APPENDIX 5

SEPARATOR DESIGN METHODOLOGIES

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This appendix deals with the design of oil-water separators. Appendix 5.1 gives the design calculations for API separators; Appendix 5.2 deals with parallel plate separators; and Appendix 5.3 presents the basic equations for separator design.

Appendices 5.1-5.3 are extracts from API Publication 421 - *Design and Operation of Oil-Water Separators* (first edition, February 1990), but to better reflect the New Zealand situation, the text has been modified as follows:

- dimensions have been converted from imperial to metric (SI) units
- oil/water separator diagrams have been chosen to reflect the state of the art in the New Zealand Petroleum industry
- other departures from the API publication have been underlined

A5.1 Step-by-Step Design Calculations for API Separators

API has established certain design criteria for determining the various critical dimensions and physical features of a separator. These are presented below in a series of step-by-step design calculations. The derivations of the basic equations for oil-water separator design are given in Appendix 5.3.

Oil-water separation theory is based on the rise rate of the oil globules (vertical velocity) and its relationship to the surface-loading rate of the separator. The rise rate is the velocity at which oil particles move toward the separator surface as a result of the differential density of the oil and the aqueous phase of the wastewater. The surface-loading rate is ratio of the flow rate to the separator to the surface area of the separator. The required surface-loading rate for removal of a specified size of oil droplet can be determined from the equation for rise rate.

A5.1.1 General

The following parameters are required for the design of an oil-water separator:

a. Design flow (Q_m), the maximum wastewater flow. The design flow should include allowance for plant expansion and stormwater runoff, if applicable.

b. Wastewater temperature. Lower temperatures are used for conservative design.

c. Wastewater specific gravity (S_w).

d. Wastewater absolute (dynamic) viscosity (μ). Note: Kinematic viscosity (ν) of a fluid of density (ρ) is $\nu = \mu / \rho$.

e. Wastewater oil-fraction specific gravity (S_o). Higher values are used for conservative design.

f. Globule size to be removed. The nominal size is 0.015 centimetres (150 micrometres), although other values can be used if indicated by specific data.

The design of conventional separators is subject to the following constraints:

a. Horizontal velocity (V_H) through the separator should be less than or equal to 1.5 cm/s (0.015 m/s) or equal to 15 times the rise rate of the oil globules (V_t), whichever is smaller.

b. Separator water depth (*d*) should not be less than 1 m, to minimise turbulence caused by oil/sludge flight scrapers and high flows. Additional depth may be necessary for installations equipped with flight scrapers. It is usually not common practice to exceed a water depth of 2.4 m.

c. The ratio of separator depth to separator width (d/B) typically ranges from 0.3 to 0.5 in refinery services.

d. Separator width (B) is typically between 1.8 and 6 m in refinery services. Note: Typical sizes at Petroleum Industry sites in New Zealand are smaller.

e. By providing two separator channels, one channel is available for use when it becomes necessary to remove the other from service for repair or cleaning. In New Zealand Petroleum Industry applications, one channel is usually sufficient.

f. The amount of freeboard specified should be based on consideration of the type of cover to be installed and the maximum hydraulic surge used for design.

g. A length-to-width ratio (L/B) of at least 5 is suggested to provide more uniform flow distribution and to minimise the effects of inlet and outlet turbulence on the main separator channel. This requirement has not been considered necessary for the New Zealand Petroleum Industry sites and a TOTAL length to breadth ratio of at least 2 is preferred.

Figure A5.1.1 shows a typical oil-water separator and depicts the design variables listed above.

