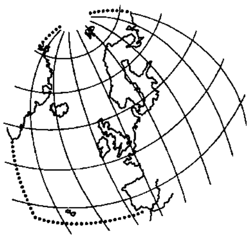
Offshore Industry Series

Addendum to the OSPAR Background Document Concerning Techniques for the Management of Produced Water from Offshore Installations

(Publication number 162/2002)



OSPAR Commission

2006

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l’Espagne.

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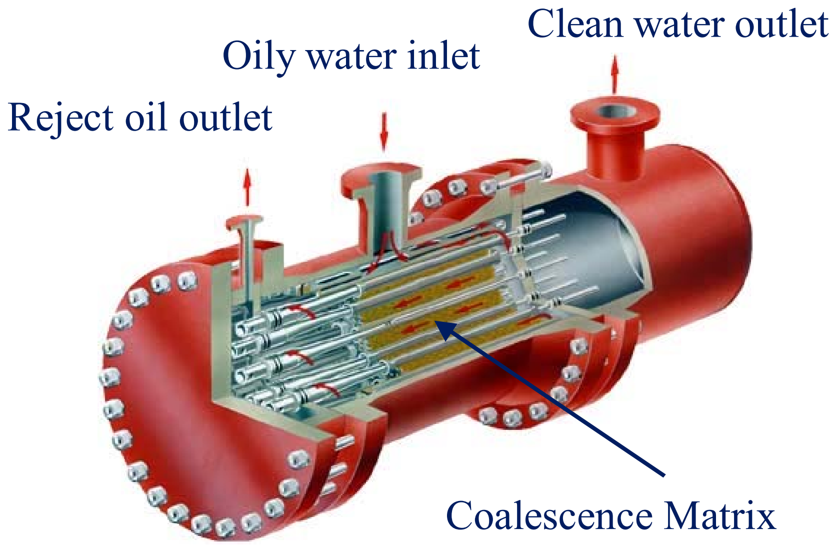
This document contains 5 additional fact sheets as finalised in accordance with the agreement at the 2005 meeting of the OSPAR Offshore Industry Committee (OIC 2005 Summary Record OIC 05/15/1).

<table>
<tr><th colspan="3">Table B - 10: In Vessel Coalescence Technology for Improved Performance of Deoiling Hydrocyclones</th></tr>
<tr><td>Principle</td><td colspan="2">Cartridge assembly containing specialised coalescence media installed into either the inlet chamber of the Deoiling Hydrocyclone vessel or into a vessel located upstream of the PWT system. The inlet chamber of a conventional Deoiling Hydrocyclone can have a residence time of up to 20 seconds. This residence time is used constructively to achieve partial droplet coalescence while maintaining a high insensitivity to solids blocking. This is achieved by optimising a number of the technology design parameters including media material selection, media density, media surface treatment, flow regime and mechanical orientation. The resulting enhanced coalescence activity can boost the performance of the downstream deoiling hydrocyclones and reduce the oil in water concentration in the discharge stream by up to 80%.

Installing this technology in the inlet chamber of a deoiling hydrocyclone vessel has many benefits:
• it allows flow velocities to be low (crucial for good coalescence)
• technology can be retrofitted without the requirement of any modification to plant or hot work
• Low risk and very cost effective to install (installation possible within one shift)</td></tr>
<tr><td>Process diagram</td><td colspan="2"> </td></tr>
<tr><td>Basic elements</td><td colspan="2">Cartridge housing typically constructed from 316L or Duplex Stainless Steel, containing support plates fitted with the optimised media material which is surface treated to optimise performance for specific applications.</td></tr>
<tr><td rowspan="2">Suitable for the removal of:</td><td>Hydrocarbons
■ Dispersed oil
■ Dissolved oil (partially)</td><td>☐ Other contaminants (specify)

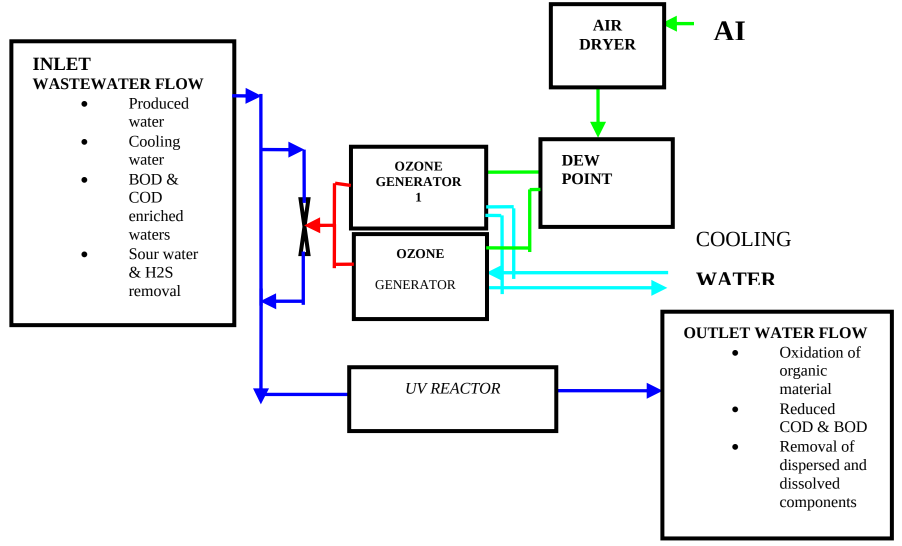
See table at the bottom of the next page</td></tr>
<tr><td colspan="2"><i>Remarks:</i></td></tr>
</table>

