14. SCREENS

The primary treatment incorporates unit operations for removal of floating and suspended solids from the wastewater. They are also referred as the physical unit operations. The unit operations used are screening for removing floating papers, rages, cloths, plastics, cans stoppers, labels, etc.; grit chambers or detritus tanks for removing grit and sand; skimming tanks for removing oils and grease; and primary settling tank for removal of residual settleable suspended matter.

Screen is the first unit operation in wastewater treatment plant. This is used to remove larger particles of floating and suspended matter by coarse screening. This is accomplished by a set of inclined parallel bars, fixed at certain distance apart in a channel. The screen can be of circular or rectangular opening. The screen composed of parallel bars or rods is called a rack. The screens are used to protect pumps, valves, pipelines, and other appurtenances from damage or clogging by rags and large objects.

Industrial wastewater treatment plant may or may not need the screens. However, when packing of the product and cleaning of packing bottles/ containers is carried out, it is necessary to provide screens even for industrial wastewater treatment plant to separate labels, stopper, cardboard, and other packing materials. The cross section of the screen chamber is always greater (about 200 to 300 %) than the incoming sewer. The length of this channel should be sufficiently long to prevent eddies around the screen. The schematic diagram of the screen is shown in the Figure 8.1.

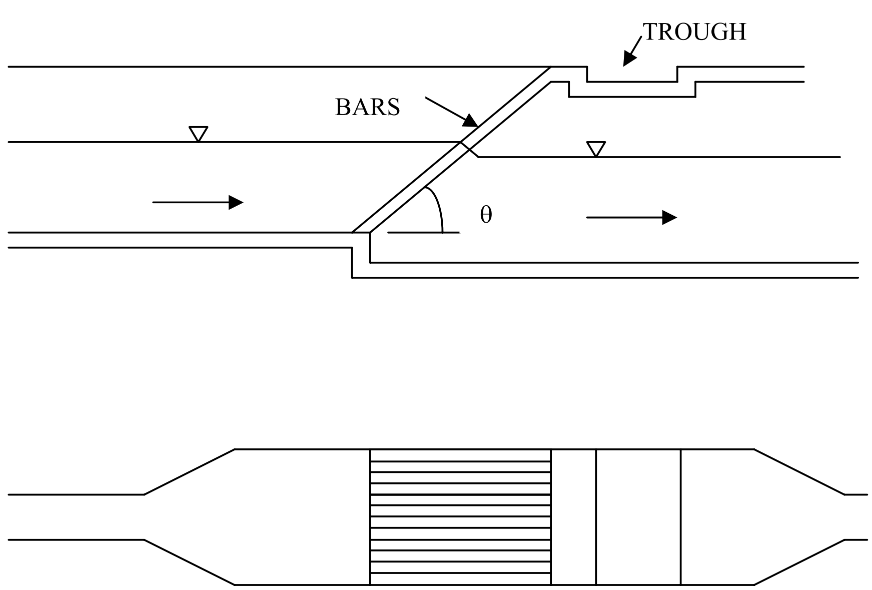


Figure 8.1 Bar Screen

14.1 Types of Screens

Screens can be broadly classified depending upon the opening size provided as coarse screen (bar screens) and fine screens. Based on the cleaning operation they are classified as manually cleaned screens or mechanically cleaned screens. Due to need of more and more compact treatment facilities many advancement in the screen design are coming up.

14.1.1 Coarse Screen

It is used primarily as protective device and hence used as first treatment unit. Common type of these screens are bar racks (or bar screen), coarse woven-wire screens, and comminutors. Bar screens are used ahead of the pumps and grit removal facility. This screen can be manually cleaned or mechanically cleaned. Manually cleaned screens are used in small treatment plants. Clear spacing between the bars in these screens may be in the range of 15 mm to 40 mm.

14.1.2 Grinder or Comminutor

It is used in conjunction with coarse screens to grind or cut the screenings. They utilize cutting teeth (or shredding device) on a rotating or oscillating drum that passes through stationary combs (or disks). Object of large size are shredded when it will pass through the thin opening of size 0.6 to 1.0 cm. Provision of bye pass to this device should always be made.

