Chapter 10
Oil and water separators

10.1 Introduction

Oil and water separation devices are applicable for treating stormwater runoff from areas where hydrocarbon products are handled (e.g. petrol stations, airports, storage terminals) or where small spills routinely fall on paved surfaces exposed to rain. Treatment should be as close to the source of the hydrocarbon products as possible to retain the oil in a floatable, non-emulsified form. Oil separators are not usually applicable for general urban runoff, because by the time the oil reaches the device it has emulsified or coated sediment in the runoff and is too difficult to separate.

The objective of oil and water separators is to treat most of the flow (90 to 95%) from the catchment to an acceptable degree (15 mg/l oil and grease) and to remove free floating oil, so as not to produce a discharge that causes an ongoing or recurring visible sheen in the stormwater discharge or in the receiving water.

Oil and water separators are not primarily designed to remove suspended sediment. Sites that generate both TSS and hydrocarbons will need separate treatment systems. The sediment laden runoff from other areas can be routed away from the separator and treated for sediment and other contaminant removal using other stormwater practices discussed in this manual.

Oil and water separators have significant benefits for spill containment. Spills enter the separator and mix with the water, then the oil in the spill will rise to the surface. All separators should hold the 2500 litres of oil that is the standard that has been agreed upon by the oil industry.

10.2 Types of oil and water separators

This manual only accepts API and plate separators achieving the goal of removal of oil and grease down to approximately 15 mg/l. Historical practices such as the triple interceptor tank (TIT) are no longer accepted by the ARC as meeting water treatment expectations.

API tanks are shown in Figure 14-1 and separators which contain packs of closely separated coalescing collection plates, are shown in Figure 14-2. These devices are designed to remove oil droplets from runoff, and hence provide more treatment than other practices. API tanks which use baffles were designed by the American Petroleum Council for use in refinery applications.

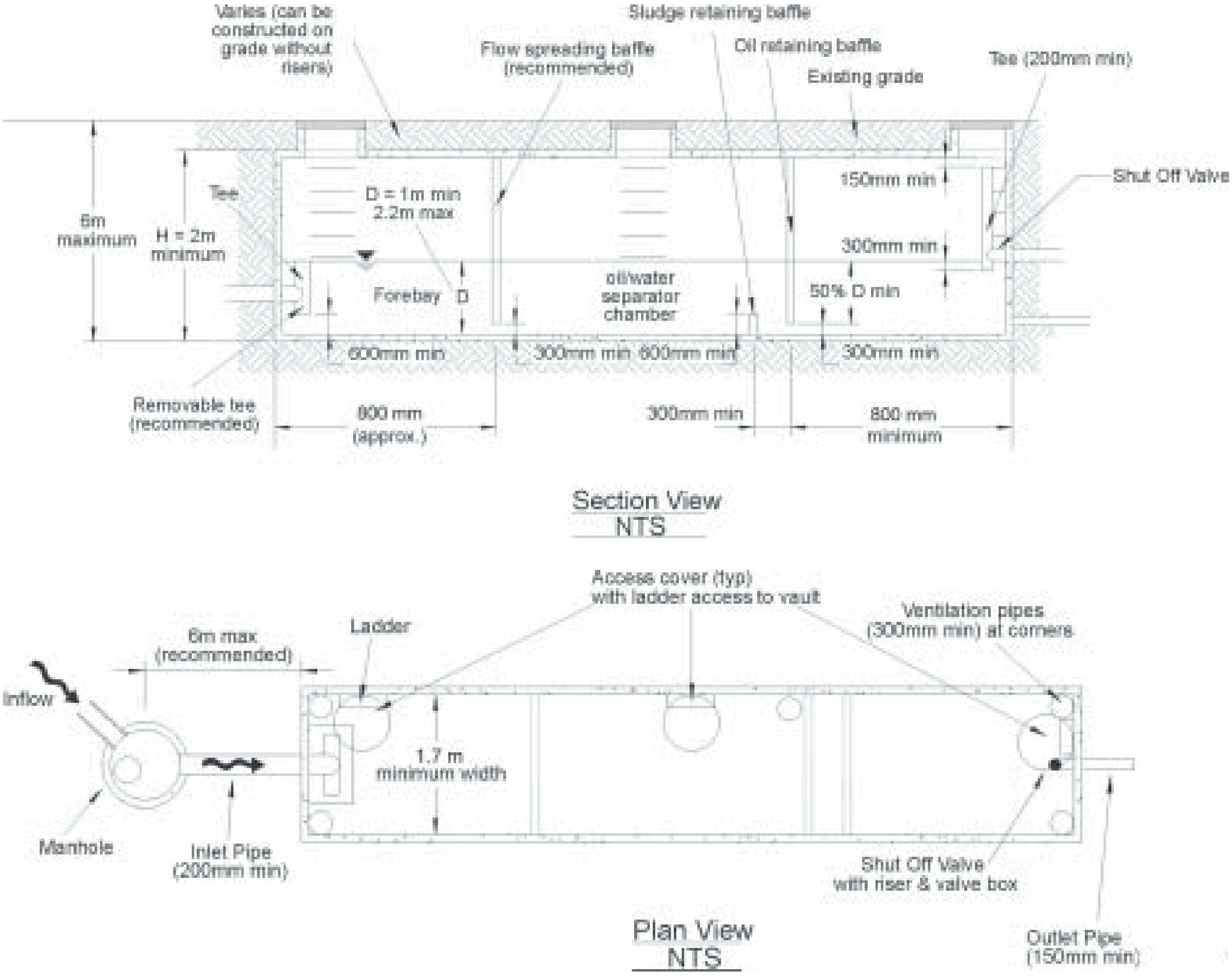
Plate separators contain packs of plates, typically spaced at 10-20 mm centres. The plates increase the effective surface of the device. Viewed another way, the close spacing of the plates reduces the height that an oil droplet must rise before it reaches a collecting surface. Therefore, to achieve the same degree of treatment as an API tank, a smaller device can be used.