Technical details	**Per Unit**	Minimum Maximum
	Treatment capacity (m3 produced water per hour)	Units can be designed for any capacity. Typical capacities are 5 to 5,000 m3/h
	Gross Package volume (LxWxH)	As the unit normally fits inside an existing vessel, there is no additional space required.
	Operating weight	Weight typically ranges from 10 to 300 kg, depending on the size of unit
	CAPEX (€)	CAPEX typically ranges from €5,000 to €100,000 depending on the capacity
	OPEX (€/year)	OPEX is normally nil
	Cost per m3 produced water(€/m3)	Based on 4 years continuous operation, < € 0.01/m3
Critical operational parameters	Temperature, droplet size, water density, viscosity, wax content, solids content and type.	
Operational reliability, incl. information on downtime	On the basis that the unit is operated and maintained fully in accordance with the O & M Manual, then operational reliability has been found to be very high. Only minimal downtime is required to remove the cartridge from the Hydrocyclone vessel for cleaning, unless media is to be replaced.	
	Remarks:	
Cross media effects	**Air**	Not applicable
	Energy	No energy input required
	Added chemicals	The technology is structurally insensitive to typical oilfield chemicals e.g. corrosion inhibitor, scale inhibitor, demulsifier although its performance improvement potential can be influenced by excessive addition of some corrosion and scale inhibitors since these chemicals can have a dramatic impact on the water chemistry (particularly interfacial tension).
	Waste	The technology does not generate any specific waste

Other impacts	**Health and safety**	None – Passive, no moving parts
	Maintenance interval & availability (% per year)	It is recommended that the internals are inspected on an annual basis. Availability > 99.8%
Practical experience	**General**	**Onshore / Offshore**
State of development	■ Implemented offshore, commercial technology ☐ Used onshore ☐ Offshore field trials ☐ Testing	Practical applicability: The technology is a highly practical technology, suitable both for new facilities and for retrofits
		Driving force for implementation (e.g. legislation, increased yield, improvement product quality): OSPAR Legislation Improved Hydrocyclone Performance Operator stretch targets
		Example plants: Britannia, Bruce, Nelson, Draugen, Heidrun, Balmoral
Literature source	"Choosing Produced Water Treatment Technologies Based on Environmental Impact Reduction", SPE Paper 74002. "Performance Enhanced Hydrocyclone Systems : Development & Field Experience", 7th IBC Production Separation Systems, Oslo, 23rd – 25th May 2000. "A Novel Pre-Coalescence Technology to Improve Deoiling Hydrocyclone Efficiency" 3rd IBC Water Management Offshore, Stavanger, 20thMay 1999.	

	Suitable for		Removal Efficiency (%)		Reference to source documentation
	Oil installations	Gas installations	Oil installations	Gas installations	
Hydrocarbons - Dispersed oil - Dissolved oil	 √ √	 √ √	 Up to 99% > 50%	 Up to 99% > 50%	Field test reports. Commissioning reports. "Choosing Produced Water Treatment Technologies Based on Environmental Impact Reduction", SPE Paper 74002. "Performance Enhanced Hydrocyclone Systems : Development & Field Experience", 7th IBC Production Separation Systems, Oslo, 23rd – 25th May 2000. " A Novel Pre-Coalescence Technology to Improve Deoiling Hydrocyclone Efficiency", 3rd IBC Water Management Offshore, Stavanger, 20thMay 1999.
Specific oil components: - BTEX - NPD - PAH's 16 EPA - Others (indicate)	 √ Unknown √	 √ Unknown √	 > 50% Unknown > 50%	 > 50% Unknown > 50%	Whilst the technology is primarily designed to remove free oil droplets, reports (eg SPE paper 74002) show that BTEX's and PAH's often partition to a significant proportion into free oil droplets. Therefore, the technology can reduce the total discharges of BTEX's and PAH's. The actual efficiency will depend on the chemistry of the application, which will vary widely from platform to platform. No work has been done on the effectiveness of the technology on NPD's.
Heavy metals	*	*	*	*	* Heavy metals will only be removed if they partition into the free oil phase.
Offshore chemicals - methanol - glycol - corrosion inhibitors - biocides - scale inhibitors - surfactants - others (indicate)	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	* The technology is not affected by these oilfield chemicals. The extent of removal of these chemicals depends on the extent to which they partition into the oil phase.

<table>
<tr><th colspan="3">Table C - 14: Advanced Oxidation Process</th></tr>
<tr><td>Principle</td><td colspan="2">All AOP systems degrade organic species by utilising the powerful hydroxyl radical ($OH^{\cdot}$). This results in degradation of the organics to carbon dioxide, water and inorganic salts. The UV/O_3 process is the best developed AOP method currently available to industry. The generation of the hydroxyl radicals is thought to happen by one of the following processes:
$$O_3 \xrightarrow{h\upsilon} O_2 + O^{\cdot} \qquad (1)$$
$$O^{\cdot} + H_2O \longrightarrow 2OH^{\cdot} \qquad (2)$$
$$O_3 + H_2O \xrightarrow{h\upsilon} H_2O_2 + O_2 \qquad (3)$$
$$H_2O_2 \xrightarrow{h\upsilon} 2OH^{\cdot} \qquad (4)$$
With the production of the Hydroxyl radicals, interaction with an organic substrate can occur by a number of reaction mechanisms of which the most likely to occur is the Hydrogen abstraction process:
$$OH^{\cdot} + RH \qquad R^{\cdot} + H_2O \qquad (5)$$
On completion of this reaction an organic radical is produced ($R^{\cdot}$) which will start a series of chain reactions that will eventually lead to the complete mineralisation of the organic molecule.

