typhonix cleaner production

Typhoon Valve System

ONS 2018

Innovation Award Winner!

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typhonix
cleaner production

Why develop a low shear control system (produced water)

New fields

- Formation water ~5% of oil production

Mature fields -

- Formation water+Injection water ~ 500-5000m³/hr
- Formation water+Injection water+Produced water re-injection ~ 5-10 bbl water per bbl oil

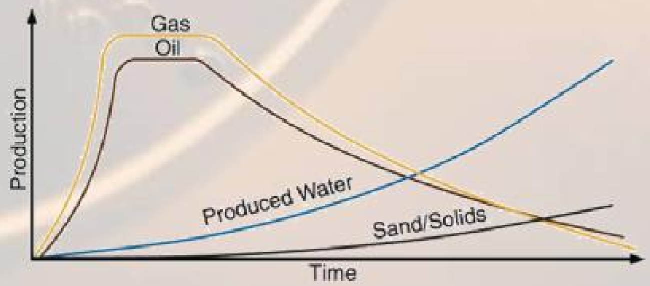

Fig. 1—A typical oilfield production profile.

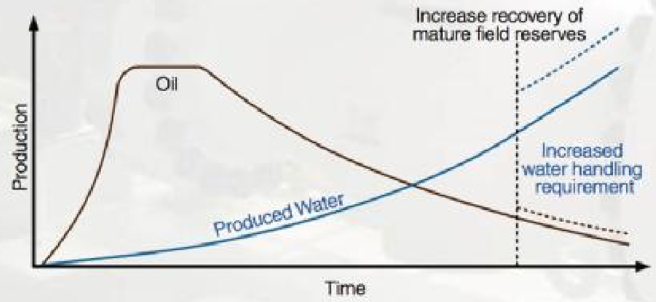

Fig. 3—Mature field production optimization.

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Why develop a low shear control system (produced water)

WATER PRODUCED DURING OIL AND GAS EXTRACTION OPERATIONS CONSTITUTES THE INDUSTRY'S MOST IMPORTANT WASTE STREAM ON THE BASIS OF VOLUME. THE OIL AND GAS INDUSTRY PRODUCES APPROXIMATELY 14 BILLION BBL. OF WATER ANNUALLY. PRODUCED WATER IS MOST OFTEN CONSIDERED A WASTE. WATER HANDLING PRACTICES MUST ALSO BE ENVIRONMENTALLY PROTECTIVE OR THE OPERATOR COULD FACE REGULATORY ACTION.

Source ALL Consulting LLC – Argonne National Laboratory & US D.O.E. 2004

What do we do with all this water?

- Water overboard in case offshore
- Evaporation ponds, agriculture, re-inject into wells in case onshore

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Regulation (cleaner production)

Produced water requires treatment;

- To remove volatile organic compounds (toxicity)
- To remove solids, bacteria for PWRI to protect reservoir & equipment
- To manage scale, corrosion in piping systems (acidity)
- To meet environmental regulations (<30ppm OiW – OSPAR convention - BREF)

Improving the oil / water separation process
- reduces processing and operational costs
- increases production longevity of the well / platform

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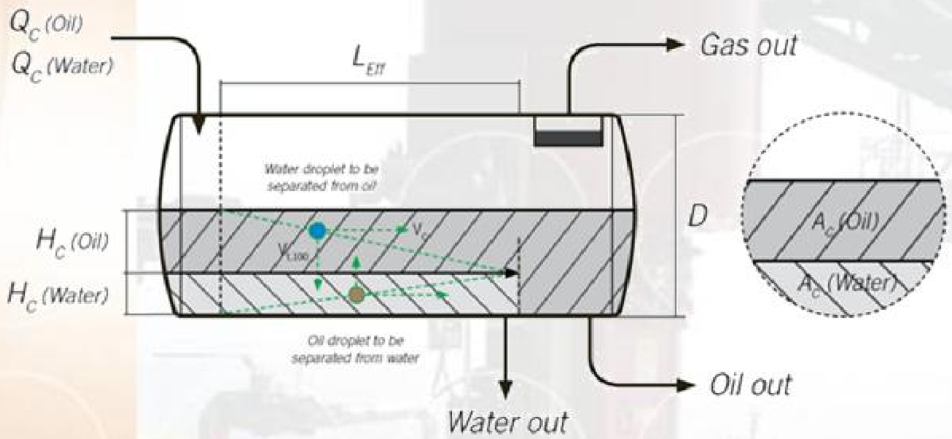
Gravity Based Separation (Stokes Law)

$$v_t = \frac{g \cdot d^2_{droplet} \cdot (|\rho_c - \rho_d|)}{18 \cdot \mu_c} \text{ [m/s]}$$

$$H/vt = L_{eff}/v_h \text{[m/s]}$$



- $d_{droplet}$ influences terminal velocity, v_t , of dispersed droplet according to Stokes' Law
- $d_{droplet}$ influences separation efficiency (performance) of existing vessels
- $d_{droplet}$ influences retention time (by definition of v_t)
  Higher v_t, shorter required retention time
  Less retention time → more capacity

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Oil / Water Separation Technologies

Separator Type	Technology	Droplet Size Removal
API separator	Gravity	~ min. 150 µm
Corrugated Plate / Tilted Plate Interceptor	Gravity with coalesce	~ min. 40 – 50 µm
Horizontal IGF	Gas flotation (no flocculants)	~ min. 20 – 25 µm
Hydro-cyclones	Centrifugal Force	~ min. 10 – 15 µm
Horizontal IGF	Gas flotation (with flocculants)	~ min. 5 µm .
Filtration	Adsorption / Barrier	< 0.01 – 5 µm

Source ALL Consulting LLC – Argonne National Laboratory & US D.O.E. 2004

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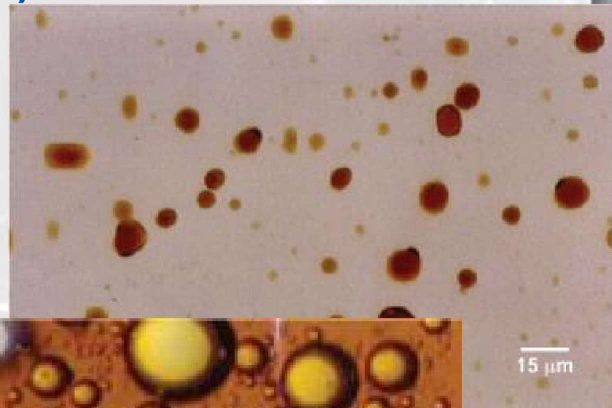
Emulsification (Increased production)

Emulsions are more difficult to separate.

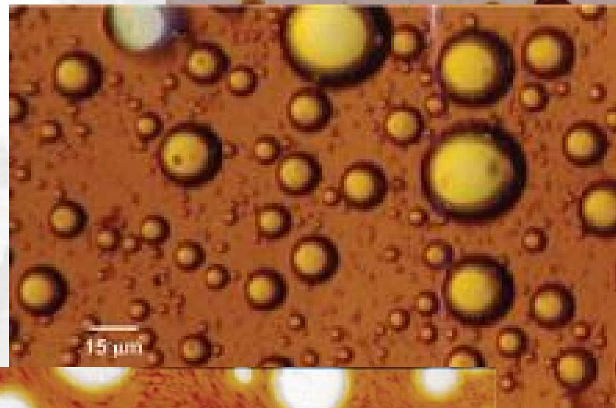
Factors affecting stability of emulsions

- Heavy polar material in the crude oil
- Fine solids including organics (asphaltenes, waxes) and inorganics (clays, scales, corrosion products)
- Temperature
- ***Droplet size and droplet size distribution***
- pH of the brine
- Brine composition
- Surfactants

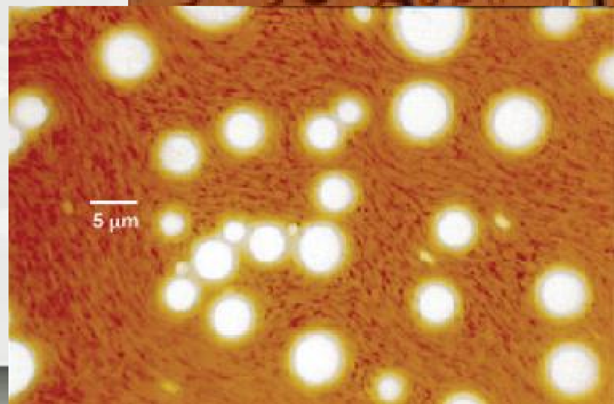
[OiW]



[WiO]



[Solids]



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Droplet breakup caused by energy dissipation (viscous and inviscid/inertial shear forces)

Davies (1985)

$d_{max} = C^*((4 * \sigma_{interface} + \eta_d * u_{in}) / \rho_c)^{3/5} * \varepsilon^{-2/5}$

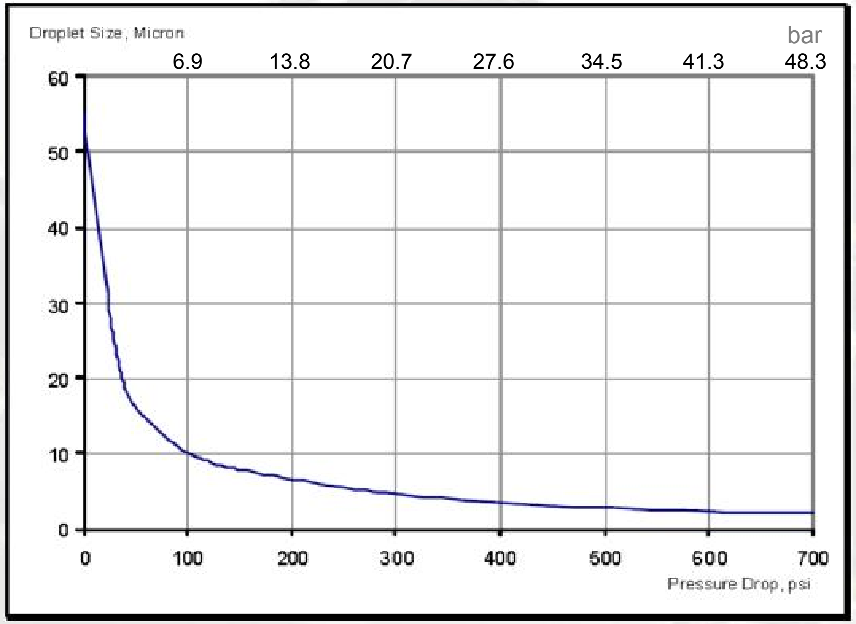
Hinze (1955)