The flow through the plate pack may be either downward (against the direction of the rising droplets) or across (where the flow is not biased in the direction of either sediment or droplets).

10.3 Water quality performance

There is concern that oil and water separators used for stormwater treatment have not performed to expectations (Schueler, Shepp, 1993) due to poor design or the need for very frequent maintenance (which is not

Figure 10-1
API separator schematics



done). Therefore, emphasis must be given to proper application, design, operation and maintenance and prevention of plugging. Other treatment systems, such as sand filters should be considered for the removal of insoluble oil and TPH.

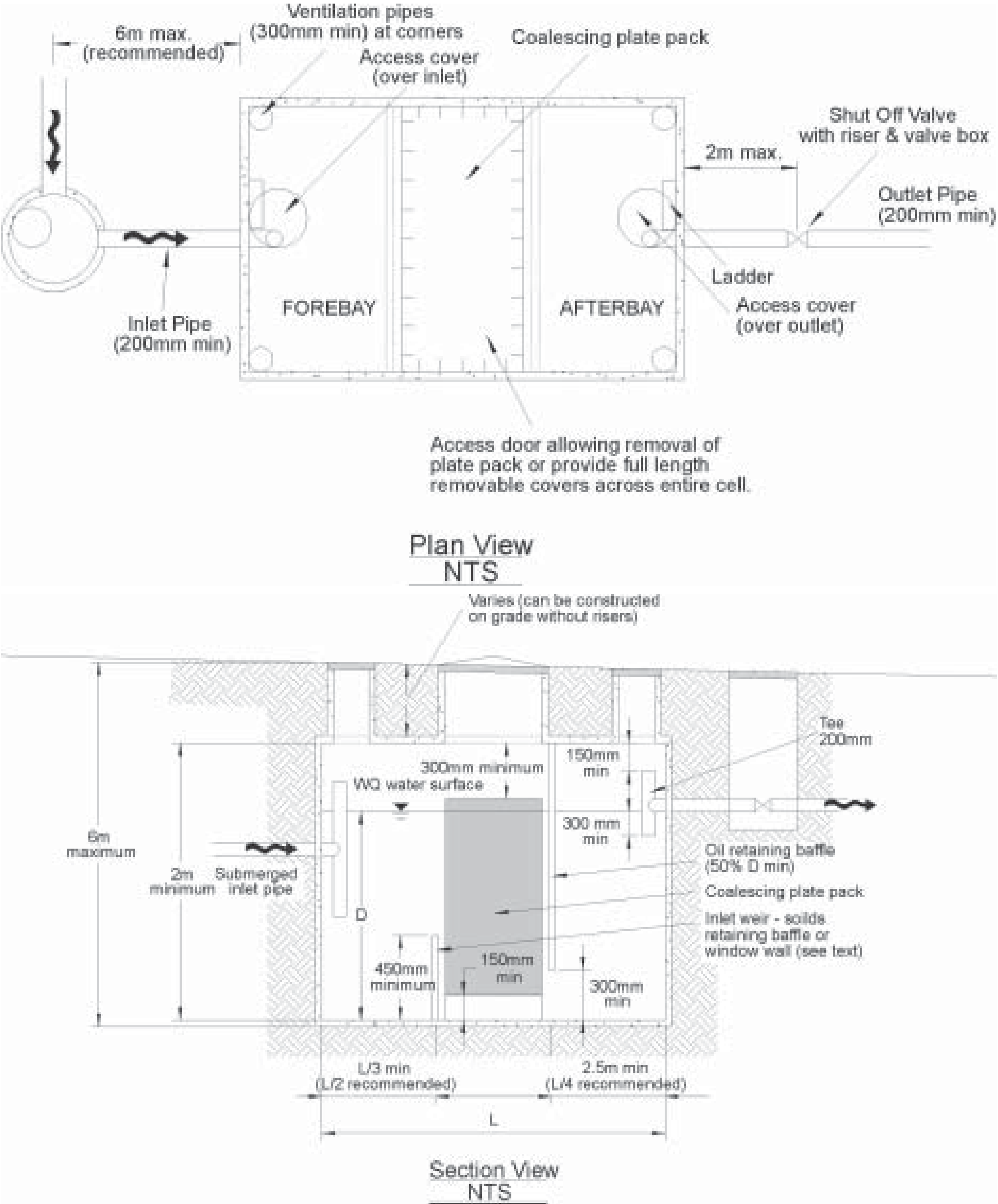
Certain contaminant "hotspots" or areas of significant contaminant generation in the urban environment produce significantly greater loadings of hydrocarbons and trace metals than other areas. Hotspots are often linked to places where vehicles are fuelled and serviced, such as petrol stations, bus depots, and vehicle maintenance areas. Others occur where many vehicles are parked for brief periods during the day (dairies, fast food restaurants, etc.) or where large numbers of vehicles are parked for a long time.

