RHODIUS ◎

Safety and Environmental Solutions

knitted mesh & separation
SOLUTIONS BY **RHODIUS**©

Technical Documentation

Droplet Separation
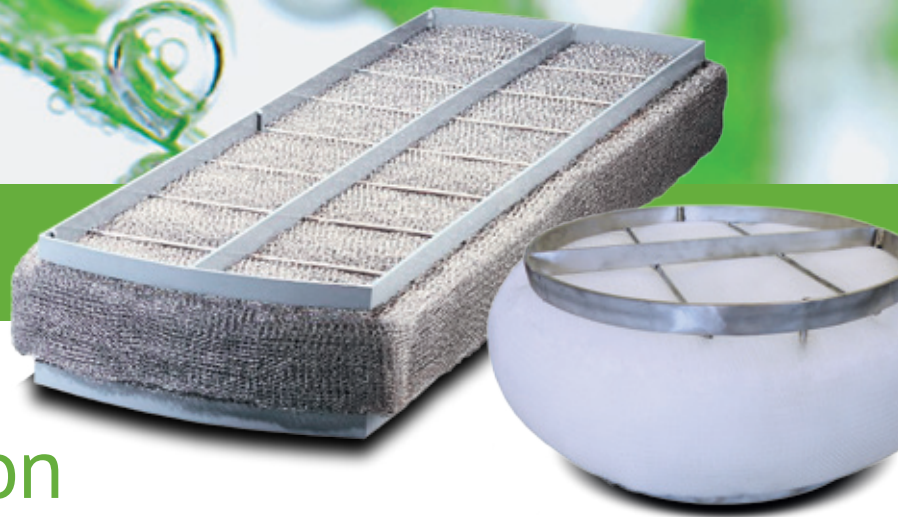
Contents

1 Introduction

Gas and vapour streams are very important in chemical process technology. Different process steps necessitate generation, cleaning and separation of this streams. An enrichment of gas streams with liquids can be reached both through mechanical or thermal droplet generation – as e.g. in scrubbers and absorption columns – as well as through physical-chemical reactions (condensation). Certain process runs then require a separation of liquid portions from the gas or vapour stream. Different systems are used depending on liquid amount, droplet size and required purity.

Beneath cyclones and impact plates mainly droplet separators made of knitted wire mesh are employed. With little expenditure of energy (low pressure drop) finest droplets with diameters of nearly 1 µm can be separated and efficiencies up to 99.9 % can be achieved. Therefore separation problems with gas-liquid-separation are solved economically and cost-saving.

2 Fundamentals

A knitted wire mesh droplet separator is an industrial instrumentation which retains droplets carried by a gas or vapour stream, i.e. which effects a phase separation between gas and liquid stream. Droplet separators are predominantly used for exhaust air decontamination. Besides liquid droplets carried in process gas streams have to be separated, too, as they could cause damage on the instrumentation due to corrosion or erosion or due to depositing, caking and product contamination.

The efficiency of a droplet separator can be characterized with its fraction efficiency curve. The required expenditure of the separation is crucially governed by the feed droplet spectrum and the specified size limit of the droplets.
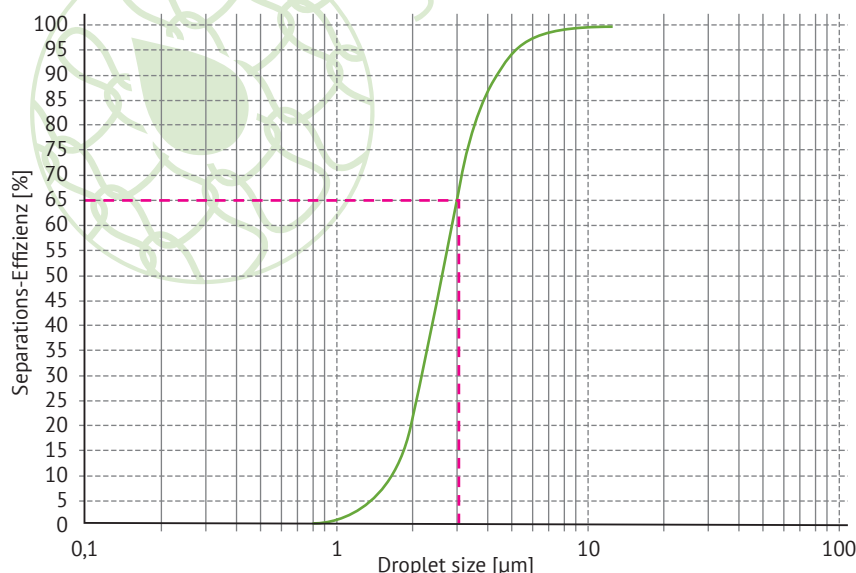

Figure 1:
Exemplary fractional separation curve
(Example: 65 % of all 3 µm drops are deposited)

2.1 Droplet Size

The size of the droplets decisively depends on their kind of origin and their prehistory. Two principal mechanisms are responsible for their formation: mechanical generation as well as condensation.
A rough distinction of the droplet size can be made to the effect, that droplets bigger than 10 µm are called spray and smaller ones are called mist or aerosoles. Spray is mainly formed when liquids are atomized and the droplet spectrum is the finer the more energy is put into the atomization process.
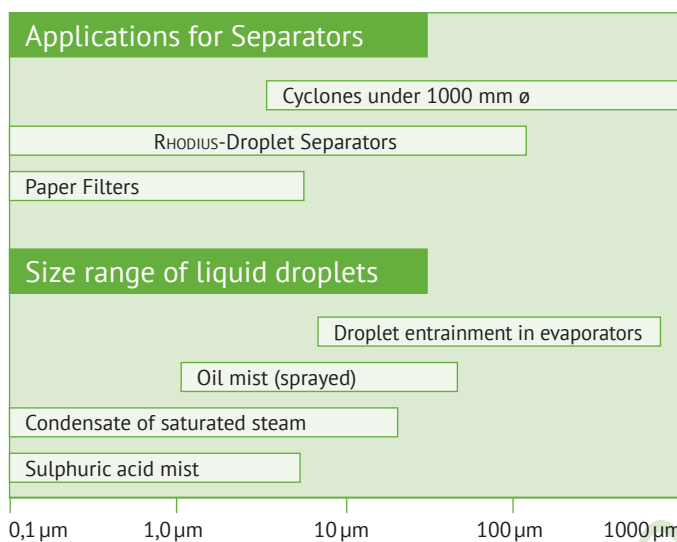
Aerosoles are mainly generated by condensation of saturated steam and occur as mist in chemical reactions of gas mixtures, e.g. during the formation of liquid sulphuric acid through gaseous SO_3 and H_2O.

Beneath the formation of the droplets also the physical properties of the fluids are very important. A low surface tension favours the formation of small droplets, a high viscosity on the other hand favours the formation of large droplets. The liquid droplets in a gas flow normally have different sizes. The distribution of the droplet sizes is similar to the normal distribution by Gauss.

Applications for Separators

Cyclones under 1000 mm ø

Rhodius-Droplet Separators

Paper Filters

Size range of liquid droplets

Droplet entrainment in evaporators

Oil mist (sprayed)

Condensate of saturated steam

Sulphuric acid mist

| 0,1 µm | 1,0 µm | 10 µm | 100 µm | 1000 µm |

Figure 2: Applications for separators and characteristic particle sizes.

2.2 Separation Mechanisms

The separation of droplets bigger than 30 µm normally causes no problems, as an inertia separation can easily be carried out due to the relatively large mass of drops. Therefore the application of Rhodius knitted wire mesh droplet separators predominantly yields droplet size ranges smaller than 30 µm. In this droplet size range and a liquid load of about 1 – 5 weight-% the disperse phase follows the streamlines, so that the gas flow itself is not influenced.

The separation of liquid droplets is based on the effect, that the particles can not follow the streamlines of the gas when they hit an obstacle and stick to a periphery. In principle, the most important separation mechanism for droplet separation is the separation by inertia. In Fig. 2 separation by inertia is shown schematically.

Every single wire in a knitted wire mesh droplet separator is an obstacle in the gas flow, therefore a deviation of the streamlines takes place. Entrained droplets can not follow this deviation due to their inertia and hit the obstacle. This effect is mainly relevant for droplets bigger than 10 µm.
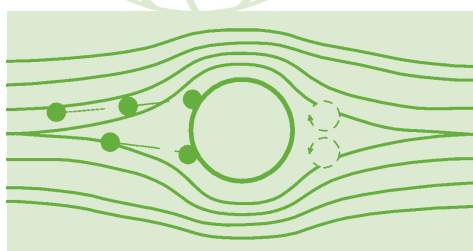
At the wires the single droplets grow together (coalesce) to bigger drops, then they form a liquid film on the wire surface and fall down due to gravity where the liquid is drawn off. The efficiency of the droplet separation increases with an increasing number of deviations.

Figure 3: Separation by inertia

3   Design of Droplet Separators

Knitted wire mesh droplet separators for gasliquid- separation are designed computer aided.
The optimum calculation yields a complete separation of the liquid phase from the gas flow.
Therefore the following parameters have to be taken into account:

- Gas flow velocity

- Permissible pressure drop

- Required efficiency

- Liquid amount to be separated

RHODIUS produces the appropriate droplet separator for every special application.
For this purpose a large variety of materials is available to facilitate manufacturing to order.
A selection of RHODIUS standard droplet separators is shown on page 11.

3.1   Gas Flow Velocity

The maximum gas flow velocity refers to that operating point of the droplet separator where the knitted wire mesh package is flooded and a liquid entrainment of mostly agglomerated drops occurs. Therefore the operating point has to be below the flooding point.

For calculating the maximum gas flow velocity u_{max} a variety of parameters have to be taken into account, e.g. gas and liquid density and the surface tension of the liquid to be separated.

The following simplified formula can be used:

$$u_{max} = K \cdot \sqrt{\frac{\rho_{Fl} - \rho_G}{\rho_G}}$$

where:

u_{max}	[m/s]	Max. gas flow velocity
ρ_{Fl}	[kg/m³]	Liquid density
ρ_G	[kg/m³]	Gas density
K	[-]	Constant: 0,04 - 0,15

The maximum permissible velocity excludes the formation of secondary drops
due to impingement on the fibres and avoids flooding of the knitted wire mesh package.
The design velocity is about $0,75 \cdot u_{max}$.