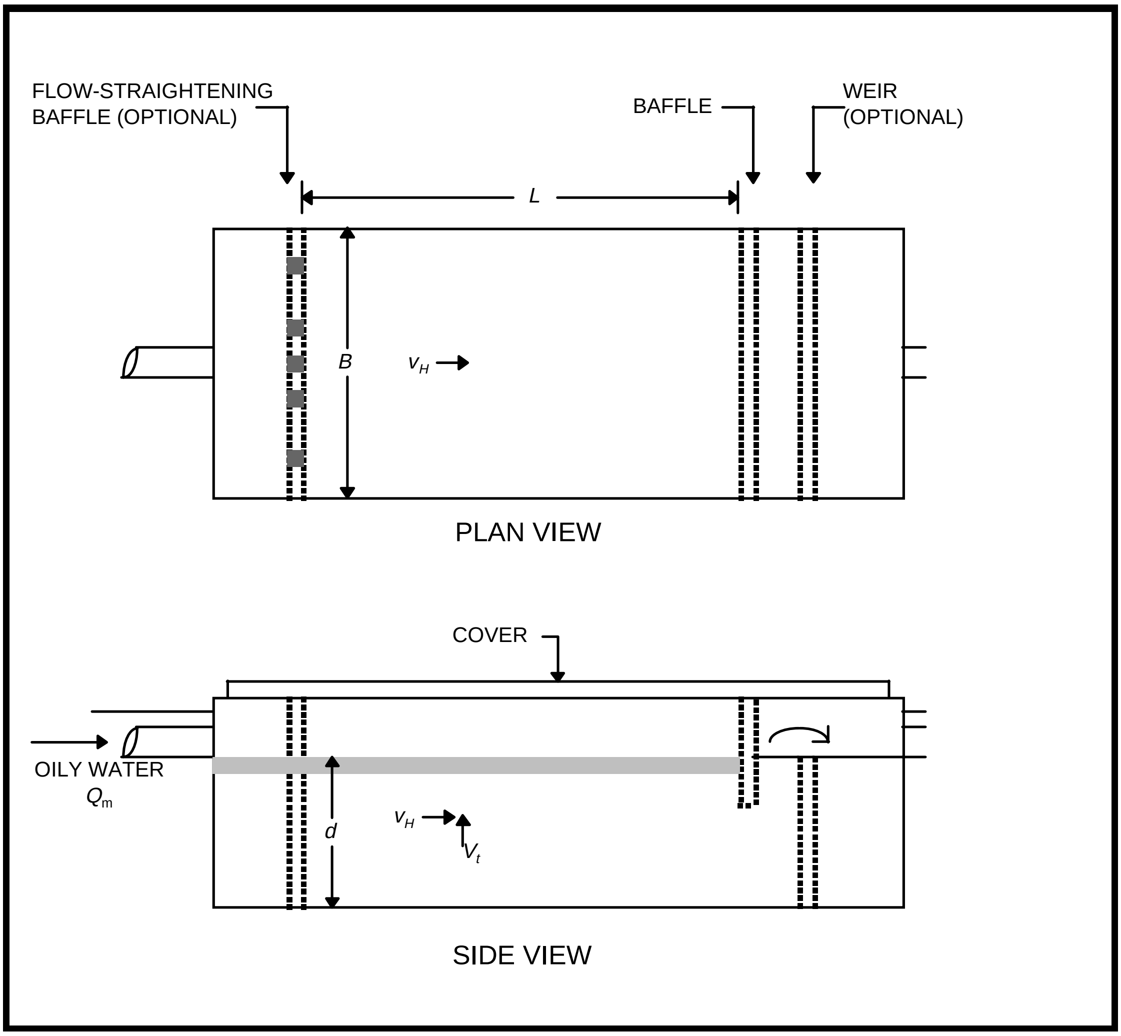

Figure A5.1.1. Design variables for oil interceptors.

The oil-globule rise rate (V_t) can be calculated by Equation 1 or 2 shown below. Equation 1 should be used when the target diameter of the oil globules to be removed is known to be other than 0.015 cm and represents a typical design approach. Equation 2 assumes an oil globule size of 0.015 cm.

$$V_t = \frac{g}{18\mu}(\rho_w - \rho_o)D^2 \quad (1)$$

$$V_t = 0.0123\left(\frac{S_w - S_o}{\mu}\right) \quad \text{(where } D = 0.015 \text{ cm)} \quad (2)$$

where:

V_t = vertical velocity, or rise rate, of the design oil globule, in cm/s.

g = acceleration due to gravity (981 cm/s^2).

μ = absolute viscosity of wastewater at the design temperature, in poise. Note: 1 P = 1 g/cm.s; 10 P = 1 Pa.s.

ρ_w = density of water at the design temperature, in g/cm^3. Note: 1 g/cm^3 = 1 kg/litre.

ρ_o = density of oil at the design temperature, in g/cm^3.

D = diameter of the oil globule to be removed, in cm.

S_w = specific gravity of the wastewater at the design temperature (dimensionless).

S_o = specific gravity of the oil present in the wastewater (dimensionless, not degrees API).

Alternatively, if using kinematic viscosity, Equations 1 and 2 may be rearranged as follows:

$$V_t = \frac{g}{18\nu}\left(1 - S_o\right)D^2 \qquad \text{(1a)}$$

$$V_t = 0.0123\left(\frac{1 - S_o}{\nu}\right) \qquad \text{(where } D = 0.015 \text{ cm)} \qquad \text{(2a)}$$

where:

ν = kinematic viscosity of the wastewater at design temperature, in Stokes. Note: 1 Stoke = 1 cm^2/s; 10,000 Stokes = 1 m^2/s.