$d_{max} = (We_{crit})^{3/5} * (\sigma_{interface}/\rho_c)^{3/5} * \varepsilon^{-2/5}$

Kolmogorov scale (1949)

$\lambda_0 = (\eta^{3/4} * \rho_c^{3/4} \varepsilon^{-1/4})$

ε = Mean energy dissipation rate per unit mass
$\varepsilon = \bar{E}/m$ where $\bar{E}$ is the turbulent energy dissipation rate, the rate at which the turbulence energy is absorbed by breaking the eddies down into smaller and smaller eddies until it is ultimately converted into heat by viscous forces (shear forces exerted on the fluid)
Kundu 1990: $\bar{E} = \Delta P * Q$



Anne Finborud, Mark Faucher, Erik Sellman - SPE 56643

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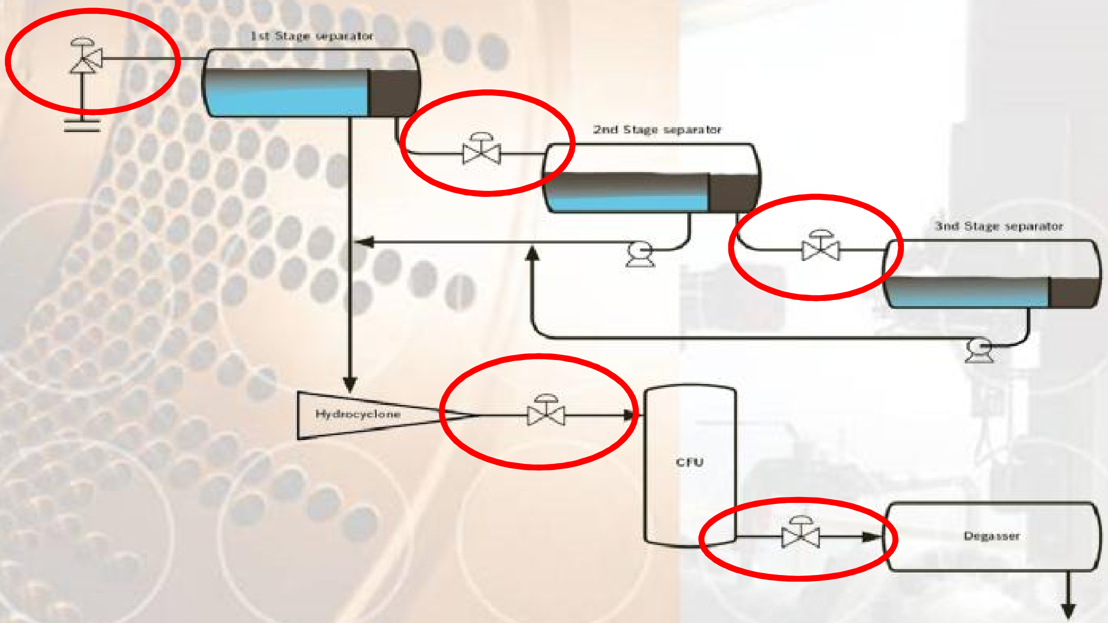
Droplet size reduced by shear forces



- Energy dissipation rate → break droplets
- Main energy dissipation developed in valves (energy dissipation)
- **Choke and control valves degrade oil-water separation and we place them in front of separation vessels!**

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Shear Reduction

- Maximum stable droplet size in turbulence zone as defined by Hinze (1955);

$$d_{max} = We_{crit}^{3/5} \cdot \left(\frac{\sigma}{\rho_c}\right)^{3/5} \cdot \varepsilon^{-2/5} \; [m]$$

We_{crit} : Weber Number is the ratio between the inertial force and the surface tension force
Hinze (1955) determined by experiments that We_{crit} ~0.725

σ : interfacial tension [N/m]

ρ_c : density [kg/m³]

- Mean energy dissipation rate per unit mass, ε ;

$\varepsilon = \bar{E}/m$ — $\bar{E}$=Turbulent energy dissipation rate, the rate at which the turbulence energy is absorbed by breaking the eddies down into smaller and smaller eddies until it is ultimately converted into heat by viscous forces (shear forces exerted on the fluid)

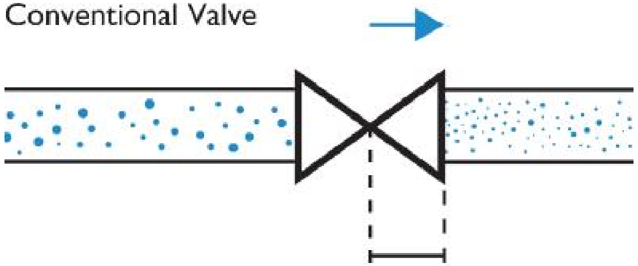
$\bar{E} = \Delta P * Q$ — P pressure [Pa], Q flowrate [m³/s] [Kundu 1990]

$m = V_{dis} * \rho_c$ — V [m³], ρ_c [kg/m³]