3.2 Flooding Point

The determination of the flooding limit of droplet separators has to be taken into account in the stage of design in order to ensure faultless function of the droplet separator.
In Fig. 4 the design curve of knitted wire mesh as well as its flooding limit is shown [1].
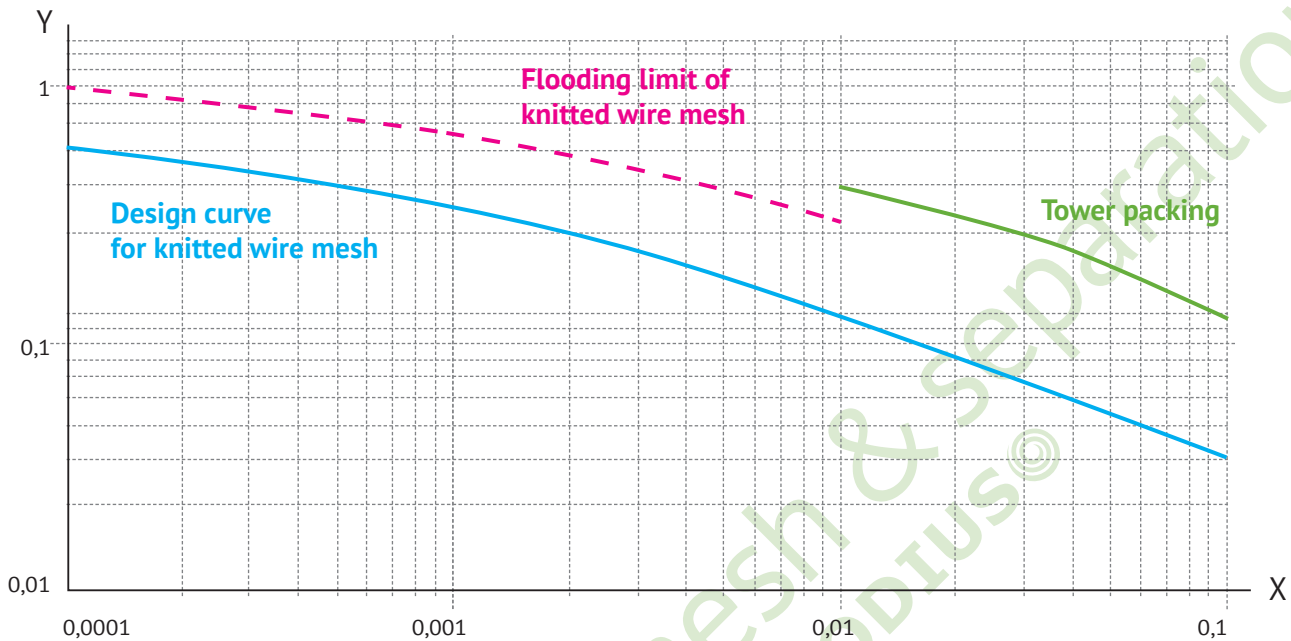
Figure 4: Calculation diagram for designing knitted wire mesh droplet separators

Where:

$$X = \frac{L}{G} \cdot \sqrt{\frac{\rho_G}{\rho_L}}$$

$$Y = \frac{u^2 \cdot a \cdot \rho_G \cdot (\mu^L)^{0,2}}{g \cdot \varepsilon^3 \cdot \rho}$$

L	[kg/h]	Liquid flow rate
G	[kg/h]	Gas flow rate
ρ_L	[kg/m³]	Liquid density
ρ_G	[kg/m³]	Gas density
u	[m/s]	Elocity across an unobstructed cross section
a	[m2/m³]	Surface area of the knitted wire mesh package
μ_L	[cP]	Viscosity of the liquid
g	[m/s²]	Acceleration due to gravity
ε	[-]	Porosity

3.3 Pressure Drop

The pressure drop of knitted wire mesh droplet separators is very low due to the large free volumes even at higher velocities. It rises almost proportional with the thickness of the package and acts nearly proportional to its density (with the same wire diameter and knitted wire mesh specification).

Liquid load, viscosity, wetting behaviour of the liquid, as well as the contamination level of the gas stream (solid particles) have a strong influence on the pressure drop.

Saemundsson gives a theoretical pressure drop calculation for pouring knitted wire mesh [2]. This relation is valid for dry packages and takes all relevant parameters of different knitted wire mesh specifications into account (e.g. wire diameter and porosity). The calculation of the pressure loss coefficient was modified through the empirical formulations g and f.

This new equation confirms the measured pressure drops (dry measurements) of stainless steel types relatively exact shown on page 12.

This relation is:

$$\Delta p = \zeta \cdot \frac{H}{R_h} \cdot \frac{\rho_L}{2} \cdot \frac{u^2}{(1-\alpha)^2}$$

with:

$$R_h = \frac{1-\alpha}{\alpha} \cdot \frac{D_F}{4} \qquad \text{Hydraulic radius}$$

$$\zeta = \frac{g}{Re} + \frac{f}{Re^{0,2}} \qquad \text{Pressure loss coefficient}$$

$$Re = \frac{u}{1-\alpha} \cdot 4 \cdot R_h \cdot \frac{\rho_L}{\mu_L} \qquad \text{Reynolds' number}$$

where are:
g = -1,56 · ρ + 771,2
f = -0,0038 · ρ + 2,72
for ρ ⩽ 300

D [m]	Wire diameter
H [m]	Thickness of the packing
α [-]	Packing density (1-ε)
μ [Pas]	Dynamic viscosity
ρ [kg/m³]	Gas density
g, f	Functions
Index: L	Referring to gas (air)
F	Referring to wire (fibre)

3.4   Separation Efficiency

Below the flooding limit efficiency increases with increasing gas flow velocity. At the same time the pressure drop rises square what causes higher investments and essentially higher operating costs. Therefore each plant operator has to find out the optimum point between high separation efficiency and economic efficiency. The evaluation will turn out in favour of efficiency or low operating costs depending on the kind of application.

Proper design of the RHODIUS droplet separators yields separation efficiencies up to 99.9 %. Separation efficiencies always have to be seen in connection with the size limit of the droplets. Therefore RHODIUS always specifies separation efficiencies with the corresponding size limit, e.g. efficiency 99.9 % for droplets ≥ 5 µm. The efficiency curves shown on page 13. are based on the theoretical calculation of Bürkholz [1] and depend on the measured pressure drops.

Influences of the process parameters on the target variables, at …

	… increasing pressure drop	… increasing separation (drops > 3 µm)	… increasing diameter border drops	… increasing potential throughput
… increasing wire diameter	⬇	⬇	⬆	⬆
… increasing thickness of the packing	⬆	⬆	●	●
… increasing packing density	⬆	⬆	●	⬇
… increasing porosity	⬇	⬇	⬆	⬆
… increasing specific surface	⬆	⬆	⬇	⬇
… increasing aerosol speed	⬆	⬆	⬇	━
… increasing gas density	⬆	⬇	⬆	⬇
… increasing liquid density	●	⬆	⬇	●
… increasing amount of liquid	●	●	●	⬇
… increasing separation area	⬇	⬇	⬆	⬆

● constant, insignificant | ⬆ is increasing | ⬇ decreases | ━ no rating possible

4   Agglomeration

In order to achieve high efficiencies for droplet spectrums in the range of a few microns either an increase of the gas flow velocity or the use of a two-stage separator is necessary. This construction ensures high operational flexibility at a comparatively low pressure drop. The first stage acts as an agglomerator. Increasing the gas flow velocity (e.g. by reducing the gas flow area) as well as chosing appropriate packages ensures that the packing will be flooded.

In this process it has to be taken into account that the stage of coalescence is run with sufficient liquid. If necessary, a part of the separated liquid can be sprayed before the first stage. In the first stage an agglomeration of very small droplets into larger ones takes place, and these are subsequently separated without any problems in a second stage that is run with lower velocity. An additional – often desirable – effect comes with the use of an agglomerator, namely the liquid column forming in the package facilitates a postabsorption of gaseous hazardous substances.

5   Literature

[1]   Bürkholz, Armin
       Droplet Separation
       VCH-Verlag, Weinheim, 1989

[2]   Saemundsson, Helgi B.
       Abscheidung von Öltropfen aus strömender Luft mit Drahtgestrickpaketen Verfahrenstechnik 2
       Nr. 11 (1968), S. 480-486

[3]   Bulag, S.
       Hochwirksame Tropfenabscheider bei der Rauchgasreinigung Chemische Industrie
       Jan. 1983

[4]   Fritz, W.; Kern, H.
       Reinigung von Abgasen
       Vogel Verlag, Würzburg, 1990

[5]   Riemer, H.
       Abscheidung von Nebeln, Sprays und löslichen Feststoffen aus Gasströmen
       CAV, Mai 1979

6   Construction

The design of the droplet separator according to the required operational conditions leads to an exact definition of the knitted wire mesh type. However, additional manufacturing details must be determined.

Depending on the specific requirement, the knitted wire mesh may be finished in the form of a roll (wrapped roll) or as a combination of layers (knitted wire mesh mats).

The cutting edges stemming from the fabrication of a package are provided with a framing. In order to ensure an optimum press fit with the installation, the droplet separator is manufactured in oversize relative to the inside dimensions of the vessel.

The data sheets in the appendix show further details with regard to installation, grids and support constructions as well as subdivision of the droplet separators into different segments.

A great variety of materials and an own engine and tool construction enables RHODIUS to match her knitted wire mesh droplet separators to almost every application. The orders of magnitude for droplet separators range from small pressed parts of a few centimeters in diameter and thickness to constructions with diameters up to 10 metres.

Please notice, however, that RHODIUS does not produce vessels or complete solutions.

7   Applications

From the many possible applications of RHODIUS droplet separators a few may be listed here:

- **Evaporators / Seawater desalination plants –** to avoid entrainment and to improve product purity

- **Absorption- and destillation columns –** increase of flow rates and product purity at the same time

- **Vacuum- and compressed air systems –** separation of the condensate generated

- **Oil mist separator –** waste air abatement and recovery of oils and lubricants

- **Fat filters/ fatty acid systems –** separation of fatty acids

- **Paint shops –** separation of lacquer particles

- **Sulphuric acid plants –** separation of sulphuric acid mist

- **Air conditioning and waste air systems –** separation of liquid and solid particles

- **Cooling towers –** retaining aerosoles

8   Assembly instructions

The single segments of the droplet seperator should be arranged according to the presentation on page 16 or the attached detailed drawing, respectively. Before installing the segments you should check which manner of fastening is prescribed. Some possible fastening methods are shown on page 24.

In case of fastening with stud bolts (see page 23) these have to be fixed to the drawing before putting these segments in place. Installation of the single segments is carried out crosswise to the support bars. The outer segments are installed first then the inner ones follow, i.e. the middle segment is the one to be installed at last. As for sealing purposes the single segments are oversized they have to be laid tightly together.

For pushing in the last segment metal plates are used which are laid left and right to the segments already installed. Then you have to remove the metal plates and check the sealing effect of the segments. Now the segments can be fastened to the supporting structure as prescribed.

9   Maintenance

Due to their high porosity of 89 to 99 % droplet separators are relatively insensitive to soiling. Under normal operating conditions with sufficient high liquid flow the droplet separator cleans automatically by itself.

Solids are washed out by the liquid flow. In case of less liquid flow and high solid concentration it is advisable to install a scrubber in front of the knitted wire mesh droplet separator.