Once the oil-globule rise rate (V_t) has been obtained from Equation 1 or 2, the remaining design calculations may be carried out as described in Sections A5.1.2 - A5.1.7.

A5.1.2 Horizontal Velocity (v_H)

The design mean horizontal velocity is defined by the smaller of the values for v_H in cm/s obtained from the following two constraints:

$$v_H = 15V_t \leq 1.5 \qquad \text{(3)}$$

These constraints have been established based on operating experience with oil-water separators. Although some separators may be able to operate at higher velocities, 1.5 cm/s has been selected as a recommended upper limit for conventional refinery oil-water separators. Most refinery process-water separators operate at horizontal velocities much less than 1.5 cm/s at average flow. All separators surveyed by the API in 1985 had average horizontal velocities of less than 1 cm/s, and more than half had average velocities less than 0.5 cm/s, based on typical or average flow rates. Maximum flow rates were not reported in the survey; however, design flow rates were typically 1.5-3 times the typical average flow rates.

A5.1.3 Minimum Vertical Cross-Sectional Area (A_c)

Using the design flow to the separator (Q_m) and the selected value for horizontal velocity (v_H), the minimum total cross-sectional area of the separator (A_c) can be determined from the following equation:

$$A_c = \frac{Q_m \times 100}{v_H} \qquad (4)$$

Where :

A_c = minimum vertical cross-sectional area, in m^2.

Q_m = design flow to the separator, in m^3/s.

v_H = horizontal velocity, in cm/s.

Note: The 100 factor is to convert from cm/s to m/s.

A5.1.4 Number of Separator Channels Required (n)

Not applicable to this document. In New Zealand oil industry applications, one channel is usually sufficient, i.e., assume $n = 1$.

A5.1.5 Channel Width and Depth

Given the total cross-sectional area of the channels (A_c) and the number of channels desired (n), the width and depth of each channel can be determined. A channel width (B), generally between 1.8 - 6 m, should be substituted into the following equation, solving for depth (d):

$$d = \frac{A_c}{Bn} \qquad (6)$$

where:

d = depth of channel, in m.

A_c = minimum vertical cross-sectional area, in m^2.

B = width of channel, in m.

n = number of channels (dimensionless) = 1.

The channel depth obtained should conform to the accepted ranges for depth (1-2.4 m) and for the depth to width ratio (0.3-0.5).

A5.1.6 Separator Length

Once the separator depth and width have been determined, the final dimension, the channel length (L), is found using the following equation:

$$L = F\left(\frac{v_H}{V_t}\right)d \qquad (7)$$

where:

L = length of channel, in m.

F = turbulence and short-circuiting factor (dimensionless), see Figure 2.

v_H = horizontal velocity, in cm/s.

V_t = vertical velocity of the design oil globule, in cm/s.

d = depth of channel, in m.

If necessary, the separator's length should be adjusted to be at least five times its width, to minimise the disturbing effects of the inlet and outlet zones.

Equation 7 is derived from several basic separator relations:

a. The equation for horizontal velocity ($v_H = Q_m/A_c/$), where A_c is the minimum total cross-sectional area of the separator.

b. The equation for surface-loading rate ($V_t = Q_m/A_H$), where A_H is the minimum total surface area of the separator.

c. Two geometrical relations for separator surface and cross-section area ($A_H = LBn$ and $A_c = dBn$), where n is the number of separator channels.

A derivation of this equation is given in Appendix 5.3.

The turbulence and short-circuiting factor (F) is a composite of an experimentally determined short-cutting factor of 1.21 and a turbulence factor whose value depends on the ratio of mean horizontal velocity (v_H) to the rise rate of the oil globules (V_t). A graph of F versus the ratio v_H/V_t is given in Figure A5.1.2; the data used to generate the graph are also given below.

v_H/V_t	Turbulence factor (F_t)	F=1.2F_t
3	1.07	1.28
6	1.14	1.37
10	1.27	1.52
15	1.37	1.64
20	1.45	1.74

