

DEP SPECIFICATION

LIQUID/LIQUID AND GAS/LIQUID/LIQUID SEPARATORS - TYPE SELECTION AND DESIGN RULES

DEP 31.22.05.12-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the selection and design of liquid/liquid and three-phase (gas/liquid/liquid) separators. Design rules are given only for **vessel** separators. Settling tanks, e.g., those used for the dewatering of crude, and basin-type settlers such as the API interceptor used for de-oiling of oil-contaminated surface water, are excluded from the scope of this DEP.

The scope is further focused on the use of separators in duties in which settling is the controlling factor in the separation process, i.e., separation of coarse dispersions with a relatively low dispersed phase concentration and relatively low liquid viscosities. The design of production separators for the removal of gas and water from crude oil, and settlers in mixer/settler plants require a different approach, see (Appendix I) and example V.4.

Also excluded from the scope of this DEP are gas/liquid separators; these are covered by DEP 31.22.05.11-Gen. (which is also applicable to the gas/liquid separation part of three-phase separators).

In this DEP two-phase and three-phase separators are also referred to as two-phase and three-phase settlers, respectively. The term "settling" will also be used for the separation of light-phase droplets in this DEP in order to be consistent with the term "settlers" which is used both for the separation of light-phase and heavy-phase droplets.

Design rules are given for the following types of separators (or settlers):

- L/L separators in (3):
 - Horizontal open settler
 - Horizontal settler with plate pack
 - Coalescers (with either a coalescer bed, mat or cartridges)
- G/L/L separators in (4):
 - Horizontal open settler
 - Plate pack settlers (both horizontal and vertical)

Users of this DEP should first consult (2) to make an initial selection of a suitable type of separator for a given duty.

After selection of the desired separator, the design rules can be obtained from either (3) or (4).

Information on the vessel internals, L/L separation mechanism and the vessel sizing calculation schemes are given in the Appendices.

This DEP is a revision of the DEP with the same number dated January 2008; a summary of the main changes is given in (1.5).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Abbreviations and symbols

1.3.2.1 General

Unless explicitly stated otherwise, all abbreviations and symbols used in this DEP are expressed in the units given below.

1.3.2.2 Abbreviations

Abbreviation	Definition	Unit
A	Area	m ²
BTL	bottom tangent line	
conc	local volumetric fraction of dispersed phase	-
D	internal diameter of vessel, skirt, large pipe, etc. (if no subscript, internal diameter of vessel)	m
d	diameter of pipe, nozzle, bubble or droplet plate distance (e.g. of plates in plate pack)	m
F	correction factor (in plate pack design)	-
Fr _G	gas Froude number: $Fr_G = v_G \sqrt{\frac{\rho_G}{(\rho_L - \rho_G)gD}}$	-
Fr _L	liquid Froude number: $Fr_L = v_L \sqrt{\frac{\rho_L}{(\rho_L - \rho_G)gD}}$	-
f	correction factor	-
G	gas	
g	acceleration due to gravity	m/s ²
H	height	m

Abbreviation	Definition	Unit
h	height of vessel for liquid hold-up (to LZA(HH))	m
ID	inside diameter	m
IL	interface level (normally used for L/L interface)	
L	length	m
	liquid	
LA(H)	high level pre-alarm	
LA(L)	low level pre-alarm	
LZA(HH)	high level trip	
LZA(LL)	low level trip	
NFA	net free area	-
NL	normal level	
$\max(a_1, a_2)$	maximum value of the numbers a_1 and a_2	
$\min(a_1, a_2)$	minimum value of the numbers a_1 and a_2	
n	number	
P	pressure	Pa
p	pressure	Pa
Q	volumetric flow rate	m ³ /s
Re	Reynolds number: $Re = \rho v d_H / \eta$	-
SMS	Shell-proprietary G/L separator with Schoepentoeter™, Mistmat and Swirldeck	
TFC	Shell Twin-Flange Coalescer	
TTL	top tangent line	
t	thickness (e.g., of plates in plate pack)	m
	duration	sec
V	volume	m ³
v	velocity	m/s
W	width	m
w	width	m
X	distance	m

1.3.2.3 Greek symbols

Symbol	Definition	Unit
α	ratio of the short and long axes of the vessel head	
Δ	difference (used in conjunction with other symbols)	
η	dynamic viscosity	Pa.s
θ	angle	degrees
λ	load factor	m/s

Symbol	Definition	Unit
λ_G	gas load factor: $\lambda_G = \frac{Q_G}{A_G} \sqrt{\frac{\rho_G}{(\rho_l - \rho_G)}}$	m/s
ρ	density	kg/m ³
φ	liquid flux = Q_L/A_L	m/s
σ	interfacial tension	N/m

1.3.2.4 Subscripts

Term	Definition
ax	Axial
bed	coalescer bed
d	dispersed phase
c	continuous phase
col	collection compartment
coleff	effective length of collection compartment
con	control requirements or specific control band
conc	local volumetric fraction of dispersed phase
contot	total control band
crit	Critical
cs	cross section or cross-sectional area
db	dispersion band
dh	droplet of heavy liquid phase
dl	droplet of light liquid phase
f	front
feed	feed flow
fp	feed pipe (perforated) front plate of L/L separation plate pack
fw	front weir of a collection compartment
G	gas
H	hydraulic diameter
h	heavy liquid phase
hd	header
in	inlet
int	L/L interface
L	liquid (in general)
l	light liquid phase
laminar	laminar flow
loss	part of plate pack front face available for flow

Term	Definition
low	lower part
m	mixture
max	maximum
min	minimum
out	outlet
ow	overflow weir of a collection compartment in horizontal three-phase settler with double weir
p	droplet or particle
pp	plate pack for L/L separation
ret	retention time
set	settling compartment or settling process
spec	specified
tl	transition from turbulent to laminar flow
turbulent	turbulent flow
up	upper part
	underflow passage of front weir of heavy-phase compartment in horizontal three-phase settler with double weir
ves	vessel
ww	the two heavy-phase weirs in horizontal three-phase settler with weir configuration
1	feed inlet
2	gas outlet
3	outlet of the light liquid phase
4	outlet of the heavy liquid phase
	Numbers 0 to 6 inclusive also refer to principal distances/clearances in the separator vessels. See the individual layout drawings and (Appendix VI.)

1.3.2.5 Superscript

Dimensionless representation of length or area. See (Appendix VI).

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (6).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated January 2008. The following are the main, non-editorial changes.

Old Section	New Section	Change
4.1.4.3	4.1.4.3	Added leak tightness requirement for wiers and baffles.
4.1.4.4	4.1.4.4	Modified item 2.
4.3.8	4.3.8	Modified X_5 , to accommodate slug volume.
4.3.6	4.3.7	Modified item 2, the degassing criterion.
4.4.5	4.4.6.	Modified item 2, the degassing criterion.
Appendix IV, 4	Appendix IV, 4	Added to 4. Calculation of control times.
Appendix V, 1.2	Appendix V, 1.2	Modified first item under V.1.2 Calculations.
Appendix V, 1.3	Appendix V, 1.3	Changed requirement in table for check on de-gassing (step 1).
Appendix V, 2.2	Appendix V, 2.2	Modified Check of vessel dimensions with respect to de-gassing (if required).
Appendix V, 2.3	Appendix V, 2.3	Changed requirement under step 7.
Appendix V, 3.1	Appendix V, 3.1	Changed requirement under Diameter to satisfy the de-gassing criterion.
Appendix VIII	Appendix VIII	Guidelines are provided for the acceptance of a higher than design liquid velocity in the liquid outlet nozzles for existing separators.
Appendix IX	Appendix IX	Design margins may be reduced.
	Appendix XI	Added appendix.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://swwww.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. SELECTION OF L/L AND G/L/L (THREE-PHASE) SEPARATORS

2.1 GENERAL

The selection of a suitable L/L or G/L/L separator for a given application depends on several factors, such as:

- a) feed composition, i.e. the phase ratio of the liquid phases,
- b) required separation efficiency,
- c) required gas and liquid handling capacity,
- d) whether L/L separation or G/L separation is the controlling factor (in G/L/L separators),
- e) required fouling tolerance.

These requirements may be conflicting, such as high fouling tolerance and high separation efficiency.

To facilitate the choice of suitable separator types for a given application, Table 2.1 has been included, indicating for each separator described in this DEP those applications for which it is recommended or shall not be used.

It serves as a first selection guide, after which a final choice can be made after consulting the parts of the DEP where the provisionally selected separator types are described.

Each of these parts starts with the profile of the separator (e.g., detailed characteristics and typical process applications) and then subsequently gives the sizing rules to be followed for a proper design. The detailed vessel sizing procedures are given, and illustrated with examples, in the corresponding appendices.

The various terms used in the first column of Table 2.1 are explained below and the relevant sizing criteria for L/L and G/L/L separators are defined.

2.2 L/L SEPARATION

2.2.1 Separation efficiency

Normally, the separation efficiency of L/L separators is specified in terms of the "**cut-off diameter**". This is the diameter of the smallest droplets removed with an efficiency of 100%.

The separation efficiency depends on the droplet size distribution of the dispersed phase. It is customary to distinguish between primary and secondary dispersions. A primary dispersion is one in which the majority of the dispersed droplets are larger than 30 μm . These are droplets large enough to separate from the dispersion by gravity settling. A secondary dispersion is one in which the majority of the dispersed droplets are smaller than 30 μm . To separate these dispersions the droplet size shall be increased first by means of a coalescer or use shall be made of hydrocyclones or centrifuges.

The term 'bulk separation' is used for separation in open settlers designed for a cut-off diameter of 150 μm . This is equivalent to an entrainment rate of $\leq 1.5\%v$.