However, in the event of deposits or caking in the knitted wire mesh package, it can be cleaned by jets of water, vapour, or diluted bases or acids. This treatment must be chemically compatible with the materials involved.

The cleaning may be done within the vessel with an equipment already installed (counter stream rinsing equipment) or externally. For designing the cleaning equipment the kind and quantity of the pollution has to be taken into account.

RHODIUS suggests the following standard values:

- Quantity of water: 20-80 l/m²min
- Jetting time: 5-10 min
- Distance of the nozzles: 300-500 mm
- Distance nozzles wire mesh: 300-500 mm
- Jetting admission pressure: approx. 3 bar

10 Materials and Sizes

Metals	Synthetics	Fibre-Material
● All usual stainless and acid resistant steels (SS) ● Special materials: – Monel * – Inconel * – Incoloy * – Titanium – Copper – Aluminium – Brass – Galvanized steel	● PE (Polyethylen) ● PP (Polypropylen) ● PVC (Polyvinylchlorid) ● PVDF (Polyvinylidenfluorid) ● ETFE (modif. PTFE; Polytetrafluoroethylene)* ● PES (Polyester) ● FEP (Perfluorethylenpropylen) ● PFA (Perlfuoralkoxycopolymer)	● Glas fibre ● PP-Fibre ● PES-Fibre
* Trade Mark	* Trade Mark: Hostaflon (HM)	

| **Wire Diameters** Ø 0,05 - 0,50 mm **Standard** Ø 0,12 / 0,28 mm	**Dimensions of monofilament** Ø 0,22 - 0,60 mm **Standard** Ø 0,27 / 0,40 mm **Multifilaments of PP and PES**	**Single fibre** Ø approx. 0,01 mm

Droplet separator sizes:

● Diameter: any size in the range of [mm] to [m].

● Thickness: any thickness at all. Standard: 25 mm, 50 mm, 100 mm, 150 mm, 200 mm
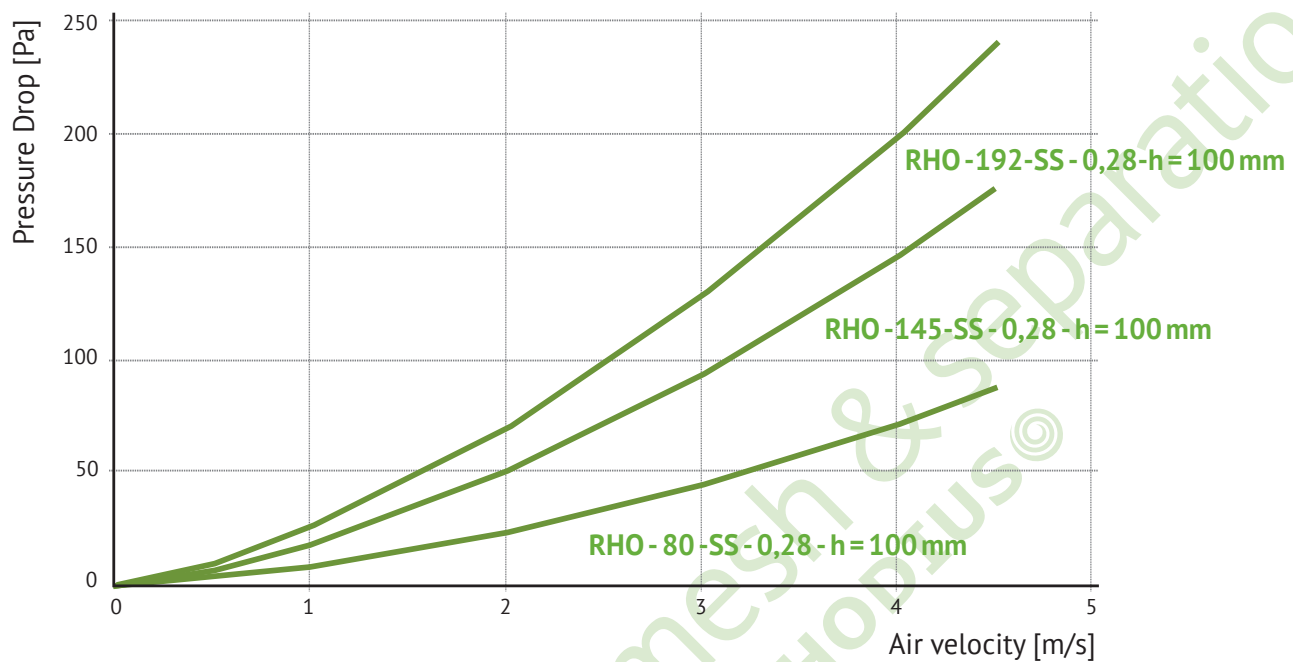
11   RHODIUS standard Types

Types	Density [kg/m³]	Density [lbs/ft³]	Surface [m²/m³]	Surface [ft²/ft³]	Porosity [%]	Application
Metal types						
RHO-80-SS-0,28	80	5	145	44	99,0	High liquid amount
RHO-110-SS-0,28	110	7	200	61	98,6	High flow velocity
RHO-130-SS-0,28	130	8	236	72	98,3	Standard version
RHO-145-SS-0,28	145	9	265	80	98,1	Normal process conditions
RHO-175-SS-0,28	175	11	320	98	97,8	
RHO-192-SS-0,28	192	12	350	107	97,5	High efficiency
RHO-240-SS-0,28	240	15	435	133	97,0	Oil mist separation
RHO-240-SS-0,14	240	15	868	265	97,0	Agglomeration
RHO-432-SS-0,12	432	27	1835	560	94,5	Smallest liquid drops
Synthetic types						
RHO-50-PP-0,40	50	3	550	170	94,5	Standard version
RHO-80-PP-0,40	70	4,4	880	270	91,2	Corrosive media
RHO-100-PP-0,40	100	6,2	1100	335	89,0	High efficiency
RHO-100-PP-0,22	100	6,2	2000	610	89,0	Acid mists
RHO-80-PVDF-0,27	80	5	690	210	95,5	High process temperatures
RHO-100-ETFE-0,27	100	6,2	850	260	94,2	
RHO-100-PTA-0,27	100	6,2	690	210	95,4	
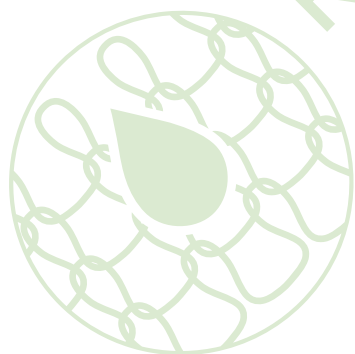
12 Pressure Drops

12.1 Metal Types
Dry / 1 bar / 20 °C / h = 100 mm

Pressure Drop [Pa] vs Air velocity [m/s]

RHO - 192 - SS - 0,28 - h = 100 mm

RHO - 145 - SS - 0,28 - h = 100 mm

RHO - 80 - SS - 0,28 - h = 100 mm

12.2 Synthetic Types
Dry / 1 bar / 20 °C / h = 100 mm
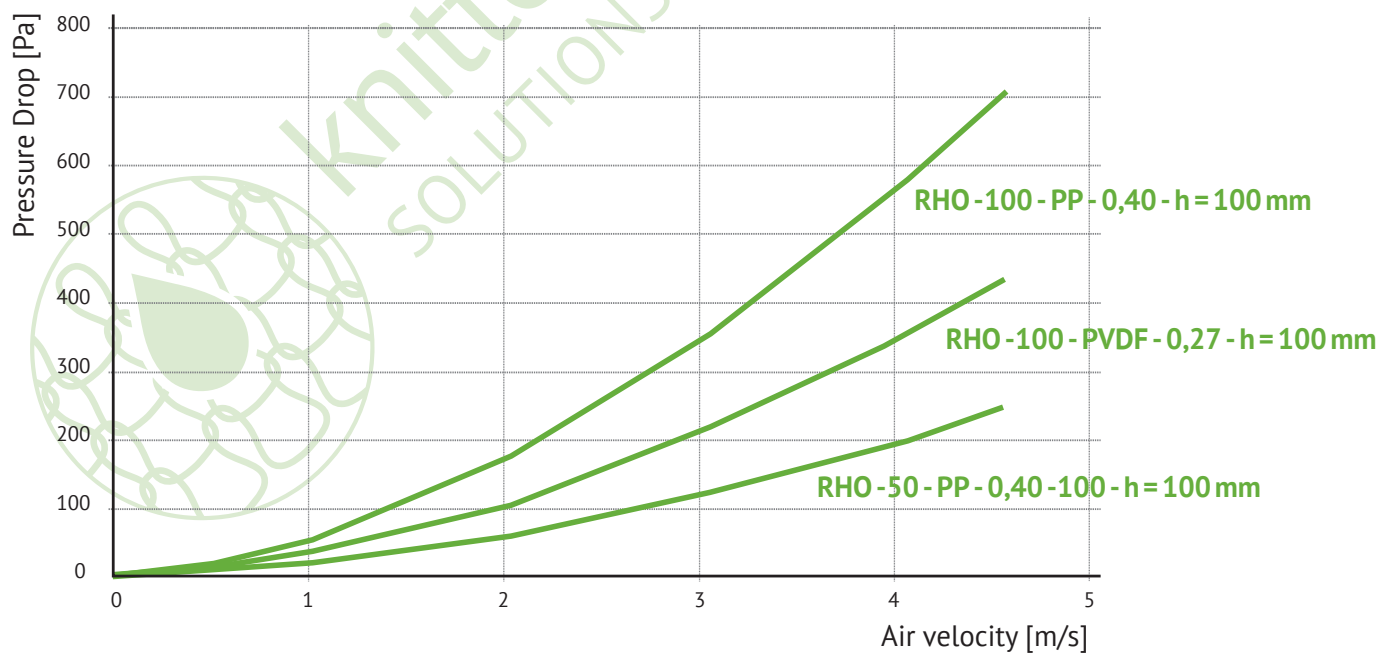
Pressure Drop [Pa] vs Air velocity [m/s]

RHO - 100 - PP - 0,40 - h = 100 mm

RHO - 100 - PVDF - 0,27 - h = 100 mm

RHO - 50 - PP - 0,40 - 100 - h = 100 mm

Predictions on performance data such as pressure loss and separation efficiency are based on semi-empirical equations, taking into account the mentioned process data. These expectation values do not represent an assurance of properties and do not constitute a guarantee.