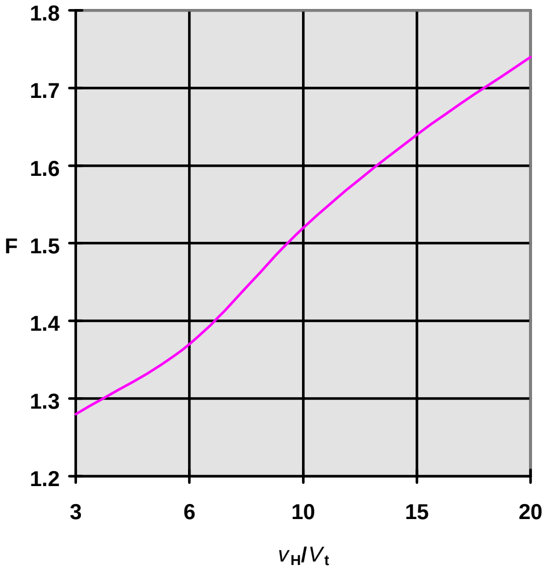

Figure A5.1.2. Recommended values of F for various values of V_h/V_t

A5.1.7 Minimum Horizontal Area

In an ideal separator - one in which there is no short-circuiting, turbulence, or eddies - the removal of a given suspension is a function of the overflow rate, that is, the flow rate divided by the surface area. The overflow rate has the dimensions of velocity. In an ideal separator, any oil globule whose rise rate is greater than or equal to the overflow rate will be removed. This means that any particle whose rise rate is greater than or equal to the water depth divided by the retention time will reach the surface, even if it starts from the bottom of the chamber. When the rise rate is equal to the overflow rate, this relationship is expressed as follows:

$$V_t = \frac{d_i}{T_i} = \frac{100 d_i}{\frac{L_i B_i d_i}{Q_m}} = \frac{100 Q_m}{L_i B_i} = v_o \qquad (8)$$

where:

d_i = depth of wastewater in an ideal separator, in cm.

t_i = retention time in an ideal separator, in s.

L_i = length of an ideal separator, in cm.

B_i = width of an ideal separator, in cm.

Q_m = design flow to the separator, in m^3/s.

v_o = overflow rate, in cm/s.

Note: The 100 factor is to convert from cm/s to m/s.

Equation 8 establishes that the surface area required for an ideal separator is equal to the flow of wastewater divided by the rise rate of the oil globules, regardless of any given or assigned depth.

By taking into account the design factor (*F*), the minimum horizontal area (A_H), is obtained as follows:

$$A_H = F\left(\frac{Q_m \times 100}{V_t}\right) \qquad (9)$$

where:

A_H = minimum horizontal area, in m^2.

F = turbulence and short-circuiting factor (dimensionless), see Figure A5.1.2.

Q_m = wastewater flow, in m^3/s.

V_t = vertical velocity of the design oil globule, in cm/s.

A5.2 Parallel-Plate Separators[1,2,3,4]

A5.2.1 Introduction

The efficiency of an oil-water separator is inversely proportional to the ratio of its discharge rate to the unit's surface area. A separator's surface area can be increased by the installation of parallel plates in the separator chamber. The resulting parallel-plate separator will have a surface area increased by the sum of the horizontal projections of the plates added. In cases where available space for a separator is limited, the extra surface area provided by a more compact parallel-plate unit makes the parallel-plate separator an attractive alternative to the conventional separator. Flow through a parallel-plate unit can be two to three times that of an equivalent conventional separator. According to vendors, the spatial requirements of oil-water separators can be reduced up to twofold on width and tenfold on length when a parallel-plate unit is used in place of a conventional one. Current refinery experience using parallel-plate separators on a large scale is not very extensive, however.

In addition to increasing separator surface area, the presence of parallel plates may decrease tendencies toward short-circuiting and reduce turbulence in the separator, thus improving efficiency. The plates are usually installed in an inclined position to encourage oil collected on the undersides of the plates to move toward the surface of the separator, whereas sludge collected on the plates will gravitate toward the bottom of the separator. To improve oil and sludge collection, the plates are usually corrugated. For downflow separators (see Section 5.2.6), vertical gutters adjacent to the plates allow segregation of the separated oil and sludge fractions from the influent stream; these vertical gutters are located at both ends of the plate pack. At the lower (effluent) end of the plate pack, the vertical gutters are placed adjacent to the "valleys" in the corrugated plates to help channel sludge downward. At the higher (influent) end of the plate pack, these gutters are placed adjacent to the "peaks" in the corrugated plates to help convey oil to the surface.

Oil collected from parallel-plate systems is said to have a lower water content than that removed from conventional separators, and the overall effluent oil content has been reported to be up to 60% lower for parallel-plate systems, with a higher proportion of small oil droplets recovered[1].

