Side Entry Vane Inlet Device

Optimal vane design with diffusers for high momentum retrofits

The Vane Inlet Device is designed to be a versatile inlet device capable of handling a wide range of fluids, from gas dominated to liquid dominated flows. While the inlet device is currently considered an industry standard, NOV has optimized the design to improve momentum dampening and fluid handling capacity for both separators and scrubbers. For high inlet loading and slugging conditions a heavy-duty version of the device, complete with an additional momentum damping 'diffuser baffle', is available.

The fluid enters the inlet device and is divided into smaller streams by vanes. Due to the difference in momentum, gas readily slows as it enters the device disengaging from the liquid stream. The curved vanes enforce a directional change in the fluids which helps to encourage further gas-liquid separation and deliver the fluids into a purpose designed inlet zone of the separator.

The device, in conjunction with appropriate baffling, forms part of the inlet zone. The vane type device can handle segregated and mixed multiphase flow regimes and provides a versatility that few other inlet device types can cater for.

A unique diffuser technology is offered for retrofits where the size of the inlet nozzle is too small to accommodate an efficient traditional vane inlet device. The diffusers fit around the Vane Inlet Device and add an additional layer of momentum damping to further control momentum and minimize recirculation of flow in the liquid pool below the inlet. The diffuser technology offers an attractive alternative to inlet cyclones for high momentum applications.

Key advantages

- Optimal vane design provides momentum dissipation with minimum droplet shattering
- Robust and open design ideal for slugging conditions and with minimal pressure drop
- Wide operational range
- Unique diffuser technology retrofitted for constrained systems with small inlet nozzle
- Many successful offshore installations

Top Entry Vane Inlet Device

Optimal vane design with diffusers for high momentum retrofits

The Top Entry Vane Inlet Device was originally designed to manage ultra-high momentum flows associated with debottlenecking flare knockout drums. The device has been adapted to allow for application in multiphase separators and can handle a wide range of flow regimes. The device is particularly useful for retrofit applications and is often used to replace bulkier and less efficient cascade tray designs.

The fluid enters the top of the inlet device and is divided into smaller streams by vanes gradually increasing the cross-sectional area of the incoming flow and therefore reducing velocity and momentum.

The device is considerably more robust and open in design compared to alternative top entry cascade trays on the market. Our retrofit experience has demonstrated the weakness of alternative designs which have been replaced due to mechanical damage or inability to adequately dissipate the momentum without significant entrainment of gas in liquid and droplet shattering.

A unique diffuser technology is offered for retrofits where the size of the inlet nozzle is too small to accommodate an efficient traditional vane inlet device. The diffusers fit around the Vane Inlet Device to further control momentum and minimize adverse effects creating recirculation of flow in the liquid pool below the inlet.

The equipment has been successfully applied in numerous offshore separators, often where process conditions are particularly challenging and expected to change considerably over the life of the field.

Key advantages

- Attractive solution for top entry inlet nozzle configurations
- Robust and open design ideal for slugging conditions and with minimal pressure drop
- Wide operational range
- Unique diffuser technology retrofitted for constrained systems with too small inlet nozzle

Cyclonic Inlet Device

Gas-liquid separation for high momentum applications and retrofits

The Inlet Cyclone is a highly efficient inlet device when it comes to handling high momentum inlet flow. In addition to having a high capacity it also provides bulk separation of gas and liquid at a higher efficiency than most inlet devices. The liquid is injected close to the liquid interface level, giving any entrained water droplets a shorter distance to travel before reaching the water-continuous phase. Inlet Cyclones are also well suited for breaking foam generated in the upstream piping.

While Inlet Cyclones can be highly efficient, they can also cause a lot of problems for the separator when operated incorrectly. These problems are mainly related to gas being injected into the liquid phase, also known as gas blow-by. This can result in generation of foam and gas-hindered settling of water droplets. This effect has caused Inlet Cyclones to be generally found unwanted by some operators.