More efficient separation is achievable by installing internals such as a plate pack, a coalescer mat or coalescer cartridges. A plate pack is designed for a cut-off diameter of 50 μm , which reduces the dispersed phase entrainment to $\leq 0.2\%v$. Coalescers can reduce this to between 50 ppmv and 500 ppmv.

Hydrocyclones and centrifuges fall outside the scope of this DEP.

2.2.2 Liquid handling capacity

The liquid handling capacity of a separator depends on the liquid flux φ :

$$\varphi = \frac{Q_L}{A_L} \quad [\text{m/s}]$$

where Q_L is the liquid feed flowrate and A_L is the area available for separation. In vertical vessels this is the cross section of the vessel, in horizontal vessels the horizontal area of the liquid-liquid interface of the separation compartment.

For low dispersed phase concentrations ($\leq 5\%$) the flux is directly related to the cut off droplet size via the Stokes settling velocity. For higher dispersed phase concentrations the interaction between the dispersed phase droplets shall be taken into account. This will be discussed in more detail in (Appendix I).

2.3 G/L SEPARATION

2.3.1 Separation efficiency

It is common practice to characterise the separation efficiency of G/L separators in terms of percentage removal. This is justified for the more efficient G/L separators, where the liquid remaining in the gas stream after passing through the separator consists of re-entrained droplets of which the size is little affected by the droplet size distribution in the feed.

A bulk G/L separation is defined as a separation where less than 90% to 95% of the liquid is removed from the gas phase. This can be achieved in separators without demisting internals.

The efficiency of G/L separators equipped with a mist mat, vane pack or swirl deck (or a combination of these internals) is higher.

For more information, see DEP 31.22.05.11-Gen.

2.3.2 Gas handling capacity

The gas handling capacity in three-phase separators is characterised by the gas load factor, λ_G :

$$\lambda_G = \frac{Q_G}{A_G} \sqrt{\frac{\rho_G}{(\rho_L - \rho_G)}} \quad [\text{m/s}]$$

where Q_G is the volumetric gas flow rate,

ρ_L and ρ_G are the densities of the lightest liquid phase and the gas phase respectively.

If the volumetric flow rate of the light liquid phase is less than 5% of the total volumetric liquid flow rate, then ρ_L should be replaced by a flow rate averaged liquid density, ρ_L (see also (Appendix VII) for definition of ρ_L).

A_G is the area available for gas flow. In vertical separators, this is the vessel cross-sectional area, whereas in horizontal separators, it is the cross sectional area of the gas cap.

The separator shall be sized so that it is able to handle the gas flow rate under the most severe process conditions. The gas load factor shall not exceed a critical value, the maximum allowable gas load factor $\lambda_{\max}$, whose value is dependent on the type of G/L separation used. For more information, see DEP 31.22.05.11-Gen.

2.4 G/L/L SEPARATORS: LIQUID HANDLING OR GAS HANDLING CONTROLLED

A three-phase separator is liquid handling controlled if:

- the feed to the separator is mainly liquid;

and/or

- a low superficial liquid velocity is required (for de-gassing or foam handling purposes, or in cases of difficult L/L separation).

Normally, a horizontal vessel will then be selected.

If the three-phase separator is gas handling controlled, e.g., if a relatively large gas flow rate has to be handled, the first choice will be a vertical vessel.

2.5 FOULING SERVICE

The requirements of high fouling tolerance and high separation efficiency are conflicting, because the internals required for efficient separation are sensitive to fouling. Fouling service requires provisions to keep the settler clean, such as sand-wash facilities in Upstream applications.

Under severe fouling conditions, it may be advantageous to select a vertical settler with a conical lower end to facilitate the removal of solids.

Plate packs may only be used under (at most) moderately fouling conditions. If used under such conditions, the plate pack layout and supports should be adapted to facilitate the removal of solids.

Upstream of Shell Twin Flange coalescers and cartridge coalescers, prefiltering is always required.

2.6 SEPARATORS SUBJECT TO MOTION

More and more separators are installed on floaters and other installations subject to motion, e.g., tension leg platforms. The performance of these separators can be adversely affected by the motion imposed by waves and wind. The accompanying sloshing will compromise liquid handling capacity, separation efficiency and the functioning of level instrumentation. Mitigation of these effects will require the installation of additional internals and other measures.

Guidelines for the design of separators subject to motion are being developed and will be listed in a new Appendix in the future. For the present, the Principal shall be consulted for the further advice.

Table 2.1 Screening of L/L and G/L/L separators

Separator types	L/L separators					G/L/L separators			
	L1	L2	C1	C2	C3	T1	T2	T3	T4 /T5
L/L separation									
primary dispersion	√	√		√		√	√	√	√
bulk separation	√					√	√		√
efficient separation		√		√				√	√
secondary dispersion	X	X	√ ¹	X	√	X	X	X	X
ill-defined L/L interface	X	X					√ ²	√ ²	
G/L separation									
bulk separation						√	√	√	
efficient separation									√ ³
liquid handling controlled (in G/L/L separators)						√	√	√	X
gas handling controlled (in G/L/L separators)								X	√
Fouling service	√		X	X	X	√	√		
High temperature			X	X	X				
√ : Recommended use X : Shall not be used									
¹ If properly packed and NO compressed crinkled wiremat is installed. ² Provided there is a double weir arrangement with no IL control; also to be used if there are corresponding L/L separators. ³ If wiremesh or wiremesh / swirl deck assembly is installed.									
L1: Horizontal open two-phase settler (3.1) and (Appendix IV) L2: Horizontal two-phase settler with plate pack (3.2) and (Appendix IV) C1: Coalescer with compressed coalescer bed (3.3.4) C2: Coalescer fitted with a prefabricated coalescer mat (3.3.5) C3: Coalescer fitted with coalescer cartridges (3.3.6) and (Appendix III) T1: Horizontal open three-phase settler with boot (4.1.3) and (Appendix V.1) T2: Horizontal open three-phase settler with weir arrangement (4.1.4) and (Appendix V.2) T3: Horizontal three-phase settler with plate pack and weir arrangement (4.2) and (Appendix V.2) T4: Vertical three-phase settler (4.3) T5: Vertical three-phase settler with plate pack (4.4) and (Appendix V.3)									

3. DESIGN RULES FOR L/L SEPARATORS

In this section the design rules for the various liquid/ liquid separators are given.

If the separators do not contain L/L separation internals, then they are referred to as "open settlers".

For information on the mechanism of liquid/liquid separation, see (Appendix I).

Unless explicitly stated otherwise, the liquid flow rates will contain a design margin or surge factor as defined in (Appendix IX).

3.1 HORIZONTAL OPEN TWO-PHASE SETTLER (L1)

3.1.1 Selection criteria

Application:

Bulk separation of primary dispersions with good separation characteristics (i.e., relatively low viscosity of the continuous phase, relatively large droplets and low dispersed phase concentration).

Characteristics:

- insensitive to fouling;
- only for separation of a primary dispersion.

Recommended use:

- where only bulk separation is required;
- fouling service.

Not recommended:

- for secondary dispersions (i.e., droplets smaller than 30 μm);
- where a high separation efficiency is required;
- where the interface is ill-defined (this will affect the interface level control).

If the interface is ill-defined, or if there is another reason to avoid direct IL control, the three-phase separator layout with a double weir system (**T2**) should be used. See also (4.1).

Typical process applications:

- settler in mixer/settler arrays in extraction processes (outside the scope of this DEP);
- side decanter;
- rectifying absorber side draw-off vessel.