13   Separation Efficiency
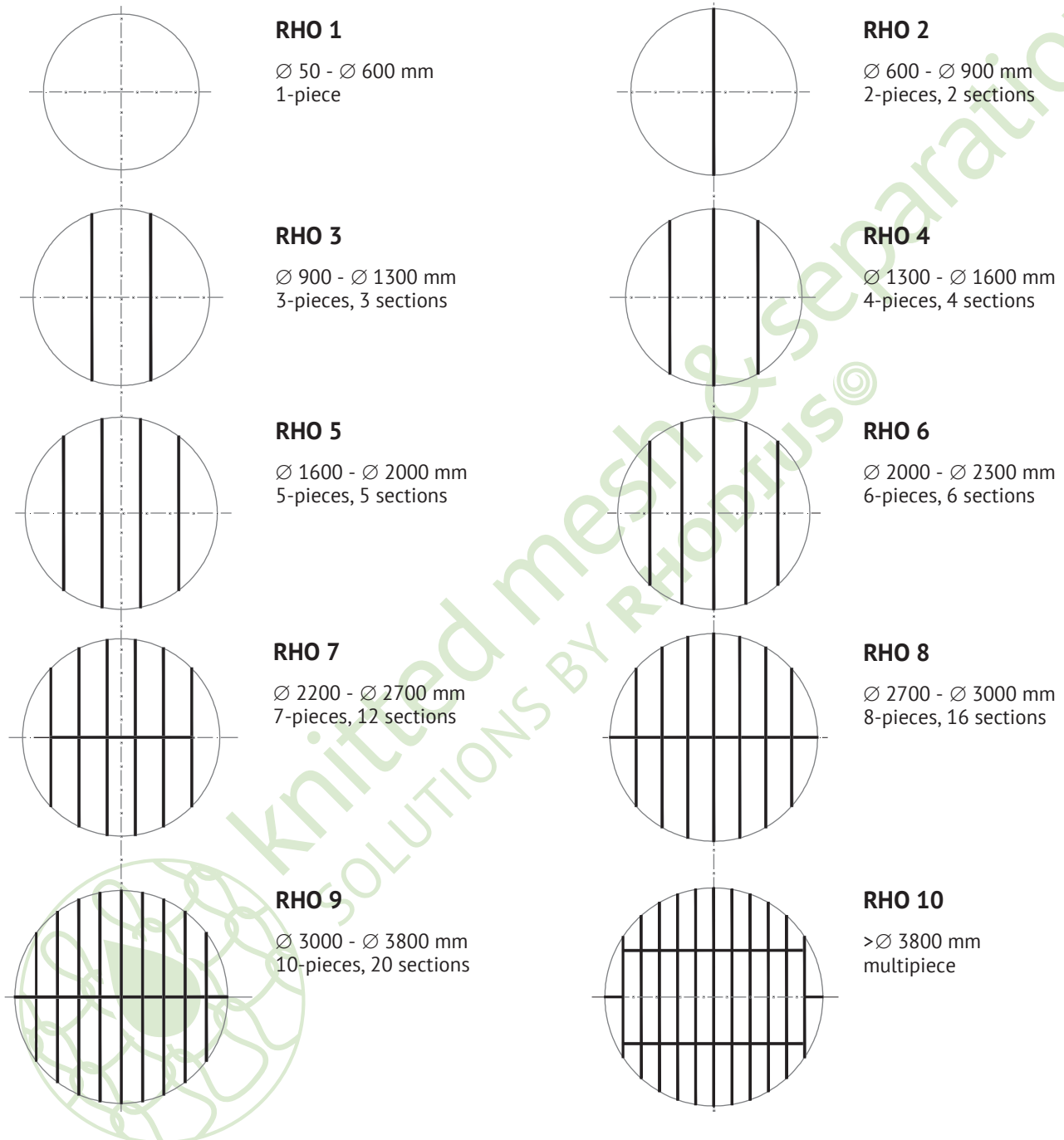
13.1   RHO - 145 - SS - 0,28 / h = 100 mm
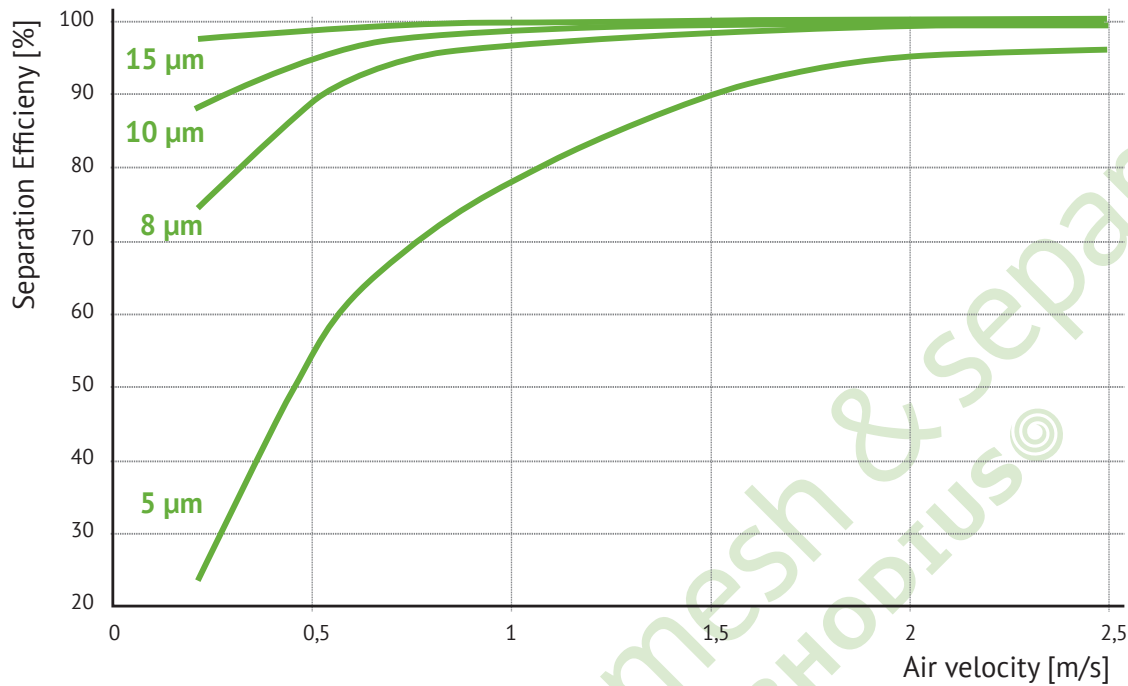
13.2   RHO - 50 - PP - 0,40 / h = 100 mm
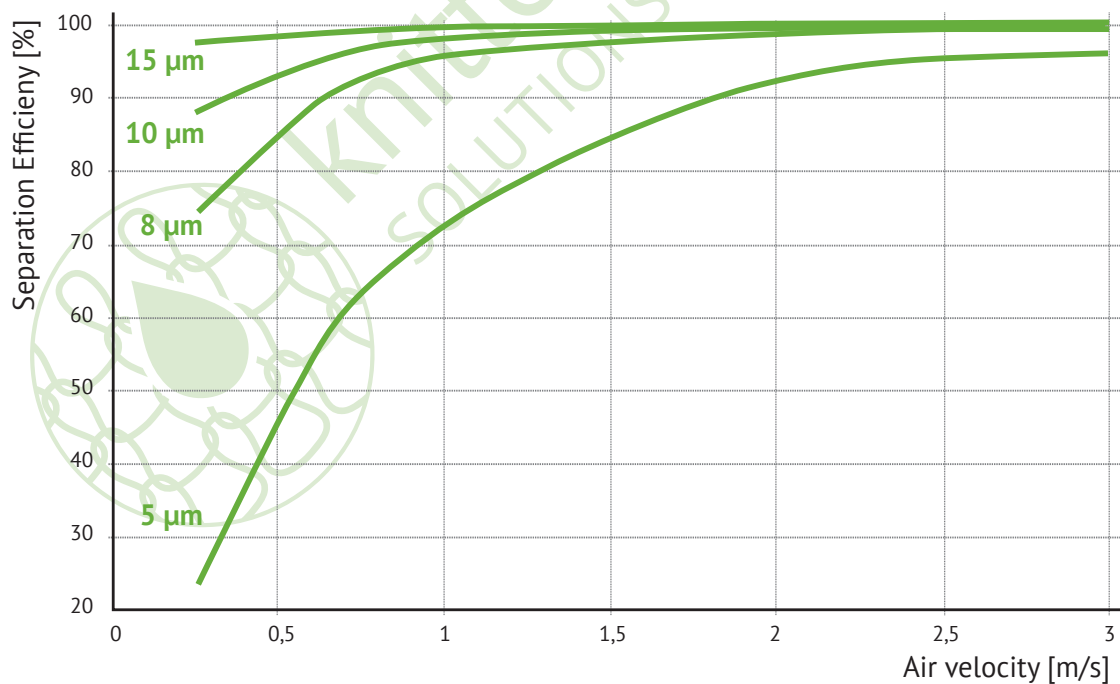
Predictions on performance data such as pressure loss and separation efficiency are based on semi-empirical equations, taking into account the mentioned process data. These expectation values do not represent an assurance of properties and do not constitute a guarantee.
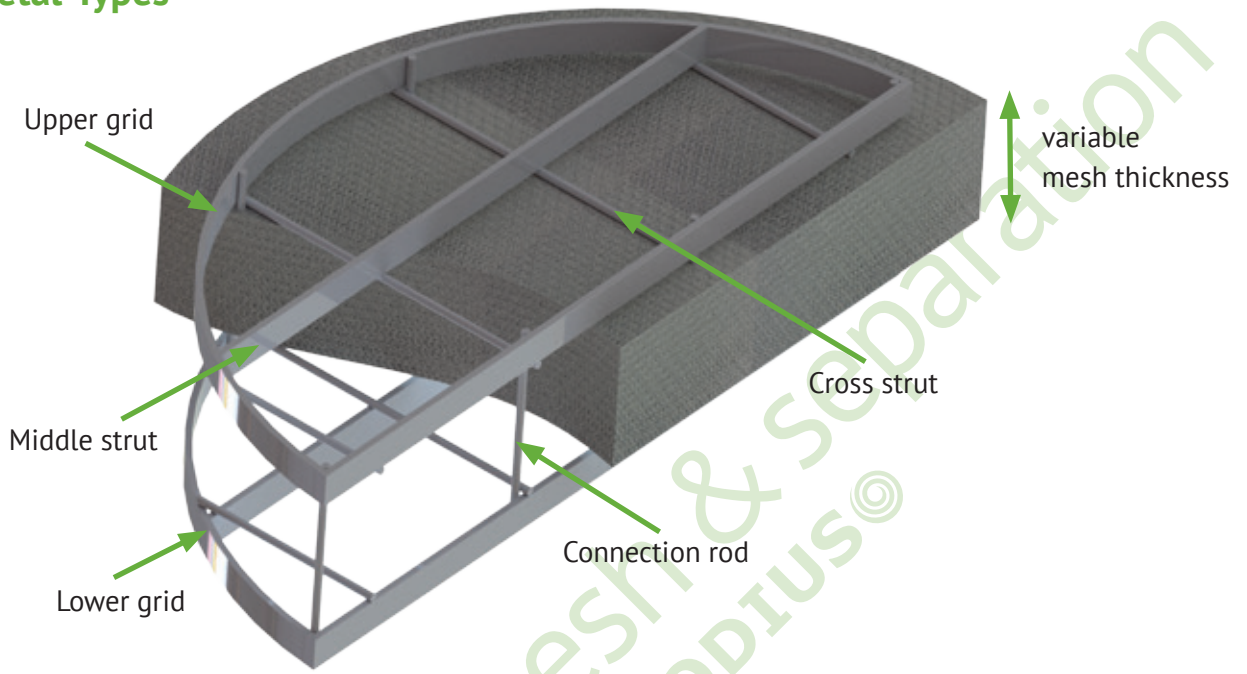
14 Knitted wire mesh droplet separator

RHO 1

∅ 50 - ∅ 600 mm
1-piece

RHO 2

∅ 600 - ∅ 900 mm
2-pieces, 2 sections

RHO 3

∅ 900 - ∅ 1300 mm
3-pieces, 3 sections

RHO 4

∅ 1300 - ∅ 1600 mm
4-pieces, 4 sections

RHO 5

∅ 1600 - ∅ 2000 mm
5-pieces, 5 sections

RHO 6

∅ 2000 - ∅ 2300 mm
6-pieces, 6 sections

RHO 7

∅ 2200 - ∅ 2700 mm
7-pieces, 12 sections

RHO 8

∅ 2700 - ∅ 3000 mm
8-pieces, 16 sections

RHO 9

∅ 3000 - ∅ 3800 mm
10-pieces, 20 sections

RHO 10

>∅ 3800 mm
multipiece

The standard design displayed is only a build suggestion
Any desired alterations to it can of course be made.