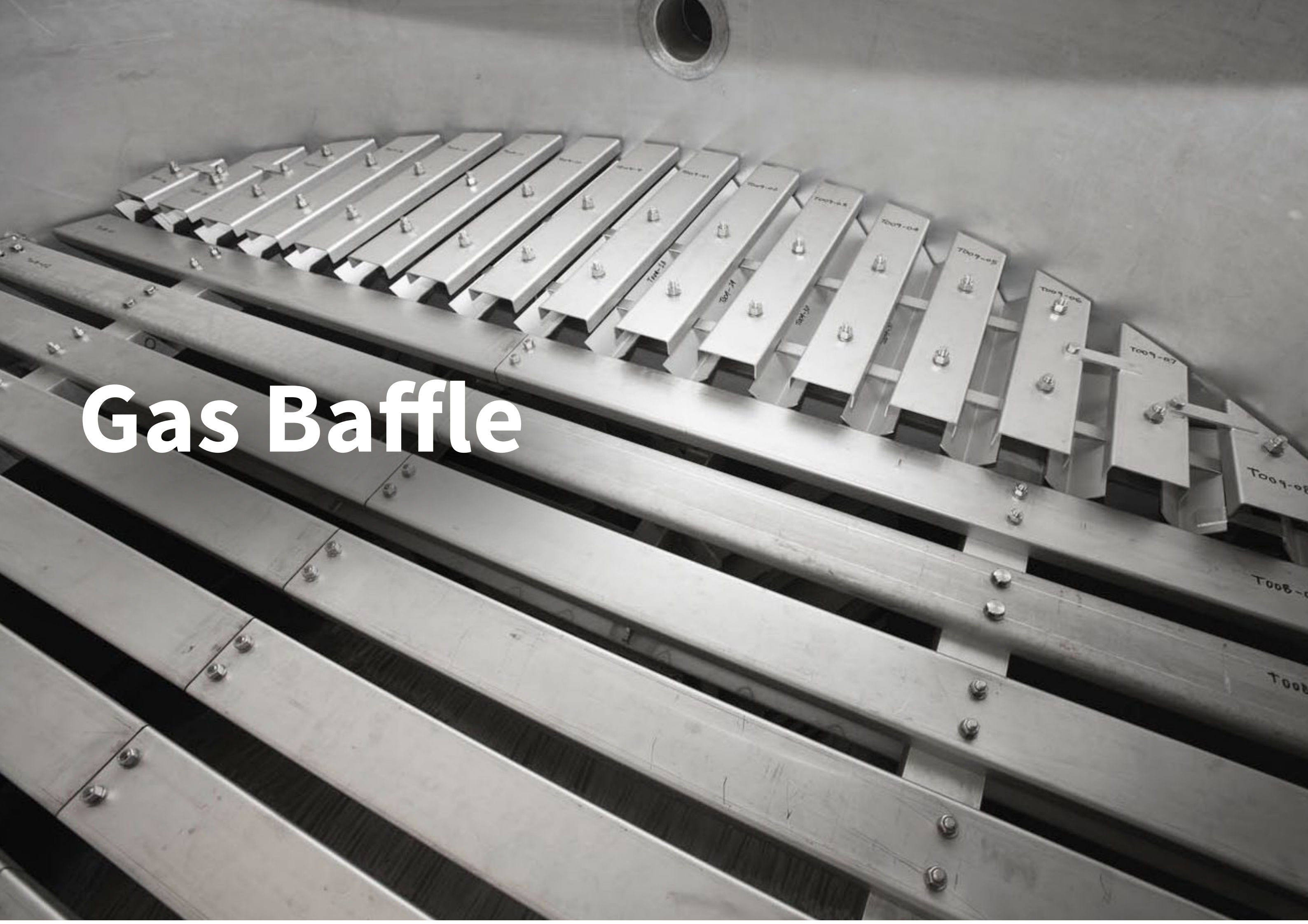
The NOV Cyclonic Inlet Device has key designs features focused on reducing the possibility for gas blow-by. At the bottom of the tube, a patented “gas blocker” is installed which helps prevent gas from entering the liquid outlet in the lower section of the cyclone.

NOV has dedicated research into understanding the limits of the inlet cyclone and has strict requirements for when inlet cyclones can be used. The result is that we tend to be more conservative when it comes to supplying inlet cyclones, often making use of alternative devices. When inlet cyclones are offered, we can be confident that they will work well.

Key advantages

- Well suited for handling high inlet momentum
- High separation efficiency
- Reduced foaming tendency enabling higher throughput of the separator and reducing OPEX for antifoam chemicals
- Conservative design approach will ensure proper performance whenever supplied

Gas Baffle



Efficient gas disengagement and demisting early in the vessel

The Gas Baffle is a tortuous baffle that is used to dampen the turbulent gas phase in the inlet zone and to assist with early gas/liquid disengagement and coalescence. The tortuous path design helps to encourage primary demisting and coalescence and improves gas distribution across the vessel gas space.