Hotspots are evident in data collected for urban cities in the U.S. (Schueler and Shepp, 1993). Their survey of oil and water separators showing the differences in the quality of pool water and trapped sediments in separators draining five different land uses is summarised in Table 10-1. Petrol stations and dairies (convenience markets) had much higher levels of hydrocarbons and metals both in the water column and the sediments. Streets and residential parking lots, on the other hand, had lower hydrocarbon and metal concentrations.

Petrol stations were found to be an extremely significant hotspot for hydrocarbons. Composite priority contaminant scans at the service station sites revealed the presence of 37 potentially toxic compounds in the sediment and 19 in the water column. Many compounds were polycyclic aromatic hydrocarbons (PAHs) that are harmful to humans and aquatic organisms.

Pitt and Field (1990) monitored metal and PAH levels in runoff from a number of sites in Alabama including

Figure 10-2
Coalescing collection plate separator schematics



vehicle service areas, parking lots, salvage yards, landscaped areas and loading docks. Although their monitoring data was variable, they reported that many of the maximum PAH and metals concentrations in runoff samples were found at vehicle service areas and parking lots, as opposed to ordinary street surfaces. Of greater concern was that nearly 60% of the hotspot runoff samples were classified as moderately to most toxic, according to their relative toxicity screening procedure.