Ozone may be injected into the waste-water stream as part of an airstream. The ozone starts to react with the water to form hydroxyl radicals but this process is enhanced in the presence of Ultraviolet light. Following injection of ozone, the water is passed through a vessel containing Ultraviolet lamps, encased in quartz glass. This is the essence of the process.</td></tr>
<tr><td>Process diagram</td><td colspan="2">
</td></tr>
<tr><td>Basic elements</td><td colspan="2">Ozone injection and UV vessel</td></tr>
<tr><td rowspan="2">Suitable for the removal of:</td><td>Hydrocarbons
✓ Dispersed oil
✓ Dissolved oil</td><td>✓ Other contaminants (specify)
See table at the bottom of the next page</td></tr>
<tr><td colspan="2"><i>Remarks:</i></td></tr>
</table>

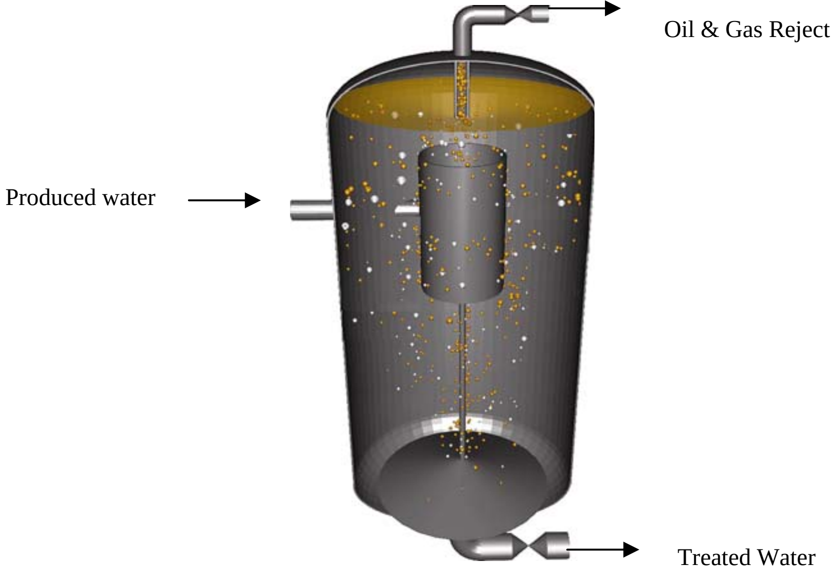
Technical details	Per Unit	Minimum	Maximum
	Treatment capacity (m3 produced water per hour)	No minimum, nominally 2M^3/hour	No Maximum – Built up in units of 70 – 350M^3/hour
	Gross Package volume (LxWxH)	2 x 1.5 x 2	3.5 x 1.5 x 2
	Operating weight	3000 Kg	5000 Kg
	CAPEX (€)	400,000	750,000
	OPEX (€/year)	40,000	75,000
	Cost per m3 produced water(€/m3)	25 (in first year – 2.28 thereafter)	0.27 (in first year – 0.024/year thereafter))

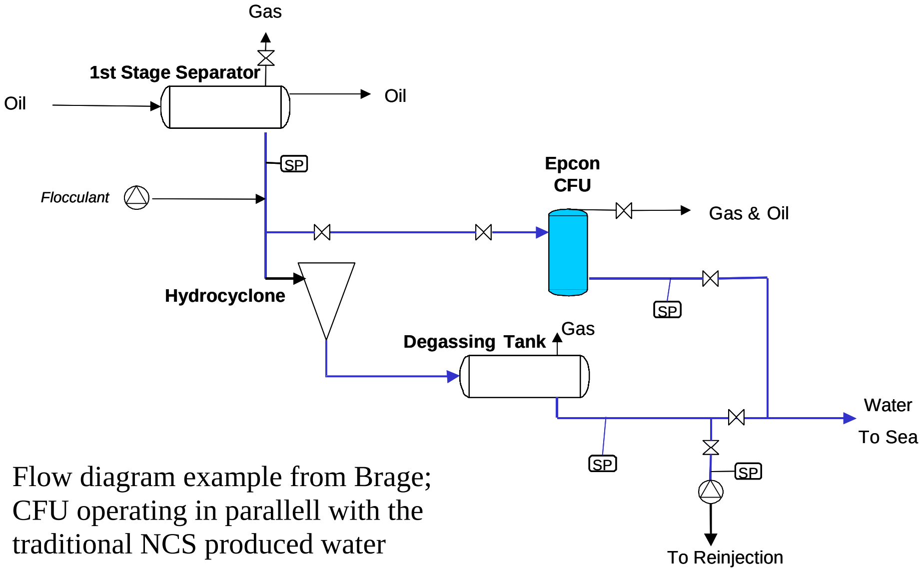
Critical operational parameters	Requires dry air, cooling water that is chloride free, and electrical power	
Operational reliability, incl. information on downtime	There should be little or no downtime as there is little in the way of moving parts in the kit. If the system fails, water will still flow through it.	
	Remarks:	
Cross media effects	**Air**	None
	Energy	Requires 23 kW for 66 m^3/h unit
	Added chemicals	None
	Waste	None