$$\varepsilon = \frac{\Delta P * Q}{\rho_c * V_{dis}} \; [W/kg]$$

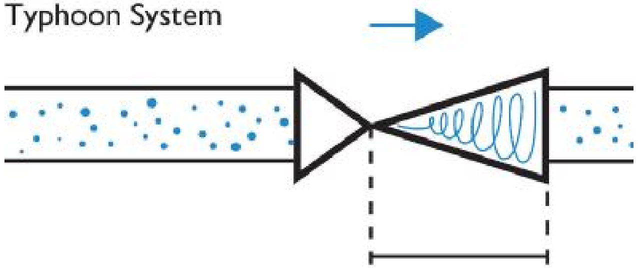
Typhoon Valve System

Conventional Valve

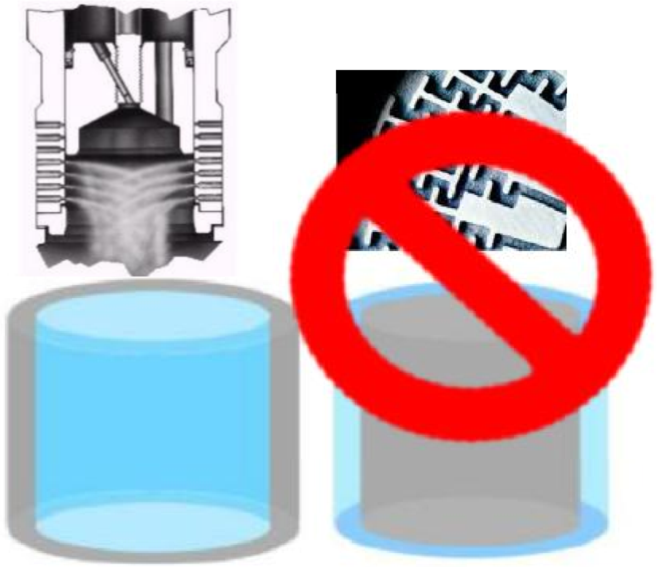


Energy
Dissipation
small V_{dis}

Typhoon System

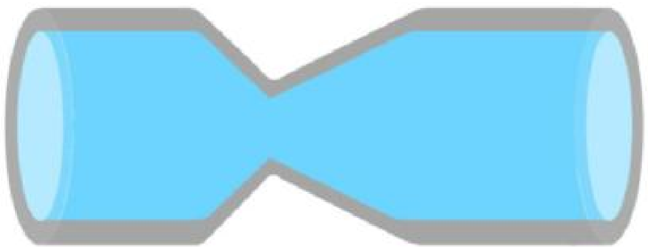


Energy
Dissipation
is much larger V_{dis}



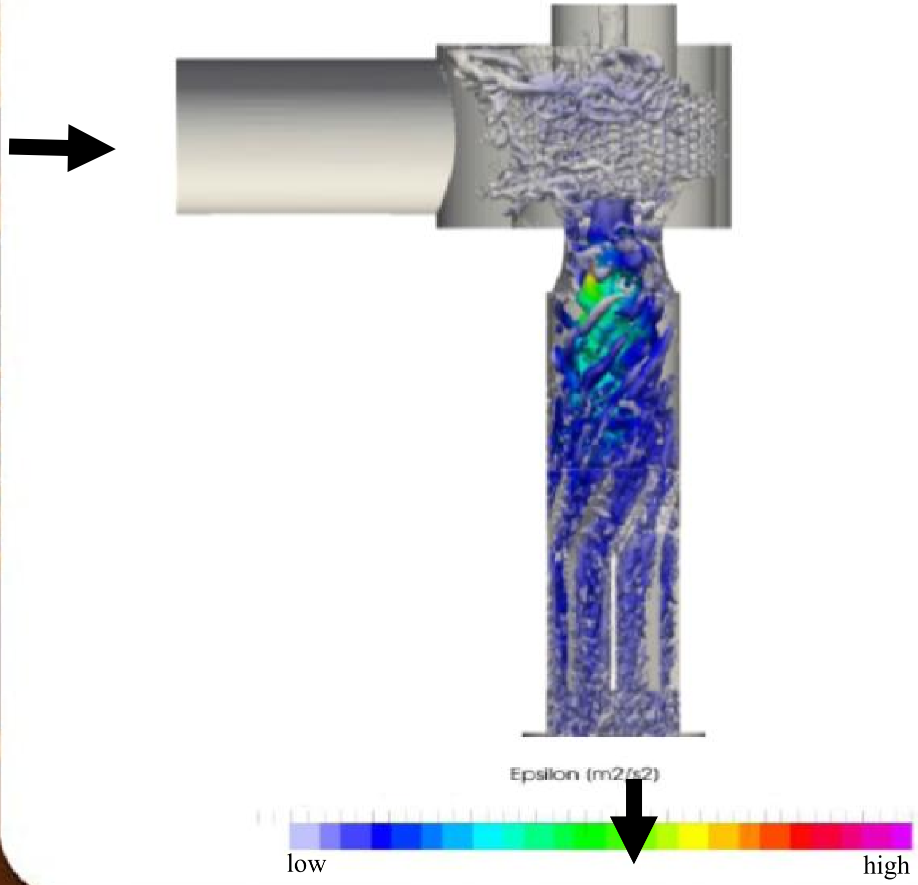
Standard valve(s)
medium volume

Other valve(s)
smallest volume

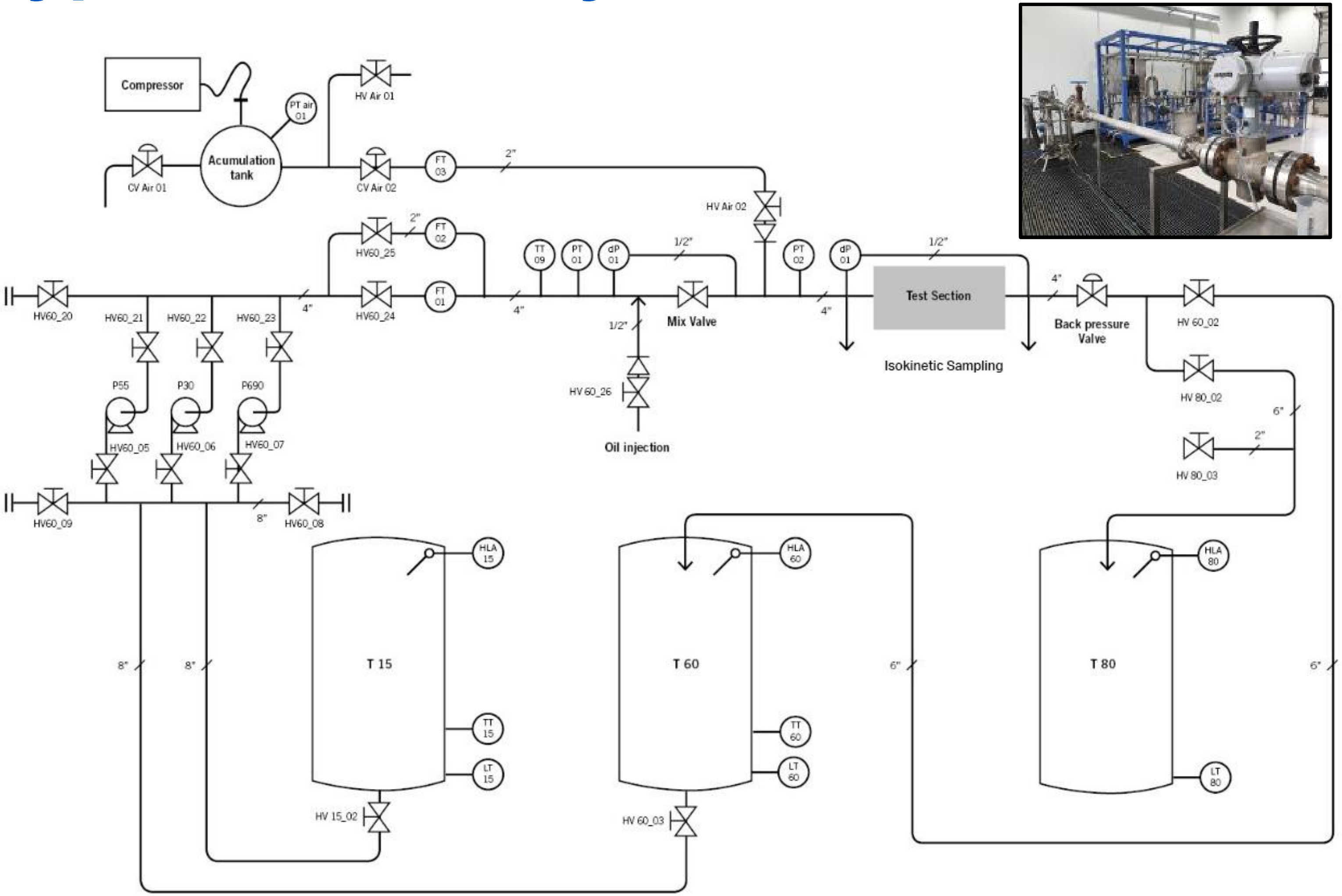


Axial Typhoon®
Largest active volume

Energy dissipation (production choke valve)

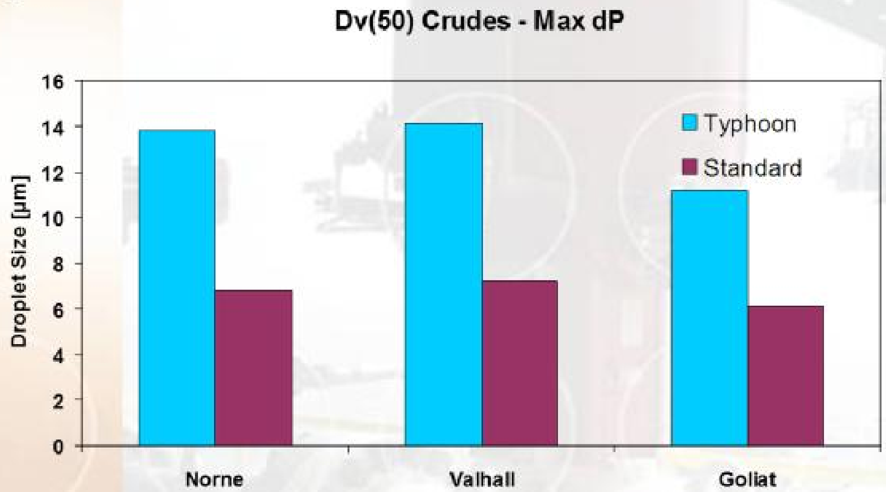


Typhoon Valve System (Laboratory Testing)



Typhoon Valve System (Laboratory Testing)

Prototype produced water testing



Typhoon Valve System was tested with produced water made up of 13 different North Sea crudes grades ranging from grades API 19 - 45

Conclusions:

- Systematic reduction of droplet break-up with all crudes
- Oil droplets are typically twice as large with Typhoon Valve System installed compared to conventional valve(s)

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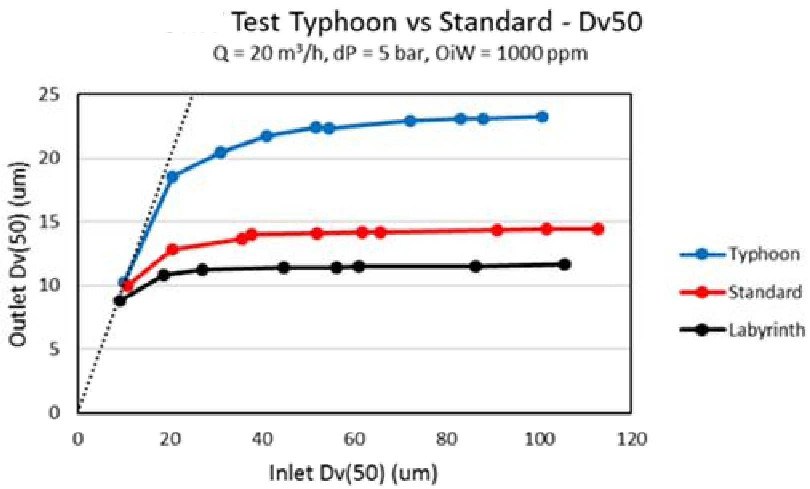
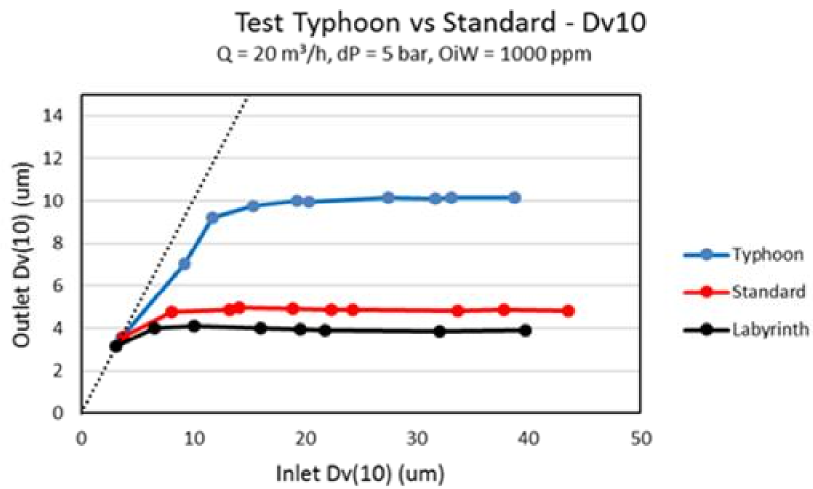
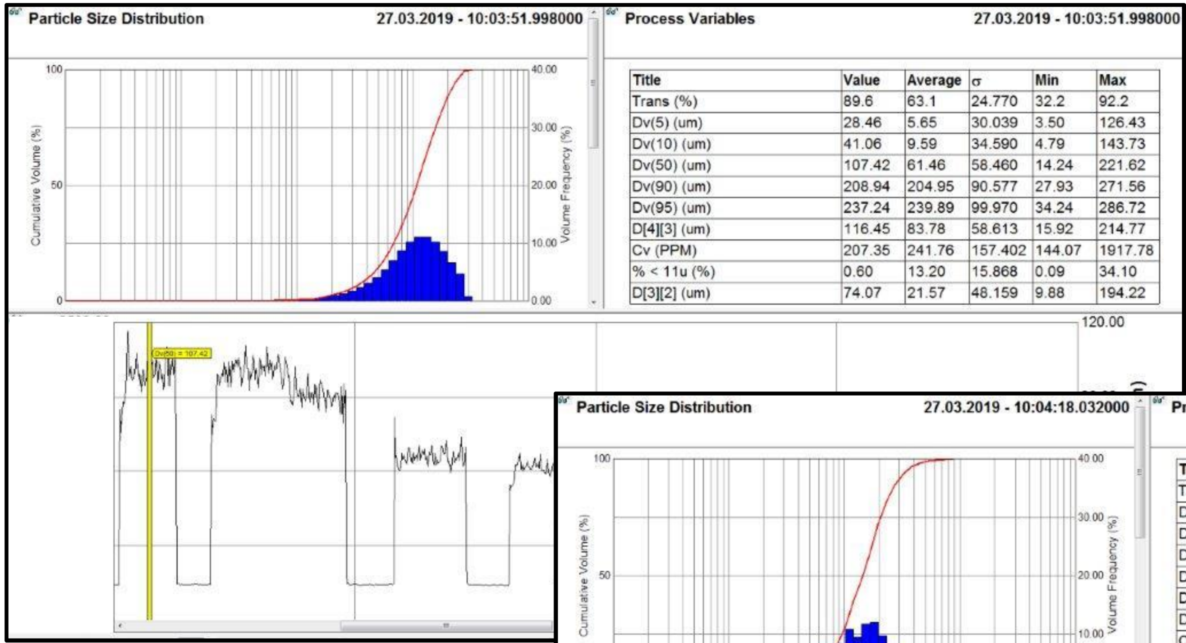
Typical droplet size distribution