15 Rhodius standard Design
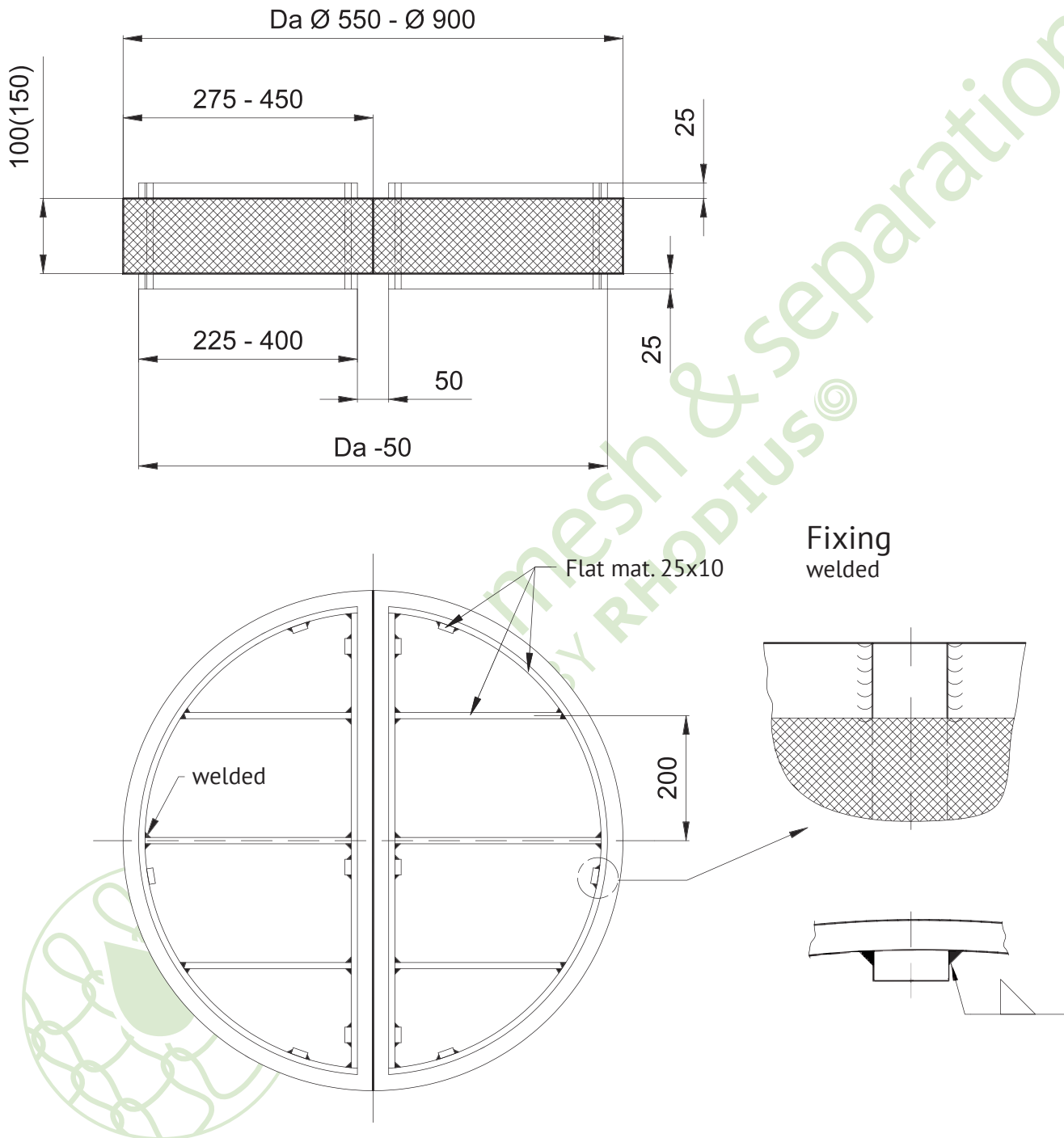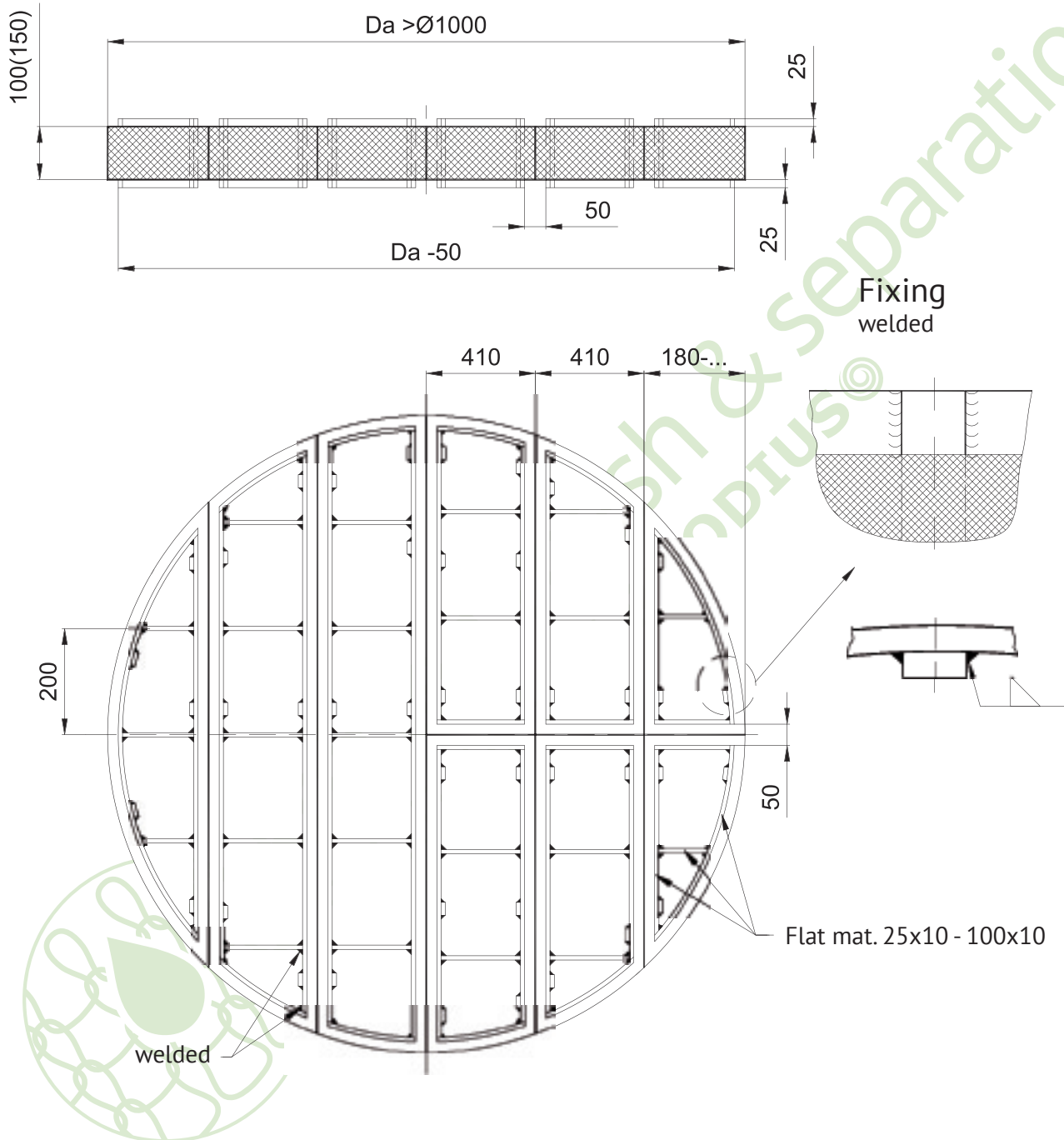
15.1 Metal-Types
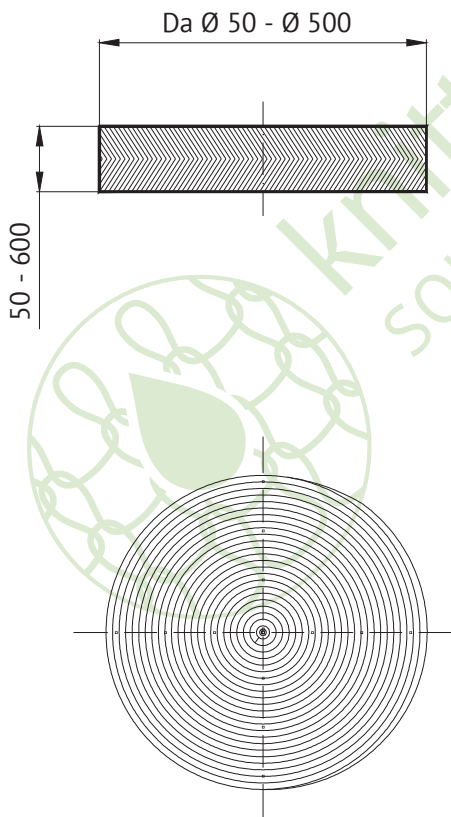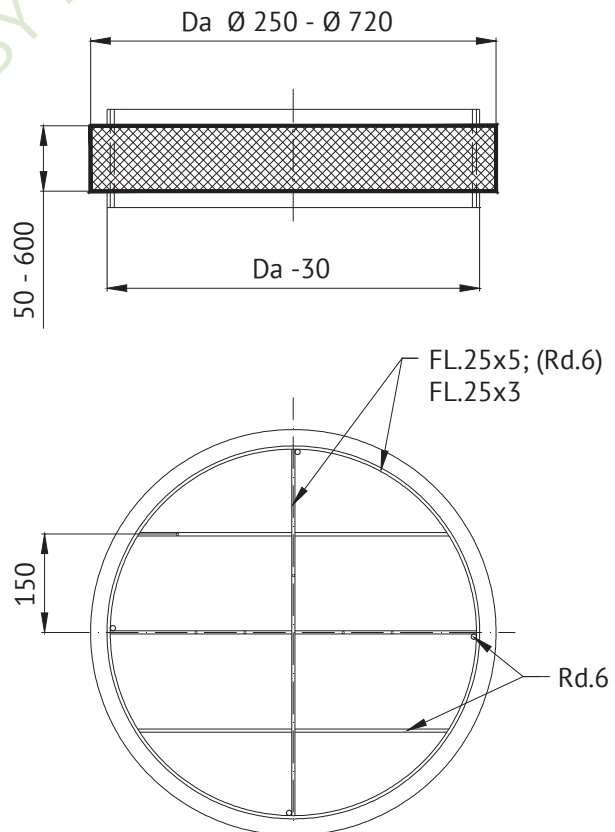
Upper grid

variable mesh thickness

Cross strut

Middle strut

Connection rod

Lower grid

Coiled design

Da Ø 50 - Ø 500

50 - 600

Layered design

Da Ø 250 - Ø 720

50 - 600

Da -30

FL.25x5; (Rd.6)
FL.25x3

150

Rd.6

The standard design displayed is only a build suggestion
Any desired alterations to it can of course be made.