Other impacts	**Health and safety**	Ozone is toxic and operators must not be exposed to this gas
	Maintenance interval & availability (% per year)	Maintenance interval: Estimated at between 1- 6 months Availability: 95%+
Practical experience	**General**	**Onshore / Offshore**
State of development	☐ Implemented offshore ☐ Used onshore ✓ Offshore field trials ☐ Testing	Practical applicability:
		Driving force for implementation (e.g. legislation, increased yield, improvement product quality):
		Example plants:
Literature source	"A Practical Method for the Reduction of Hydrocarbon Concentration in Produced Water using an Advanced Oxidation Process", Sneddon et al, GPA, Bergen, 13th May 2002.	

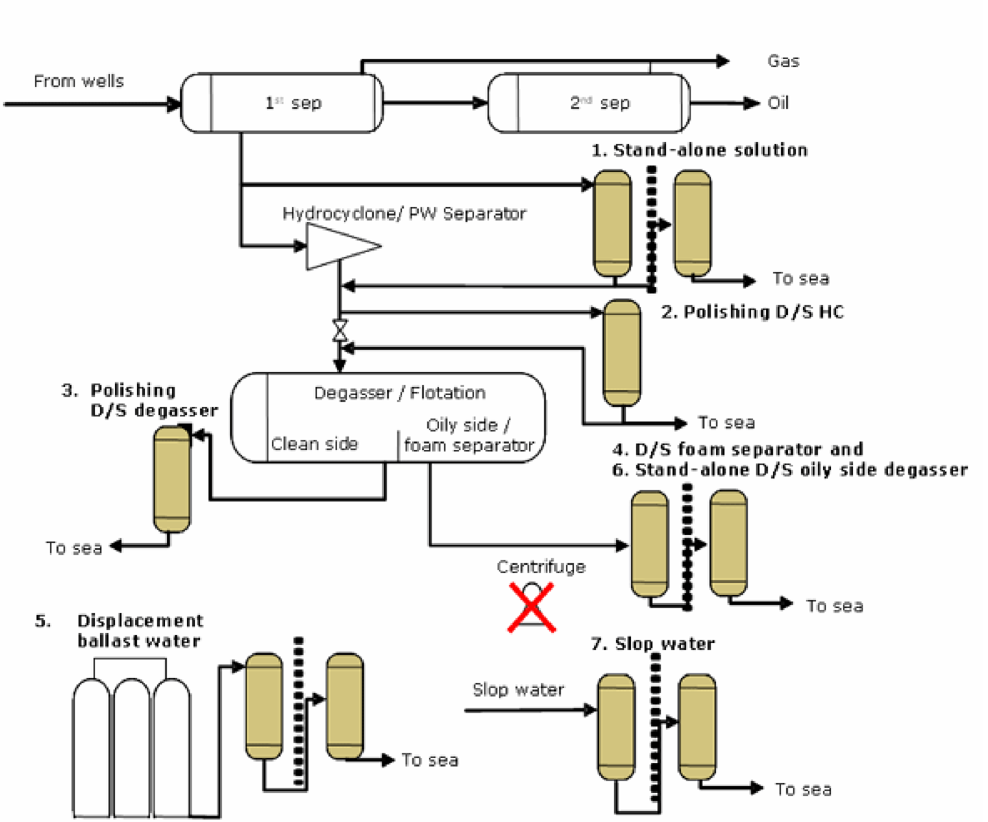
	Suitable for		Removal Efficiency (Typical %)		Reference to source documentation
	Oil installations	Gas installations	Oil installations	Gas installations	
Hydrocarbons					
- Dispersed oil	✓	✓	50	75	
- Dissolved oil	✓	✓	50	75	
Specific oil components:					
- BTEX	✓	✓	50	75	
- NPD	✓	✓	50	75	
- PAH’s 16 EPA	✓	✓	50	75	
- Others (indicate)	✓	✓	[☐]	[75]	
Heavy metals	☐	☐	☐	☐	
Offshore chemicals					
- methanol	✓	✓	50	75	
- glycol	✓	✓	50	75	
- corrosion inhibitors	✓	✓	50	75	
- biocides	✓	✓	50	75	
- scale inhibitors	✓	✓	50	75	
- surfactants	✓	✓	50	75	
- others (indicate)	✓	✓	50	75	

<table>
<tr><th colspan="2">Table C-15: Compact Flotation Unit (CFU) Separation process</th></tr>
<tr><td>Principle</td><td>The CFU is a vertical pressure vessel separating oil and gas from produced water. The CFU is a compact unit with detention time down to 0.5 minute. Centrifugal forces (G-forces up to 10-20) and gas-flotation enhance the separation process. The produced water inlet is tangential on the CFU vessel. Oil droplets are coalesced into larger agglomerates during the transport through the vessel. The CFU has a compact design making it especially suitable for offshore installations where space is a limiting factor. The technology is flexible, and once optimised for site specific conditions, simple in operation. Several stages can easily be added in series or in parallel to improve treated quality, to account for changes in upstream facilities or to increase capacity according to the flexibility needed on site. Smaller units can be used to treat problematic fluids separately from the bulk fluid.