14.1.3 Fine Screen

Fine screens are mechanically cleaned screens using perforated plates, woven wire cloths, or very closely spaced bars with clear openings of less than 20 mm, less than 6 mm typical. **Commonly these are available in the opening size ranging from 0.035 to 6 mm.** Fine screens are used for pretreatment of industrial wastewaters and are not suitable for sewage due to clogging problems, but can be used after coarse screening. Fine screens are also used to remove solids from primary effluent to reduce clogging problem

of trickling filters. Various types of microscreens have been developed that are used to upgrade effluent quality from secondary treatment plant. Fine screen can be fixed or static wedge-wire type, drum type, step type and centrifugal screens. Fixed or static screens are permanently set in vertical, inclined, or horizontal position and must be cleaned by rakes, teeth or brushes. Movable screens are cleaned continuously while in operation. Centrifugal screens utilize the rotating screens that separate effluent and solids are concentrated.

14.1.4 Types of Medium and Fine Screens

Inclined (fixed): These are flat, cage, or disk type screens meant for removal of smaller particles. These are provided with opening of 0.25 to 2.5 mm. They are used for primary treatment of industrial effluents.

Band: It consists of an endless perforated band that passes over upper and lower sprocket. Brushes are installed to remove the material retained over the screen. Water jet can be used to flush the debris. **Opening size of 0.8 to 2.5 mm** is provided in this screen. They are used for primary treatment of industrial effluents.

Drum Screen or strainer: It consists of rotating cylinder that has screen covering the circumferential area of the drum. The liquid enters the drum axially and moves radially out. The solids deposited are removed by a jet of water from the top and discharged into a trough. The micro-strainers have very fine size screens and are used to polish secondary effluent or remove algae from the effluent of stabilization ponds. **Opening size of 1 to 5 mm and 0.25 to 2.5 mm** is used **for primary treatment** and opening **size of 6 to 40 μm** is used for **polishing treatment** of secondary effluents.

14.2 Screen Chamber

It consists of rectangular channel. Floor of the channel is normally 7 to 15 cm lower than the invert of the incoming sewer. Bed of the channel may be flat or made with desired slope. This channel is design to avoid deposition of grit and other materials in to it. Sufficient straight approach length should be provided to assure uniform distribution of screenings over the entire screen area. At least two bar racks, each designed to carry peak flow, must be provided. Arrangement of stopping the flow and draining the channel should be made for routine maintenance. The entrance structure should have a smooth transition or divergence to avoid excessive head loss and deposition of solids (Figure 8.2). Effluent structure should be having uniform convergence. The effluent from the individual rack may be combined or kept separate as necessary.

