Chapter 9   Oil and Water Separators

9.1   Purpose

Oil and water separators remove oil and other water-insoluble hydrocarbons and settleable solids from stormwater runoff. This chapter provides a discussion of their application and design criteria. BMPs are described for baffle type and coalescing plate separators.

9.2   Description

Oil and water separators are typically the American Petroleum Institute (API) (also called baffle type) (American Petroleum Institute, 1990) or the coalescing plate (CP) type using a gravity mechanism for separation. See Figure 166 and Figure 167. Oil and water separators typically consist of three bays; forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. A spill control (SC) separator (Figure 168) is a simple catch basin with a T-inlet for temporarily trapping small volumes of oil. The spill control separator is included here for comparison only and is not designed for, or to be used for, treatment purposes.

9.3   Applications/Limitations

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator.

- Commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations. (King County Surface Water Management, 2005).
- Facilities that would require oil control BMPs under the high-use site threshold described in Chapter 2 including parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery services. (King County Surface Water Management, 2005).

For low concentrations of oil, other treatments may be more applicable. These include sand filters and emerging technologies.

Without intense maintenance oil/water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels.

Pretreatment should be considered if the level of total suspended solids (TSS) in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

For inflows from small drainage areas (fueling stations, maintenance shops, etc.) a coalescing plate (CP) type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis (see Section 9.6).
Figure 166. API (Baffle Type) Separator
**Figure 167. Coalescing Plate Separator**
9.4 Site Suitability

Consider the following site characteristics:

- Sufficient land area
- Adequate TSS control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O & M)
9.5 Design Criteria

9.5.1 General Considerations

The following are design criteria applicable to API and CP oil/water separators:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH, empirical oil rise rates in the runoff, and the viscosity and specific gravity of the oil. Also determine whether the oil is emulsified or dissolved. 
  \( \text{(Washington State Department of Ecology, 2005) Do not use oil/water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.} \)

- Locate the separator off-line and bypass the incremental portion of flows that exceed the off-line 15-minute water quality design flow rate multiplied by 3.5. If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the on-line water quality design flow rate multiplied by 2.0.

- Use only storm drain pipes or impervious conveyances for routing oil contaminated stormwater to the oil and water separator.

- Specify appropriate performance tests after installation and shakedown, and/or certification by a professional engineer that the separator is functioning in accordance with design objectives. Expeditious corrective actions must be taken if it is determined that the separator is not achieving acceptable performance levels.

- Add pretreatment for TSS that could clog the separator, or otherwise impair the long-term effectiveness of the separator.

9.5.2 Criteria for Separator Bays

- Size the separator bay for the off-line 15-minute water quality design flow rate predicted by WWHM multiplied by 3.5.

- To collect floatables and settleable solids, design the surface area of the forebay at \( \geq 20 \text{ ft}^2 \) per 10,000 ft² of area draining to the separator. The length of the forebay shall be 1/3-1/2 of the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed. Screen openings shall be about 3/4 inch.

- Include a submerged inlet pipe with a down-turned elbow in the first bay at least two feet from the bottom. The outlet pipe shall be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.

- Include a shutoff mechanism at the separator outlet pipe.

- Use absorbents and/or skimmers in the afterbay as needed.

9.5.3 Criteria for Baffles

- Oil retaining baffles (top baffles) shall be located at least 1/4 of the total separator length from the outlet and shall extend down at least 50% of the water depth and at least 1 foot from the separator bottom.
• Baffle height to water depth ratios shall be 0.85 for top baffles and 0.15 for bottom baffles.

9.6 Oil and Water Separator BMPs

Two BMPs are described in this section:

• BMP T1110 for baffle type separators
• BMP T1111 for coalescing plate separators
9.6.1 BMP T1110 API (Baffle type) Separator Bay

9.6.1.1 Design Criteria

The criteria for small drainages is based on $V_h$, $V_t$, residence time, width, depth, and length considerations. As a correction factor API's turbulence criteria is applied to increase the length.

9.6.1.2 Sizing Criteria

- Determine the oil rise rate, $V_t$, in cm/sec, using Stokes’ Law, or empirical determination, or 0.033 ft./min. for 60 μ (micron) oil droplet size. The application of Stokes’ Law to site-based oil droplet sizes and densities, or empirical rise rate determinations recognizes the need to consider actual site conditions. In those cases the design basis would not be the 60 micron droplet size and the 0.033 ft/min. rise rate.