The oil and gas together with a small amount of water is skimmed from the surface by a suspended pipe. The oil content in the reject varies from 10 to 50 %. Typically, the reject is approximately 1 % of the total flow. Treated water exits the vessels at the bottom outlet for discharge to sea, produced water re-injection or to further water treatment downstream. The reject is routed to the closed drain or to a separate treatment stage depending on local requirements. The effectiveness of flotation depends on the amount of residual gas present in the produced water. When limited or no gas is available in the system, the effectiveness of the flotation process is maintained by injecting additional gas (nitrogen or fuel gas) upstream of each CFU vessels. The amount of gas injected is ≤ 0.1 Sm^3/m^3 produced water per vessel. Normal operation pressure will be from 0.5 barg and upwards. Flocculants will occasionally aid the effectiveness of the separation process.</td></tr>
<tr><td>Process diagram</td><td>




Flow diagram example from Brage; CFU operating in parallell with the traditional NCS produced water
</td></tr>
</table>



Comparisons of the CFU vs. traditional produced water trains.

Comparable information	**Relative comparison of the CFU applied offshore**		
	Hydrocyclones and degasser	**1 stage CFU**	**2 stages CFU**
Capacity basis Bpd m^3/h	 81,000 540	 81,000 540	 81,000 540
Wet weight (metric tons)	45	8	16
Footprint (m^2)	30	6	12
Performance OiW (mg/l)	<40	<30	<10
Sensitivity to upstream - oil slugging - flow variation - solids - gas - movement (FPSO)	 High High High Sensitive (<5%) Low	 Less sensitive Low Low Not sensitive Low	 Low Low Low Not sensitive Low
Minimum inlet pressure required (barg)	5	0.7	1.5
Performance on high pressure	Good	No negative effect, but only tested to 30 bars	
CAPEX	High	Low	Medium
OPEX	High	Low	Low

Source: Vik and Engebretsen, 2005

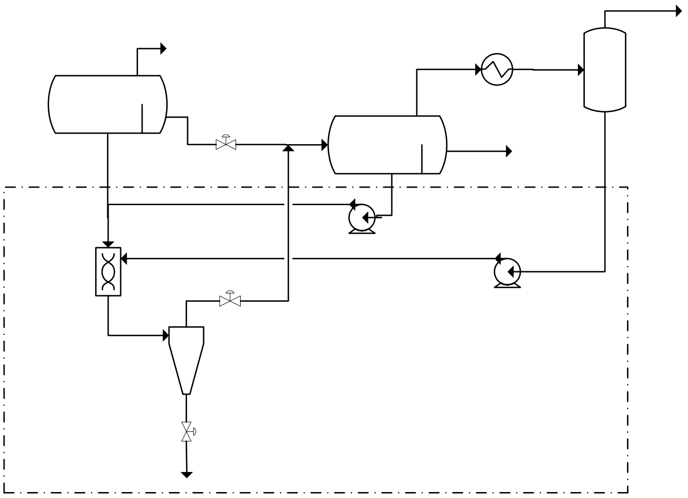
Basic elements	Gas flotation combined with centrifugal forces (Soft cyclone) and coalescing effect.		
Suitable for the removal of:	**Hydrocarbons** Dispersed oil droplets down to 3 µm droplet size	✓ **Other contaminants** (specify) PAH, BTEX, phenols (C5+), Oil soluble chemicals	
Technical details	Treatment capacity (m^3/h) 1)	Minimum 3 m^3/h	Maximum 2200 m^3/h

	Gross Package volume (LxWxH)	3.5 x 2.5 x 3.5 m 2)
	Operating weight	Dry weight 6.5/11 tons 2)
	CAPEX (€)	NOK 7 million (€ 900.000) (Duplex steel)3)
	OPEX (€/year)	Minimal: no maintenance, no energy required
	Remarks: 1. Capacity mentioned is related to projects installed or under installation. 2. Figures on weight and footprint is based on CFU standard equipment 2xCFU220 (540 m^3/h). 3. CAPEX & OPEX is related to same standard equipment	
Critical operational parameters	Oil droplet size, surfactants stabilising small oil droplets, gas in water, some well and operational chemicals backflowed to the produced water system, oil coated solids	
Operational reliability, incl. information on downtime	100% reliable, no downtime, no maintenance on the technology equipment, no operators, no rotating parts or small bore openings. Large operational window (down to 20% of design flow). Not vulnerable for solids or scaling.	
	Remarks: Regarded as proven technology by Norsk Hydro, Statoil, ConocoPhillips, Shell, ChevronTexaco and others.	
Cross media effects	**Air**	No impact on air. Gas is returned to the oil system.
	Energy	Low or no additional energy needed. The pressure drop is down to 0.5 bar
	Added chemicals	If needed in general process (flocculant)
	Waste	No waste generation. Oil and gas are normally returned to oil system
Other impacts	**Health and safety**	No negative effects. If high benzene concentrations in produced water, special precautions needed during water sampling
	Maintenance interval & availability (% per year)	Limited maintenance required for the CFU since solids are not accumulated in the system. Maintenance during normal shutdown periods.
Practical experience	**General**	**Onshore / Offshore**
State of development	✓ Implemented offshore (15) ✓ Offshore field trials (37)	Practical applicability: Offshore / Onshore The Compact Flotation Unit (CFU) was first installed offshore on the Norwegian Continental Shelf (NCS) in 2001, and has since then been further developed, tested and installed on several installations.
	Driving force for implementation (e.g. legislation, increased capacity, improved water quality): Legislation and economic drivers caused by increased water cut	