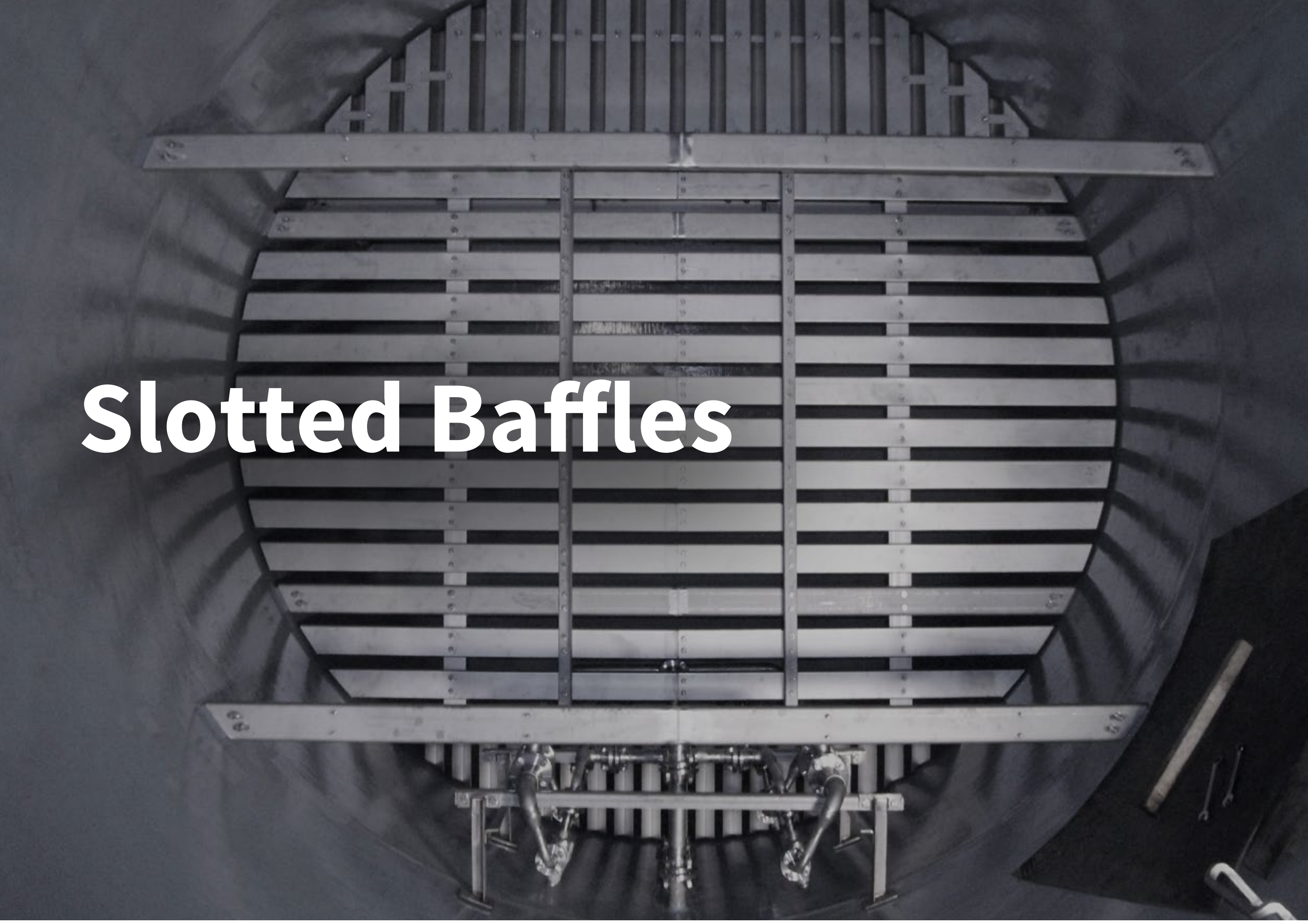
Liquid laden gas flows between baffle elements where the gas is subject to rapid change of direction. The inertia of the liquid droplet causes them to impinge onto the baffle elements where they coalesce. The agglomerated liquid drains down the vertical baffles into the liquid pool.

The baffle can break light foam or froth. The baffle elements act as a wetted surface for the foam to drain onto. Breaking down foam early in the separator can prevent severe operational problems further downstream.

Inclusion of the gas baffle results in a less liquid loading to the demister, as well as growth of liquid droplets entrained in gas, thus increasing the efficiency of the demister. This results in increased gas quality, and makes it easier to reach the gas specification, especially for high gas loads.

Key advantages

- Early liquid disengagement
- Promotes coalescence of liquid droplets
- Breaks foam
- Reduces liquid loading on droplet separator



Slotted Baffles

Flow distribution and sloshing mitigation with reduced shear and risk of blockages

Flow calming baffles within a multiphase separator are essential to form an efficient inlet zone and to calm and condition fluids as they flow through the vessel or are subjected to motion due to wave motion on the host facility.

The Slotted Baffle philosophy has been developed as a response to challenges experienced when retrofitting separators worldwide. The baffles were designed to allow primary turbulence (created by inlet fluids or motion) to be controlled without imparting excessive secondary turbulence such as jetting (which is often observed in low porosity baffles). The Slotted Baffles have been successfully applied in the retrofitting of numerous separators on offshore installations, often where traditional perforated baffles tend to become blocked by asphaltenes, inorganic scale, or calcium naphthenates. The large distance between the baffle elements reduce the risk of fouling.