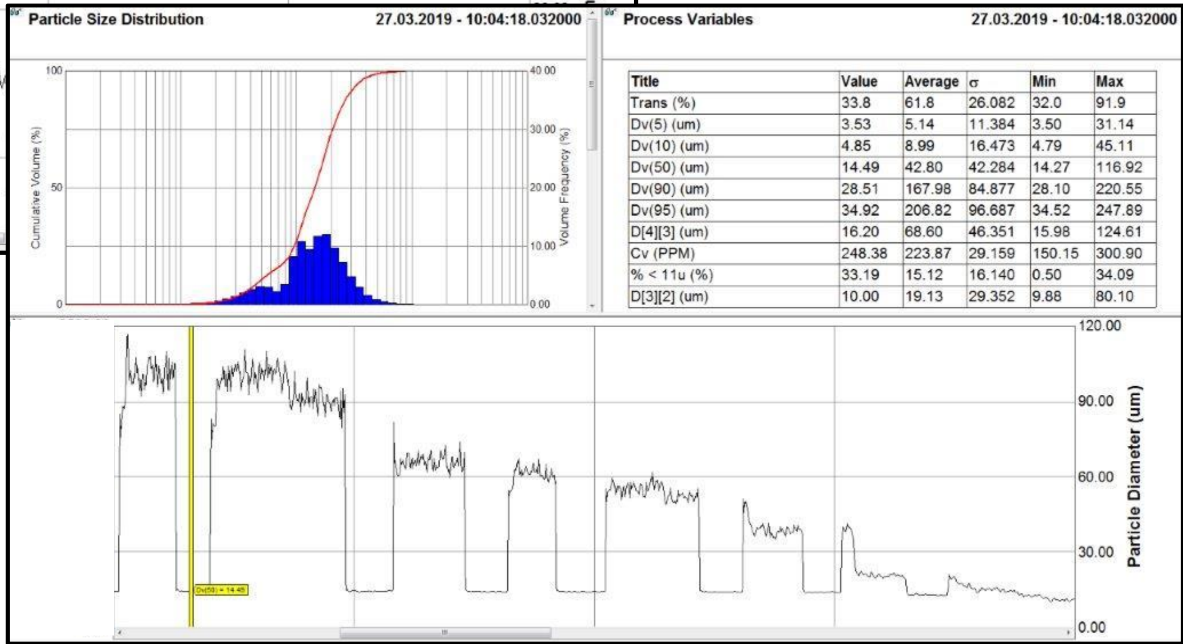


Dv(x) on valve outlet typically 2 - 3 times larger with Typhoon System

Standard valve (Laboratory Testing)



Title	Value	Average	σ	Min	Max
Trans (%)	89.6	63.1	24.770	32.2	92.2
Dv(5) (um)	28.46	5.65	30.039	3.50	126.43
Dv(10) (um)	41.06	9.59	34.590	4.79	143.73
Dv(50) (um)	107.42	61.46	58.460	14.24	221.62
Dv(90) (um)	208.94	204.95	90.577	27.93	271.56
Dv(95) (um)	237.24	239.89	99.970	34.24	286.72
D[4][3] (um)	116.45	83.78	58.613	15.92	214.77
Cv (PPM)	207.35	241.76	157.402	144.07	1917.78
% < 11u (%)	0.60	13.20	15.868	0.09	34.10
D[3][2] (um)	74.07	21.57	48.159	9.88	194.22



Title	Value	Average	σ	Min	Max
Trans (%)	33.8	61.8	26.082	32.0	91.9
Dv(5) (um)	3.53	5.14	11.384	3.50	31.14
Dv(10) (um)	4.85	8.99	16.473	4.79	45.11
Dv(50) (um)	14.49	42.80	42.284	14.27	116.92
Dv(90) (um)	28.51	167.98	84.877	28.10	220.55
Dv(95) (um)	34.92	206.82	96.687	34.52	247.89
D[4][3] (um)	16.20	68.60	46.351	15.98	124.61
Cv (PPM)	248.38	223.87	29.159	150.15	300.90
% < 11u (%)	33.19	15.12	16.140	0.50	34.09
D[3][2] (um)	10.00	19.13	29.352	9.88	80.10

OiW – 1000 ppm,
Q - 20 m³/h,
ΔP - 5 bar

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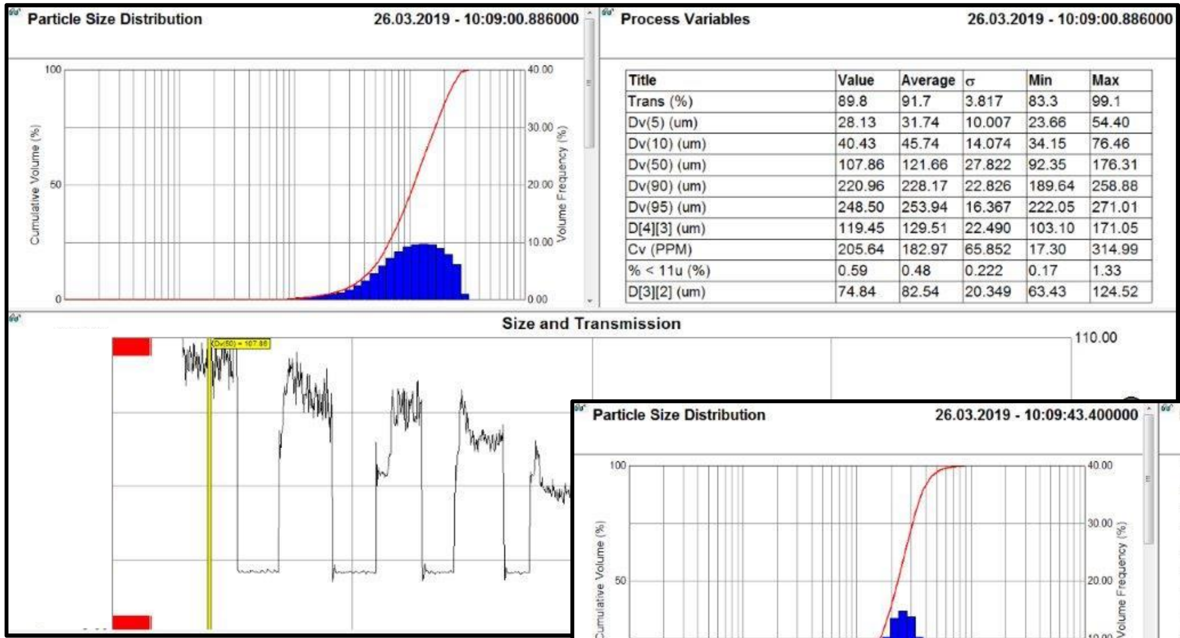
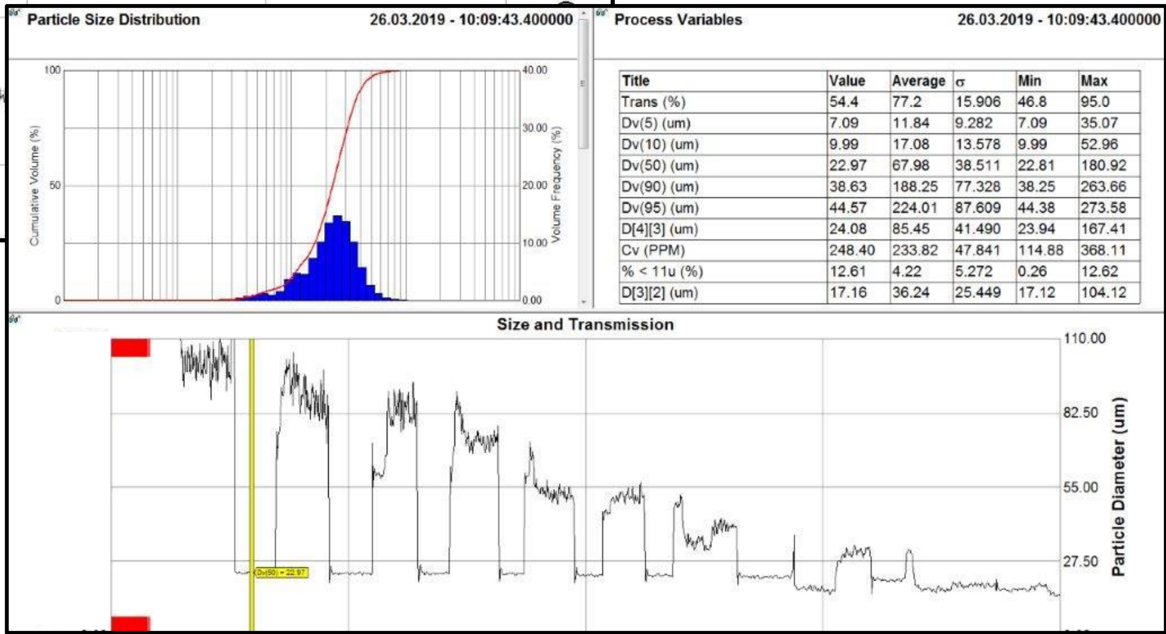
Typhoon Valve System (Laboratory Testing)



Title	Value	Average	σ	Min	Max
Trans (%)	89.8	91.7	3.817	83.3	99.1
Dv(5) (um)	28.13	31.74	10.007	23.66	54.40
Dv(10) (um)	40.43	45.74	14.074	34.15	76.46
Dv(50) (um)	107.86	121.66	27.822	92.35	176.31
Dv(90) (um)	220.96	228.17	22.826	189.64	258.88
Dv(95) (um)	248.50	253.94	16.367	222.05	271.01
D[4][3] (um)	119.45	129.51	22.490	103.10	171.05
Cv (PPM)	205.64	182.97	65.852	17.30	314.99
% < 11u (%)	0.59	0.48	0.222	0.17	1.33
D[3][2] (um)	74.84	82.54	20.349	63.43	124.52



Title	Value	Average	σ	Min	Max
Trans (%)	54.4	77.2	15.906	46.8	95.0
Dv(5) (um)	7.09	11.84	9.282	7.09	35.07
Dv(10) (um)	9.99	17.08	13.578	9.99	52.96
Dv(50) (um)	22.97	67.98	38.511	22.81	180.92
Dv(90) (um)	38.63	188.25	77.328	38.25	263.66
Dv(95) (um)	44.57	224.01	87.609	44.38	273.58
D[4][3] (um)	24.08	85.45	41.490	23.94	167.41
Cv (PPM)	248.40	233.82	47.841	114.88	368.11
% < 11u (%)	12.61	4.22	5.272	0.26	12.62
D[3][2] (um)	17.16	36.24	25.449	17.12	104.12