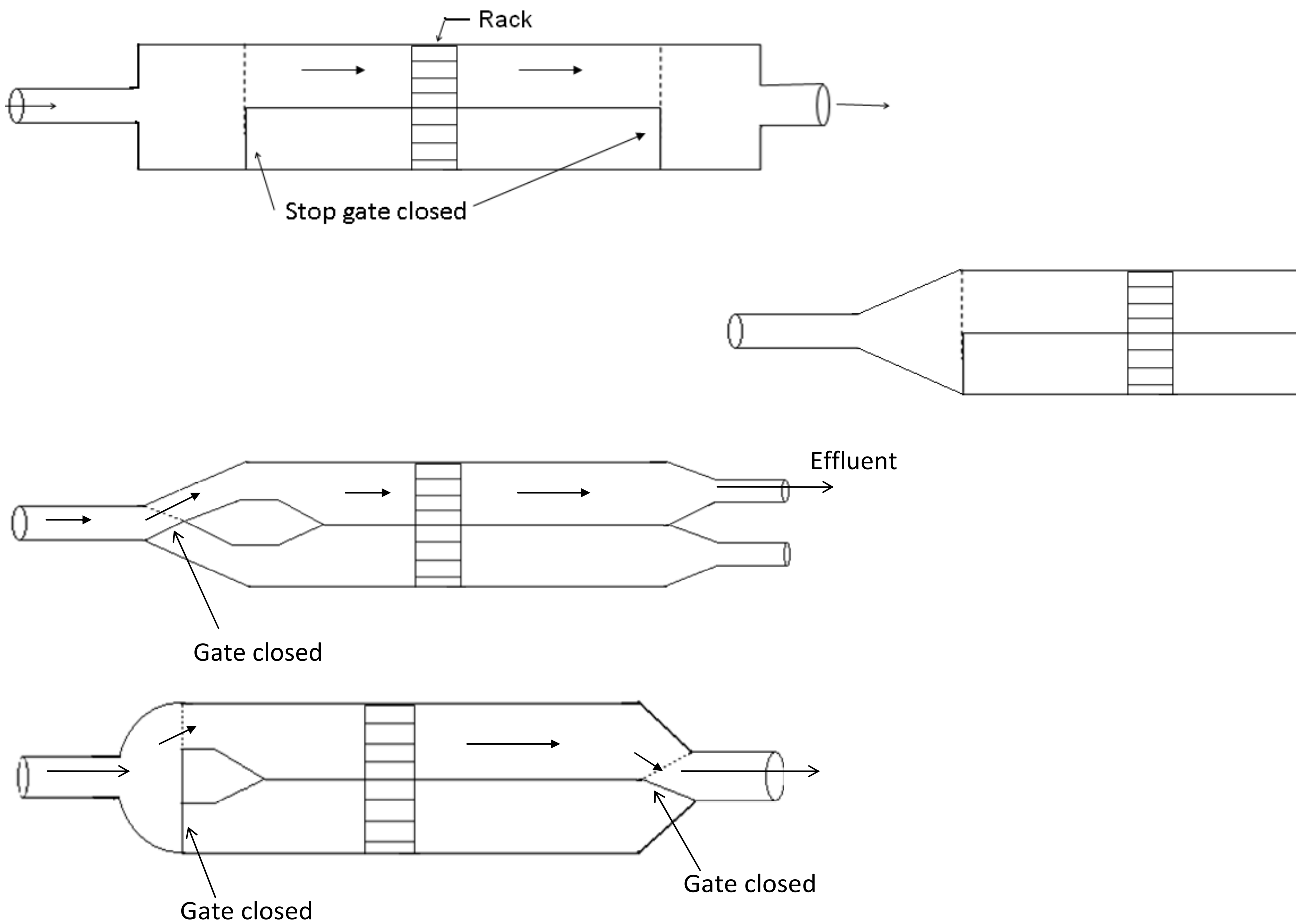


Figure 8.2 Double chamber bar screen and influent and effluent arrangement

14.3 Requirements and Specifications for Design of Bar Screen

1. The velocity of flow ahead of and through a screen varies materially and affects its operation. Lower the velocity through the screen, the greater is the amount of screening that would be removed. However, at lower velocity greater amount of solids would be deposited at the bottom of the screen channel.
2. Approach velocity of wastewater in the screening channel shall not fall below a self cleansing velocity of 0.42 m/sec or rise to a magnitude at which screenings will be dislodged from the bars.
   - The suggested approach velocity is 0.6 to 0.75 m/sec for the grit bearing wastewaters. Accordingly the bed slope of the channel should be adjusted to develop this velocity.
   - The suggested maximum velocity through the screen is 0.3 m/sec at average flow for hand cleaned bar screens and 0.75 m/sec at the normal maximum flow for

mechanically cleaned bar screen (Rao and Dutta, 2007). Velocity of 0.6 to 1.2 m/sec through the screen opening for the peak flow gives satisfactory result.