Oil and water separators can be designed to remove oil and TPH down to 15 mg/l at any time. Their performance depends on a systematic, regular maintenance programme. Without that programme, oil and

Table 10-1
Sediment and pool water quality found in oil and water separators at various locations

Parameter	Petrol stations	Dairies	All day parking lots	Streets	Residential parking
Comparative sediment quality (reported in mg/kg of sediment)					
Total P	1,056	1,020	466	365	267
TOC	98,071	55,167	37,915	33,025	32,392
Hydrocarbons	18,155	7,003	7,114	3,482	892
Cadmium	35.6	17	13.2	13.6	13.5
Chromium	350	233	258	291	323
Copper	788	326	186	173	162
Lead	1,183	677	309	544	180
Zinc	6,785	4,025	1,580	1,800	878
Comparative pool water quality (reported in *u*g/l)					
Total P*	0.53	0.50	0.30	0.06	0.19
TOC*	95.51	26.8	20.6	9.9	15.8
Hydrocarbons*	22.0	10.9	15.4	2.9	2.4
Cadmium	15.3	7.9	6.5	ND	ND
Chromium	17.6	13.9	5.4	5.5	ND
Copper	112.6	22.1	11.6	9.5	3.6
Lead	162.4	28.8	13.0	8.2	ND
Zinc	554	201	190	92	ND

ND - Not detected   * in units of mg/l

water separators may not achieve oil and TPH removal to the required level. Pretreatment for TSS may be necessary if the inflow has sediment levels that would cause clogging or otherwise impair the long-term performance of the separator, such as from sites with high sediment loads from heavy vehicle traffic over metalled rather than from sealed areas

10.4 Design approach

In light of overseas experence that oil and water separators used for stormwater treatment have not performed to expectations, proper application, design, proper construction, prevention of coalescing plate fouling and plugging, and operation and maintenance are essential. Other treatment systems, such as sand filters or other emerging technologies should be considered for removal of insoluble oil and TPH.

The following general design criteria should be followed:

> If practicable, determine oil/grease 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. Do not use oil and 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 the water quality storm flow rate.
> Use only impervious conveyances for oil contaminated stormwater.
> Oil and water separators are not accepted for general stormwater treatment of TSS.

10.5 Design Procedure

Grease and oil which is not emulsified, dissolved or attached to sediment will be present as oil droplets of different sizes or as a surface slick.

No data are available on the size distribution of oil droplets in stormwater from commercial or industrial areas, but some data are available for petroleum products storage terminals. These data indicate that about 80% of droplets (by volume) are greater than 90 *u*m and 30% are greater than 150 *u*m in diameter.

Traditionally, 150 *u*m separation has been used, which typically results in an effluent oil and grease concentration of 50 - 60 mg/l. Typically, standards for industrial discharges in Australia are 10 - 20 mg/l, which generally corresponds to the removal of droplets larger than 60 *u*m.

Separation of the 60 *u*m droplet will be adopted as the basis for design for devices in Auckland, which corresponds to the lower tail of the droplet size distribution and should result in an effluent quality of 10 - 20 mg/l at the design flow.

The rise velocity for a 60 *u*m droplet can be calculated, given the water temperature (which affects the viscosity of the water) and the density of the oil. This rise velocity is then used in the sizing calculations for the device. At 15^{o}C and for an oil specific gravity of 0.9, the rise velocity of a 60 *u*m droplet is 0.62 m/hr and this is the recommended value for Auckland.

The use of oil specific gravity of 0.9 is considered appropriate for general use as diesel has a specific gravity of 0.85, kerosene of 0.79, and gasoline has a specific gravity of 0.75.

For other conditions, the rise velocity may be calculated according to:

$$v_r = (gD^2(1-s)) / 18\upsilon$$

where:

s	= specific gravity of the oil
D	= droplet diameter
υ	= kinematic viscosity of the water
g	= gravitational acceleration

10.5.1 Design Flow Rate for Oil and Water Separators

The required design flow rate for separators is from a rainfall intensity of 15 mm/hr. If this flow (and smaller flows) are passed through the device, then 93% of the total runoff from the catchment will be passed through the device.

The design storm intensity of 15 mm/hr was determined by analysis of 10 minute average rain intensities from the Botanic Gardens rain gauge in Auckland. The results of that analysis are given in Table 10-2 which shows the fraction of total rain depth corresponding to various rain intensities, which in turn indicates what fraction of the runoff would be passed through or captured by a separator designed to treat the runoff from a given rainfall intensity. The table shows that increasing the design intensity from 10 mm/hr to 15 mm/hr would increase the capture by 6%, while increasing from 15 mm/hr to 20 mm/hr will result in only a 2% improvement in capture. The design value of 15 mm/hr is therefore reasonable, and will result in 93% of the runoff being treated. This analysis does not take first flush effects into account, so is somewhat conservative, that is, it is expected that more than 93% of the oil in the runoff from the catchment will be passed through the separator.

