   2. Surface wash with high pressure water jets
G. Water for backwashing is treated water and is supplied from
   1. An elevated backwash water tank
   2. Backwash pumps

II. Backwash Hydraulics
A. Headloss in filter is equal to the buoyant weight of filter media in water

1. Equation for headloss equal to buoyant weight

\[ h_L = L \left(1 - \varepsilon\right)\left(SG_{\text{Media}} - SG_{\text{Water}}\right) \]

\( h_L \) = Head loss, ft (m)
\( \varepsilon \) = Media porosity
\( L \) = Depth of media, ft (m)
\( SG_{\text{Media}} \) = Specific gravity of media
\( SG_{\text{Water}} \) = Specific gravity of water

\[ L (1 - \varepsilon) A_{Bed} = L_e (1 - \varepsilon_e) A_{Bed} \]

\( A_{Bed} \) = Surface area of filter bed  
\( L \) = Depth of unexpanded filter bed  
\( L_e \) = Depth of expanded filter bed  
\( \varepsilon, \varepsilon_e \) = Porosity of unexpanded and expanded filter bed, respectively.

Rearranged.

\[ L_e = \frac{L (1 - \varepsilon)}{(1 - \varepsilon_e)} \]

3. Fair and Geyer have shown that:

\[ \varepsilon_e = \left( \frac{V_b}{V_s} \right)^{0.22} \]

\[ V_b = V_s \varepsilon_e^{4.5} \]

4. Expanded bed of Uniform Media.

\[ L_e = \frac{L (1 - \varepsilon)}{\left[ 1 - \left( \frac{V_b}{V_s} \right)^{0.22} \right]} \]

\( V_b \) = upflow velocity of backwash velocity  
\( V_s \) = settling velocity of particle

5. Expanded bed of Non-uniform Media.

\[ L_e = L (1 - \varepsilon) \sum \frac{x}{(1 - \varepsilon_e)} \]

6. Develop an equation for settling velocity as a function of diameter and temperature.
7. Linvil Rich, Unit Operations, page 86

\[ C_D = \frac{18.5}{N_{Re}^{0.6}} \]

For Reynolds numbers ranging from 1.9 to 500

8. Continue with the development of an equation for settling velocity as a function of diameter and temperature.

\[ C_D = \frac{18.5}{(\phi \rho V_s d / \mu)^{0.6}} \]

\[ V_s = \left[ \frac{4}{3} \left( \frac{g \phi \rho V_s d}{18.5 \mu^{0.6}} \right)^{0.6} \rho \left( S_{Sand} - 1 \right) \right]^{0.5} \]

\[ V_s = \left[ \frac{4}{3} \times 32.2 \text{ ft/s}^2 \left( 0.95 \times 1.936 V_s d \right)^{0.6} \frac{18.5 \mu^{0.6}}{(2.65 - 1)d} \right]^{0.5} \]

\[ V_s = \left[ \frac{5.52 V_s^{0.6} d^{1.6}}{\mu^{0.6}} \right]^{0.5} \]

\[ V_s^2 = 5.52 V_s^{0.6} d^{1.6} / \mu^{0.6} \]

\[ V_s^{1.4} = 5.52 d^{1.6} / \mu^{0.6} \]

\[ V_s = \left( \frac{5.52 d^{1.6}}{\mu^{0.6}} \right)^{0.714} = \left( \frac{5.52 d^{1.6}}{\mu^{0.6}} \right)^{0.714} \]
\[ V_s = \left( \frac{5.52 \, d^{1.6}}{(2.735 \times 10^{-5})^{0.6}} \right)^{0.714} \]

\[ V_s = [3017.9 \, d^{1.6}]^{0.714} \]

\[ V_s \approx 306 \, d^{1.143} \]


\[ V_b = \varepsilon_e^{4.5} \, V_s \]

\( V_s \) of the first sieve combination is used

The porosity \( \varepsilon \) is substituted for \( \varepsilon_e \)

10. Example problem illustrating the calculation of headloss and the expanded bed depth for a 24-inch sand filter with specific gravity of 2.65, shape factor of 0.95, and a water temperature of 55 °F.

\[ \mu = 2.547 \times 10^{-5} \text{ lb-sec/ft}^2 \quad \rho = 1.935 \text{ lb-sec}^2/\text{ft}^4 \quad \varepsilon = 0.40 \]

See next page.
\[ V_s = 315 \, d^{1.143} \]

\[ \varepsilon_e = \left( \frac{V_b}{V_s} \right)^{0.22} \]

\[ X_{ij} \text{ is expressed as a fraction} \]

<table>
<thead>
<tr>
<th>SIEVE #</th>
<th>% Sand Retained ((X_{ij}))</th>
<th>(d_{ij}) ((\text{ftx} 10^{-3}))</th>
<th>(V_s) ((\text{fps}))</th>
<th>(\varepsilon_e)</th>
<th>(X_{ij}/(1 - \varepsilon_e))</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-20</td>
<td>1.05</td>
<td>3.28</td>
<td>0.456</td>
<td>0.404</td>
<td>0.0176</td>
</tr>
<tr>
<td>20-28</td>
<td>6.65</td>
<td>2.29</td>
<td>0.302</td>
<td>0.442</td>
<td>0.1191</td>
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<tr>
<td>28-32</td>
<td>15.7</td>
<td>1.77</td>
<td>0.225</td>
<td>0.471</td>
<td>0.2970</td>
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<tr>
<td>32-35</td>
<td>18.84</td>
<td>1.51</td>
<td>0.188</td>
<td>0.491</td>
<td>0.3699</td>
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<tr>
<td>35-42</td>
<td>18.98</td>
<td>1.25</td>
<td>0.151</td>
<td>0.515</td>
<td>0.3909</td>
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<td>42-48</td>
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<td>1.05</td>
<td>0.124</td>
<td>0.538</td>
<td>0.3832</td>
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<td>48-60</td>
<td>14.25</td>
<td>0.88</td>
<td>0.101</td>
<td>0.562</td>
<td>0.3253</td>
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<tr>
<td>60-65</td>
<td>5.15</td>
<td>0.75</td>
<td>0.844</td>
<td>0.585</td>
<td>0.1241</td>
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<tr>
<td>65-100</td>
<td>1.66</td>
<td>0.59</td>
<td>0.642</td>
<td>0.621</td>
<td>0.0438</td>
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<tr>
<td><strong>100</strong></td>
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<td><strong>2.0711</strong></td>
</tr>
</tbody>
</table>

HEADLOSS @ BEGINNING OF BACKWASH \(h_e = \)

**2.0711** ft

<table>
<thead>
<tr>
<th>EXPANDED BED DEPTH=</th>
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<tbody>
<tr>
<td>2.49 ft</td>
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</table>

\[ V_b = V_s \varepsilon_e^{4.5} = 0.456 \left(0.40\right)^{4.5} = 0.00738 \text{ fps} \]

\[ V_s = 315 \, d^{1.143} = 315 \left(0.00328\right)^{1.143} = 0.456 \text{ fps} \]

\[ \varepsilon_e = \left( \frac{V_b}{V_s} \right)^{0.22} = \left( \frac{0.00738}{0.456} \right)^{0.22} = 0.404 \]

\[ h_L = (S.G_{\text{media}} - 1)(1 - \varepsilon) \, L = 1.98 \, \text{ ft}. \]

\[ L_e = L \left(1 - \varepsilon\right) \sum X_{ij} / (1 - \varepsilon_e) = 2.49 \, \text{ ft}. \]