3. Head losses due to installation of screens must be controlled so that back water will not cause the entrant sewer to operate under pressure. Head loss through a bar rack can be calculated by using Kirchmer's equation:

$$h = \beta\, (W/b)^{4/3}\, h_v \sin\theta$$

where,

h		= head loss, m
β		= Bar shape factor
		= 2.42 for sharp edge rectangular bars
		= 1.83 for rectangular bars with semicircular upstream
		= 1.79 for circular bars
		= 1.67 for rectangular bars with both u/s and d/s faces as semicircular.
W		= Width of bars facing the flow, m
b		= Clear spacing between the bars, m
h_v		= Velocity head of flow approaching the bars, m
		= $V^2/2g$
V		= geometric mean of the approach velocity, m/sec
θ		= Angle of inclination of the bars with horizontal.

Usually accepted practice is to provide loss of head of 0.15 m but the maximum loss of head with the clogged hand cleaned screen should not exceed 0.3 m. For mechanically cleaned screen, the head loss is specified by the manufacturer, and it can be between 150 to 600 mm.

The head loss through the cleaned or partially clogged flat bar screen can also be calculated using following formula:

$$h = 0.0729\, (V^2 - v^2)$$

Where,

h = loss of head, m

V = velocity through the screen, m/sec

v = velocity before the screen, m/sec

The head loss through the fine screen can be calculated as:

$$h = (1/(2g.C_d))(Q/A)^2$$

Where, g = gravity acceleration (m/sec^2); C_d is coefficient of discharge = 0.6 for clean rack; Q is discharge through screen (m^3/sec); and A is effective open submerged area (m^2).

4. The slope of the hand cleaned screen should be in between 30 to 60^o with horizontal. The mechanically cleaned bar screens are generally erected almost vertical; however the angle with the horizontal can be in the range 45 to 85^o.
5. The submerged area of the surface of the screen, including bars and opening should be about 200% of the cross sectional area of the incoming sewer for separate system, and 300% for the combined system.
6. The clear spacing between the bars may be in the range of 15 mm to 75 mm in case of mechanically cleaned bar screen. However, for the manually cleaned bar screen the clear spacing used is in the range 25 mm to 50 mm. Bar Screens with opening between 75 to 150 mm are used ahead of raw sewage pumping. **For industrial wastewater treatment the spacing between the bars could be between 6 mm and 20 mm.**
7. The width of bars facing the flow may vary from 5 mm to 15 mm, and the depth may very from 25 mm to 75 mm. Generally bars with size less than 5 mm x 25 mm are not used. These bars are welded together with plate from downstream side to avoid deformation.

14.4 Quantities of Screening

The quantity of screening varies depending on the type of rack or screen used as well as sewer system (combined or separate) and geographic location. Quantity of screening removed by bar screen is 0.0035 to 0.0375 m^3/ 1000 m^3 of wastewater treated (Typical value = 0.015 m^3/1000 m^3 of wastewater) (Metcalf & Eddy, 2003). In combined system, the quantity of screening increases during storm and can be as high as 0.225 m^3/1000 m^3 of wastewater. For industrial wastewaters quantity of the screening depends on the characteristics of the wastewater being treated.

14.5 Disposal of Screenings

Screening can be discharged to grinders or disintegrator pumps, where they are ground and returned to the wastewater. Screenings can be disposed off along with municipal solid waste on sanitary landfill. In large sewage treatment plant, screenings can be incinerated. For small wastewater treatment plant, screenings may be disposed off by burial on the plant site.

Example: 1

Design a bar screen chamber for average sewage flow 20 MLD, minimum sewage flow of 12 MLD and maximum flow of 30 MLD.

Solution:

1. Average flow = 20 MLD
   = 0.231 m^3/Sec
   Maximum Flow = 30 MLD
   = 0.347 m^3/Sec
   Minimum flow = 12 MLD
   = 0.139 m^3/Sec
2. Assume manual cleaning and angle of inclination of bars with horizontal as 30^o. Assume size of bars 9 mm x 50 mm, 9 mm facing the flow. A clear spacing of 30 mm between the bars is provided.
3. Assume velocity of flow normal to screen as 0.3 m/sec at average flow.
4. Net submerged area of the screen opening required

   $$= \frac{0.231\ m^3/Sec}{0.3\ m/sec} = 0.77\ m^2$$

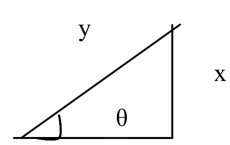
   Assume velocity of flow normal to the screen as 0.75 m/sec at maximum flow, hence net submerged area of screen opening

   $$\frac{0.347\ m^3/Sec}{0.75\ m/sec} = 0.46\ m^2$$

   Provide net submerged area = 0.77 m^2
5. Gross submerged area of the screen

   When 'n' numbers of bars are used the ratio of opening to the gross width will be $[(n+1)30] / [(n+1)30 + 9 \times n] \approx 0.77$ (for 20 to 30 number of bars)