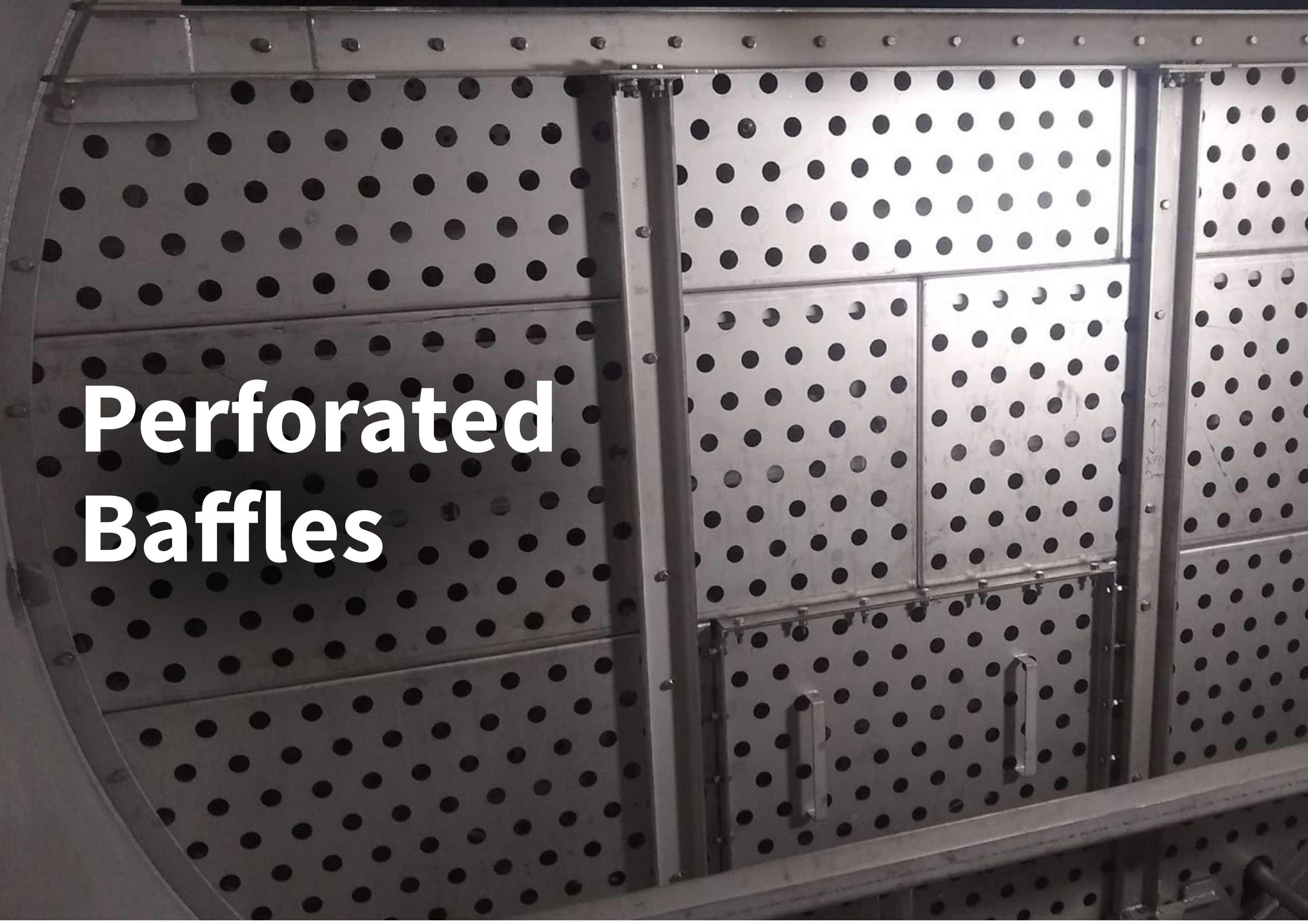
A typical baffle configuration that creates the inlet zone of a separator consists of one Horizontally Slotted Baffle, followed by a Vertically Slotted Baffle, creating a boundary that will dissipate turbulence and the increased inlet momentum of a slug entering the vessel.

For long separators or for FPSO applications, inlet zone baffles are followed by additional vertically slotted flow distribution baffles. The lower part of the baffles consists of a sand baffle which allows solids to pass through the baffle while still preventing the shortcutting of liquids.

The Slotted Baffle can be supplied either with or without a Gas Baffle depending on the gas quality specification and tendency of foaming.

Key advantages

- Efficient liquid hold up without interfering with the liquid and interface levels inside vessel
- Optimal liquid distribution and minimal jetting and shear imposed on emulsions
- Reduced mixing of separated fluids passing through baffle repeatedly during each transit on FPSO



Perforated Baffles

Flow distribution and sloshing mitigation baffles

Flow calming baffles within a multiphase separator are essential to form an efficient inlet zone and to calm and condition fluids as they flow through the vessel or are subjected to motion due to wave motion on the host facility.

The perforated distributor baffle has a uniform pattern of holes which ensures even flow of fluids into the gravity separation section of the separator. The size and net free area (NFA) of the holes vary depending on vessel size, process conditions, and whether the unit is installed on a moving structure. The openings are formed as circular holes to achieve an open area, typically equivalent to 20-35% of the total area of the plate.

A typical baffle configuration that creates the inlet zone of a separator consists of one or two Perforated Baffles creating a boundary that will dissipate turbulence and the increased inlet momentum of a slug entering the vessel. For long separators, this is followed by flow distribution baffles. Equally spaced Perforated Baffles are also used to protect against sloshing in separators on floating assets. The lower part of the baffles consists of a sand baffle which allows solids to pass through the baffle while still preventing the shortcutting of liquids.