Literature source	*Descousse, A., Mönig, K. and Voldum, K. (2004): Comparison of new and traditional produced water treatment technologies for their potential to remove dissolved aromatic components, 2nd Produced Water Workshop 21-22 April 2004, NEL East Kilbride, Glasgow* *Dolonen, O.S. (2004): Operational experiences at Snorre/Vigdis. Produced Water – Zero Discharge. Myth or Reality? Tekna 15-16 January 2004, Stavanger, Norway* *Hammerstad, T. and Rinde, S. (2004): New purification technology lowers discharges on Troll. Hydro, 5.07.2004. Presentation on OTC, Houston. Http://www.hydro.com/cgi-bin/* *Jahnsen, L. (2004): Epcon CFUs- a produced water treatment technology improving environment and efficiency of oil production, International Seminar on Oilfield Water Management, Rio, Brasil August 16th – 18th4* *Jahnsen, L. (2005): Epcon CFU Technology: The alternative to traditional produced water treatment systems. Russian Arctic Offshore and CIS Continental Shelf, September 13-15, 2005, St.Petersburg, Russia* *Jahnsen, L. (2005): Epcon CFU Technology – A produced water treatment technology improving the environment and the efficiency of oil production, Iran Oil & Gas Show, April 14th 2005* *Jahnsen, L. and Vik, E.A. (2003): Field Trials with Epcon Technology for Produced Water Treatment, Produced Water Workshop 26th-27th March 2003, NEL East Kilbride Glasgow* *Pollestad, A. (2005): The Troll Oil Case – Practical Approach Towards Zero Discharge. Tekna Produced Water Conference 18-19 January 2005, Tekna* *Vik, E. A. (2005): Environmental Risk Based Wastewater Treatment in the E&P Industry. Editorial Input to Business Briefing: Exploration & Production: The Oil & Gas Review* *Vik, E.A. and Bruås, L. (2005): Results of the Epcon CFU Zero Discharge Tests. Case studies 2001-2005. Aquateam Report no. 04-025. Version 2.* *Vik, E.A. and Engebretsen, S. (2005a): Documentation of Performance of the Epcon CFU Process. Case Studies Year 2001-2005. Aquateam Report No. 05-039* *Vik,E.A. and Dinning, A.J. (2005): Upscaling the Epcon CFU Technology. Comparison of test and full scale performance data from 2000-2005. Aquateam Report No. 05-057.* *Vik, E.A. and Engebretsen, S. (2005): Technology Assessment of Epcon CFU. Aquateam Report No.05-052.* *Vik, E.A., Folkvang, J., Jahnsen, L. and Oseroed, S.E. (2002): Improved Offshore Produced Water Treatment and Increased Technical Flexibility using the Epcon Compact Flotation Unit. Discussion of Case Studies from Norsk Hydro Brage and Troll C Platforms, 13th International Oil Field Chemistry Symposium, Norwegian Society of Charted Engineers*

	Suitable for		Removal Efficiency (%)		Reference to source documentation
	Oil installations	Gas installations	Oil installations	Gas installations	
Hydrocarbons					Applications have so far focussed on oil installations Removal efficiency depends on starting point (Vik and Engebretsen, 2005 a)
- Dispersed oil	✓	☐	80-95	☐	
- Dissolved oil	☐	☐	Low	☐	
Specific oil components:					Vik and Bruås (2005). BTEX removal is dependent on the gas rate used (stripping effect) and the cleanliness of the gas with respect to BTEX. Removal efficiency of other compounds are depending on starting level in the water
- BTEX	✓	☐	40-80	☐	
- NPD	✓	☐	45-60	☐	
- PAH's 16 EPA	✓	☐	60-85	☐	
- Naphthalenes	✓	☐	40-60	☐	
- C6-C9 phenols	✓	☐	40-60	☐	
Heavy metals	☐	☐	☐	☐	Not measured
Offshore chemicals					Not measured, but expected to have same removal efficiency for removing oil soluble chemicals as for removing dispersed oil, but reduced efficiency for removing water soluble chemicals. Efficiency is related to degree of water solubility.
- methanol	☐	☐	☐	☐	
- glycol	☐	☐	☐	☐	
- corrosion inhibitors	☐	☐	☐	☐	
- biocides	☐	☐	☐	☐	
- scale inhibitors	☐	☐	☐	☐	
- surfactants	☐	☐	☐	☐	
- others (indicate)	☐	☐	☐	☐	

Table C - 16: Condensate induced extraction

Principle	Condesate induced extraction is based on extraction of hydrocarbons from produced water, using condensate (NGL) from a suction scrubber in the production stream. Condensate (NGL) is injected and mixed with the produced water stream, by means of a special designed injection & mixing system. The condensate acts as a solvent, i.e. extracts the watersoluble aromatic components from the water into the condensate phase. The condensate and the oil particles coalesces into larger, low-density droplets that are efficiently separated from the produced water by the downstream separation unit (i.e. hydrocyclone, compact flotation unit or similar). The condensate requirement for a given removal efficiency is proportional to feed Oil-in-Water concentration into the condensate induced extraction process.
Process diagram	
Basic elements	Condensate, injection & mixing system
Suitable for the removal of:	Hydrocarbons √ **Dispersed oil** √ **Dissolved oil**
	☐ Other contaminants **(specify)** Production chemicals with Log (octanol/water partition) greater than 2.0. **See table at the bottom of the next page**
	Remarks: For dissolved oil: the technique is suitable for the removal of dissolved aromatic hydrocarbons.