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[1] J.J. Brunsmann, J. Cornelissen, and H. Eilers, "Improved Oil Separation in Gravity Separators, " *Journal of the Water Pollution Control Federation*, 1962, Volume 34, Number 1, pp. 44-55.

[2] "Tilted-Plate Separator Effortlessly Purifies Water," *Chemical Engineering,* 1969, Volume 76, Number 2, pp. 102-104.

[3] E.C. Shaw and W.L. Caughman, Jr., The Parallel Plate Interceptor, *NLGI Spokesman*, 1970, Volume 33, Number 11, pp. 395-399.

[4] S.J. Thomson, "Report of Investigation on Gravity-Type Oil-Water Separators," *Proceedings of the 28th Industrial Waste Conference*, Purdue University, 1973, pp. 558-563.

A5.2.2 Design

Typical ranges for the basic design variables of parallel-plate separation are given in Table A5.2.1 below.

Table A5.2.1. Typical ranges for the basic design variables of parallel-plate separators.

Variable	Range
Perpendicular distance between plates	2-4 cm
Angle of plate inclination from the horizontal	45^o - 60^o
Type of oil removed	Free oil only
Direction of wastewater flow	Crossflow, downflow

Even with the knowledge of acceptable values for these separator design parameters, it is difficult, if not impossible, to specify a set procedure for the detailed design of parallel-plate separator systems. Manufacturers have empirically determined that certain plate-inclination, flow-pattern and spacing configurations are most effective at removal of free oil over a given range of oily-wastewater conditions. Although in practice a design range is used for these variables as shown in Table A5.2.1, the values used can only be empirically justified. Refinery and vendor experience is the best basis for choosing a value for these empirical parameters that is appropriate for the wastewater being treated.

The determination of the surface area required for the plate pack and the number of packs needed is theoretically based and is standard for most parallel-place configurations. A procedure for determining these parameters is given in Section 5.2.3.

A5.2.3 Wastewater Characteristics Required for Separator Sizing

In general, the parameters used for design of conventional separators are also used for sizing of parallel-plate system maximum (design) wastewater flow, specific gravity and viscosity of the waste water’s aqueous phase, and specific gravity of the wastewater oil. An oil-globule size distribution is also useful to determine a design oil-globule size, but in the absence of such data, a design globule diameter of 60 micrometres (0.006 cm) can be assumed. Conventional oil-water separators are designed to achieve complete capture of oil globules 150 micrometres (0.015 cm) and larger in diameter. Because of the greatly increased effective surface area of parallel-plate separators they have been designed to achieve satisfactory effluent quality based on complete removal of oil globules 60 micrometres and larger in diameter. As with conventional separators, wastewater flow should include primarily process flow with allowance for stormwater flow and facility expansion where appropriate. The oil’s specific gravity should reflect cold-weather conditions.

A5.2.4 Parallel-Plate Surface Area[5,6]

Several equations have been set forth for sizing the surface area of parallel plates. In general, their basis is Stokes' law. As with conventional separators, the oil globules' rise rate can be equated with the surface-loading rate (Q_m/A_H), assuming a design mean oil-globule diameter of 60 micrometres:

$$\frac{Q_m}{A_H} = 0.00196\frac{(S_w - S_o)}{\mu} \qquad (10)$$

Where:

Q_m = design flow, in m^3/s.

A_H = horizontal separator area, in m^2.

S_w = specific gravity of the waste water's aqueous phase (dimensionless).

S_o = specific gravity of the waste water's oil phase (dimensionless).

μ = waste water's absolute (dynamic) viscosity, in poise. (Note: 1 P = 1 g/cm.s; 10 P = 1 Pa.s).

Solving Equation 9 for A_H provides the total surface area required to separate oil globules with a design diameter of 60 micrometres from the wastewater under a given set of influent conditions.

The number and area configuration of plates required, in conjunction with the open (not plate-filled) surface area of the separator (if significant), comprise the total required surface area, A_H. Owing to the great variability among manufacturers with respect to plate size, spacing, and inclination, it is strongly recommended that a vendor be consulted for specification of these parameters.

Packaged parallel-plate separators are often not in a rectangular configuration. Sludge hoppers, tapered walls, and inlet and outlet arrangements to minimise turbulence vary from supplier to supplier. If a new parallel-plate installation or a major retrofit of an existing unit is contemplated, it may be appropriate to work closely with the equipment supplier during the preliminary and detailed engineering phases. Treatability pilot testing of parallel-plate units is available and highly recommended. Process problems (for example, oil and solids removal, clogging) can be diagnosed at this time and taken into account in equipment selection and separator design.