The Perforated Baffle can be supplied either as partial or full diameter depending on the application. The use of Perforated Baffles is limited to applications without significant scaling potential.

Key advantages

- Contain the turbulence of the incoming fluids creating an inlet zone and providing an even distribution of fluids into the downstream separation zone
- Create a boundary that will dissipate the increased inlet momentum of a slug entering the vessel reducing the disruption to the separation zone
- Increase the natural frequency of the liquid phase in the separator to avoid resonance
- Dampening of motion effects to prevent tripping alarm levels and avoid polluting outlets

Plate Pack Coalescer

Enhanced separation for increased throughput or reduced vessel size

A Plate Pack Coalescer will improve the liquid/liquid separation performance and offer an opportunity to reduce the size and weight of a new separator or increase the throughput of a revamped vessel.

The NOV Plate Pack Coalescer comprises an assembly of inclined plates arranged in an 'inverted v' configuration. When placed in the oil phase, entrained water droplets settle onto the top surface of the plates where they coalesce. The coalesced droplets drain off the surface of the plate to the interface region. The inverted V configuration allows solids to settle out of the plate pack into the base of the separator.

As the flow between the plates is laminar and the distance a dispersed droplet must travel to hit a surface is short, smaller droplets can be separated compared to an open gravity settler. This will increase the performance after a retrofit of an existing separator thereby increasing the throughput or enable a reduced vessel size of a new separator.

The plate pack spacing, length, and inclination angle are optimized based on the process conditions and service. Focus is on providing improved separation without compromising the mitigation for fouling. Plate packs are normally used for clean service. If light sand production is expected the coalescing plates should be sloped at 60 degrees to improve drainage.

Plate Pack Coalescers have excellent motion dampening capabilities, enabling their use to minimize surface waves and sloshing effects in separation equipment on floating production units. For FPSOs, a reinforced plate pack is used, to ensure that the design can withstand the high forces.

Key advantages

- Increased liquid/liquid separation efficiency
- Limits size of separator
- Dampens surface waves and sloshing
- Modular system for implementation on retrofit

Vane Pack Mist Eliminator

Vane profile design selected to meet the needs of the application

The Vane Pack Demister is a reliable and cost-efficient alternative for demisting at low to moderate pressures. It is widely used for horizontal separators due to its compact design, low pressure drop, and robustness to fouling.

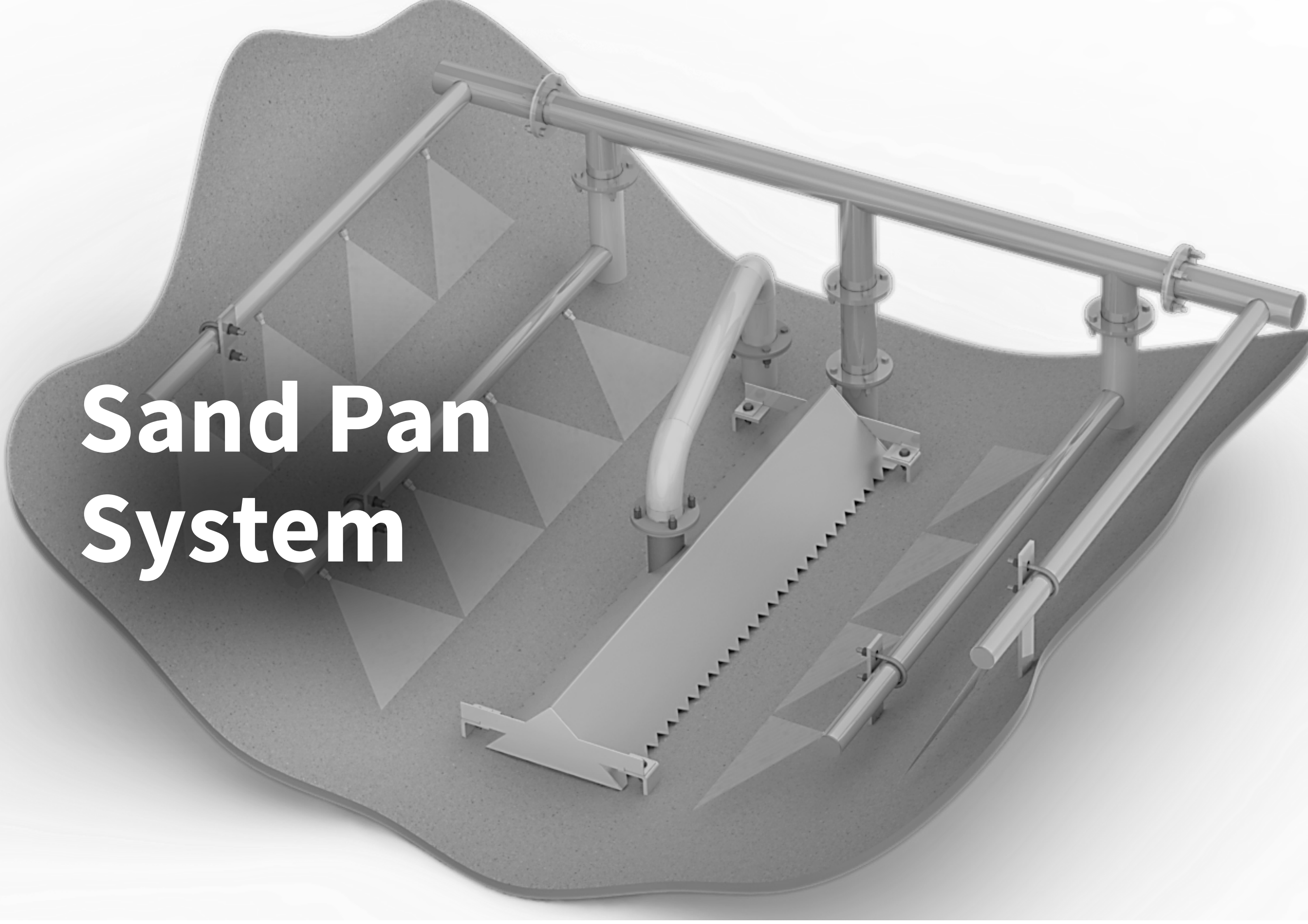
Liquid laden gas enters the Vane Pack and flows between vanes where the gas is subject to several changes of direction. The inertia of the liquid droplet causes them to impinge onto the vanes where they coalesce on the wetted surface of the vane. The agglomerated liquid is gathered in a liquid hopper underneath the vanes and drained through a downcomer system.