15.2 Standard Design: RHO 2 – RHO 10 Metal Types Multipiece
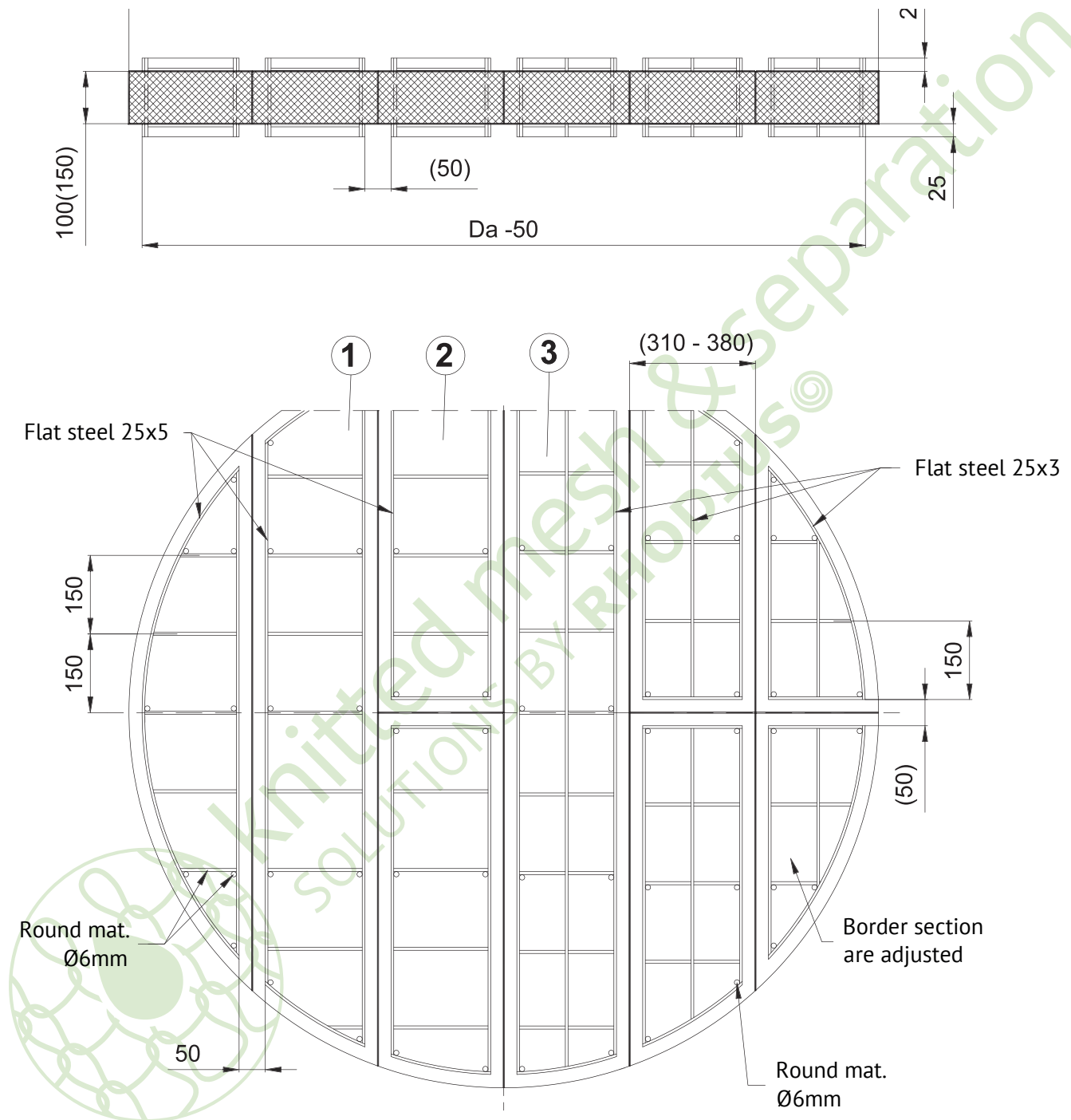
Flat steel 25x5

Flat steel 25x3

Round mat. Ø6mm

Round mat. Ø6mm

Border section are adjusted

The standard design displayed is only a build suggestion
Any desired alterations to it can of course be made.

15.3   Standard Design: Plastic

Da Ø 550 - Ø 900

275 - 450

100(150)

25

225 - 400

50

25

Da -50

Flat mat. 25x10

Fixing
welded

welded

200

The standard design displayed is only a build suggestion
Any desired alterations to it can of course be made.
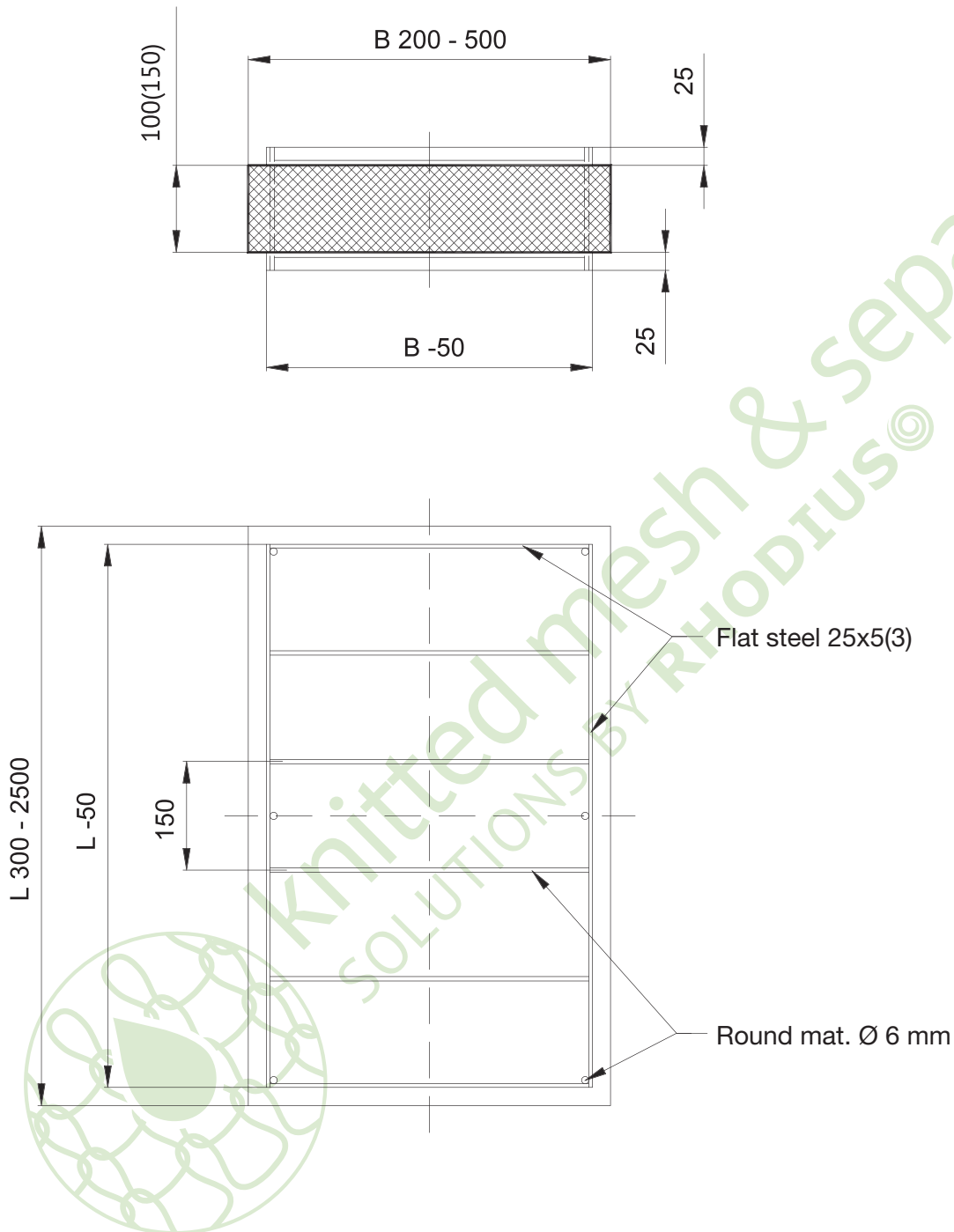
15.4 Standard Design: Plastic Multipiece

Da >Ø1000

100(150)

25

50

25

Da -50

Fixing
welded

410 410 180-...