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[5] G.J. Iggleden, "The Design and Application of Tilted Plate Separator Oil Interceptors, *Chemistry and Industry,* November 4, 1978, pp. 826-831.

[6] J.G. Miranda, "Designing Parallel-Plate Separators," *Chemical Engineering,* 1977, Volume 84, Number 2, pp. 105-107

A5.2.5 Maintenance

Parallel-plate units may experience clogging problems if the plate inclination is too shallow or the plate-to-plate spacing is too narrow. It has also been reported that sand entering the plate system can collect at the entrance to the plate assembly and reduce flow through the lower plate sections. Should blockages develop, they may be cleared by removing the accumulated solids, flushing the plate pack with water or air, or mechanical cleaning. Operating and maintenance manuals and equipment suppliers should be consulted with regard to approved procedures. Solids accumulation and clogging should be considered before installation and designed for accordingly.

Parallel-plate packs do not generally clog if they are properly designed, installed, and maintained. If significant solids levels are expected, the plate inclination should be about 60^o, which exceeds the angle of repose of practically all solids encountered in such systems. A plate slope of 60^o and periodic blowdown of accumulated solids should help to avoid most parallel-plate separator plugging problems.

A5.2.6 Construction Details

A variety of parallel-plate equipment configurations are commercially available. In the case of conventional separators retrofitted with parallel plates few, if any, additional fitments are required in addition to those already present. New parallel-plate separators have a wide range of design features and may be purchased as packaged units, with oil and sludge-drawoff equipment provided. Consequently, specific construction and fitment details are omitted from this subsection.

Two major types of parallel-plate separators are marketed: the cross-flow inclined plate and the down-flow inclined plate. Cross-flow separators that employ parallel plates oriented vertically and horizontally are also available, although there are few applications for them in refineries.

In a cross-flow separator, shown in Figure A5.2.1, flow enters the plate section from the side and flows horizontally between the plates. Oil and sludge accumulate on the plate surfaces above and below the wastewater flowing between the plates. As the oil and sludge build up, the oil globules rise to the separator surface and sludge gravitates toward the separator bottom.

In a down-flow separator, the wastewater flows down between the parallel plates, sludge deposited on the lower plates flows to the bottom of the separator, and oil accumulated beneath the upper plates flows counter-current to the waste flow to the top of the separator.