OiW – 1000 ppm,
Q - 20 m³/h,
ΔP - 5 bar

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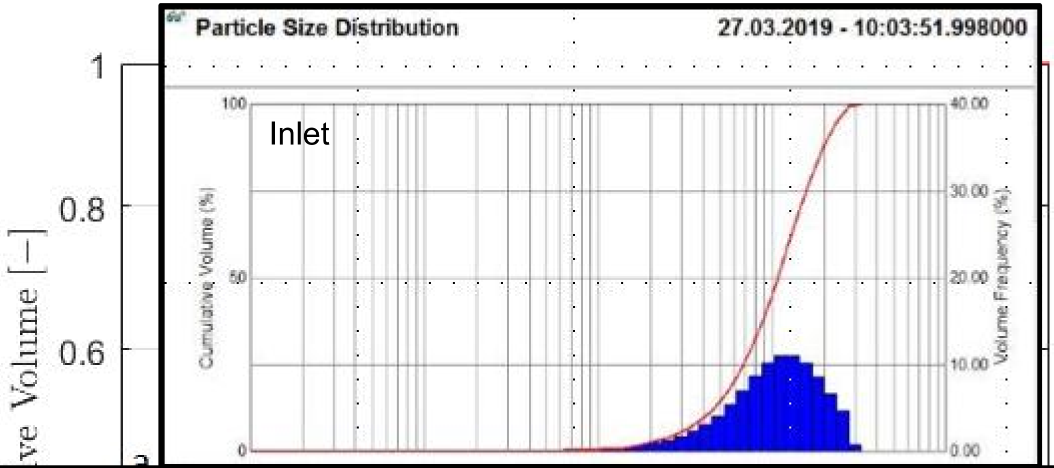
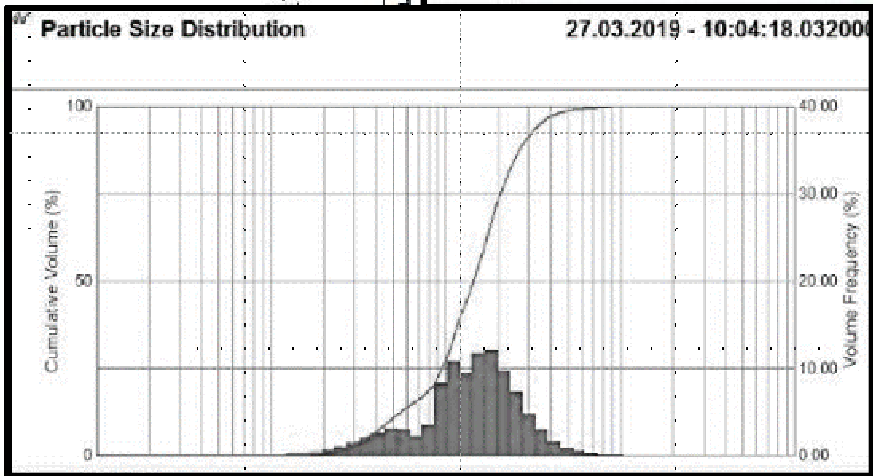
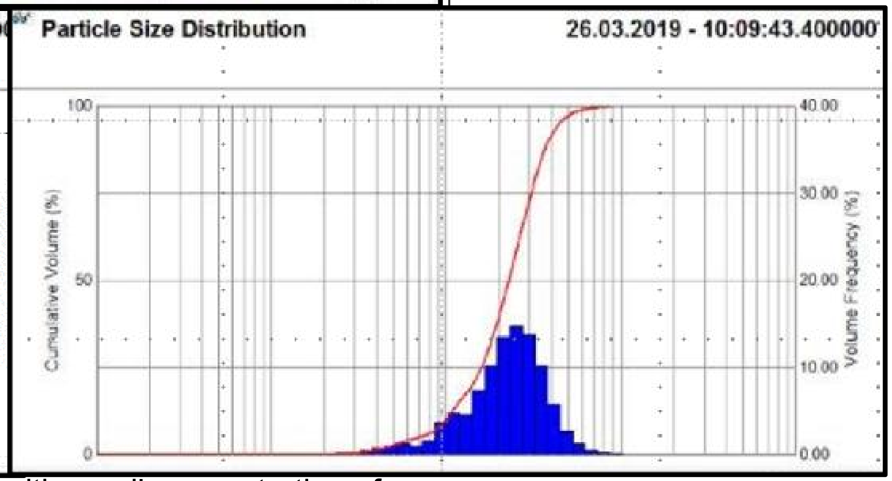
Typical droplet size distribution



OiW – 1000 ppm,
Q - 20 m³/h,
ΔP - 5 bar



Standard valve outlet



Typhoon Valve System outlet

are performed with a water/oil mixture with an oil concentration of approximately 2000ppm.

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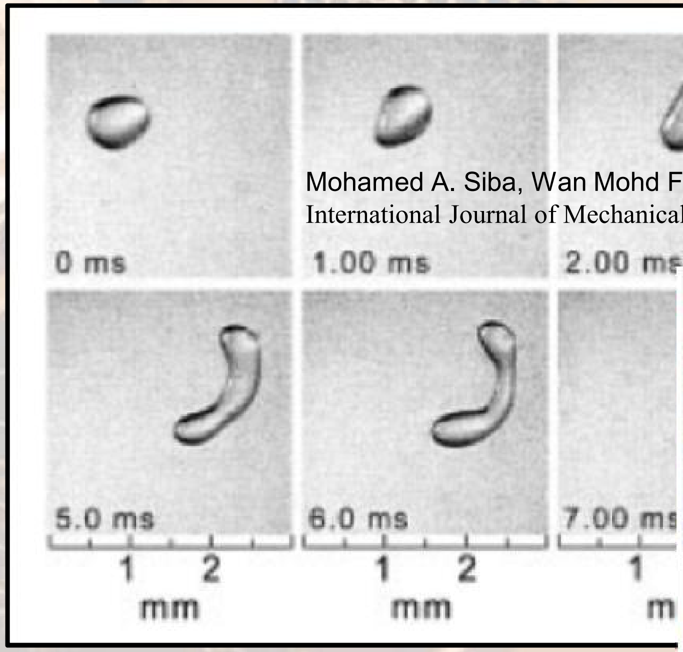
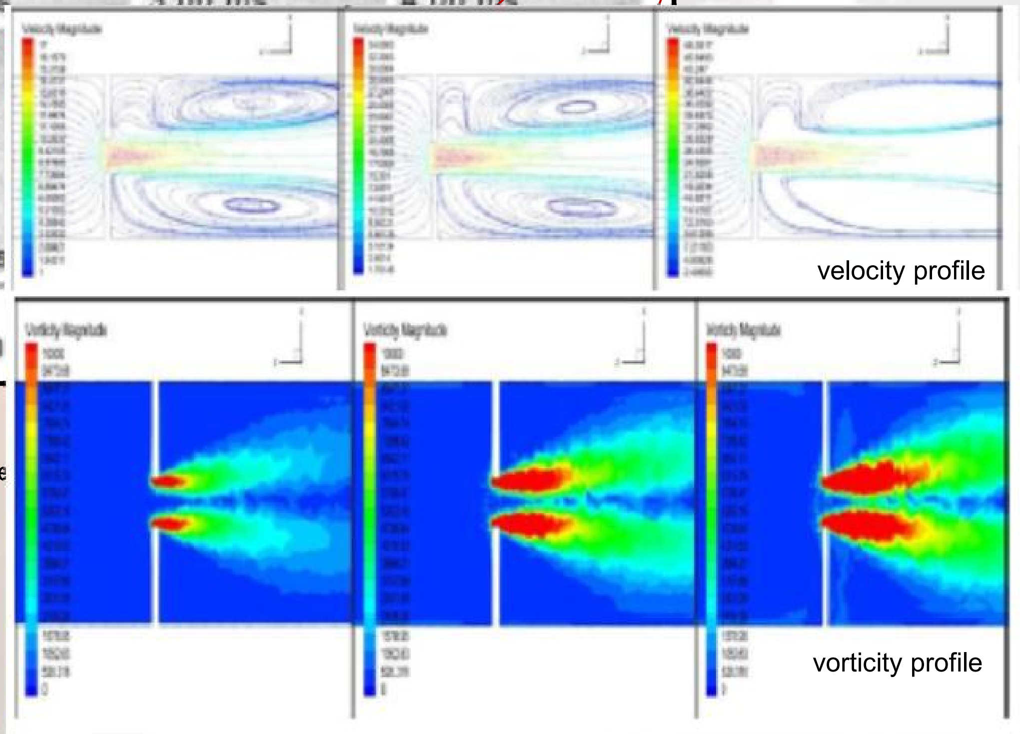
Droplet Breakup (Bimodal distribution)

(Sub-)micron range



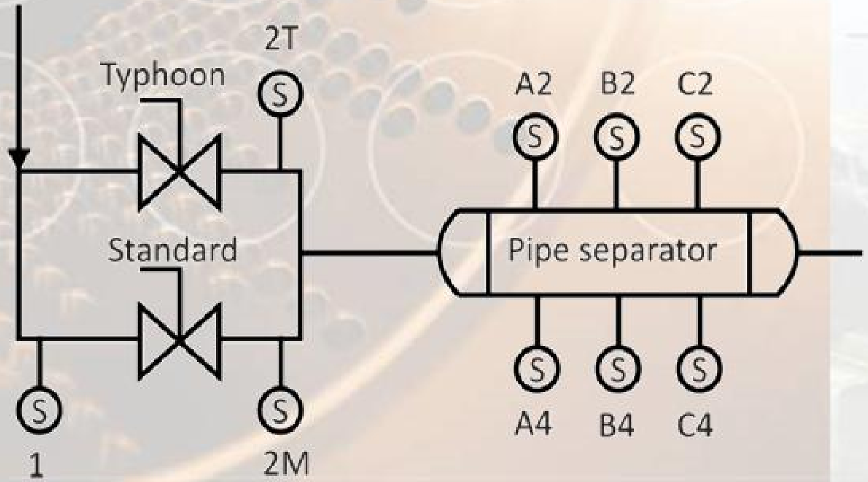
Mohamed A. Siba, Wan Mohd Faizal Wan Mahmood, Mohd Z. Nuawi, Rasidi Rasani and Mohamed H. Nassir
International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol:15 No:02



Ronnie Andersson, Bengt Andersson
Dept. of Chemical and Biological Engineering, Chalmers University of Technology, SE-41296, Gothenburg, Swede
DOI 10.1002/aic.10831
Published online March 24, 2006 in Wiley InterScience (www.interscience.wiley.com).