   Therefore gross submerged area of the screen 0.77 / 0.77 = 1 m^2



Sin 30 = x/Y

6. The submerged vertical cross sectional area of the screen

   = 1.0 x Sin 30 = 0.5 m^2

This is equal to c/s area of screen chamber, therefore velocity of flow in screen chamber

= 0.231 / 0.5 = 0.462 m/sec

This velocity is greater than the self cleansing velocity of 0.42 m/sec

7. Provide 30 numbers of bars. The gross width of the screen chamber will be:

   = 30 x 0.009 + 31 x 0.03 = 1.2 m

   Therefore, liquid depth at average flow = 0.5 / 1.2 = 0.416 m

   Provide free board of 0.3 m

   Hence, total depth of the screen = 0.416 + 0.3 = 0.716 m, say 0.75 m

   Thus, the size of the channel = 1.2 m (width) x 0.75 m (depth)

8. Calculation for bed slope:

   R = A/P = (0.416 x 1.2) / (2 x 0.416 + 1.2)

   = 0.246 m

   Now, $V = (1/n)\, R^{2/3}\, S^{1/2}$

   $S^{1/2} = V.n / R^{2/3}$

   $= 0.462 \times 0.013 / (0.246)^{2/3}$

   $S^{1/2} = 0.0153$

   Therefore bed slope is nearly 1 in 4272 m

9. Head loss through the screen, h, when screen is not clogged.

   $$h = \beta\, (W/b)^{4/3}\, h_v \,\text{Sin}\, \theta$$

   $$= 2.42\, (9/30)^{4/3}\, [(0.462)^2/(2 \times 9.81)]\, \text{Sin}\, 30$$

   $$= 2.65 \times 10^{-3}\ \text{m} = 0.00265\ \text{m} = 2.65\ \text{mm}$$

   For half clogged screen, the head loss can be worked out using opening width as half

   Thus, b = 30/2 = 15 mm

   And $h = 6.67 \times 10^{-3}$ m = 6.67 mm < 150 mm

However, provide 150 mm drop of after screen.

If this head loss is very excessive, this can be reduced by providing bars with rounded edges at upstream, or by reducing width of bars to 6 to 8 mm, or by slight reduction in velocity. Except for the change in shape of bars in other cases the channel dimensions will change.

For minimum flow and maximum flow, the depth of flow can be worked out using Manning's formula using known discharge, and check for velocity under both these cases, as self cleansing and non-scouring, respectively, and also depth of flow at maximum discharge.

Questions

1. Describe types of screens used in wastewater treatment.
2. Discuss classification of screens and state application of each class.

3. With schematic describe how double chamber bar screen channels can be arranged? For what discharge each of them will be designed?
4. Describe design guidelines for the bar racks.
5. Determine head loss through a bar screen when it is 50% clogged. The approach velocity of wastewater in the channel is 0.6 m/sec, velocity of flow through the clear rack is 0.8 m/sec. Clear opening area in the screen is 0.2 m^2. Consider flow coefficient for clogged bar rack as 0.6.