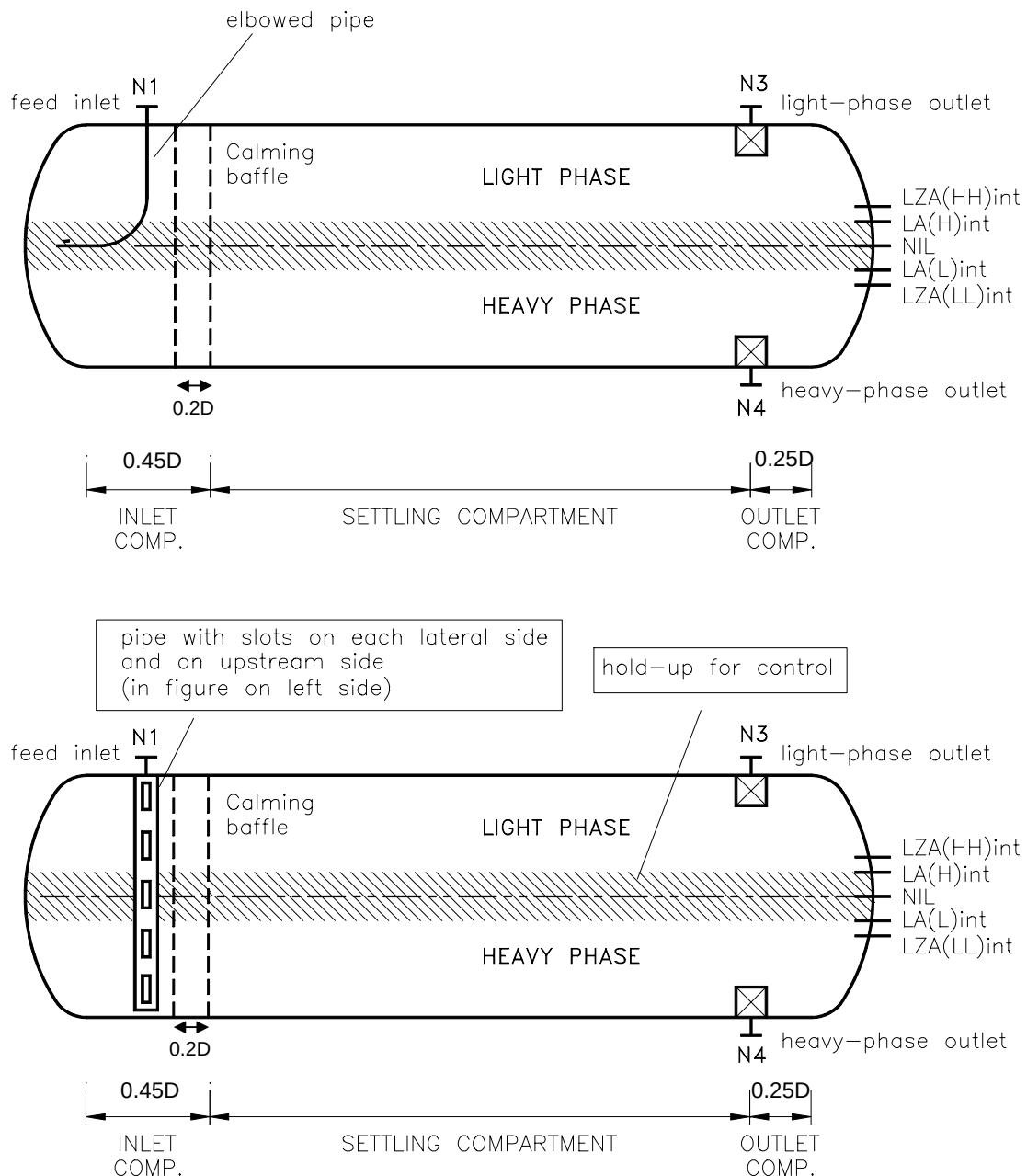


Figure 3.1 Horizontal open two-phase settler (feed internal either elbowed or slotted pipe)

3.1.2 General description

Figure 3.1 shows a typical layout of a horizontal open two-phase settler for cases where both phases have to be cleaned. Basically, the settler consists of three compartments: an inlet compartment, a settling compartment and an outlet compartment containing the outlet nozzles.

The feed enters the inlet compartment via the feed nozzle equipped with a feed inlet device.

There are two possibilities for the inlet device: a pipe directed to the vessel head or a slotted pipe (as shown in the upper and lower part of Figure 3.1, respectively).

Between the inlet and settling compartment a double calming baffle (perforated plates) shall be installed to prevent flow maldistribution in the settling compartment. The resulting even

flow in the settling compartment will facilitate the separation of the two liquid phases.

The settling compartment ends at the liquid outlet nozzles which are both fitted with vortex breakers.

If the cleaning of only one phase is required and the other phase is only a small fraction of the total flow (typically less than 5%), it is not necessary to perform the separation in the vessel itself. In that case, a dome or boot is used to collect the dispersed phase (e.g., in a rectifying absorber side draw-off vessel). For the use of a boot, see also the sizing of three-phase settlers equipped with a boot (4.1.1).

3.1.3 Inlet and outlet compartments

The inlet compartment shall be sufficiently large to accommodate the feed inlet device and to allow a reasonable flow path length of the feed to the calming baffle.

The inlet compartment should have a length of at least $0.45D$ (distance between tangent line and second calming baffle).

The calming baffles shall be mounted with a gasket on a full perimeter support ring and occupy the whole vessel cross-section. At the bottom, a small opening (≤ 150 mm) is allowed for cleaning purposes.

The Net Free Area is 30% for the first baffle and 50% for the second baffle with 12 mm diameter holes (± 0.1 mm).

The baffle thickness should be at least 3 mm, excluding corrosion allowance.

The distance between the baffles is $0.2D$.

There shall be sufficient clearance between the first calming baffle and the tangent line to accommodate the feed inlet device. Therefore the minimum length upstream of the first baffle is either $0.25D$ or $= 150 \text{ mm} + ID_{\text{inlet nozzle}} + \max(150 \text{ mm}, 0.5 \cdot ID_{\text{inlet nozzle}})$, whichever is the larger.

The outlet compartment shall be sufficiently large to accommodate the outlet nozzles. Its length is typically $0.25D$.

3.1.4 Settling compartment

The settling compartment is divided into three horizontal zones:

- An upper zone through which in every flow scenario the light phase flows and from which the heavy-phase droplets have to be separated. This is the zone above high interface trip level, $LZA(HH)_{\text{int}}$.
- An intermediate zone for level control and accommodation of an eventual dispersion band. See Figure I.1 in (Appendix I).
- A lower zone through which in every flow scenario the heavy phase flows and from which the light-phase droplets have to be separated.
This is the zone below low interface trip level, $LZA(LL)_{\text{int}}$.

3.1.5 Sizing of the settler

For a proper sizing of the settler the following main rules apply:

- 1) The cross-sectional area of the upper and lower zones shall be at least 14.2% of the vessel cross-sectional area. (This is equivalent to a minimum central height of these cross-sectional areas of $0.2D$).
- 2) The minimum height of $LZA(LL)_{int}$ is equal to the nozzle ID of the heavy liquid outlet.
- 3) The horizontal cross-section of the settling compartment shall be sufficient to achieve the specified separation efficiency in terms of droplet cut off size i.e., $<150 \mu m$. A practical approximation of this area is $A_{set}=L_{set} \times D \times 0.8$, where the factor 0.8 accounts for the fact that the interface is generally not located in the midplane of the separator and provides some allowance for flow maldistribution.
- 4) The control volume (contained between $LA(L)_{int}$ and $LA(H)_{int}$) shall be sufficiently large to meet the specified interface level control time. See (Appendix X).
- 5) The cross-sectional area of the zones above and below NIL shall be sufficiently large to limit the axial velocity in the light and heavy phase to $\leq 0.015 \text{ m/s}$.
- 6) Preferably $2.5 \leq L/D \leq 6$.

In (Appendix IV) the procedure is presented for checking the sizing of an existing settler. It can also be treated as the sizing procedure for a new settler starting with the specification of the vessel diameter and length and interface level control heights.

If certain criteria cannot be met, the procedure has to be repeated with adjusted vessel dimensions and level control heights.

A calculation example is given in (Appendix IV).

3.1.6 Nozzles

The feed nozzle should be fitted with an inlet device. There are two options for this:

- an elbowed pipe directed towards the vessel head (as is shown in the upper part of Figure 3.1);
- a vertical pipe with rectangular slots (as is shown in the lower part of Figure 3.1).
- The total area of the slots is typically 3.3 times the cross-sectional area of the feed nozzle. A feed inlet velocity of 1 m/s maximum will then be reduced to 0.3 m/s maximum in the slots. The slots should be on each lateral side and on the upstream side (i.e., the side facing the nearest vessel head, as shown in Figure 3.1).

For the sizing of the feed nozzle, see (Appendix VIII).

For the sizing of the outlet nozzles and the specification of the required vortex breakers, see (Appendix VIII).

The vortex breaker shall be at least a half nozzle diameter away from the corresponding control level, $LZA(LL)_{int}$ (heavy-phase outlet) and $LZA(HH)_{int}$ (light-phase outlet).

3.2 HORIZONTAL TWO-PHASE SETTLER WITH PLATE PACK (L2)

3.2.1 Selection criteria

Application:

Efficient separation of primary dispersions.

Characteristics:

- efficient separation, provided the dispersion is of the primary type;
- Moderately robust to fouling; a certain degree of fouling can be accommodated by e.g., selecting a relatively large plate distance and plate angle.

Recommended use:

For the efficient separation of a primary dispersion provided:

- the L/L interface is well-defined;
- the service is at most moderately fouling.

Not recommended:

- for secondary dispersions;
- in heavy fouling service.

Where the interface is ill-defined (this will affect the interface level control) or if there is some other reason to avoid direct IL control, the three-phase separator layout with a double weir system (T3) should be used. See also (4.2).

Typical process applications:

- acid settler of HF-alkylation plant;
- water draw off vessel in condensate stabiliser plant.

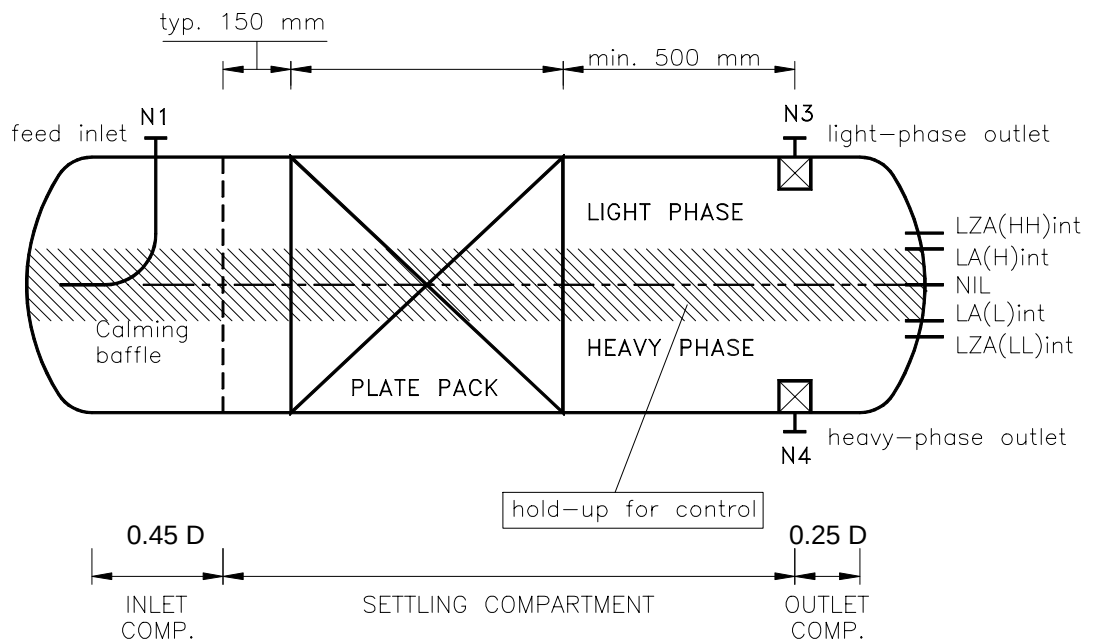


Figure 3.2 Horizontal two-phase settler with plate pack

3.2.2 General description

Figure 3.2 shows a typical layout of a horizontal two-phase settler, fitted with a plate pack, for cases where both phases have to be cleaned from the other liquid phase.