200

50

Flat mat. 25x10 - 100x10

welded

The division of the droplet separators depends on a max. width of 410mm

The standard design displayed is only a build suggestion
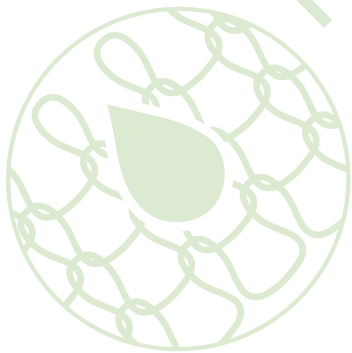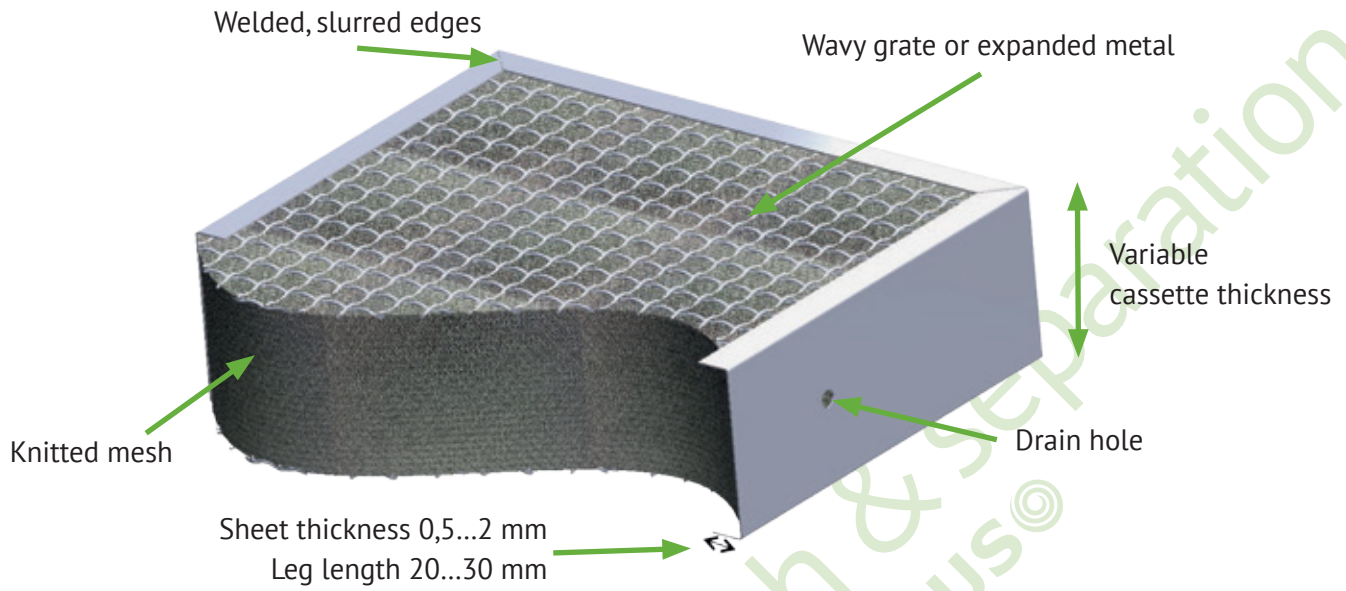Any desired alterations to it can of course be made.

15.5   Standard Rectangle Design: Metal Types

B 200 - 500

100(150)

25

B -50

25

Flat steel 25x5(3)

L 300 - 2500

L -50

150

Round mat. Ø 6 mm

The standard design displayed is only a build suggestion
Any desired alterations to it can of course be made.

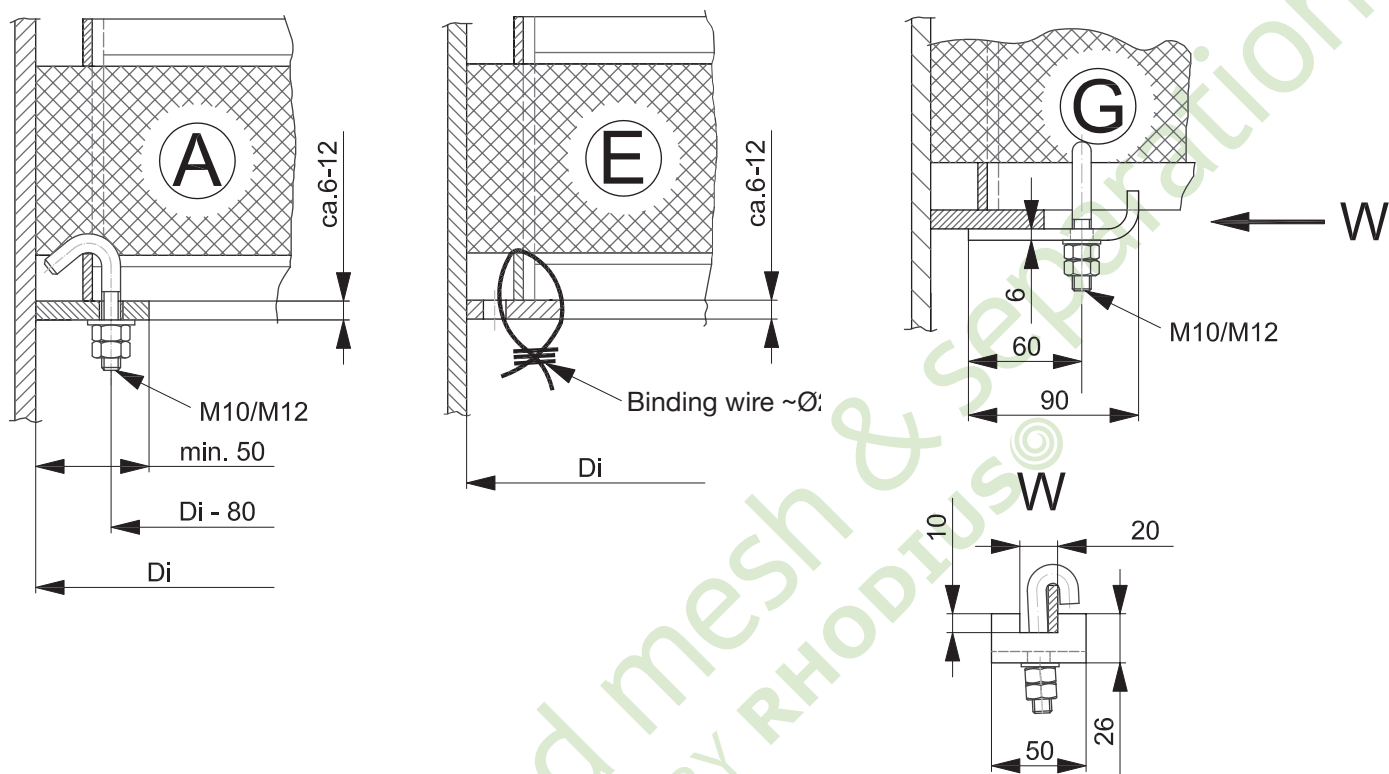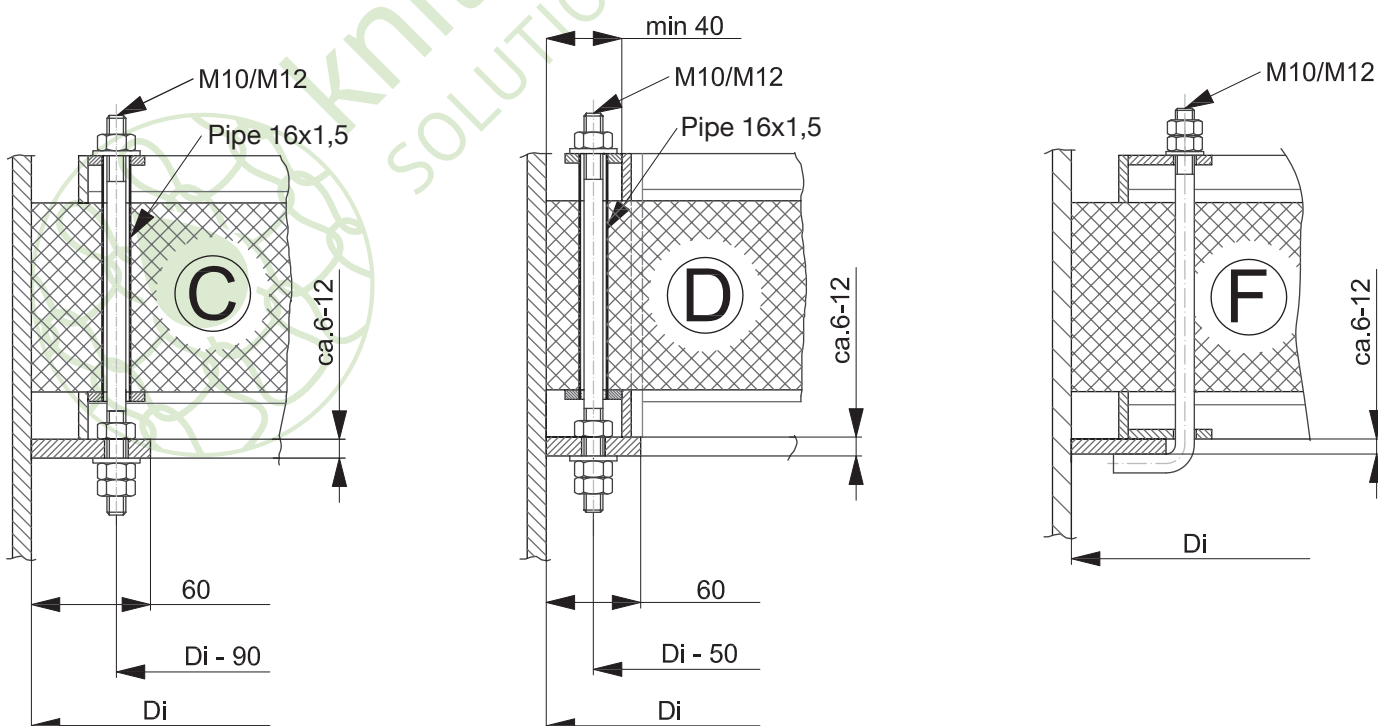## 15.6 Standard Design: Knitted mesh with U-profile frame

Welded, slurred edges

Wavy grate or expanded metal

Variable cassette thickness

Knitted mesh

Drain hole

Sheet thickness 0,5...2 mm
Leg length 20...30 mm

The standard design displayed is only a build suggestion
Any desired alterations to it can of course be made.