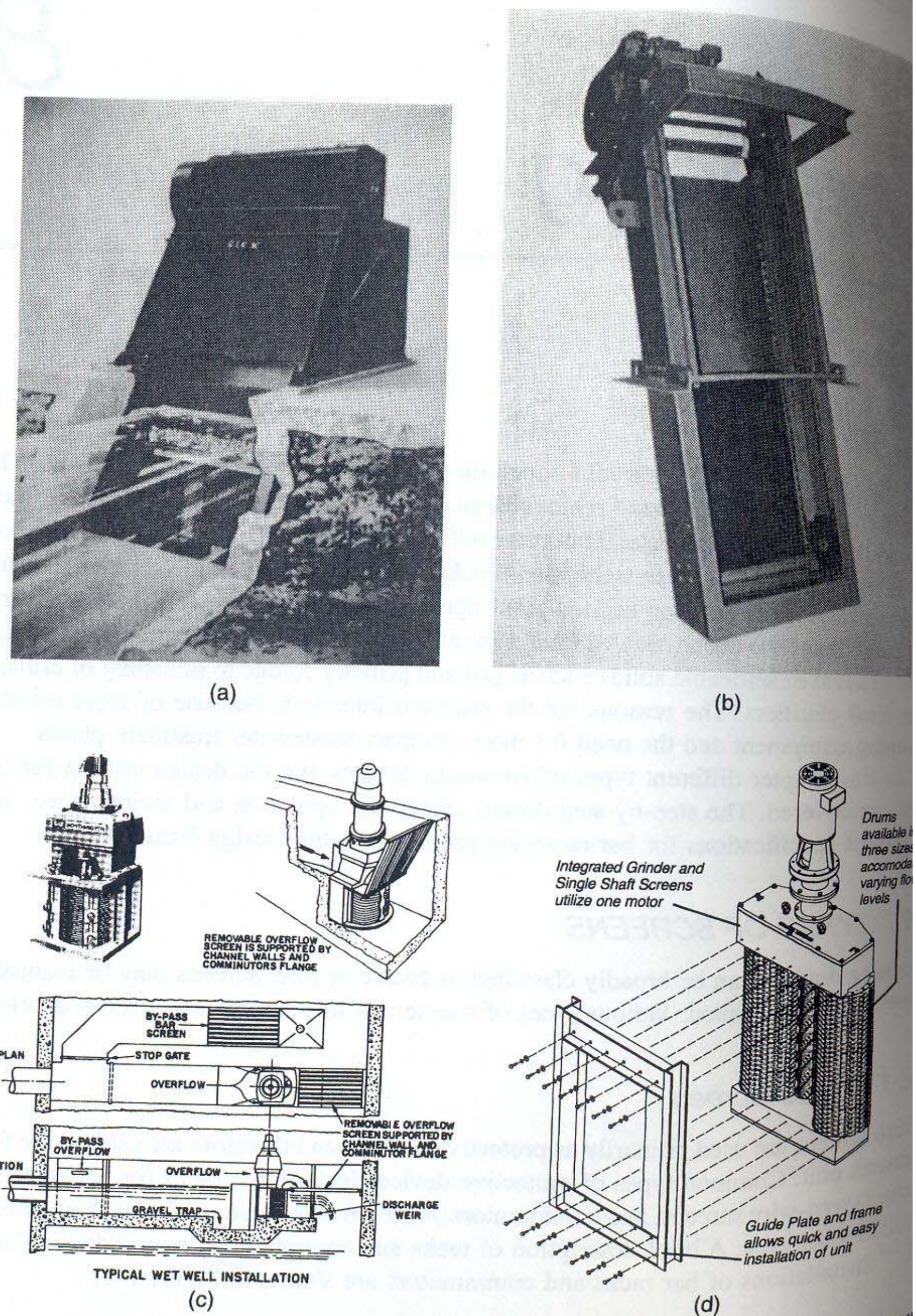


Figure 8-1 Bar Rack and Comminutor Assembly: (a) inclined rack, front cleaned (cou tesy Envirex, U.S. Filter); (b) cable-operated bar rack (courtesy Envirex, U.S. Filter); (c comminutor assembly and typical wet well installation (courtesy Worthington Pump Corp.) and (d) double drum integrated grinder and single shaft screen and motor (courtesy JWC Environmental).