The feed inlet shown is a pipe directed to the nearest vessel head, but alternatively a slotted pipe can be used. See (3.1.2).

The manholes shall be located so that the plate pack internals can easily be installed, and are accessible from both sides.

Other features are equivalent to those described in (3.1.2).

3.2.3 Inlet and outlet compartments

Requirements for inlet and outlet compartments are equivalent to those described in (3.1.3), with the difference that only one baffle is installed. The Net Free Area of this baffle should be 20%.

3.2.4 Settling compartment

The settling compartment contains a plate pack. In the standard layout, a cross-flow plate pack is used. For more information on plate packs and their design, see (Appendix II).

The distance from the calming baffle to the plate pack should be 150 mm.

The minimum distance from the plate pack to the outlet nozzles should be 500 mm.

To prevent bypass, the clearance between the plate pack and the vessel wall shall be sealed, apart from a small opening underneath the plate pack required for cleaning purposes.

3.2.5 Sizing of the settler

For a proper sizing of the settler the following main rules apply:

- 1) The cross-sectional area of the upper and lower zones in the plate pack shall be sufficiently large, to ensure that the flow is laminar.
- 2) The cross-sectional area of the upper and lower zones shall be at least 14.2 % of the vessel cross-sectional area. (This is equivalent to a minimum central height of these cross-sectional areas of 0.2D).
- 3) The length of the settling compartment (distance between calming baffle and outlet nozzles) should be at least the length of the required plate pack + 650 mm.
- 4) The control volume (contained between $LA(L)_{int}$ and $LA(H)_{int}$) shall be sufficiently large to meet the specified interface level control time (see Appendix X).
- 5) Preferably $2.5 \leq L/D \leq 6$.

In (Appendix IV) the procedure is presented for upgrading an existing open settler by installing a plate pack.

It can also be treated as the sizing procedure for a new settler starting with the specification of the vessel diameter and length and interface level control heights.

If certain criteria cannot be met, the procedure has to be repeated with adjusted dimensions.

A calculation example is given in (Appendix IV).

3.2.6 Nozzles

Requirements for feed nozzle and outlet nozzles are equivalent to those described in (3.1.6).

3.3 COALESCERS (**C1**, **C2**, **C3**)

3.3.1 Selection criteria

Application:

Coalescence and removal of low concentrations (5% or less) of dispersed droplets from primary or secondary dispersions. Coalescers are not suitable for bulk separation.

Coalescers should not be applied for liquids with a kinematic viscosity above 15 mm²/s.

Characteristics:

- a) In situ compressed coalescer mats (**C1**)
 - suitable for the coalescence of primary and secondary dispersions;
 - economic, because of low-cost material and possibility of backwashing;
 - manually packed: packing should be installed by properly trained personnel to avoid channelling and bypassing;
 - sensitive to fouling: prefiltering is required, unless service is absolutely clean.
- b) Prefabricated coalescer mat (**C2**)
 - suitable for the coalescence of primary dispersions only;
 - little likelihood of channelling or bypassing since it is pre-fabricated;
 - density is lower than that of **C1** and **C2** hence less sensitive to fouling.
- c) Cartridge coalescers (**C3**)
 - suitable for the coalescence of primary and secondary dispersions;
 - little likelihood of bypassing because the cartridges are pre-fabricated;
 - sensitive to fouling: prefiltering is required, unless service is absolutely clean.

Recommended use:

- a) Compressed coalescer bed:
 - for secondary dispersions, if properly packed and **NO compressed** crinkled wiremat is installed;
 - vertical vessels only.
- b) Coalescer mat:
 - for primary dispersions;
 - if local phase inversion can occur (i.e., the dispersed phase becomes locally the continuous phase), use dual material (e.g., stainless steel and polymer filaments).
- c) Coalescer cartridges:
 - for secondary dispersions;
 - to upgrade Shell Twin-Flange Coalescers (equipped with compressed coalescer bed): with cartridges a wider choice of packing materials is possible.

Not recommended:

- In fouling service without pre-filtering.

Material considerations: The thermal, mechanical and chemical stability of the coalescer material should be considered as well:

- Polypropylene shall not be used if the operating (or steam out) temperature exceeds 80°C. Teflon should not be used above 200°C.

- Fibre glass should not be used in systems with pH > 9.
- Because fibre glass is brittle, it should not be used in the open structured mats of type **C2** coalescers.

Typical process application:

- Dewatering of hydrocarbons (ranging from LPG to gasoil fractions).

3.3.2 General description

A coalescer is a separator which makes use of the fact that droplets in dispersions grow in size when they pass through fibrous packed beds. The enlarged droplets are subsequently removed in a settling compartment, which can be either downstream or upstream of the packed bed, or eventually in a separate vessel.

The packed bed can be either a mat, compressed in situ (**C1**), or pre-fabricated (**C2**), or an arrangement of parallel cartridges (**C3**). The packing material can be stainless steel, glass fibre or a polymer, like polypropylene, PTFE, or poly-aramid. Combinations of these materials are applied as well and have interesting synergies.

Coalescers of type **C1** and **C3** are intended for secondary dispersions (droplets smaller than 30 micron). The droplets grow as a result of interception by and adhesion to the fibres. Therefore, the fibre structure, filament size and free volume of the packing medium are the important parameters. The packing in these coalescers has a relatively high density and the fibres are relatively fine. The finer the filament, the more effective the coalescence process will be. Droplet growth will continue until viscous drag forces, acting on the droplets as a result of the continuous flow of the mixture through the coalescer medium, exceed the force of adhesion. Normally, this coalescence process will subsequently convert the secondary dispersion into a primary dispersion, which can be separated by gravity.

Coalescers of type **C2** with a prefabricated coalescer mat are intended for primary dispersions. The choice of the coalescer material is determined by the criterion that the dispersed phase shall preferentially wet the packing surface. In de-oiling, service polymers such as polypropylene or Teflon® should be used, for water removal stainless steel is required.

It is of course also possible to use combinations of coalescers, e.g., C3 followed by C2, or a combination of coalescers and plate pack separators.

3.3.3 Treatment of the coalescer feed

3.3.3.1 Selection of feed pump

Normally centrifugal pumps are used to pump the feed to the coalescer. However, due to the high level of energy dissipation in this type of pump, the droplets in the feed will be dispersed further to smaller droplets and more stable dispersions will be formed.

In critical systems where degradation can readily take place, other types of pumps should be used in which less energy is dissipated, e.g., displacement pumps.

3.3.3.2 Measures to avoid flashing in the coalescer

In cases where the feed of the coalescer originates from a three-phase separator in which vapour and liquids are in equilibrium and no pump upstream of the coalescer is used, precautions have to be taken to avoid flashing in the coalescer due to the pressure drop across the coalescer bed.

This can be done by placing the upstream three-phase vessel at a higher elevation relative to the coalescer. Further, the coalescer vessel shall always be equipped with a vent.

3.3.3.3 Prefilters

In fouling service pre-filtering should be done upstream of a coalescer.

Two pre-filters should be used in parallel, with one in use and the other on standby. Measurement of the pressure drop across the prefilter in use will indicate the degree of fouling.

If the pressure drop across the pre-filter in operation has exceeded the maximum, then the flow to be cleaned out has to be routed via the other pre-filter. This will allow the fouled pre-filter to be cleaned out without putting the coalescer at risk.

Within the Group, both cartridge and filter basket (which may include a filter bag) systems are applied; cartridge systems should normally be used and are now the industry standard. Both cleanable (steel) and propylene/cellulose paper cartridges are used. Steel type filters, typically cleaned with LP steam, are used in high temperature applications or in systems which require frequent cleaning.

Sometimes, filter cartridges are classified by the Manufacturer as absolute rated for a given particle size. This means that the pores of the filter cartridge are smaller than that particle size. (If the pores of the cartridge are larger than the particle size, the particles will penetrate the filter medium where they will be trapped by adhesion and other mechanisms.)

The pre-filter shall retain all solid particles larger in size than the pore size of the coalescer cartridge. This would rarely be larger than 5 μm .

Normally the pre-filters are sized so that under the prevailing flow conditions the pressure drop across the clean cartridges is 0.1 bar. Change-out is done when the cartridge pressure drop reaches a given limit, as recommended by the Manufacturer, which is typically 3 bar for absolute rated pre-filters and 1 bar for other types.

The area and number of cartridges and the sizing of the pre-filter pressure vessel shall be specified by the pre-filter Manufacturer.

Since the velocity through the filter medium can be higher than that through the coalescer cartridges and therefore less cartridge surface area is required, a pre-filter vessel will be smaller than a coalescer vessel for a given feed flow rate.

3.3.4 Coalescer fitted with a compressed coalescer bed (Shell Twin-Flange Coalescer)

3.3.4.1 General

The Shell Twin-Flange Coalescer (TFC) has always been the standard coalescer within the Shell Group.

A schematic layout is presented in Figure 3.3.

The detailed layout is defined in Standard Drawing S 22.007.