The required treatment flow rate, Q_d, (the flow from 15 mm/hr of rain) can be calculated according to the rational formula:

$$Q_d = CiA_c$$

where Q_d is in m^3/hr, C is the storm runoff coefficient (1 for paved areas), A_c is the catchment area (in m^2)

Table 10-2 Fraction of total rain depth corresponding to various rain intensities	
Rain intensity (10 minute average, mm/hr)	**Fraction of total rain depth**
5	73
10	87
15	93
20	95
25	97
30	98

Note: Fraction of total rain depth is $\frac{\sum \min(i_j, I)}{\sum i_j}$

where *i* is the rainfall intensity for the *jth* record of a long set of rainfall intensity measurement, and I is the intensity of interest (the intensity in the left hand column of the table).

and i is the rainfall intensity in m/hr (i.e. 0.015 m/hr). For service stations, the catchment areas should include an allowance for rain which manages to get under the canopy by including in the site a 1 m strip under the canopy along its longest face.

10.5.2 API (American Petroleum Institute) tank sizing

The API area (A_d) is based on the rise velocity (V_r) and design flow rate (Q_d), according to the formula

$$A_d = (FQ_d)/V_r$$

Based on plug flow, the above relationship ensures that a droplet with rise velocity V_r will rise to the surface during its passage through the tank. The required rise velocity is 0.62m/hr. as discussed earlier. The factor F (dimensionless) accounts for short-circuiting and turbulence effects which degrade the performance of the tank. The factor depends on the ratio of horizontal velocity (U) to rise velocity (V_r) as shown in Table 10-3.

Table 10-3
F factor for APIs

U/V_r	F factor
15	1.64
10	1.52
6	1.37
3	1.28

The volume and area determined from this tank sizing refer to the dimensions of the main compartment of the tank. Additional volume should be allowed for inlet and outlet sections in the tank.

Other sizing details:

> $U \leq 15\ V_r$
> $0.3\ W \leq d \leq 0.5W$ (typically d = 0.5W
> 1.5 m < W < 5 m
> 0.75 m < d < 2.5 m

where d is the depth and W is the width of the tank.

Some of these dimensions will not be appropriate for smaller catchments, and may be relaxed. It is necessary, however, to keep the length at least twice the width, the depth at least 0.75 m and $U < 15V_r$ at the design flow.

To avoid re-entrainment of oil and degradation of performance, it is required that the maximum horizontal flow velocity in the main part of the tank be less than 25 m/hr.

10.5.3 Coalescing collection plate sizing

Plate separator suppliers can provide an approximate size of device to achieve 60 *u*m droplet separation at the chosen design flow rate (Q_d). As an approximation, the plan area of each plate can be calculated from the following equation.

$A_{plan} = Q_d/v_rN$ where there are N plates in the pack

Some increase in size should be allowed, to account for short-circuiting.

10.5.4 Other design considerations

Flow Bypass

The catchments draining to oil and water separators will be small and it is not recommended that larger flows bypass them. In the event of a spill, having a bypass increases the potential for spilled material to bypass the separator and enter the receiving system.

Oil retention baffles

As there is no bypass system, an inlet baffle is not required. If, for some specific reason, there is a bypass system prior to flow entering the oil and water separator, an inlet baffle must be installed. This will ensure that oil collected in the tank does not pass back into the bypass and then off-site.

Flow spreading baffles

To achieve even flow distribution across tanks at the inlet, baffled inlet ports or other devices are used. The sizing of the inlet ports or baffles should be such that some head loss is provided to spread the flow. It is recommended that velocities should be less than 0.5 m/s, at the maximum separator flow to avoid oil emulsification.

Access

Ease of access for maintenance and inspection is required. In particular, lids should be kept as lightweight as practicable.