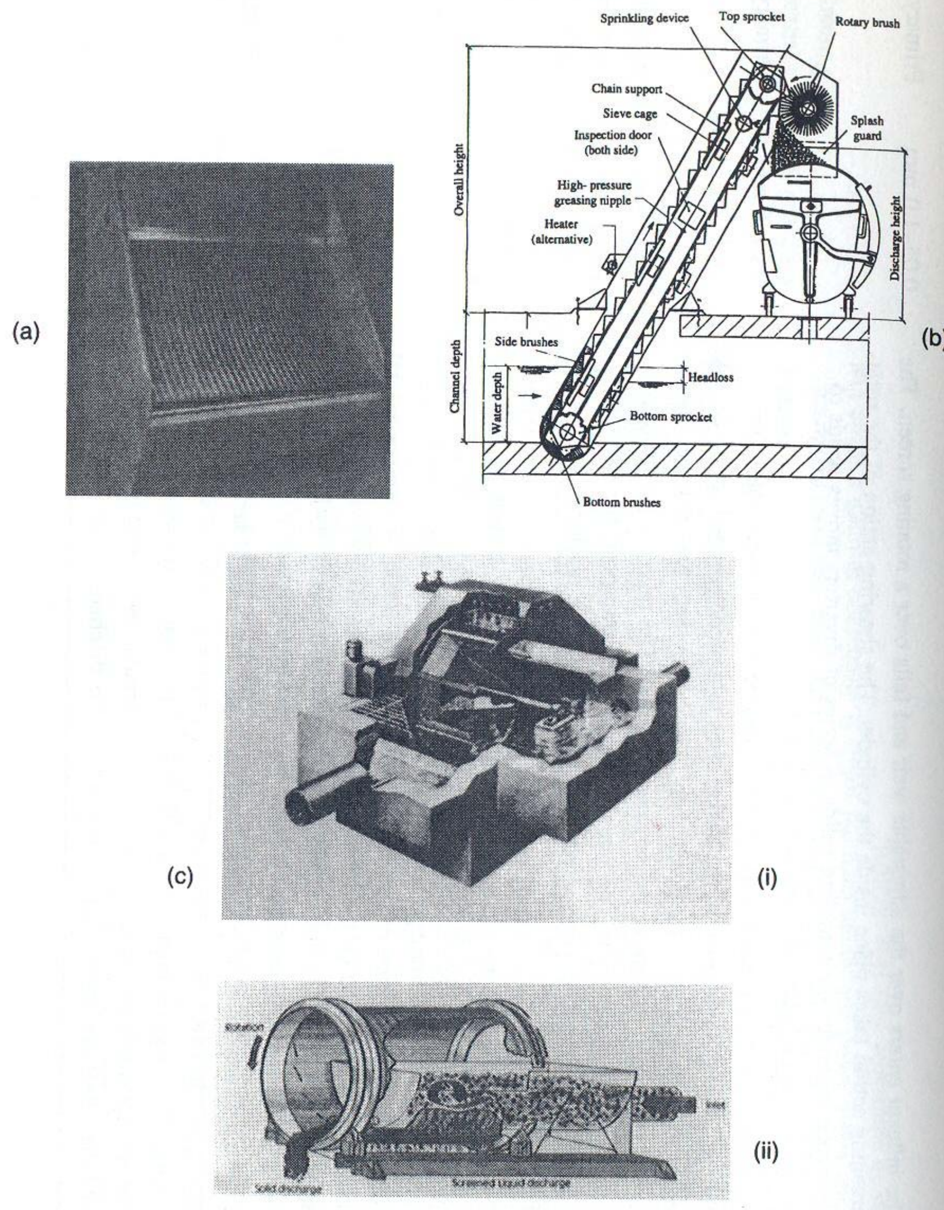


Figure 8-2 Various Types of Screens in Common Use: (a) Inclined Static Wedgewire Screen (courtesy Hycore Corp.); (b) endless traveling vertical or inclined band screen (courtesy Jones & Attwood Inc.); (c) rotating drum screen [(i) courtesy Envirex, U.S. Filter, (ii) courtesy Andritz Inc.].

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