The TFC is a top-flanged vessel of which the lower part has a larger diameter than the upper part. The coalescer bed is compressed in a skirt between two grids. The feed (in most cases a hydrocarbon feed which has to be dewatered) flows downwards through the bed where coalescence of the dispersed phase takes place. After this, the heavy liquid phase leaves the vessel via a bottom outlet and the light liquid phase leaves via four side outlets. These side outlets are located just below where the skirt is attached to the vessel wall. A vent is connected to the upper part of this annular compartment to evacuate any vapour formed locally.

The sizing rules of the Shell Twin-Flange Coalescer are given below.

3.3.4.2 Skirt and coalescer bed

In its standard layout the coalescer bed consists of compressed polypropylene wool of which the fibres have typically a diameter of 30 μm .

If polypropylene is used, no steaming out can be applied since the maximum allowable temperature is 80°C. Where steaming out, or any other process where the temperature will rise above this limit, is required, more heat-resistant material shall be used. In a non-corrosive environment stainless steel wool may be an alternative, and the filament diameter should also be 30 μm .

The uncompressed bed shall not extend above the lower flange face.

The bed is manually packed by means of rolls/blankets of uncompressed coalescer material. Proper packing is important to avoid channelling. The top grid is provided with a rim which fits into an inner groove of the face of the top flange. The bed is compressed by

the top cover being placed on the top grid and pulled down onto the lower flange face by means of long bolts.

After packing and compression, the bed shall satisfy the following requirements:

If made from polypropylene filaments:

- Bulk density 110 kg/m³ and typical height in range of 540 mm to 700 mm.

If made from stainless steel filaments:

- Bulk density in the range of 400 - 425 kg/m³ and typical height in range of 640 mm to 800 mm.

NO crinkled wiremat shall be used underneath the PP-wool bed **unless** measures are taken to prevent the compression of the mat during the compression of the PP-wool bed, since a compressed mat will spoil the effect of the PP-wool bed. The reason for this adverse effect is that, due to this compression, the bulk density of liquid velocity in the bed becomes too high. This will spoil the coalescence process because the relatively high velocities will lead to re-dispersion of the coalesced droplets.

For the same reason, propylene felt mats should not be used as an alternative for polypropylene wool.

In Standard Drawing S 22.007, two options are given for the packing in the TFC:

- PP-wool bed alone;
- PP-wool bed with one underlying layer of crinkled wiremat which is safeguarded against compression.

Before the coalescer can be used, it shall be de-gassed first by being filled with either the process liquid or mains water via the utility connection. It will then be degassed via a venting connection on the feed piping.

The ID of the skirt shall be sufficiently large to limit the average velocity of the total liquid flow through the bed to at most 0.015 m/s.

$$ID_{\text{skirt}} \geq 9.21 \sqrt{Q_l + Q_h} \quad [\text{m}]$$

Q_h and Q_l are the volumetric flow rates of the heavy and light liquid phase, respectively.

The Net Free Area of the grids of the bed shall be at least 80%.

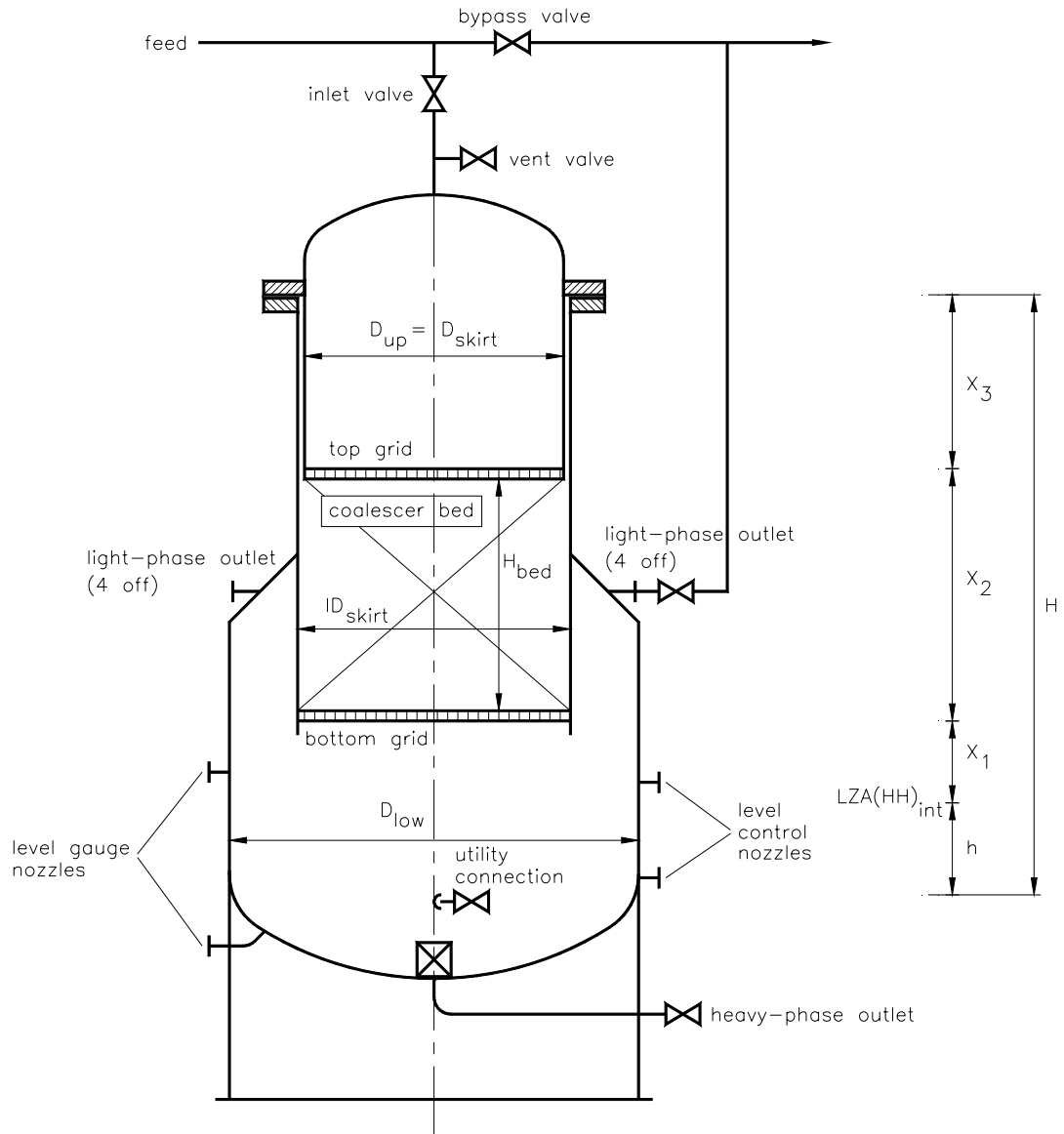


Figure 3.3 Schematic layout of the shell twin-flange coalescer

3.3.4.3 Upper and lower vessel diameter

The inner diameter of the upper part of the coalescer vessel, D_{up} , is equal to the inner diameter of the skirt.

The inner diameter of the lower part of the coalescer vessel, D_{low} , should be selected so that the upward velocity of the continuous light phase in the entrance of the annular space between the vessel wall and coalescing bed is equal to the superficial velocity of this phase through the bed.

Consequently, ignoring the wall thickness of the skirt

$$D_{low} = D_{up} \sqrt{2} = ID_{skirt} \sqrt{2} \geq 13 \sqrt{Q_l + Q_h} \quad [m]$$

3.3.4.4 Vessel tangent-tangent (H)

The bottom compartment of the TFC shall be sufficiently large to provide a sufficiently long control time of the interface level.

Moreover, the distance between the highest level of the interface $(LZA(HH)_{int})$ and the bottom of the skirt, X_1 shall be such that the local velocity of the continuous light phase is not higher than its superficial velocity in the bed, hence X_1 is at least $0.25D_{up}$.

Let h be the height required for interface level control (up to $LZA(HH)_{int}$), then:

$$H = h + X_1 + X_2 + X_3 \quad [m] \quad (\text{see also Figure 3.3})$$

$$X_1 = 0.25 D_{up}$$

$$X_2 = H_{bed} + 2 H_{grid}$$

X_3 is typically 450 mm for stainless steel packing and 650 mm for polypropylene packing

X_3 shall be sufficiently large to accommodate the coalescer material before compression.

3.3.4.5 Nozzles

The feed nozzle should be sized so that the velocity does not exceed 1 m/s. It should be provided with a baffle plate in accordance with Standard Drawing S.22.007.

For the sizing of the outlet nozzles and the specification of the required vortex breakers, see (Appendix VIII).

The vent connection on the vessel and the utility connection shall both have a minimum diameter of 50 mm.

3.3.4.6 Pressure drop

The pressure drop across a clean standard compressed polypropylene coalescer bed with a bulk density of 110 kg/m^3 is about 0.1 bar at a total superficial liquid velocity of 0.015 m/s and a dynamic viscosity of about 1 mPa·s. However, the pressure drop will increase due to fouling.

To monitor the degree of fouling during service, a facility should be installed for pressure differential measurement across the coalescer bed. It is common practice to allow a maximum pressure drop of 1 bar across the bed before the bed is exchanged or back-washed.

3.3.5 Coalescer fitted with a prefabricated coalescer mat

3.3.5.1 General

Prefabricated coalescer mats can be used both in horizontal and in vertical coalescer vessels. Due to their relatively open structure plugging is less of a concern.

A schematic layout of a horizontal coalescer vessel equipped with boot is shown in Figure 3.4. For the sizing of the boot, see (4.1.3) in which the sizing of open three-phase settlers equipped with a boot is given.

A vertical vessel with upflow is preferred in slugging service, to avoid flooding of the coalescer mat. The efficiency is somewhat lower due to the countercurrent flow of the feed and the separated dispersed phase.

