Chapter 11 - Oil and Water Separators

This chapter provides a discussion of oil and water separators, including their application and design criteria. BMPs are described for baffle type and coalescing plate separators.

11.1 Purpose of Oil and Water Separators
To remove oil and other water-insoluble hydrocarbons, and settleable solids from storm water runoff.

11.2 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 Figures 11.1 and 11.2. Oil removal 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 11.3) is a simple catchbasin 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.

11.3 Performance Objectives
Oil and water separators should be designed to remove oil and TPH down to 15 mg/L at any time and 10 mg/L on a 24-hr average, and produce a discharge that does not cause an ongoing or recurring visible sheen in the storm water discharge, or in the receiving water (see also Chapter 3).

11.4 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. (Seattle METRO, 1990; Watershed Protection Techniques, 1994; King County Surface Water Management, 1998) For low concentrations of oil, other treatments may be more applicable. These include sand filters and emerging technologies.

- 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, 1998)
- 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, 1998)

- 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 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 11.6 Design Criteria).

11.5 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)

11.6 Design Criteria-General Considerations

There is concern that oil/water separators used for storm water treatment have not performed to expectations. (Watershed Protection Techniques, 1994; Schueler, Thomas R., 1990) Therefore, emphasis should be given to proper application (see Section 11.4), design, O & M, (particularly sludge and oil removal) and prevention of CP fouling and plugging. (US Army of Engineers, 1994) Other treatment systems, such as sand filters and emerging technologies, should be considered for the removal of insoluble oil and TPH.

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; and 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. (Washington State Department of Ecology, 1995) 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 flows in excess of 2.15 times the Water Quality design flow rate.
- Use only impervious conveyances for oil contaminated storm water.
• 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. Expeditive corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.

• Add pretreatment for TSS that could cause clogging of the CP separator, or otherwise impair the long-term effectiveness of the separator.

Criteria for Separator Bays:

• Size the separator bay for the Water Quality design flow rate x a correction factor of 2.15 (see Chapter 4 of this Volume for a definition of the Water Quality Design Flow Rate).

• To collect floatables and settleable solids, design the surface area of the forebay at ≥ 20 ft² per 10,000 ft² of area draining to the separator (8). The length of the forebay should 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 should be about 3/4 inch.

• Include a submerged inlet pipe with a turn-down elbow in the first bay at least two feet from the bottom. The outlet pipe should 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. (King County Surface Water Management, 1998)

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

Criteria for Baffles:

• Oil retaining baffles (top baffles) should be located at least at 1/4 of the total separator length from the outlet and should extend down at least 50% of the water depth and at least 1 ft. from the separator bottom.

• Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

11.7 Oil and Water Separator BMPs

Two BMPs are described in this section. BMP T11.10 for baffle type separators, and BMP T11.11 for coalescing plate separators.
BMP T11.10  API (Baffle type) Separator Bay

**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.

Ecology is modifying the API criteria for treating storm water runoff from small drainage area (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 12 for new technologies.

The following is the sizing procedure using modified API criteria:

- Determine the oil rise rate, $V_t$, in cm/sec, using Stokes Law (Water Pollution Control Federation, 1985), or empirical determination, or 0.033 ft./min for 60µ oil. 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):

$$V_t = g(\sigma_w-\sigma_o)D^2 / 18 \eta_w$$

Where:

$g$ = gravitational constant (981 cm/sec²)
$D$ = diameter of the oil particle in cm.

Use

Oil particle size diameter, $D=60$ microns ($0.006$ cm)
$\sigma_w=0.999$ gm/cc. at 32° F
$\sigma_o$: Select conservatively high oil density,
For example, if diesel oil @ $\sigma_o=0.85$ gm/cc and motor oil @ $\sigma_o = 0.90$ can be present then use $\sigma_o=0.90$ gm/cc
$\eta_w = 0.017921$ poise, gm/cm-sec. at $T_w=32$ °F, (See API Publication 421, February, 1990)

Use the following separator dimension criteria:

Separator water depth, $d \geq 3 \leq 8$ feet (to minimize turbulence).

Separator width, 6-20 feet (WEF & ASCE, 1998; King County Surface Water Management, 1998)

Depth/width (d/w) of 0.3-0.5 (American Petroleum Institute, 1990)
For Storm Water Inflow from Drainages under 2 Acres:

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 $V_h/V_t$ (American Petroleum Institute, 1990; US Army Corps of Engineers, 1994).
   $$V_h = \frac{Q}{dw} = \frac{Q}{A_v} \ (V_h \ maximum \ at \ < 2.0 \ ft/min.) \ (American \ Petroleum \ Institute, \ 1990)$$
   $$Q = 2.15 \times \text{the Water Quality design flow rate in ft}^3/\text{min}, \ at \ minimum \ residence \ time, \ t_m$$
   At $V_h/V_t$ determine $F$, turbulence and short-circuiting factor (Appendix V-D) API $F$ factors range from 1.28-1.74. (American Petroleum Institute, 1990)
4. Calculate the minimum length of the separator section, $l(s)$, using:
   $$l(s) = \frac{FQ t_m}{wd} = F(V_h/V_t)d$$
   $$l(t) = l(f) + l(s) + l(a)$$
   $$l(t) = l(t)/3 + l(s) + l(t)/4$$
   Where:
   $l(t)$ = total length of 3 bays
   $l(f)$ = length of forebay
   $l(a)$ = length of afterbay
5. Calculate $V = l(s)wd = FQ t_m$, and $A_h = wl(s)$
   $$V = \text{minimum hydraulic design volume}$$
   $$A_h = \text{minimum horizontal area of the separator}$$

For Storm Water 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.
BMP T11.11 Coalescing Plate (CP) Separator Bay

Design Criteria

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

\[ A_p = \frac{Q}{V_t} = \frac{Q}{0.00386(\sigma_w - \sigma_o / \eta_w)} \]

\[ A_p = A_a \cos(b) \]

Where:

- \( Q = 2.15 \times \) the water quality design flow rate, ft³/min
- \( V_t = \) Rise rate of 0.033 ft/min, or empirical determination, or Stokes Law based
- \( A_p = \) projected surface area of the plate in ft²; .00386 is unit conversion constant
- \( \sigma_w = \) density of water at 32º F
- \( \sigma_o = \) density of oil at 32º F
- \( A_a = \) actual plate area in ft² (one side only)
- \( b = \) angle of the plates with the horizontal in degrees (usually varies from 45-60 degrees).
- \( \eta_w = \) viscosity of water at 32º F

- 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 should be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent. (WEF & ASCE, 1998)
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 in. (King County Surface Water Management, 1998).
• Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

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; Woodward-Clyde Consultants) 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 (Woodward-Clyde Consultants), 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. (King County Surface Water Management, 1998) 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 (King County Surface Water Management, 1998).

• Replace oil absorbent pads before their sorbed oil content reaches capacity.

• Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.
Figure 11-1  API (Baffle Type) Separator

Source: King County (reproduced with permission)
Figure 11-2 Coalescing Plate Separator

Source: King County (reproduced with permission)
Figure 11-3  Spill Control Separator (not for oil treatment)