Typhoon Valve System (Multiphase Flow Testing)

Test at Multi Phase Flow Loop, 2009



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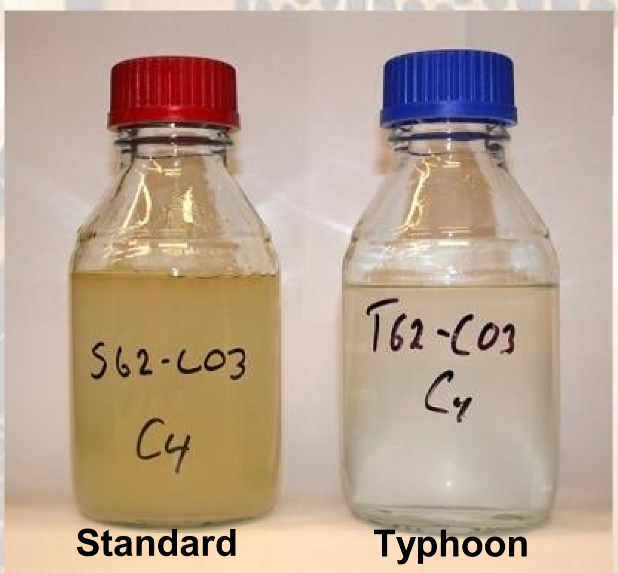
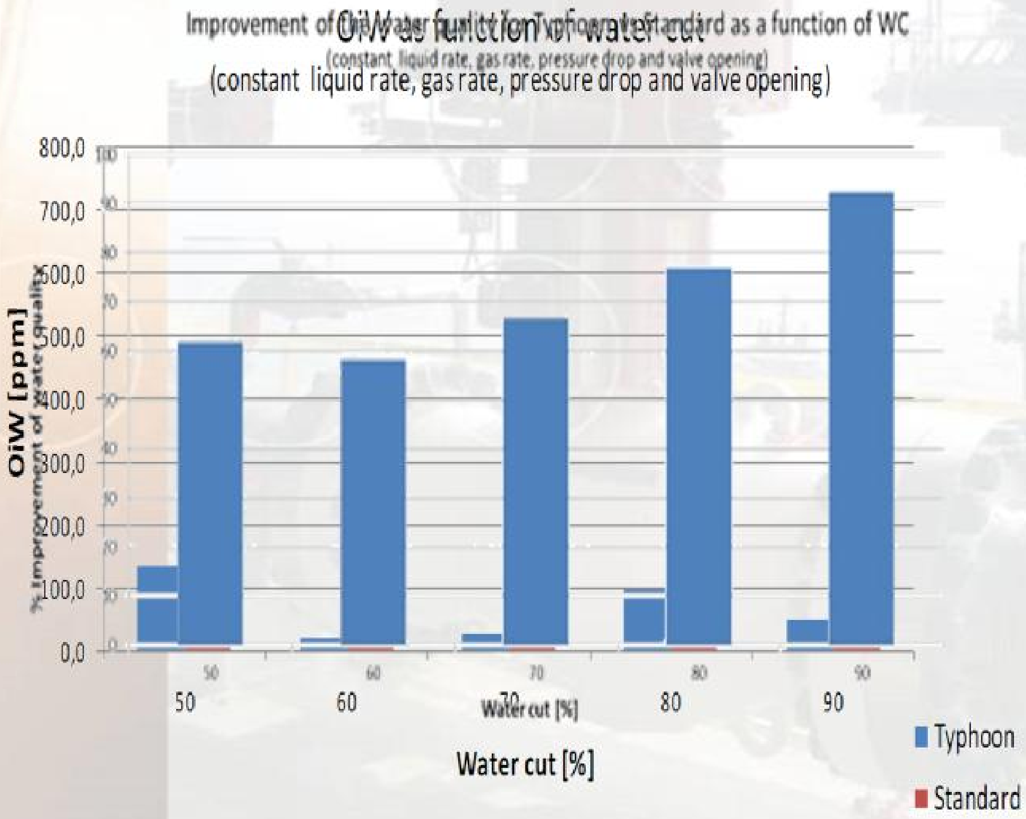
Typhoon Valve System (Multiphase Flow Testing)



Test Results Multi Phase Flow Loop, 2009



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Full scale erosion testing

Erosion testing at DNV/GL Flow Center

Typhoon® Valve at GL Flow Centre

Description		
Flow rate gas	Q_g	300m^3/hr
Flow rate sand	Q_s	0.26m^3/hr
Volume fraction sand	Vf_s	0.0256 %
Sand particle size	D_s	280 μm
Sand feed rate	F_s	115 kg/hr
Gas density	ρ_g	1.1 kg/m^3
Sand bulk density	ρ_s	1500 kg/m^3
Initial pressure drop over valve	Δp	3.58 barg

Internals in erosion resistant materials tested by injecting 500kg of sand at gas velocities of >50m/s

- Zero weight loss in cage and venturi

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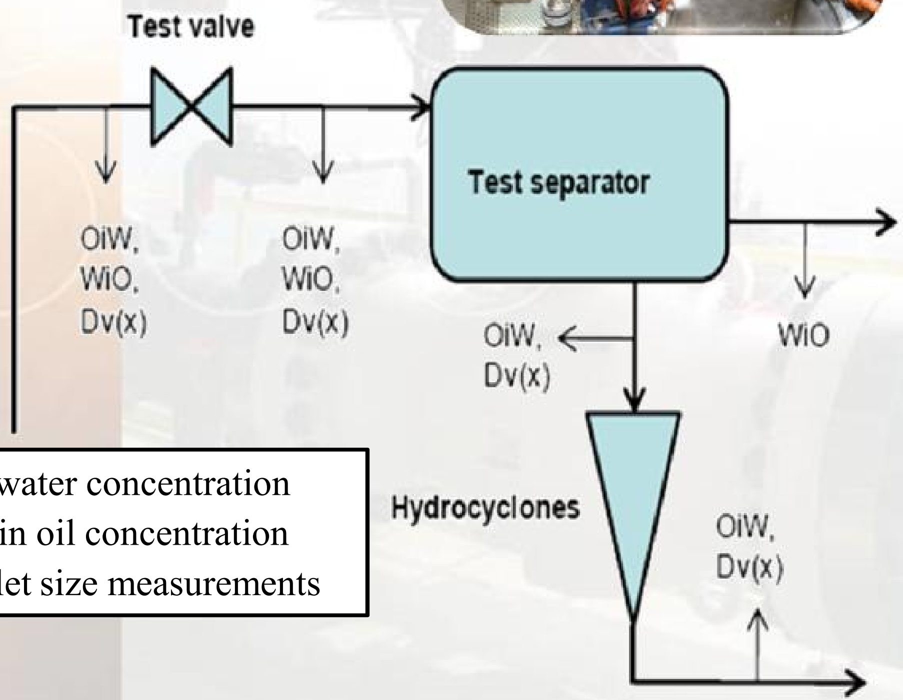
Offshore Pilot Installation (conditions), 2012

Conditions:

- 50 - 55% WC
- 10 - 13 GLR u/s choke (actual)
- 72 - 78 bar dP at normal production
- 92 - 96 bar dP at reduced production



OiW	=	Oil in water concentration
WiO	=	Water in oil concentration
Dv(x)	=	Oil droplet size measurements

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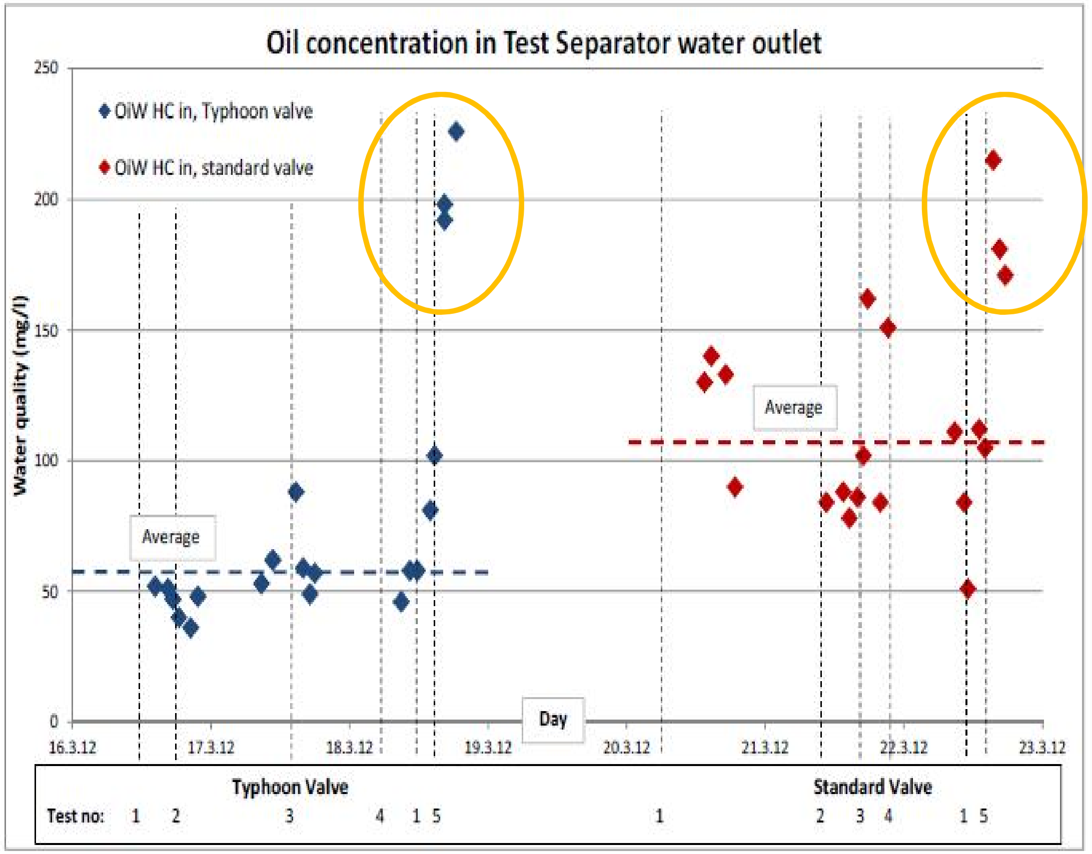
Offshore Pilot Installation (results), 2012



Challenging test conditions

Systematic improvement of water quality; **45%**

Offshore First Installation, 2016

(cleaner water effluent)

November 15, 2016

Successful offshore installation of Typhoon® System on Statoil's Troll C

Mokveld's low shear Typhoon System has once again demonstrated the robustness of the technology.