3.3.5.2 Vessel diameter

The cross-section of the mat shall be sufficiently large to limit the average velocity of the total liquid flow to at most 0.015 m/s. In vertical vessels the velocity should further be limited to a cut-off droplet size for water droplets of 200 μm to ensure sufficient draining.

3.3.5.3 Coalescer mat

The depth of the coalescer mat should be 500 mm to 700 mm.

3.3.5.4 Pressure drop

The pressure drop across the coalescer mat is relatively low, typically $\leq 20 \text{ mbar}$. This gives sufficient homogenization of the flow through the vessel so that a calming baffle is not

required.

3.3.5.5 Nozzles

Requirements for feed nozzle and outlet nozzles are equivalent to those described in (3.1.6).

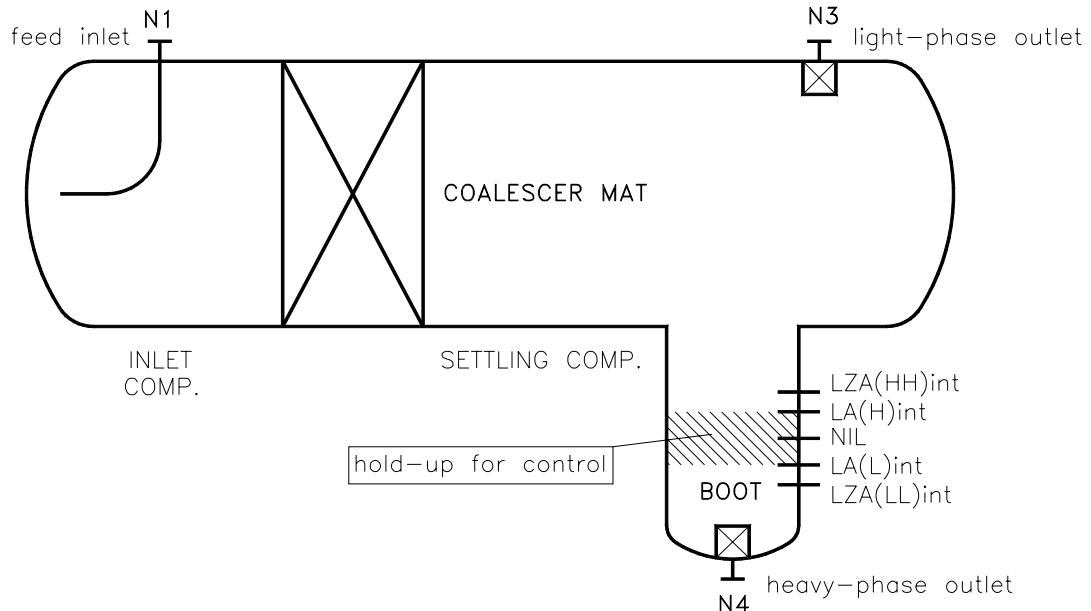


Figure 3.4 Schematic layout of coalescer vessel with boot and with prefabricated coalescer mat

3.3.6 Coalescer (retro)fitted with coalescer cartridges (C3)

3.3.6.1 General

Cartridges can be applied in horizontal as well as vertical vessels. For a new design the Shell Twin Flange Coalescer configuration is the preferred starting point. The vessel and its internals can be built around the required number of cartridges.

Knitmesh Dusec™ coalescer cartridges have frequently been retrofitted into Shell Twin Flange Coalescers to replace the polypropylene wool bed. Since the cartridges are pre-fabricated, channelling is avoided. Within a vessel of a certain size, a larger surface area can be accommodated, so the liquid handling capacity is increased.

The dispersion to be treated should enter the cartridge in the centre and flow from in to out. The coalescer material is normally wound in layers around a central perforated cylinder. Usually there is a gradient in the grade of the packing material. The finer fibres, which have to deal with the original secondary dispersion, are closest to the centre. The coarse fibres are closer to the periphery where the droplets have grown into the range of primary dispersions.

In Figure 3.5, a schematic layout is shown of a Shell Twin-Flange Coalescer fitted with coalescer cartridges. As shown, use is made of the skirt in which originally the coalescer bed was installed.

The cartridges are suspended from a plate mounted in the skirt.

The feed flows downward through the cartridges from in to out.

In general, the interface level is below the cartridges. The presence of the skirt prevents short-circuiting of the light phase to the light phase outlet.

3.3.6.2 Cartridge area

The design capacity of a cartridge depends on the application, more particularly on the viscosity of the feed. For coalescers for the deep removal of water from kerosene or gasoil, $20 \text{ m}^3/\text{m}^2\text{h}$ (based on the inner surface of the cartridge) appears to be a dependable figure. For PP/LPG, $25 \text{ m}^3/\text{m}^2\text{h}$ is acceptable.

Systems with a $\text{pH} > 9$ require alternative more resistant coalescer materials and it may be necessary to derate the design capacity. The Principal should be consulted for further advice.

3.3.6.3 Vessel sizing

To avoid re-entrainment the total cross-section of the cartridges should not exceed 40% of the cross section of the vessel compartment in which they are contained.

For coalescer vessels with a size larger than 2 m, a top flange is not practical. In these vessels the mounting plate is fixed, and provided with a removable section which can be used as internal manway.

3.3.6.4 Pressure drop

The pressure drop across the cartridges in clean conditions is of the order of 0.1 bar. The cartridges should be replaced when the pressure drop exceeds 1 bar.

3.3.6.5 Nozzles

Requirements for feed nozzle and outlet nozzles are equivalent to those described in (3.3.4.5).

A calculation example of the design of a cartridge coalescer is given in (Appendix III).

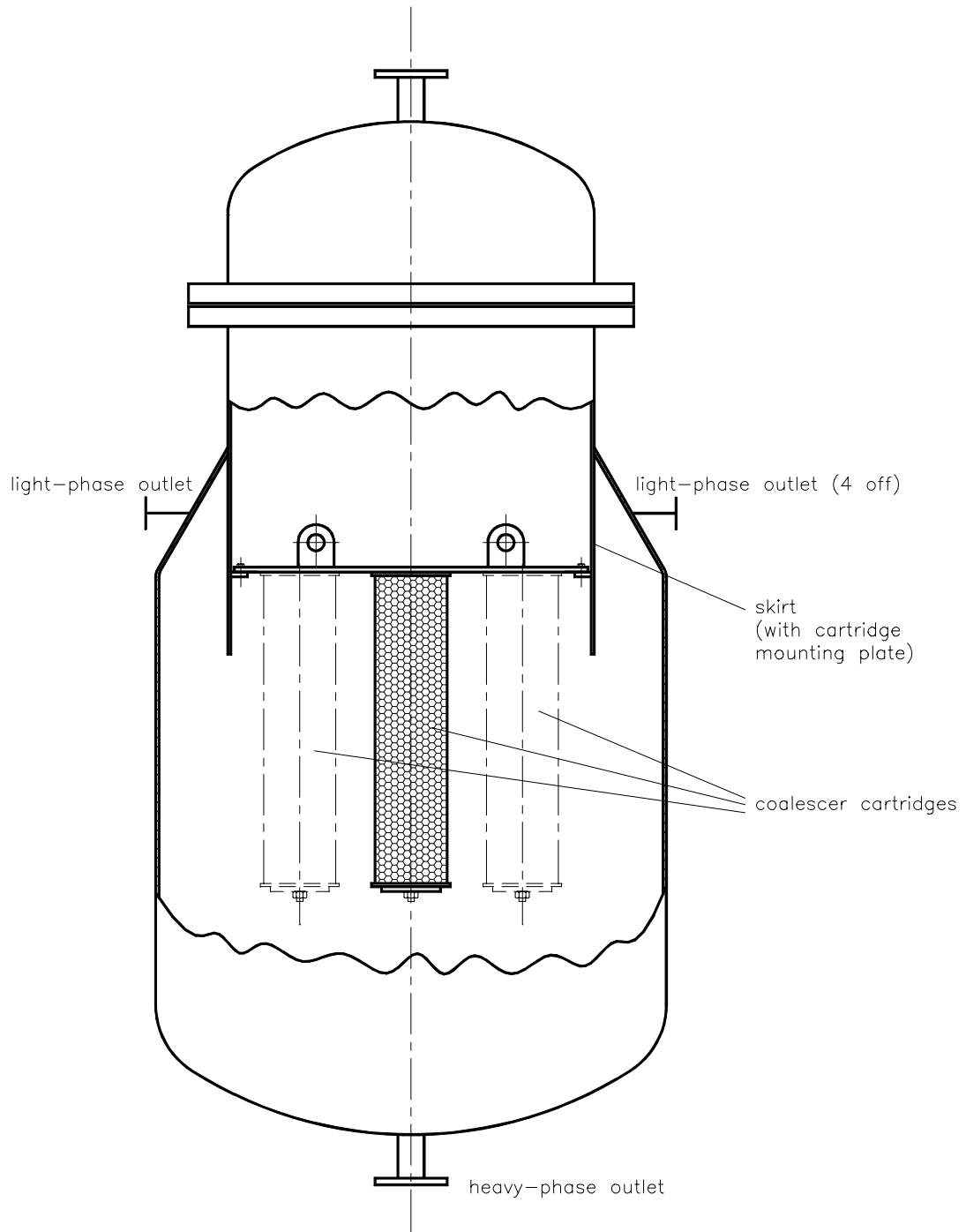


Figure 3.5 Shell twin-flange coalescer with coalescer cartridges

3.3.7 Manufacturer-proprietary coalescer vessels, equipped with cartridges.

It is also possible to procure a Manufacturer-proprietary coalescer with cartridges. This is supplied as a complete package of vessel and internals based on a Manufacturer-proprietary design. For details of Shell-approved Manufacturers, the Principal should be consulted.