10.6 Construction inspection

These units are prefabricated and delivered onsite as one unit. As such, construction concerns relate to the following:

1. Compaction of foundation to ensure that uneven settling will not occur
2. Elevations are correct to ensure inflow and outflow pipes are at the proper elevation

There is no requirement for an As-built plan.

10.7 Operation and maintenance

It is important to prepare, regularly update and implement an operation and maintenance plan for oil and water separators. They should be inspected monthly to ensure proper operation, and during and immediately after a large storm event (greater than 25 mm over a 24 hour period).

10.7.1 Surface oil removal

The oil which collects in the separator must be removed before the oil layer exceeds 3 mm depth. Oil may be removed after each storm in cases where it is important to remove the oil layer, but more generally oil removal may be on a regular (for example, bimonthly) basis. If it is expected that water will be drawn into the oil outlet, an auxiliary separator may be used. Also Oil may be removed by the following means:

1. Pumping or decanting of the surface oil layer in the dry period between storms, when there is no flow through the device. The invert of the orifice or slotted pipe used to withdraw the oil can be set at the separator outlet weir crest level. Since there will be no flow in the separator when the oil layer is being removed, and the oil outlet is set at the appropriate level, there should be minimal withdrawal of water as the oil is being removed.
2. Removing by decanting through an outlet (such as an orifice or slotted pipe) which is always open. The invert of the oil outlet may be set at the water level, when the separator is operating at the design flow Q_d. If the oil outlet invert is set lower, then water will be drawn into the oil outlet, (the orifice invert may be below the bottom of the oil layer, and the oil outlet is always open). If the oil outlet is set lower, then the water drawn into the outlet may be separated in an auxiliary separator.
3. Using oil absorbent pads. These will soak up some oil, which then cannot be re-entrained into the flow. Such pads will have a limited uptake capacity, and may present a disposal problem.

10.7.2 Sludge removal

Sludge deposits should be removed when the thickness exceeds 150 mm.

Sludge will collect at the base of the separator and must be removed. Such sludge may be allowed to collect in the tank until it is removed. Solids may be pumped out as a slurry.

10.7.3 Vapours

Since an oil layer may sit in the tank for some time, consideration should be given to appropriate venting for safety reasons. The Dangerous Goods Act Regulations contains further information on venting.

10.8 Case study

A service station is to be fitted with an oil separator. Runoff from the covered forecourt roof and other site areas are to be routed away from the oil and water separator and treated at an overall site stormwater management practice. The oil and water separator will have a catchment area of 300 m^2 draining to the device.

1. The separator design flow is the flow from 15 mm/hr of rain which, from the equation provided earlier, is.

$$\begin{aligned} Q_d &= CiA_c \\ &= (1.0)(300)(0.015) \\ &= 4.5\ m^3/hr \end{aligned}$$

2. The separator will be sized for a rise velocity of 0.62 m/hr. First an API will be considered. The maximum design flow velocity (U) for separation at the separator design flow is 15 V_r = 15 (0.62 m/hr) = 9.3 m/hr. Therefore the flow cross section (depth times the width) is $Q_d/U = 0.48\ m^2$. The depth is chosen to be half the width, which gives a depth of 0.49 m and a width of 0.98 m.

   This depth is smaller than recommended, so a depth of 0.75 m (the minimum recommended depth) and width of 1.5 m (twice the depth) is chosen, giving $U = Q_d/A = 4\ m/hr = 6.5\ V_r$ at the design flow. An F of 1.4 (from Table 10-3) is then used to calculate A_d, giving:

$$A_d = (FQ_d)/V_r = (1.4)(4.5)/0.62$$
$$= 10.2 \text{ m}^2$$

With this plan area and the width of 1.5 m, the length is 6.8 m. The volume of the main chamber of the tank will be 7.65 m^3 (excluding inlets and outlets). The tank will actually be longer to allow for an inlet chamber and an outlet section, which, as an approximate guide, could add an additional 20% to the total tank volume.

3. As a comparison, a 5 m^3/hr plate separator has a footprint of 2.0 m^2 (compare to, say 12.5 m^2 for the API tank) and a height of 0.56 m, which demonstrates the reduction in size for a plate separator.

4. A plate separator is therefore adopted in this example.

10.9 Bibliography

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