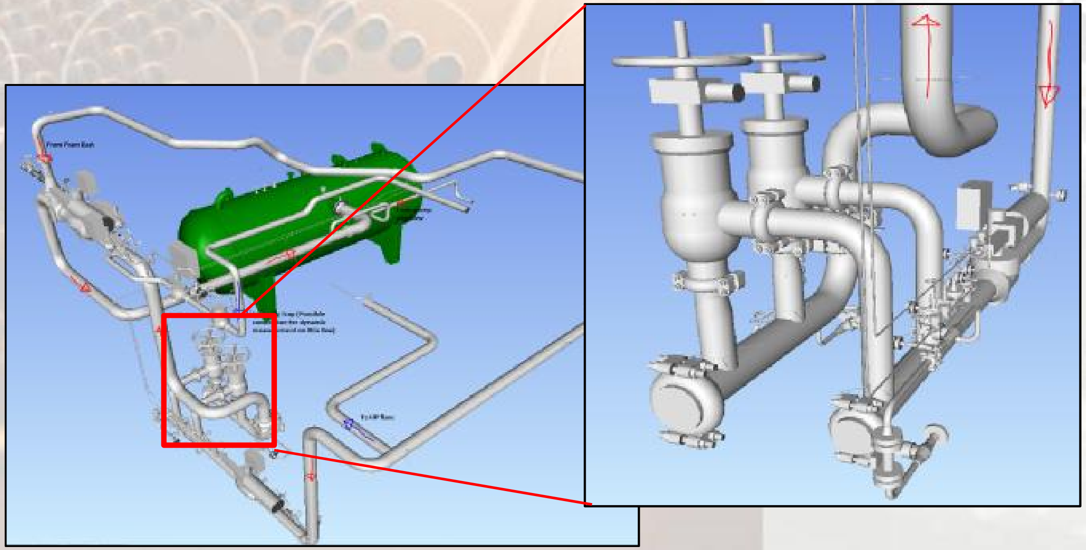
The system is installed on the Statoil operated Troll C platform controlling well fluids from the Fram Vest field. Operating at the most challenging conditions for which the unit is designed**, the Typhoon System showed an impressive 60% improvement in the produced water quality (OiW)** in comparison to the conventional choke valve that is installed in parallel with the unit.

Combined with the previously obtained improvements of 60-90% water quality during the prototype test and the 45% improvement in water quality during the pilot test on Statoil's operated Oseberg C platform, the Typhoon System's patented technology to reduce shear forces on dispersed liquids is unquestioned and unparalleled.

The low shear flow control Typhoon System, developed in cooperation with Typhonix AS, is the simplest and most cost efficient manner to improve separation of mixed liquids. No additional equipment, expensive modifications, high heat input, or chemicals are required.

Just install the Mokveld Typhoon System in place of conventional choke or control valve technology and separation is improved.

With additional units being deployed in the near future in the Dutch sector of the North Sea and in the Gulf of Mexico, the low shear flow control Typhoon System results in cleaner production, enhanced separation processes and reduced chemical usage in the production of our energy needs today. One of the reasons why the sponsors Statoil, ENI, Total, Shell, Engie, ConocoPhillips and Petrobras embraced the development of this new technology.



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Conclusion(s)

- Increased droplet size after pressure reduction in comparison to existing valve technology
- Complete droplet size distribution improves by a factor 2-3
- Both axial flow control valve as well as angle production choke valve give improvements on droplet sizes
- OiW concentration after separation decreases by 50% on average
- WiO concentration after separation decrease as well

- Longer economic field lifetime
- Less cost for chemicals, less heating of the emulsion
- Smaller vessels with same output quality, or same size vessel with higher flowrate
- Cleaner production and easy compliance to environmental regulations

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Benefits - Separator Efficiency

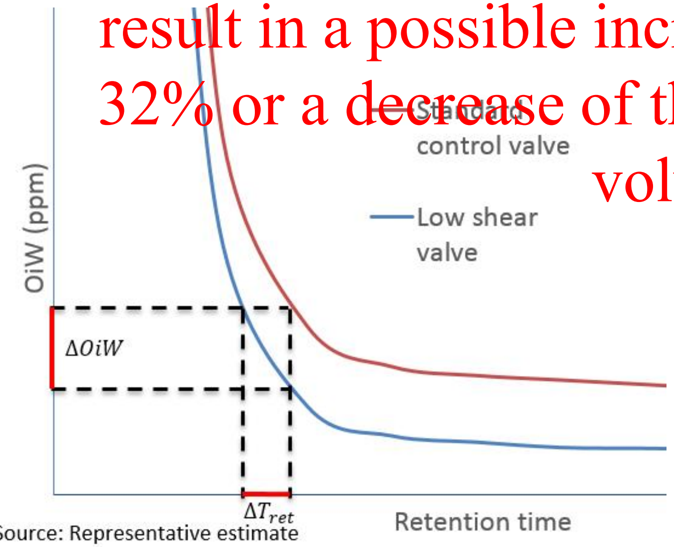
(smaller separator liquid volume or higher liquid production)

$$v_t = \frac{g \cdot d^2_{droplet} \cdot (|\rho_c - \rho_d|)}{18 \cdot \mu_c}$$ Stoke's Law

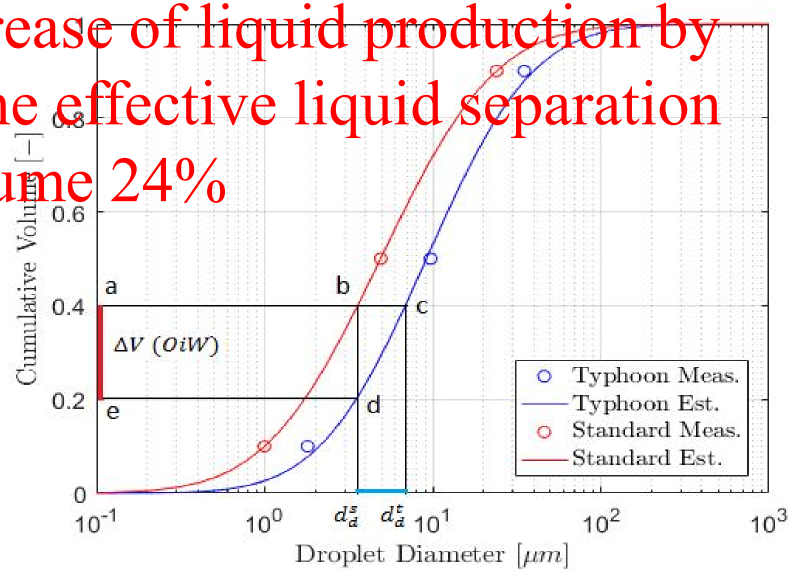
Conclusion;

$$D_{sep} \cdot L_{eff} = C \cdot \frac{Q_c \cdot \mu_c}{(|\rho_d - \rho_c|) \cdot d^2_{droplet}}$$ Droplet Settling Equation

A conservative increase in droplet size of 15% will result in a possible increase of liquid production by 32% or a decrease of the effective liquid separation volume 24%

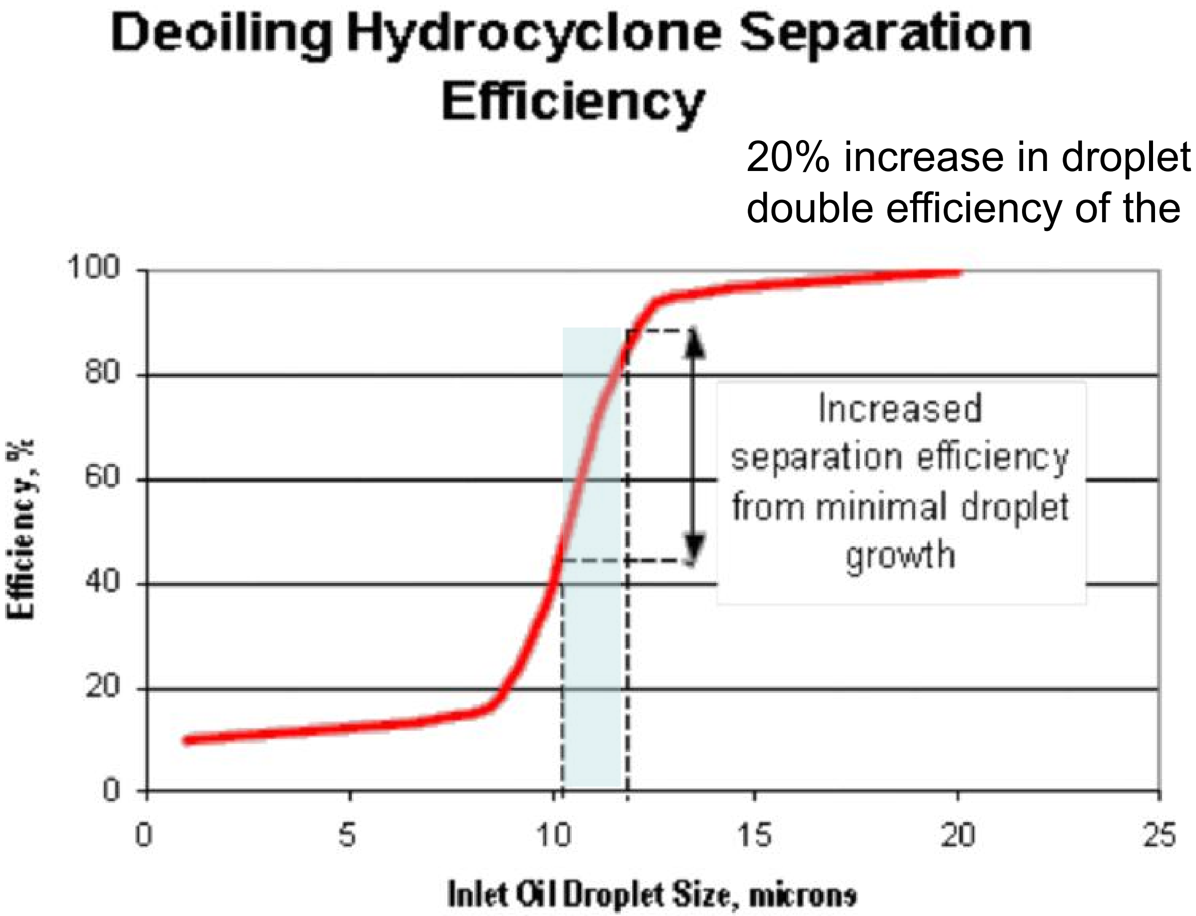


Source: Representative estimate



Benefits - Hydrocyclone Efficiency

20% increase in droplet size results in double efficiency of the hydrocyclone



Cyclotech – Separasjonsteknologi 2007, Stavanger

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Benefits - Reduced chemical usage

6 CONCLUSION

This thesis is based on the results from the typhoon pilot test at Oseberg C. The work conducted has shown that the typhoon valve gives a significant positive effect on the produced water system. For estimations all choke valves are assumed to be typhoon valves. The most important findings during this work are:

Dispersed oil released with the produced water has been revived to be reduced by 55%. The reduction increases the amount of system upsets the facility can handle before the maximal OiW limit is reached.