Technical details	**Per Unit (typical)***	Minimum	Maximum
	Treatment capacity (m3 produced water per hour)	10	500
	Gross Package volume, LxWxH, m	3 x 1.5 x 2	10 x 2 x 3
	Operating weight, tons	3	13
	CAPEX (€)	0,5 million	1,5 million
	OPEX (€/year)		
	Cost per m3 produced water(€/m3)		

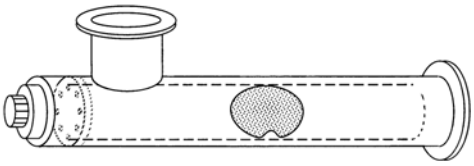
Critical operational parameters	Produced water pressure must be sufficiently high to keep the condensate in the liquid phase during the separation process. If the operating pressure does not match the phase properties of the condensate, boosting of the produced water or condensate processing might be required. This can be done without compromising the extraction process efficiency.
Operational reliability, incl. information on downtime	The condensate induced extraction process is highly reliable, presumed operating within the design specifications and with a reasonable sparing philosophy.
	Remarks: Costs for retrofit implementation of the condensate induced extraction process are case specific, depending on field specific conditions and the target removal efficiency.

Cross media effects	**Air**	
	Energy	Energy for pumping (and potentially condensate processing)
	Added chemicals	none
	Waste	none

Other impacts	**Health and safety**	Reclassification of the produced water system to a hydrocarbon containing system.	
	Maintenance interval & availability (% per year)		
Practical experience	**General**		**Onshore / Offshore**
			On and Offshore
State of development	✓ Implemented offshore ✓ Used onshore ✓ Offshore field trials ✓ Testing		Practical applicability: This can be done without compromising the extraction process efficiency.
			Driving force for implementation (e.g. legislation, increased yield, improvement product quality): Legislation and economic drivers caused by increased water cut
			Example plants: Successful testing at: Statfjord B and C Ekofisk 2/4J Snorre A Aasgard A Troll C Full-scale implementation at: Statfjord A, 2000 m3/h Statfjord B, 3000 m3/h Statfjord C, 4300 m3/h Snorre A, 1000 m3/h Ekofisk 2/4J&M, 2000 m3/h
Literature source			

	Suitable for		Removal Efficiency (%)		Reference to source documentation
	Oil installations	Gas installations	Oil installations	Gas installations	
Hydrocarbons					
- Dispersed oil	√	√	95	95	
- Dissolved oil	√	√	95	95	.
Specific oil components:					
- BTEX	☐	☐	90 (*)	80 (*)	
- NPD	☐	☐	90	90	
- PAH's 16 EPA	☐	☐	95	95	
- Others (indicate)	☐	☐	☐	☐	
Heavy metals	☐	☐	☐	☐	
Offshore chemicals					
- methanol	☐	☐	☐	☐	
- glycol	☐	☐	☐	☐	
- corrosion inhibitors	√	√	40 (**)	40 (**)	
- biocides	☐	☐	☐	☐	
- scale inhibitors	☐	☐	☐	☐	
- surfactants	☐	☐	☐	☐	
- others (indicate)	☐	☐	80 (***)	80 (***)	

Removal efficiency is referenced to a standard hydrocyclone discharge of 20 ppm. (*) Removal efficiency depending on BTEX content of condensate. (**) Specific class of corrosion inhibitors. (***) Log (octanol/water partition) greater than 2.0.

<table>
<tr><th colspan="4">Table C - 17: Tail shaped pre-coalescer</th></tr>
<tr><td>Principle</td><td colspan="3">In a tail shaped pre-coalescer, fluid enters the coalescer housing via an axial inlet nozzle, and then is forced to flow along the housing in the same longitudinal direction as the fibrous coalescer bundle. As fluid travels along the oleophilic fibres, small oil droplets are retained on the surface of the fibres. The droplets coalesce with other droplets on the fibre surface, and therefore grow as they migrate along bundle towards the outlet. Fluid drag increases as the droplet diameter grows, and eventually larger droplets are released at the end of the bundle. It is important to note that there is no phase separation in the coalescer. All the inlet fluid leaves through a common outlet, but the outlet mean droplet size is considerably enhanced, leading to easy gravity separation downstream. The coalescing action occurs within two seconds in the bundle, making a very compact device. The combination of flow along the fibres, rather than across as conventional coalescers, and relatively high fluid velocities, mean that solids are generally passed straight through the coalescer, and the product is therefore much less sensitive to fouling than conventional coalescing media.</td></tr>
<tr><td>Process diagram</td><td colspan="3">
FIGURE 1