Vane packs can be of no-pocket, single-pocket, or double-pocket design. Selection of the most appropriate design is carried out by considering the required separation efficiency, the fouling potential, and the expected liquid loading. Double pocket design has superior performance compared to single or no-pocket designs with regards liquid drainage, but a higher susceptibility for fouling. Double pocket vane packs are the most common due to the superior efficiency.

Pressure drop is low (a few millibars) and unlike wire mesh pads, a properly designed Vane Pack Mist Eliminator is not likely to block, even in fouling service. The operation is however limited to low and moderate operating pressures. With increasing pressures, typically above 20-40 bar, depending on the fluid properties, performance decreases due to the reduced density difference between gas and liquid as well as reduced surface tension leading to re-entrainment of accumulated liquid on the vane.

Key advantages

- Compact
- Cost-efficient
- Fouling service robustness
- Low pressure drop



Sand Pan System

Engineered for reduced erosion and plugging risk

Sand removal is a critical function within separators as accumulated sand may plug other internals, cause corrosion, and interfere with fluid flow patterns to reduce separation efficiency.

Sand pans comprise a series of inverted troughs fitted along the bottom of the separator which connect the area inside the trough to the vessel drain system. The edges of each side of the trough are serrated to achieve an open area between the trough and the vessel wall. Running along each side of the trough are the jet pipes and spray jets which are directed along the base of the vessel. The sand removal system is divided in sections. Sand removal from the sections occurs sequentially to prevent disruption of the process and to minimize the size of the jet water supply and drain system.

The unique sand pan top discharge design significantly reduces the effect of erosion on the dump valves compared to bottom discharge type systems. In a bottom discharge design, serious valve erosion may occur when the valve is opening. With a top discharge system, the flow is relatively clean until the valve is fully opened.

To de-sand the separator, jetting nozzles on each side of the sand pan will push the deposited sand towards the bottom of the separator (close to the sand pans).

The drain valves from the sand pan pickup pipework are then opened to cause sand and water (sand slurry) to flow out of the vessel to the downstream processing system.

A minimum under-pressure of 1-2 bar is required in the drain-pipes to enable the sand pan system to operate. If this is not possible, an eductor can be installed downstream of the drain valves.

Key advantages

- Low sand erosion effects when jetting
- System designed to minimize risk of clogging pipes and eductors
- Cost-efficient sand handling solution

Tore Online Vessel Desanding

Sand removal with controlled slurry concentration and without negatively affecting the water quality

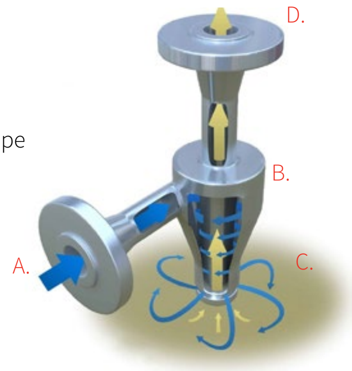
Produced sand accumulating in separators is one of the major factors limiting oil and gas production. The Tore® Online Vessel Desander technology is effectively removing sand without the negative side effects experienced with conventional technologies.

The Tore is a highly effective solids fluidization device with the unique feature that it will work perfectly even when completely buried in sand. It is thus the choice of operators expecting high solids loading who are aware of the limits of conventional sand handling technologies. There are more than 5,000 Tore devices in operation worldwide.