When OiW concentrations in the produced water is reduced the need of flocculants are also reduced. A 55 % reduction was estimated, reducing the yearly use of flocculants by 36.7-110 ton. Indirect positive effects can be that an upgrade of the chemical system can be delayed or avoided. Reduction of dispersed oil and the amount of flocculent also reduces the EIF.

Helge Vatsvag – Master Thesis 2013

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Benefits - Heating savings (fuel gas)

- One factor affecting stability of emulsions is temperature. Considering that the droplet size/distribution advantages of Typhoon technology would allow you to reduce the temperature of the fluids while maintaining the same quality of produced water, your savings on heating fuel can be calculated.

Typhoon Fuel Gas Savings		
Reduced Heating Requirements of the Emulsion		
SI UNIT		
INPUT	**Case 1**	
Oil flow rate [m³/hr]	39.7	~6000 bpd
Produced Water flow rate [m³/hr]	59.6	Watercut ~60%
Natural Gas flow rate [nm³/hr]	145.0	GOR ~20%
Operating temperature @ heater [degC]	50.0	
Heating gas price [€/kWh]	0.041	(default € 0.0413) - http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do
Specific Gravity oil [-]	0.845	~API grade 38 = Brent
Specific Gravity produced water [-]	1.010	
Molecular weight natural gas [-]	20.00	
Temperature change [degC]	2.5	
c_p crude oil [kJ/kg degK]	2.03	(default to c_p = (0.4352+0.001*tdegC)*4.1868) - TEMA standards
c_p produced water [kJ/kg degK]	3.93	(default to $c_{p\ seawater}$ 3.93)
c_p natural gas [kJ/kg degK]	2.34	(default to $c_{p\ natural\ gas}$ 2.34)
Heater efficiency [%]	75%	(default to 75%)
INTERMEDIATE CALCULATIONS		
Oil flow rate [kg/day]	805116	
Produced water flow rate [kg/day]	1444704	
Natural gas flow rate [kg/day]	3105	
Oil heating energy requirement [kJ/day/K]	1635541	
Produced water heating energy requirement [kJ/day/K]	5677687	
Natural gas heating energy requirement [kJ/day/K]	7266	
Heating energy requirement [kJ/day/K]	7320494	
Total heater energy requirement [kJ/day/K]	9760659	
Results		
Saving [€/day/degC]	€ 112	
Typhoon Total Fuel Gas Savings [€/year]	€ 102,179	

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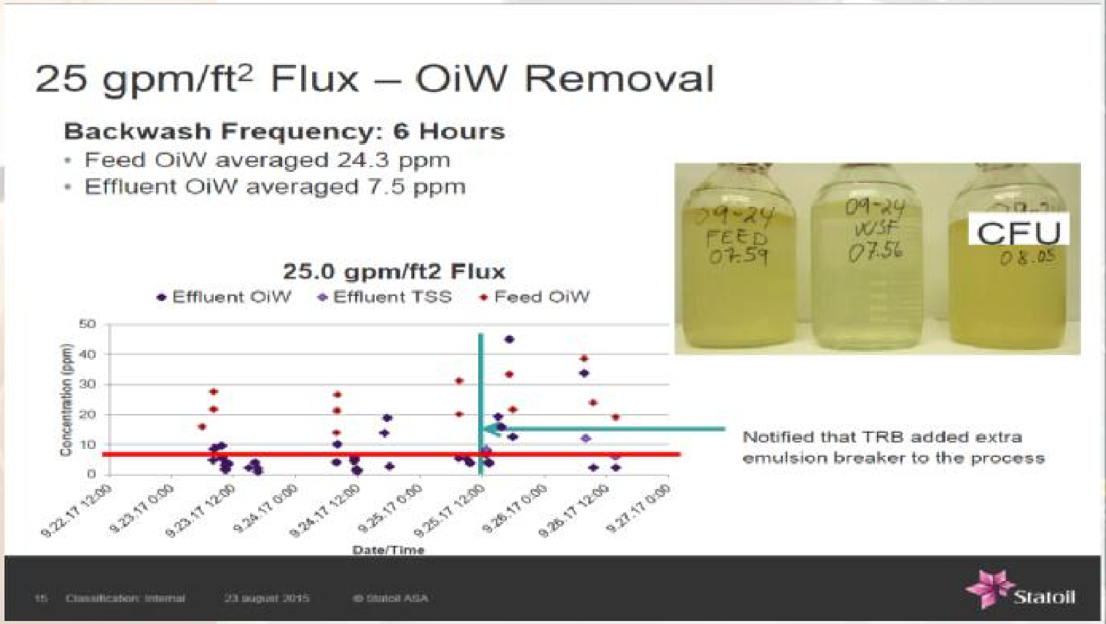
Benefits - Prolonged lifetime

(adsorption, filtration, membranes)

The adsorbent can be easily overloaded with large concentrations of organics. The media also eventually becomes consumed with contaminants and must be disposed or regenerated using chemicals. Regeneration creates a liquid waste product that must be disposed. Media may require frequent replacement or regeneration depending on type and feedwater quality.



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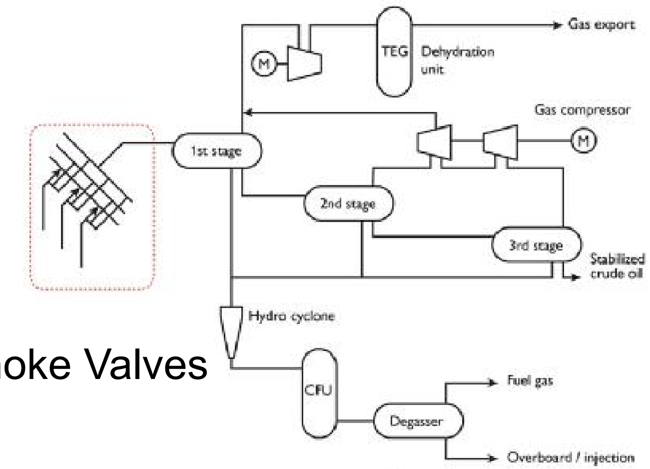
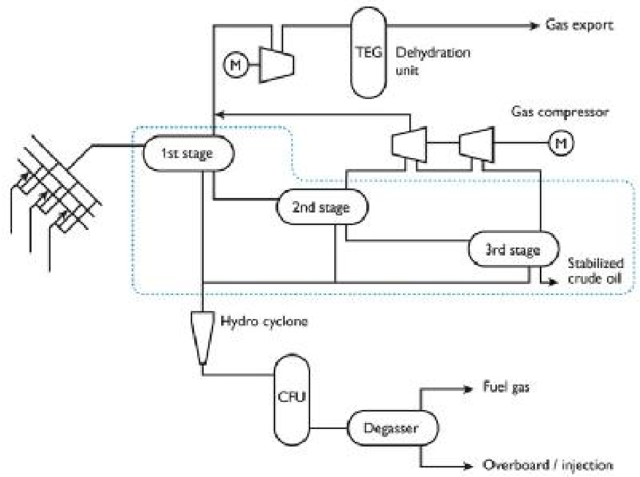
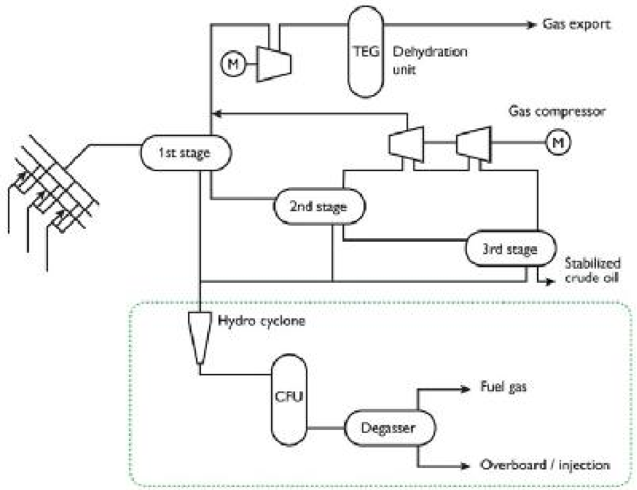
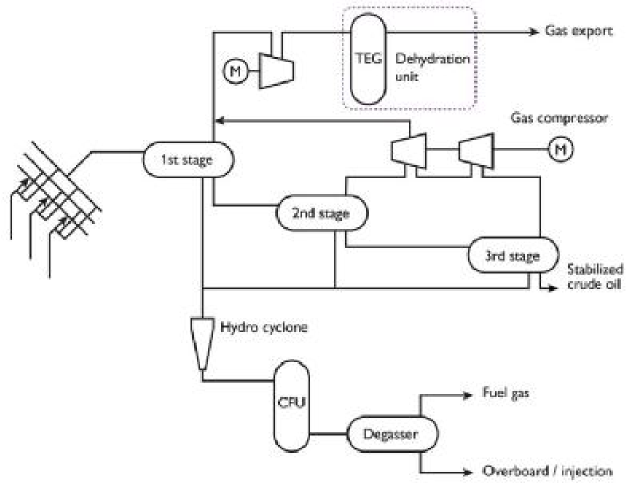
Typhoon® System Applications



Choke Valves







Level Control Valves

Typhoon Valve System

Other Publications relating to low shear

OTC-20029-MS
OTC-28660-MS
SPE OGF - SAVVY SEPARATOR SERIE, PART 5
WWW.LOWSHEARSCHOOL.COM

Thank you for your attention

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