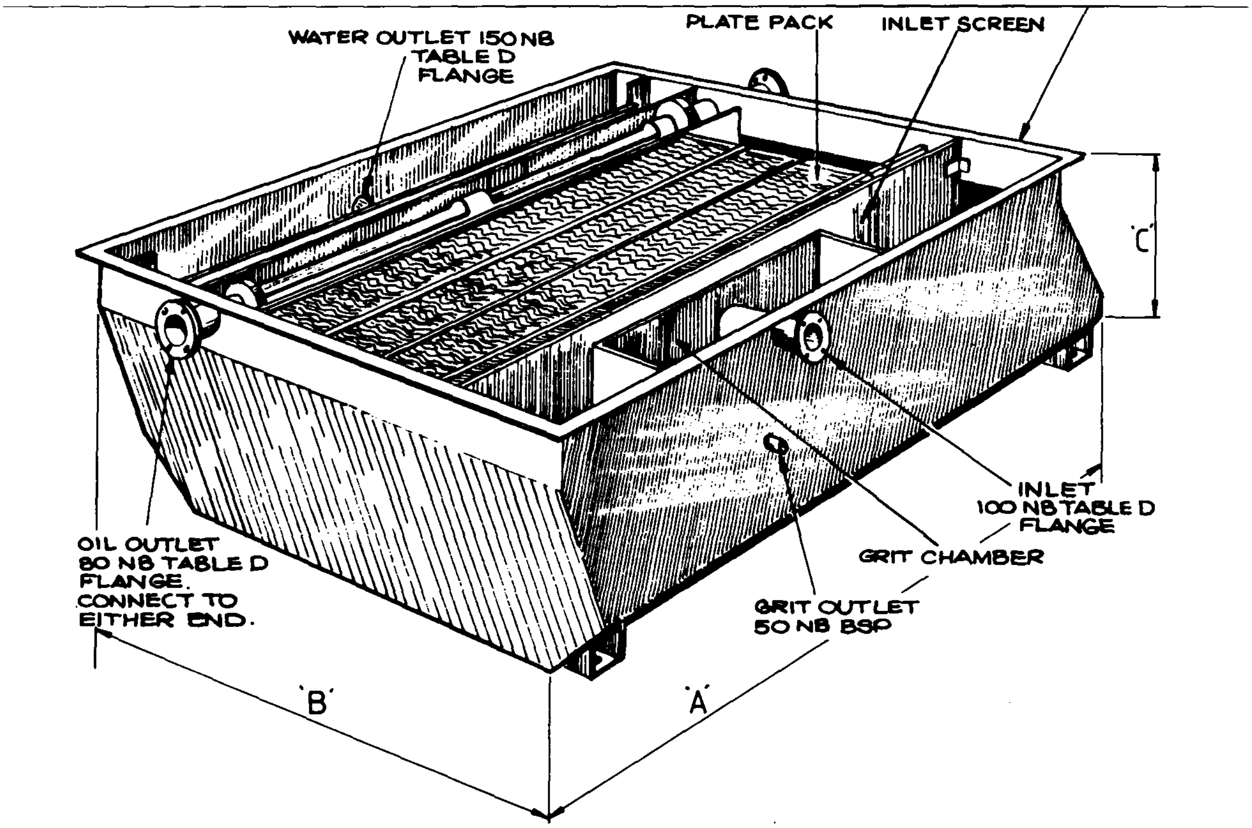

Figure A5.2.1. Parallel plate separator - cross-flow type.

[This illustration has been reproduced by courtesy of Sepa Waste Water Treatment Pty. Ltd., Australia]

A5.3 Derivation of Basic Equations for Design of Oil-Water Separators

A5.3.1 Terminal Velocity of Oil Globules in Water

The basic principles of separation by gravity differential can be expressed mathematically and applied quantitatively. When a particle is allowed to move freely in a fluid and is subjected to gravitational force, its rising or settling velocity with respect to the fluid becomes a constant when the resistance to motion equals the weight of the particle in the fluid. In other words, the resistance to motion of a particle in a liquid medium is equal to the effective weight of the particle when the terminal velocity has been reached, namely, when the acceleration caused by gravity becomes zero. The general equation for this resistance, first proposed by Newton, is as follows:

$$D_{\mathrm{f}} = CA\left(\frac{\rho_{\mathrm{w}} V^2}{2}\right) \tag{11}$$

where:

D_{f} = particle's resistance to motion in a liquid medium, in dynes.

C = coefficient of drag (dimensionless).

A = projected area of the oil globule in cm^2.

ρ_{w} = density of water, in g/cm^3.

V = terminal velocity of the oil globule in water, in cm/s.

The equation for the effective weight of the particle is as follows:

$$W = \left(\frac{\pi D^3}{6}\right)(\rho_{\mathrm{w}} - \rho_{\mathrm{o}})g \tag{12}$$

where:

W = effective weight of the oil globule in water, in dynes.

D = diameter of the oil globule, in cm.

ρ_{o} = density of the oil globule, in g/cm^3.

g = acceleration caused by the force of gravity (981 cm/s^2).

Equating Equations 11 and 12, then:

$$CA\left(\frac{\rho_{\mathrm{w}} V^2}{2}\right) = \left(\frac{\pi D^3}{6}\right)(\rho_{\mathrm{w}} - \rho_{\mathrm{o}})g \tag{13}$$

Given that, for a sphere,

$$A = \frac{\pi D^2}{4} \tag{14}$$

then the rate of rise is as follows:

$$V = \sqrt{\left(\frac{4D}{3}\right)\left[\frac{(\rho_w - \rho_o)g}{C\rho_w}\right]} \qquad (15)$$

The equation for the resistance to motion of a small spherical particle at its terminal velocity is as follows:

$$D_f = 3\pi\mu VD \qquad (16)$$

Where:

μ = absolute viscosity of wastewater at the design temperature, in poises.

If W in Equation 12 is equated to D_f in Equation 16, a new expression for V is obtained. By the substitution of V_t, the oil globules' velocity of rise (in cm/s) for the general term V, the well-known form of Stokes' law for the terminal velocity of spheres in a liquid medium becomes applicable to the rate of rise of oil globules in water.

$$V_t = \left(\frac{g}{18\mu}\right)(\rho_w - \rho_o)D^2 \qquad (17)$$

Equation 17 should theoretically include a deformation coefficient that depends on the relative viscosities of the oil and the water; however, in practice, the coefficient is not required to estimate the rate of rise of small oil globules in wastewater.