The Tore unit operates by generating a vortex which fluidizes the sand in the area next to the device. The vortex is created by introducing fluid tangentially into the swirl chamber. This establishes a swirling motion which passes through the foot of the Tore. When fluidized, sand is drawn by the central core of the vortex towards the discharge tube. With a predictable and controlled sand slurry concentration, sand can be transported without risk of blocking downstream sand cleaning equipment.

The fluidizing effect created by Tore is localized and does not have the same negative effect on the water phase and water quality as is experienced with most jetting systems. Sand can be removed from the vessel without a spike in sand or oil concentration in produced water for reinjection or discharge.

A. Motive fluids inlet
B. Swirl chamber induces spin
C. Solids fluidized in vortex, transported via discharge pipe
D. Slurry discharge



Key advantages

- Only 0.25-0.5 bar suction pressure required
- Accepts dirty motive water and limited quantity (16 m³/h each section of 4 Tore units)
- Tolerates high sand levels without risk of blockage
- Constant and controlled slurry concentration

Mesh Pad

Efficient agglomeration and demisting for a wide operational range

Mesh Pads are widely used as agglomerators and demisting devices. The design provides excellent performance for a wide operating range, but with limited gas handling capacity. The use is limited to non-fouling service.

Mesh type agglomerators and demisters consist of knitted metal wire in a pad. When gas flows through the pad, liquid droplets impinge onto the wire surface and coalesce to a size where they become large enough to disengage from the wire and fall to the liquid section of the separator. Oleophilic materials can be incorporated into the metallic mesh design to create a more efficient 'co-knit' Mesh Pad.

When used as a demisting device, the Mesh Pad is limited to moderate gas and liquid loading to avoid liquid escaping through the Mesh Pad. The Mesh Pad however provides excellent performance at turndown conditions and at high pressures where other demisting devices like vane packs have limited efficiency. The Mesh Pad is for that reason widely used in combination with other demisting technologies as agglomerators.

At high gas flow, the mesh agglomerator operates in flooded condition where the main intention is to coalesce droplets into larger sizes which will be removed by the downstream demisting device (often cyclones).

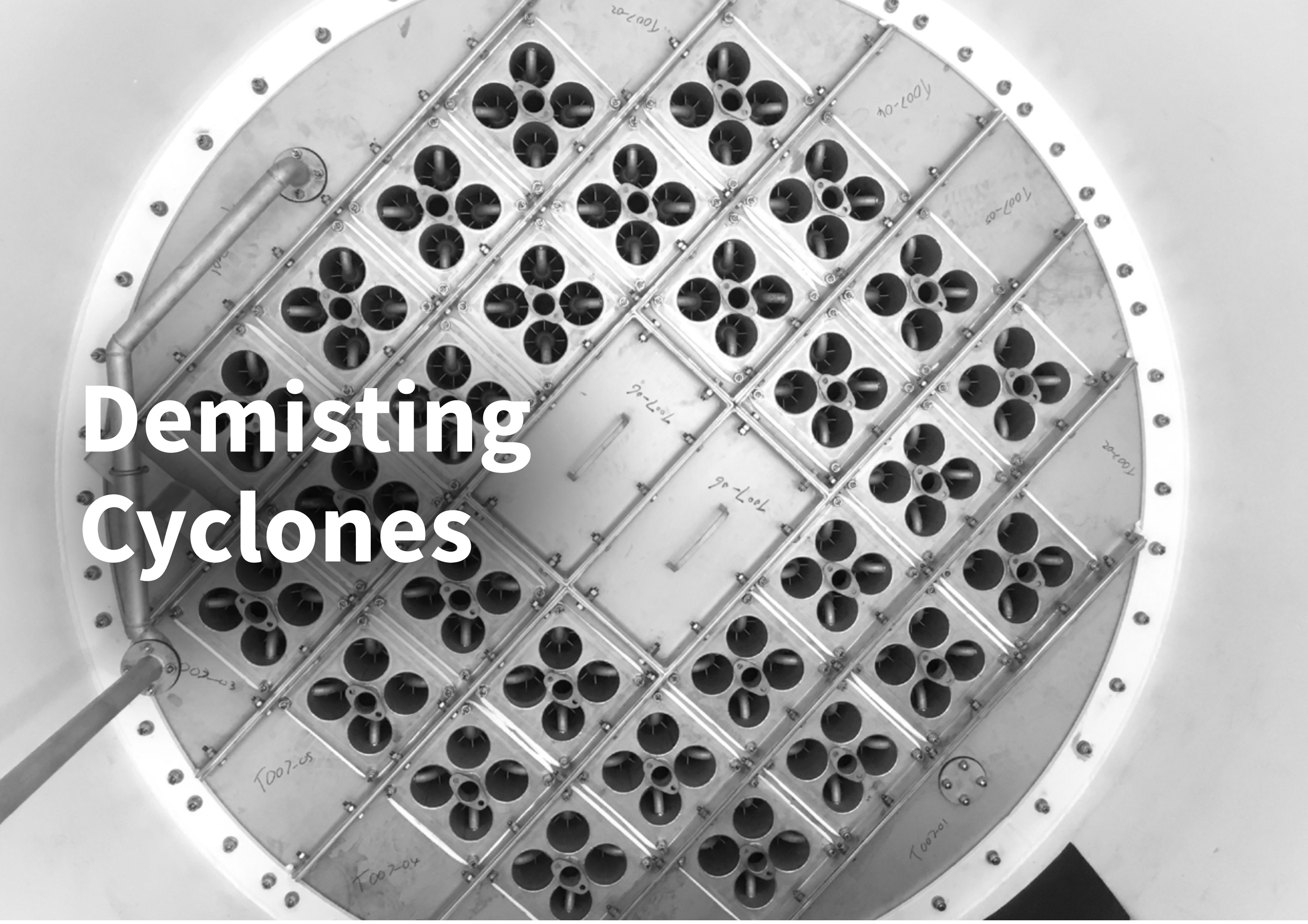
At low flow, the mesh agglomerator takes over from the downstream demisting device and acts as the demisting device itself. An agglomerator will significantly increase the overall performance of the separator.