Although the design of the separator is the primary responsibility of the Manufacturer, the guidelines given in (3.3.6) should be used to check the number of cartridges and the vessel design. Special attention shall be paid to the proper choice of coalescer material of the cartridges. As to maximum allowable temperature and pH of the feed, the same restrictions apply as indicated above.

4. DESIGN RULES FOR G/L/L (THREE-PHASE) SEPARATORS

In this section, the design rules are given for a number of G/L/L (three-phase) separators.

If the separators do not contain L/L separation internals (apart from a weir arrangement), then they are referred to as "open settlers".

Unless explicitly stated otherwise, the maximum liquid flow rates and slug volume will contain a design margin or surge factor as defined in (Appendix IX).

NOTE: Often L/L separators are designed as a vessel with a gas cap to facilitate the IL control of the two phases. This converts them, strictly speaking, into a three-phase separator geometry.

4.1 HORIZONTAL OPEN THREE-PHASE SETTLER

4.1.1 Selection criteria

Types:

1. SETTLER WITH BOOT
2. SETTLER WITH WEIR ARRANGEMENT

Application:

Bulk separation of primary L/L dispersion and a relatively small gas flow rate.

Characteristics:

- large liquid handling capacity;
- insensitive to fouling.

Recommended use:

- General:
 - where the L/L separation is the controlling factor and only bulk L/L separation is required;
 - fouling service.
- Settler with boot:
 - where the volume concentration of the heavy phase in the feed is smaller than 5% and the de-oiling of the heavy phase is not critical.
- Settler with weir arrangement:
 - ill-defined L/L interface (use double weir arrangement with no IL control);
 - where de-oiling of the heavy phase is required.

Not recommended:

- for efficient L/L separation.

Typical process applications:

- Crude/Water Separators (in E&P applications)
- Overhead Accumulators (in refinery applications)
- Ejector Effluent Separators (in refinery applications)

4.1.2 General description

In general the horizontal open three-phase settler consists of three compartments (see Figure 4.1 through Figure 4.5).

- inlet compartment;
- settling compartment;
- outlet compartment.

If the settler has a boot, this is the part of the vessel downstream of the boot.

If the settler has a weir arrangement, this compartment contains the liquid collection compartment(s).

In the following, the design rules are given for the two main types (equipped with either a boot or weirs) which will lead to a proper sizing of the settler and its internals.

In (Appendix V), the sizing procedure is elaborated in more detail.

Apart from the sizing procedure for new settlers, a retrofit procedure is also given in (Appendix V) to optimise existing open settlers by installing weirs.

4.1.3 Settler with boot

4.1.3.1 Inlet compartment

As shown in Figure 4.1, the feed enters the inlet compartment through a top entry with an inlet device connected by an elbow. For details of feed inlet device, see (4.1.3.5).

The length of the inlet compartment (i.e., distance from inlet tangent line to second baffle) is typically minimum $0.45D$.

Double calming baffles (perforated plates) shall be installed between the inlet and settling compartment of the vessel. The function of these baffles is to promote an even flow in the settling compartment which will facilitate the separation of the two liquid phases.

Recommended calming baffle characteristics:

- a) the net free area (NFA) is 30% and 50% for the first and second baffle, respectively;
- b) the hole diameter is typically 12 mm;
- c) the baffle thickness should be at least 3 mm;
- d) the distance between the baffles is $0.2D$;
- e) the baffles shall extend from the vessel bottom to LZA(HH) with at the bottom a small opening for cleaning purposes.

Sufficient clearance is required between the vertical TL and the first baffle to accommodate the feed inlet device. The minimum is $(5 \times ID_{\text{inlet nozzle}})$ or $0.25 D$, whichever is the larger.

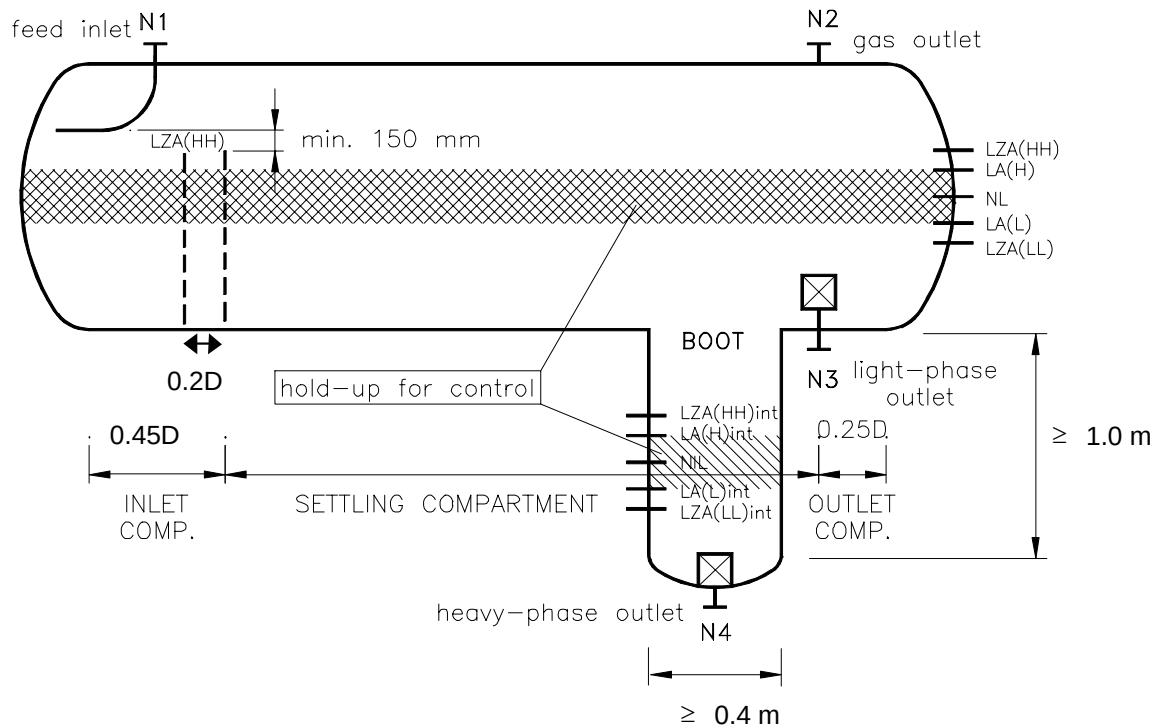


Figure 4.1 Horizontal open three-phase settler fitted with boot

4.1.3.2 Settling compartment

In this compartment the separation of the two liquid phases takes place.

It extends from the second calming baffle to the outlet of the light liquid phase and it contains the boot. The liquid/liquid interface and the heavy phase outlet are situated in the boot.

4.1.3.3 Boot

The boot will be used to withdraw the heavy phase from the vessel.

Also some additional "de-oiling" will be achieved.

The minimum boot length (i.e., the distance between the bottom of the vessel and the boot bottom tangent line) and the boot diameter should be 1 m and 0.4 m, respectively.

By maximising the boot diameter, the de-oiling of the heavy phase collected in the boot will be improved, because the downflow rate of the heavy phase will be minimised. Theoretically, all light-phase droplets larger than the critical droplet having a rising velocity equal to the heavy-phase downflow velocity are able to escape. However, in practice, the flow of the heavy phase into the boot will not be uniform, which will adversely affect the de-oiling process.

If the various control volumes are fixed (= flow rate of the heavy-phase times the specified control time), maximising the boot diameter will lead to a shorter boot. The boot shall still be sufficiently long to enable proper interface level control and the proper accommodation of all the nozzles required for IL control.

The boot outlet shall be equipped with a vortex breaker. The boot should be located as far from the inlet as possible (whilst still leaving space downstream for the outlet of the light liquid phase), in order to minimise disturbance of the settling process in the settling compartment.

The outlet of the light liquid phase shall protrude into the vessel (by typically 150 mm) and it should be located downstream of the boot. It shall be equipped with a vortex breaker.

4.1.3.4 Sizing of the settler

For a proper sizing of the settler the following main rules apply:

1. The cross-section of the gas cap above LZA(HH) shall be large enough for adequate liquid knockout (for bulk separation the maximum allowable gas load factor is 0.07 m/s).

The central height shall be at least 0.3 m.

2. The cross-sectional area above LZA(HH) (A_G) and below LZA(LL) shall both be at least 14.2% of the vessel cross-sectional area. (This is equivalent to a minimum central height of these areas of 0.2D).
3. The minimum elevation of LZA(LL) is equal to the nozzle ID of the light product outlet. If the outlet nozzle is elevated, the minimum elevation is equal to the height of the outlet line plus the nozzle diameter.
4. In slugging flow service the volume of the G/L interface control zone contained between LA(H) and normal level, NL, shall be sufficiently large to contain the hold-up volume required for the light liquid phase, PLUS the hold-up volume required for the heavy liquid phase, PLUS the slug volume. The size of the anticipated slug is the product of the estimated time that the feed pipe is 100% liquid-filled and the gas volumetric flow rate prevailing under non-slugging conditions. See (Appendix X) for a default estimate of the slug volume.
5. The vessel cross-section below NL shall be sufficiently large to ensure that the axial total liquid velocity in that zone is limited to 0.015 m/s.
6. The boot shall be sized so that the velocity of the heavy phase in the boot does not exceed the settling velocity of the smallest light-phase droplet to be separated.
7. The diameter of the boot should preferably be about 1/3 of the vessel diameter. The length of the settling compartment (i.e., the distance between the calming baffle and the light-phase outlet) shall be sufficient to meet the separation specifications (in terms of smallest heavy-phase droplet size to be separated).
8. If de-gassing and/or de-foaming are required, it has to be verified whether the vessel has sufficient capacity for this. For the criteria to be applied, see (Appendix V.1) (calculation steps 1 and 2). The foam has to be accommodated between LA(H) and LZA(HH). Between these two levels, an additional foam allowance of 250 mm shall therefore be included.
9. It has to be verified whether the gas cap is sufficiently large to accommodate the inlet device including a clearance of 150 mm above LZA(HH). The vertical space requirement of an inlet device is typically twice the inlet nozzle diameter plus 50 mm.