Note: Theoretically, consideration should be given to the deformation of an oil globule as it rises through a liquid medium, because of a change of shape caused by its contact with the liquid through which it is rising. This change of shape results from internal flow so that the particle's resistance to motion is minimised and a higher rise rate results. W.N. Bond[7] has expressed this effect in terms of the viscosities of the particle and the medium as follows:

$$C_v = \frac{\frac{2}{3} + \frac{\mu_1}{\mu_2}}{1 + \frac{\mu_1}{\mu_2}}$$

[7] WN Bond, "Bubbles and Drops and Stokes' Law", *The Philosophical Magazine*, November 1927, Series 7, Volume 4, Number 24, pp.889-898.

where:

C_v = *deformation coefficient theoretically applicable to Equation 17, (dimensionless), see the following equation.*

μ_1 = *absolute viscosity of the particle, in poises.*

μ_2 = *absolute viscosity of the medium, in poises.*

If this correction for internal flow is applied to Equation 17, Stokes' law for determining the rate of rise of an oil particle in water would become the following:

$$v_t = \left(\frac{1}{C_v}\right)\left(\frac{1}{18}\right)\left(\frac{g}{\mu}\right)(\rho_w - \rho_o)D^2$$

where:

v_t = *rise rate of oil globule (0.015 cm in diameter) in wastewater, in cm/s.*

However, in the application of this equation to the design of wastewater separators, the factor 1/C_v *may be omitted for practical purposes, because its value is very close to unity for the viscosities of oil to be separated from refinery wastewaters.*

Equations 16 and 17 are strictly correct only when the rising particle's Reynolds number (based on the particle diameter) is less than 0.5. For the range of Reynolds numbers resulting from the computations in this chapter (all substantially less than unity), however, the deviation from Stokes' law is negligible for design purposes.

A5.3.2 Size and Gravity of Oil Globules

The applicability of Equation 17 to oil globules in wastewater has been investigated. From the results of experiments and from plant operating data, it has been determined that the design of wastewater separators should be based on the rise rate of oil globules with a diameter of 0.015 cm (150 micrometres).

With a value of 0.015 for *D* in Equation 17, the rise rate of such oil globules in wastewater may be expressed as follows:

$$V_t = 0.0123\left(\frac{S_w - S_o}{\mu}\right) \qquad (18)$$

where:

V_t = rise rate of oil globule (0.015 cm in diameter) in wastewater, in cm/s.

S_w = specific gravity of wastewater at the design temperature of flow.

S_o = specific gravity of oil in wastewater at the design temperature of flow.

Note: S_w and S_o are specific gravities and are nearly the same numerically but differ dimensionally from ρ_w and ρ_o which they replace.

To check the dimensions of this formula, it is necessary to note that the number 0.0123 was obtained from dimensional factors and therefore has the dimensions of its factors, which are as follows:

$$\left(\frac{981cm}{\sec^2}\right)\left(\frac{1}{18}\right)\left(0.000225cm^2\right) = \frac{0.0123cm^3}{\sec^2}$$

If the globule diameter is 60 micrometres (i.e., D = 0.006), the factor is 0.0020, rather than 0.0123.

A5.3.3 Derivation of Equation for Separator Length

Separator length is calculated from the following equation:

$$L = F\left(\frac{\sqrt{H}}{\sqrt{t}}\right)d \qquad (19)$$

The basic equations used to derive the equation for separator length are as follows:

$$A_H = \frac{FQ_m}{\sqrt{t}} \qquad (20)$$

$$A_c = \frac{Q_m}{\sqrt{H}} \qquad (21)$$

$$A_c = dBn \qquad (22)$$

Equation 19 is derived from Equations 20, 21, and 22 as follows:

$$L = \frac{A_H}{Bn}$$

$$= \frac{A_H}{\frac{A_c}{d}}$$

$$= \frac{A_H d}{A_c}$$

$$= \frac{\frac{FQ_m}{\sqrt{t}} d}{\frac{Q_m}{\sqrt{H}}}$$

$$= F\left(\frac{\sqrt{H}}{\sqrt{t}}\right)d$$

where:

A_H = total separator surface area.

L = length of separator channel.

B = width of separator channel.

n = number of separator channels.

F = turbulence and short-circuiting factor (dimensionless).

Q_m = total design flow to the separator.

$\sqrt{t}$ = separator's surface-loading rate.

A_c = separator's total cross-sectional area.

$\sqrt{H}$ = separator's horizontal velocity.

d = depth of separator channel.