The Mesh Pad is made of sections small enough to be installed through the manway. Their use is limited to clean service where it is not likely that the dense mesh could become clogged.

Key advantages

- Efficient at high operating pressure
- Good turndown performance
- Cost efficient
- Produces low pressure drop

Demisting Cyclones



Compact solution for demisting of high-pressure gas

The NOV Axial Flow Cyclone (AFC) is designed to provide a solution for high performance gas demisting, even for high pressure applications. The AFC offers a wide operational range and high gas capacity with a moderate pressure drop. The wide operating range and high gas capacity makes it possible to not only reduce and optimize vessel sizes for new builds, but also offers a flexible solution for debottlenecking of different applications.

As wet gas enters the cyclone, it is put into rotation by a static swirl element. This result in high centrifugal force, causing liquid droplets entrained in the gas to be forced towards the cyclone wall. The liquid droplets are accumulated at the wall and form a thin film which is drained through slots in the tube wall downstream of the swirl element. The dry gas moves to the core of the cyclone and exits the cyclone.

To increase efficiency, a fraction of the gas is extracted together with the liquid. The gas is then separated from liquid and reintroduced into the cyclone through low pressure regions inside the cyclone. Recycling of the gas increases the velocity through the drainage slits, which also results in a lower risk of fouling. The cyclone has been developed with the specific emphasis on minimizing re-entrainment of liquid, which is especially important for high-pressure applications.

Critical parts of the AFC are made using high precision manufacturing techniques to ensure consistency in performance.

A mesh pad coalescer may be installed upstream the demisting cyclones to improve coalescence of fine droplets, thus further improving the high efficiency of the cyclone. The high gas capacity of the AFC means that a smaller area is required compared to other demisting devices, making it ideal for compact separators or retrofit applications. The demister can be used in both vertical and horizontal arrangements.

Key advantages

- High gas capacity
- Large operational range
- Efficient for moderate/high liquid load
- Low fouling risk
- Foam breaking characteristics due to high inertia exerted by the spinning gas
- Aerodynamic flow paths reduce unwanted turbulence and enhance liquid removal characteristics

Demisting Cyclone Bundle

Optimal solution for compact demisting of wet gas

The NOV Demisting Cyclone Bundle is a compact separator designed to remove fine mist from a gas stream. The device consists of several demisting cyclones bundled together in a small pipe spool and can be used either as a means of debottlenecking existing separators suffering from excessive liquid carryover, or as a stand-alone device where wet gas needs to be demisted.

The gas enters the unit through the gas inlet nozzle, which is the same size as the connecting piping. The piping is then expanded in order to fit enough demisting cyclone tubes, determined by the maximum gas flow.

As wet gas enters the cyclone tubes, it is put into rotation by a static swirl element. This result in high centrifugal force, causing liquid droplets entrained in the gas to be forced towards the cyclone wall. The liquid droplets are accumulated at the wall and form a thin film which is drained through slots in the tube downstream of the swirl element. The dry gas moves to the core of the cyclone and exits the cyclone.

To increase efficiency; a fraction of the gas is extracted together with the liquid. The gas is then separated from liquid and reintroduced into the cyclone through low pressure regions inside the cyclone.

Depending on existing infrastructure and location of the device, the liquid can either be drained by gravity to an upstream separator or can be collected in a separate liquid accumulation chamber which can be emptied intermittently through a drain valve.

The high gas capacity of the axial flow cyclones (AFC) means that less area is required for demisting of gas compared to other demisting devices, making it ideal for compact separators or retrofit applications.

Key advantages

- High gas capacity
- Large operational range
- Efficient for moderate/high liquid load
- Low fouling risk
- Foam breaking characteristics due to high inertia exerted by a spinning gas
- Aerodynamic flow paths reduce unwanted turbulence and hance liquid removal characteristics