16   Installation – Droplet Separator

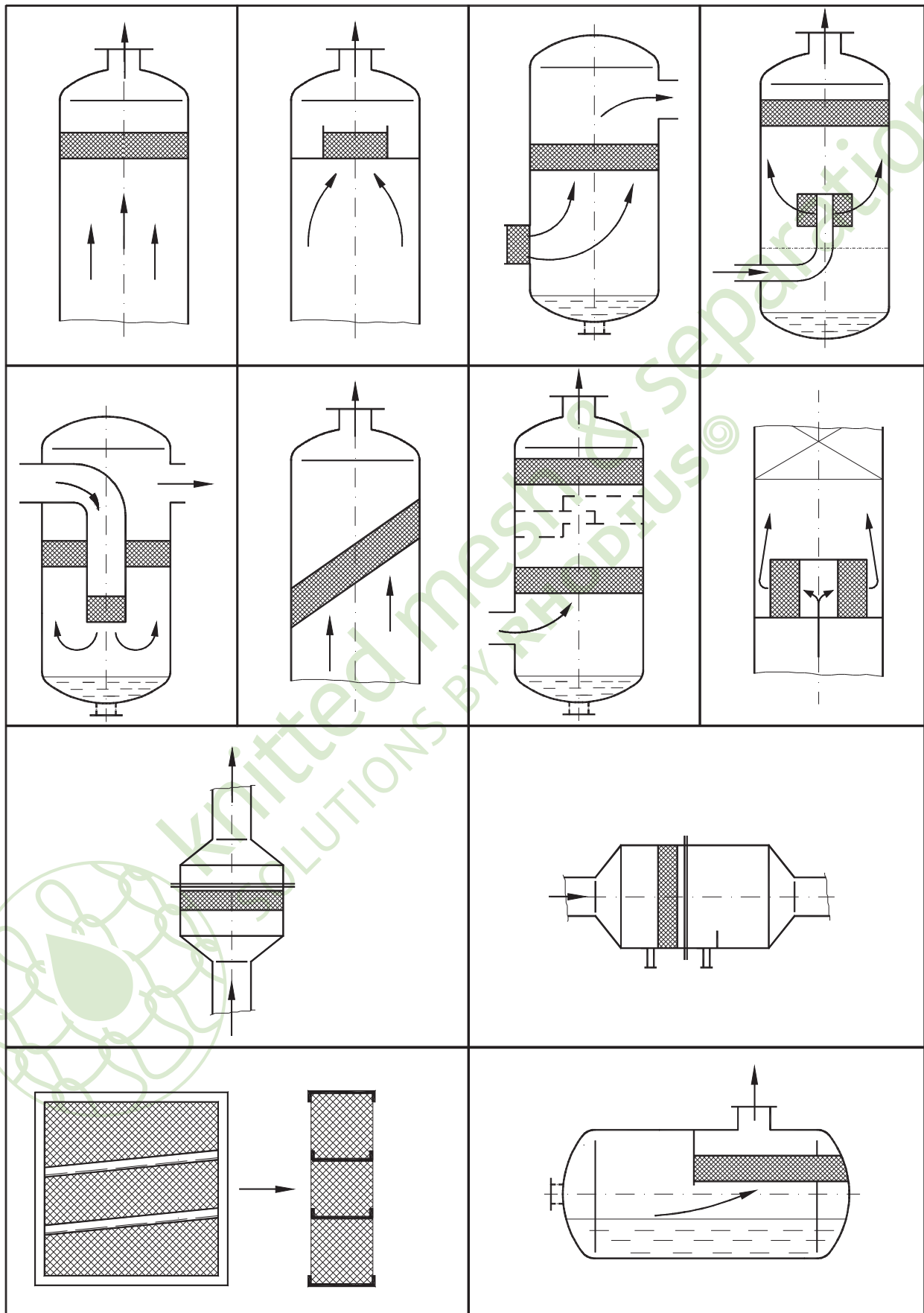## 16.1   Installation and attachment from beneath

A — ca.6-12 — M10/M12 — min. 50 — Di - 80 — Di

E — ca.6-12 — Binding wire ~Ø — Di

G — W — 6 — 60 — 90 — M10/M12 — W — 10 — 20 — 50 — 26

16.2   Installation and attachment from above

C — M10/M12 — Pipe 16x1,5 — ca.6-12 — 60 — Di - 90 — Di

D — min 40 — M10/M12 — Pipe 16x1,5 — ca.6-12 — 60 — Di - 50 — Di

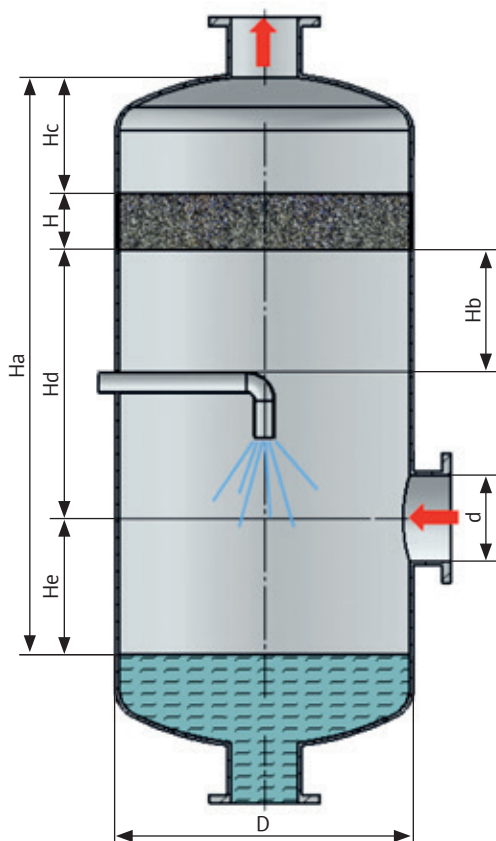F — M10/M12 — ca.6-12 — Di

16.3 Installation Examples

16.4 Rule of Thumb for the Design of Containers

The aim is always to determine the most economical size of the container. This means choosing the dimensions as small as possible while ensuring the optimum operating conditions for the mist eliminator. For this, the aim is to achieve as homogeneous a flow of the knitted fabric as possible. Local flooding of the package at too high speeds or a reduced separation efficiency at too low speeds should be avoided.

Due to a wide variety of container types and process conditions, the aforementioned rule of thumb can only be applied to a limited extent. Individual flow conditions can be analyzed more precisely at RHODIUS via fluid simulation and concluded from the results on the optimal container design.

Ha ~ 1,4 x D + H + d; at least 0,4 x D + 700 mm
Hb ~ 0,4 x D
Hc ~ 0,4 x D
Hd ~ 0,7 x D (at least height approx. 150 mm) + d/2
He ~ 0,3 x D (at least height approx. 150 mm) + d/2
H = 100...250 mm (including grates)

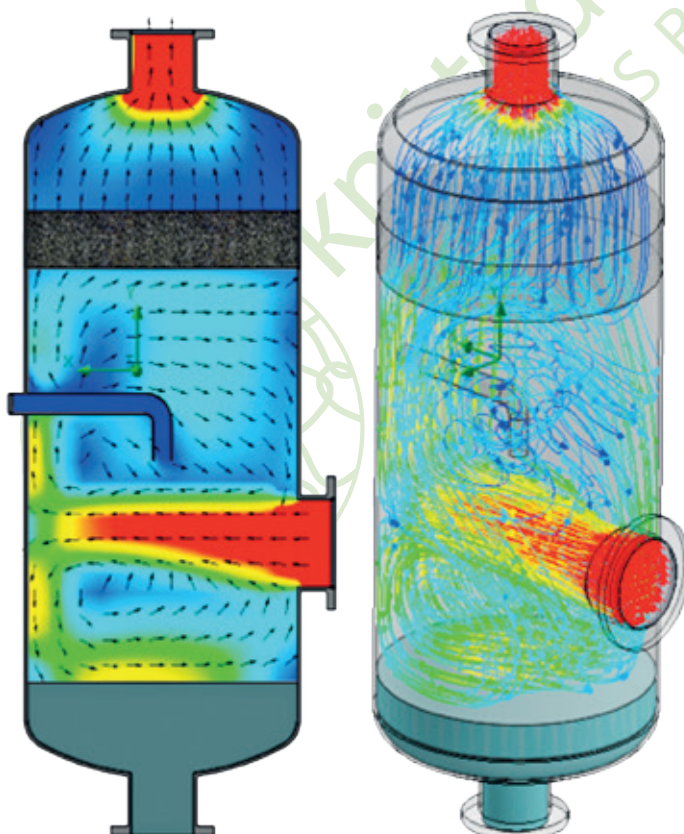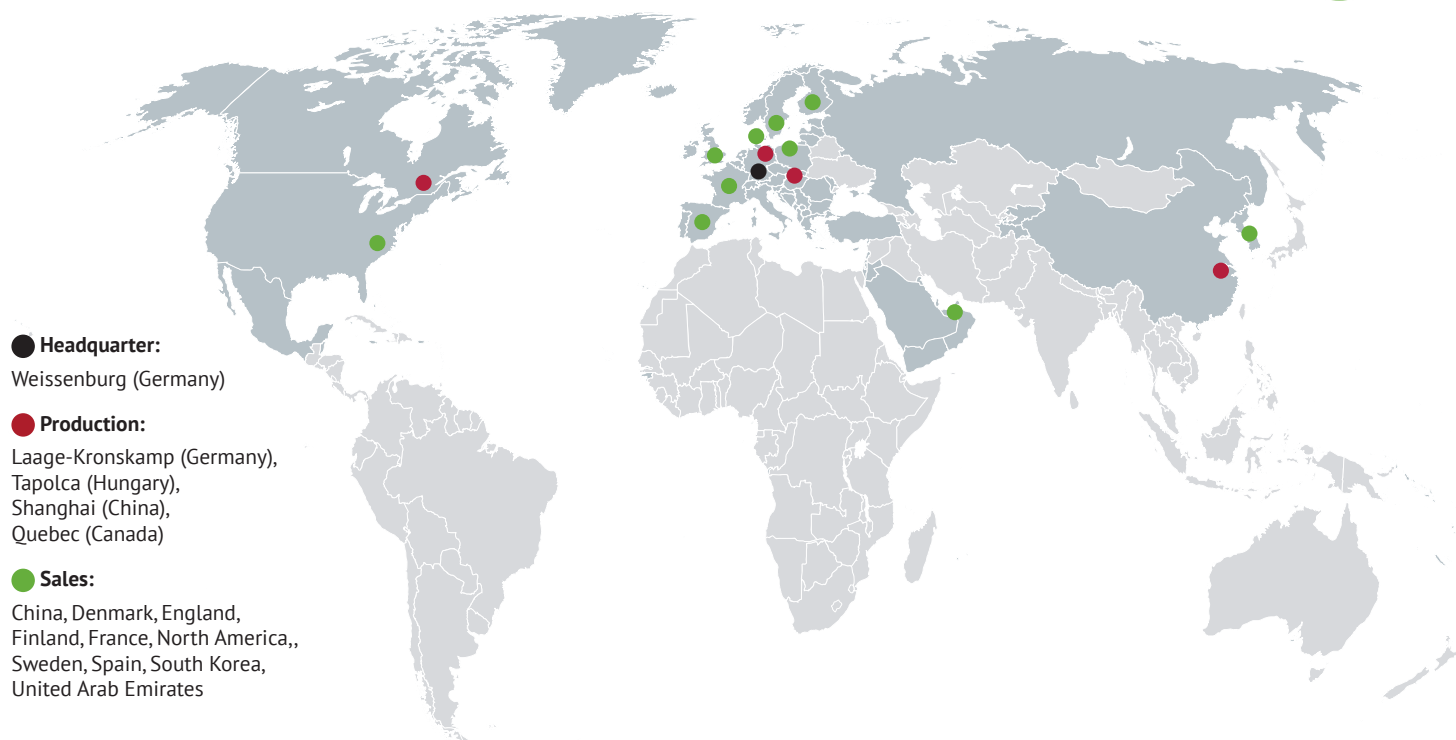Figure 5: Dimensions in standard container for droplet separator

Figure 6: Example of a CFD fluid simulation of the flow state in the tank

Notes

Notes

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