10. Preferably $2.5 \leq L/D \leq 6$.

4.1.3.5 Nozzles

Feed nozzle:

A top feed inlet equipped with an inlet device should be used. This device is connected to the inlet via an elbow and shall be directed to the nearest vessel head. Its location shall be at least 150 mm above LZA(HH).

The choice of the feed inlet device depends on the following factors:

- If the gas volumetric fraction of the feed is less than 0.15, the inlet device is a horizontal pipe section.
- If the gas volumetric fraction of the feed is between 0.15 and 0.7 the inlet device is a horizontal half-open pipe and its opening is directed upwards.

- If the gas volumetric fraction is larger than 0.7, then a Schoepentoeter™ should be selected.

If the gas flow is negligible and/or the separator has a sealing function (in the case of an Ejector Effluent Separator, for instance) a bottom rather than a top inlet is used.

For the sizing of the feed inlet nozzle, see (Appendix VIII).

For the detailed design of a Schoepentoeter™ see Appendix III of DEP 31.22.05.11-Gen.

Outlet nozzles:

The outlet of the light liquid phase shall be elevated (typically 150 mm).

Both liquid outlet nozzles shall be equipped with a vortex breaker in accordance with Standard Drawing S 10.010.

The diameter of the liquid outlet nozzles shall be chosen so that the liquid velocity does not exceed 1 m/s. The minimum diameter is 50 mm (or 2 inch).

The top of its vortex breaker shall be at least a half nozzle diameter below the corresponding lowest control level LZA(LL) for the light-phase outlet and LZA(LL)_{int} for the heavy-phase outlet). The bottom of the light-phase vortex breaker shall be at least 150 mm below LZA(LL).

In (Appendix V.1), the procedure is presented for checking the dimensions of an existing three-phase settler fitted with a boot. It can also be treated as the sizing procedure for a new settler starting with the specification of the vessel dimensions and the various level control heights.

If certain criteria cannot be met (for instance, the settling compartment is too short) the procedure has to be repeated with adjusted vessel dimensions.

A calculation example is given in (Appendix V.1).

4.1.4 Settler with weir arrangement

4.1.4.1 Inlet compartment

The inlet compartment (including feed inlet) is identical to that of the settler with boot.

4.1.4.2 Settling compartment

Since, in general, the cleaning of both liquid phases is required ("dewatering" and "de-oiling"), a liquid/liquid interface has to be maintained in this compartment (either via direct IL control or via a combination of two weirs).

4.1.4.3 Collection compartment(s)

Figure 4.2 through Figure 4.5 shows a number of possible arrangements.

The configuration with only one collection compartment (for the light liquid phase) with either a submerged or an overflow weir is shown in Figure 4.2. In both cases, direct control of the interface is required. In a submerged weir, the gas/liquid interface varies in the same way throughout the vessel, whereas in an overflow weir the gas/liquid interface upstream of the weir is fairly constant (apart from variations in the height of the weir crest due to changes in the flow rate of the light liquid phase).

If the liquid/ liquid interface is ill-defined, however, direct IL control should be avoided. Possible weir arrangements are then as shown in Figure 4.3 to Figure 4.5. The heights of the light- and heavy-phase overflow weirs plus their weir crest heights will determine the location of the interface level. The advantage of this configuration is that the liquid/liquid interface is self-controlling. Even an incoming slug (temporarily replacing the gas flow in the feed) will hardly have an effect, provided the collection compartments can accommodate the slug.

The weirs shall have hand holes for cleaning or removable weir panels. The minimum thickness of the weirs is 3 mm. Weirs and baffles separating the compartments for the light and heavy phase shall be installed leak tight, including the removable hand and man holes

in these weirs and baffles. For the perforated calming baffles, this leak tightness requirement does not apply. During commissioning of vessels with weirs and baffles, a leak test is strongly recommended.

The gutter configuration shown in Figure 4.3 can be applied to small light phase flows. A gutter side nozzle could alternatively be used instead of the nozzle with internal piping.

Otherwise the weir arrangement shown in Figure 4.4 should be used. If Q_l/Q_h is either relatively low or relatively high, this can be further refined to the configurations shown in Figure 4.5. The arrangement for small Q_l/Q_h , shown in Figure 4.5 should be used rather than an arrangement in which the width of the light-phase collection compartment has been made smaller by shifting the separation plate between the two collection compartments (because this could result in unfavourable sizing of the light-phase collection compartment and the need to have a light-phase outlet at the side of the vessel).

An oil skimming pipe should be installed in the water collection compartment, entering from the vessel bottom and extending to LA(H) for the periodic removal of the oil film which will inevitably form on top of the water.

In general, in the two collection compartments the gas/liquid interface will be controlled. The specified control times in conjunction with the liquid flows will determine the size of the collection compartments and, ultimately for a given diameter, the length of the vessel downstream of the hydrocarbon overflow weir.

NOTE Sometimes a three-phase flow settler geometry is adopted in practice with a combined inlet/settling compartment in the central part of the separator and with the collection compartments for the two liquid phases at the opposite sides of the vessel.

This geometry shall **NOT** be used because:

1. The entry of the feed into the central compartment causes disturbance which adversely affects the separation of the two liquid phases.
2. Assuming that the feed enters in the centre of the central compartment, at most, only half the compartment can be utilised for separation.

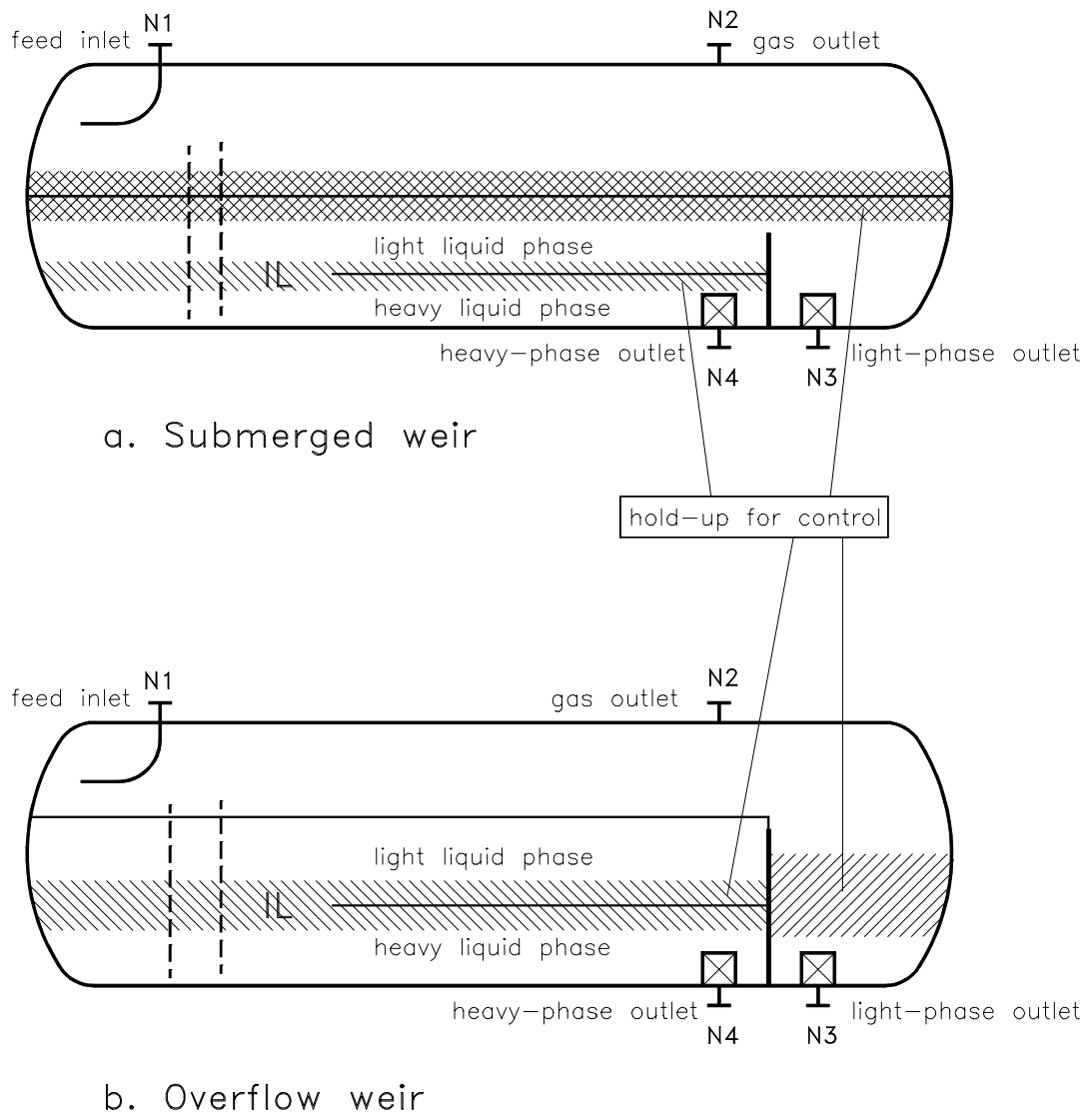


Figure 4.2 Horizontal open three-phase settler with single weir (submerged or overflow)