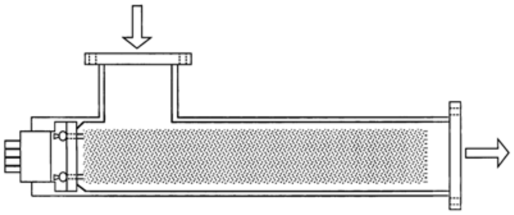



FIGURE 2
</td></tr>
<tr><td>Basic elements</td><td colspan="3"></td></tr>
<tr><td rowspan="2">Suitable for the removal of:</td><td colspan="2">Hydrocarbons
✓ Dispersed oil
✓ Dissolved oil</td><td>☐ Other contaminants (specify)
See table at the bottom of the next page</td></tr>
<tr><td colspan="3"><i>Remarks:</i> The technology itself, does not actually remove oil but improves the performance of downstream equipment (such as hydrocyclones) by coalescing the oil droplets and making them easier to separate. Hence the name pre-coalescer. Use of the technology upstream of hydrocyclones has been shown in practice that both dispersed and dissolved (naphthalenes, 2-4 ring PAH and C6-C9 phenols) oil removal can be enhanced.</td></tr>
<tr><td rowspan="7">Technical details</td><td>Per Unit</td><td>Minimum</td><td>Maximum</td></tr>
<tr><td>Treatment capacity (m3 produced water per hour)</td><td>Lower limit is typically 5 m3/hr for a 2” diameter unit</td><td>Largest units built to date have capacity of 260 m3/hr (per single unit)</td></tr>
<tr><td>Gross Package volume (LxWxH)</td><td>Approx 2.2 x 0.07 x 0.2 m</td><td>Approx 3.5 x 0.5 x 1.0 m</td></tr>
<tr><td>Operating weight</td><td>Approx 30 kg</td><td>Approx 1500 kg</td></tr>
<tr><td>CAPEX (€)</td><td>Approx €15,000 (duplex)</td><td>Approx €90,000 (duplex)</td></tr>
<tr><td>OPEX (€/year)</td><td>Unknown – insufficient operating data</td><td>Unknown – insufficient operating data</td></tr>
<tr><td>Cost per m3 produced water(€/m3)</td><td></td><td></td></tr>
<tr><td>Critical operational parameters</td><td colspan="3">Must be at least 0.5 bar head available at inlet to pre-coalescer to drive liquid through unit. Pressure drop across unit during normal operation requires monitoring. Media is typically changed out when the pressure drop reaches 3 bar.</td></tr>
</table>

Operational reliability, incl. information on downtime	Yet to be fully established as number of full scale units in service is limited. Field tests have shown that pilot scale units can operate reliably for 3 months or more before the media requires changing. Media changeout takes only a short time, after which the unit can be brought back in service. The technology is not recommended in applications where wax dropout occurs or where naphthanates are present in the produced water.
	Remarks:

Cross media effects	**Air**	
	Energy	
	Added chemicals	Certain oilfield chemicals should not injected upstream of the technology. In particular, deoilers injected upstream will have a detrimental effect on the coalescing performance, as the media strands can stick together as a result of chemical action.
	Waste	

Other impacts	**Health and safety**	Disposal of oil wetted media needs to be considered. This can be packed into specially designed shipment containers for return to shore.
	Maintenance interval & availability (% per year)	Pressure drop should be checked daily. Operational availability should be > 95%.

Practical experience	**General**	**Onshore / Offshore**
State of development	✓ Implemented offshore ☐ Used onshore ✓ Offshore field trials ✓ Testing	Practical applicability: Applicable for both offshore and onshore applications. Easy to install.
		Driving force for implementation (e.g. legislation, increased yield, improvement product quality): Legislation, improvement in discharges to sea (reduction in oil discharged)
		Example plants: Shell Pierce field (recently installed), offshore Brazil
Literature source		

	Suitable for		Removal Efficiency (%)		Reference to source documentation
	Oil installations	Gas installations	Oil installations	Gas installations	
Hydrocarbons					
- Dispersed oil	✓	✓	n.i.	n.i.	
- Dissolved oil	✓	✓	n.i.	n.i.	
Remark: The tail shaped pre-coalescer technology only promotes oil droplet growth and does not remove the oil in itself. Offshore trials have demonstrated that the use of the technology upstream can lead to significantly enhanced dispersed oil and dissolved oil removal. Oil droplet growth can be typically 400% growth in the median oil droplet size.					
Specific oil components:					
- BTEX	n.i.	n.i.	n.i.	n.i.	
- NPD	n.i.	n.i.	n.i.	n.i.	
- PAH’s 16 EPA	n.i.	n.i.	n.i.	n.i.	
- Others (indicate)	n.i.	n.i.	n.i.	n.i.	
Remark: Offshore analysis has shown that the use of the technology upstream of hydrocyclones has resulted in an improvement in the removal of both dispersed and dissolved (naphthalenes, 2-4 ring PAH and C6-C9 phenols) oil removal.					
Heavy metals	☐	☐	☐	☐	
Offshore chemicals					
- methanol	☐	☐	☐	☐	
- glycol	☐	☐	☐	☐	
- corrosion inhibitors	☐	☐	☐	☐	
- biocides	☐	☐	☐	☐	
- scale inhibitors	☐	☐	☐	☐	
- surfactants	☐	☐	☐	☐	
- others (indicate)	☐	☐	☐	☐	