Water treatment –
Rapid Sand Filter
Cross sectional view of a Rapid Sand Filter

- Wash water troughs
- Sand
- Gravel
- Perforated laterals
- Cast iron manifold with strainers
- Filter floor
Typical Rapid Flow Filter Operation

How filter operates:
1. Open valve 1. (This allows influent to flow to filter)
2. Open valve 2. (This allows water to flow through filter)
3. During filter operation all other valves are closed.

<To view click on valve no. 1 & 2>
Isometric view of Rapid Sand Filter
Clean Water Headloss

Several equations have been developed to describe the flow of clean water through a porous medium. Carman-Kozeny equation used to calculate head loss is as follows:

\[ h = \frac{f (1-\alpha) L v_s^2}{\phi \alpha^3 d g} \]

\[ h = \frac{f p (1-\alpha) L v_s^2}{\phi \alpha^3 d_g g} \]

\[ f = 150 \left(1-\alpha\right) + 1.75 \]

\[ N_g = \frac{\phi d v_s \rho}{\mu} \]

\[ N_g \]
where, \( h \) = headloss, m
\( f \) = friction factor
\( \alpha \) = porosity
\( \phi \) = particle shape factor (1.0 for spheres, 0.82 for rounded sand, 0.75 for average sand, 0.73 for crushed angular sand)
\( L \) = depth of filter bed or layer, m
\( d \) = grain size diameter, m
\( v_s \) = superficial (approach) filtration velocity, m/s
\( g \) = acceleration due to gravity, \( 9.81 \text{ m/s}^2 \)
\( p \) = fraction of particles (based on mass) within adjacent sieve sizes
\( d_g \) = geometric mean diameter between sieve sizes \( d_1 \) and \( d_2 \)
\( N_g \) = Reynolds number
\( \mu \) = viscosity, \( \text{N} \cdot \text{s/m}^2 \)
Backwashing of Rapid Sand Filter

• For a filter to operate efficiently, it must be cleaned before the next filter run. If the water applied to a filter is of very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash.
Backwashing of Rapid Sand Filter

• Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well.
• The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the floc in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter.
When is Backwashing Needed

The filter should be backwashed when the following conditions have been met:
• The head loss is so high that the filter no longer produces water at the desired rate; and/or

• Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or

• A filter run reaches a given hour of operation.
Operational Troubles in Rapid Gravity Filters

**Air Binding:**

• When the filter is newly commissioned, the loss of head of water percolating through the filter is generally very small. However, the loss of head goes on increasing as more and more impurities get trapped into it.

• A stage is finally reached when the frictional resistance offered by the filter media exceeds the static head of water above the and bed. Most of this resistance is offered by the top 10 to 15 cm sand layer. The bottom sand acts like a vacuum, and water is sucked through the filter media rather than getting filtered through it.
Operational Troubles in Rapid Gravity Filters

Air Binding:

• The negative pressure so developed, tends to release the dissolved air and other gases present in water. The formation of bubbles takes place which stick to the sand grains. This phenomenon is known as Air Binding as the air binds the filter and stops its functioning.
• To avoid such troubles, the filters are cleaned as soon as the head loss exceeds the optimum allowable value.
Formation of Mud Balls:
The mud from the atmosphere usually accumulates on the sand surface to form a dense mat. During inadequate washing this mud may sink down into the sand bed and stick to the sand grains and other arrested impurities, thereby forming mud balls.
Cracking of Filters:
The fine sand contained in the top layers of the filter bed shrinks and causes the development of shrinkage cracks in the sand bed. With the use of filter, the loss of head and, therefore, pressure on the sand bed goes on increasing, which further goes on widening these cracks.
Remedial Measures to Prevent Cracking of Filters and Formation of Mud Balls

• Breaking the top fine mud layer with rakes and washing off the particles.

• Washing the filter with a solution of caustic soda.

• Removing, cleaning and replacing the damaged filter sand.