Stokes Law equation for rise rate, $V_t$ (cm/sec):

$$V_t = \frac{\left [ \left ( g \right ) \left ( \rho_w - \rho_o \right ) \left ( d^2 \right ) \right ]}{\left [ \left ( 18 \times \mu_w \right ) \right ]}$$

Where:

- $V_t =$ the rise rate of the oil droplet (cm/s or ft/sec)
- $g =$ acceleration due to gravity (cm/s² or ft/s²)
- $\rho_w =$ density of water at the design temperature (g/cm³ or lbm/ft³)
- $\rho_o =$ density of oil at the design temperature (g/cm³ or lbm/ft³)
- $d =$ oil droplet diameter (cm or ft)
- $\mu_w =$ absolute viscosity of the water (g/cm·s or lbm/ft·s)

Use:

- oil droplet diameter, D=60 microns (0.006 cm)
- $\rho_w =$0.999 gm/cc. at 32° F
- $\rho_o$: Select conservatively high oil density,

For example, if diesel oil @ $\rho_o =$0.85 gm/cc and motor oil @ $\rho_o = 0.90$ can be present then use $\rho_o =$0.90 gm/cc

$$\eta_w = 0.017921 \text{ poise, gm/cm-s. at } T_w=32 \text{ °F}$$

Use the following separator dimension criteria:

- Separator water depth, $d \geq 3\leq 8$ feet (to minimize turbulence)
- Separator width, 6-20 feet
- Depth/width (d/w) of 0.3-0.5
For Stormwater Inflow from Drainages under 2 Acres

Ecology modified the API criteria for treating stormwater runoff from small drainage areas (fueling stations, commercial parking lots, etc.) by using the design hydraulic horizontal velocity, \( V_h \), for the design \( V_h/V_t \) ratio rather than the API minimum of \( V_h/V_t = 15 \). The API criteria appear applicable for greater than two acres of impervious drainage area.

Performance verification of this design basis must be obtained during at least one wet season using the test protocol referenced in Chapter 10 for new technologies.

The following is the sizing procedure using modified API criteria:

1. Determine \( V_t \) and select depth and width of the separator section based on above criteria.

2. Calculate the minimum residence time \( (t_m) \) of the separator at depth \( d \):
   \[
   t_m = \frac{d}{V_t}
   \]

3. Calculate the horizontal velocity of the bulk fluid, \( V_h \), vertical cross-sectional area, \( A_v \), and actual design \( V_h/V_t \):
   \[
   V_h = \frac{Q}{d w} = \frac{Q}{A_v} \quad (V_h \text{ maximum at } < 2.0 \text{ ft/min.})
   \]
   \[
   Q = (k) \quad \text{Use a value of 3.5 for } K \text{ for the site location multiplied by the off-line 15 minute water quality design flow rate in ft}^3/\text{min} \text{ determined by WWHM, at minimum residence time, } t_m
   \]
   At \( V_h/V_t \) determine \( F \), turbulence and short-circuiting factor API F factors range from 1.28-1.74 (see Appendix D).

4. Calculate the minimum length of the separator section, \( l(s) \), using:
   \[
   l(s) = F Q t_m / w d = F(V_h/V_t) d
   \]
   \[
   l(t) = l(f) + l(s) + l(a)
   \]
   \[
   l(t) = l(t)/3 + l(s) + l(t)/4
   \]
   Where:
   \[
   l(t) = \text{total length of 3 bays}
   \]
   \[
   l(f) = \text{length of forebay}
   \]
   \[
   l(a) = \text{length of afterbay}
   \]

5. Calculate \( V = l(s) w d = F Q t_m \), and \( A_h = w l(s) \)
   \[
   V = \text{minimum hydraulic design volume}
   \]
   \[
   A_h = \text{minimum horizontal area of the separator}
   \]
For Stormwater Inflow from Drainages > 2 Acres:

Use $V_h = 15 V_t$ and $d = (Q/2V_h)^{1/2}$ (with $d/w = 0.5$) and repeat above calculations 3- 5.
9.6.2  BMP T1111 Coalescing Plate (CP) Separator Bay

9.6.2.1  Design Criteria

Calculate the projected (horizontal) surface area of plates needed using the following equation:

$$A_h = \frac{Q}{V_t} = \frac{[Q]}{[0.00386 \ast (\frac{(S_w - S_o)}{\mu_w})]}$$

Where

- $A_h$ = horizontal surface area of the plates (ft²)
- $V_t$ = rise rate of the oil droplet (ft/min)
- $Q$ = design flowrate (ft³/min) The design flowrate is the off-line 15-minute water quality design flowrate predicted by WWHM multiplied by 3.5.
- $S_w$ = specific gravity of water at the design temperature
- $S_o$ = specific gravity of oil at the design temperature
- $\mu_w$ = absolute viscosity of the water (poise)

- Plate spacing shall be a minimum of 3/4 inches (perpendicular distance between plates).
- Select a plate angle between 45° to 60° from the horizontal.
- Locate plate pack at least 6 inches from the bottom of the separator for sediment storage.
- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
- Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay shall be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent.
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 in.
- Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

9.6.2.2  Operation and Maintenance

- Prepare, regularly update, and implement an O & M Manual for the oil/water separators.
- Inspect oil/water separators monthly during the wet season of October 1-April 30 (WEF & ASCE, 1998) to ensure proper operation, and, during and immediately after a large storm event of ≥1 inch per 24 hours.
- Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has
accumulated during the dry season, after all spills, and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and washwater removal. Replace wash water in the separator with clean water before returning it to service.

- Remove the accumulated oil when the thickness reaches 1-inch. Also remove sludge deposits when the thickness reaches 6 inches.
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.