Experience with disc stack centrifuges in the North Sea

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Content

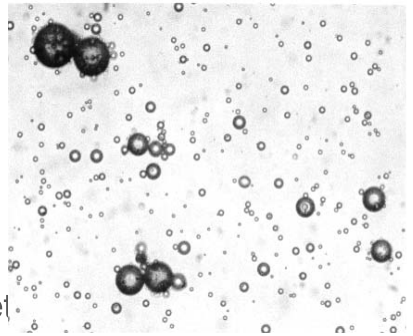
- Water characterization
- Water in oil measurement
- Disc stack Centrifuges
- Use in the North Sea （Dutch sector）
- Final observation

Water in oil removal

- Before installation of any oil in water removal equipment:
  - Critical to characterize the stream to be cleaned
  - Fully understand the requirements
    - Legislation
    - Oil in water measurement
    - Treatment for the reservoir
    - Protection of down stream equipment

Characterisation of water

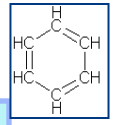
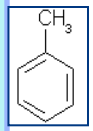
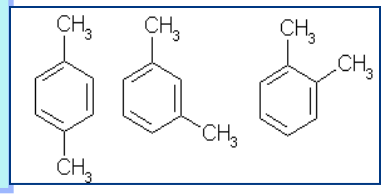
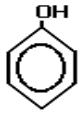
- Dissolved ions: cat- and an-ions
- Dissolved gases: oxygen, carbon dioxide, hydrogen sulphide
- Suspended solids: scales, sand, corrosion products, mud, wax, biomass
- Microbiological content: Sulphate Reducing Bacteria
- Dispersed hydrocarbons: critical factor is droplet size distribution
- Dissolved hydrocarbons: BTEX, PAH
- "Dissolved hydrocarbon": droplets <0,45 micron
- Other components: organic acids (naphtenic / carboxylic), met heavy metals
- *Oily-coated Solids ('Schmoo")*



Typical Oil Contents in Produced Water

- From Oil Production
  - dispersed to 10,000 mg/l
  - dissolved typically < 50 mg/l
- From Gas/condensate Production
  - dispersed to 1,000 mg/l
  - dissolved typically 500 mg/l

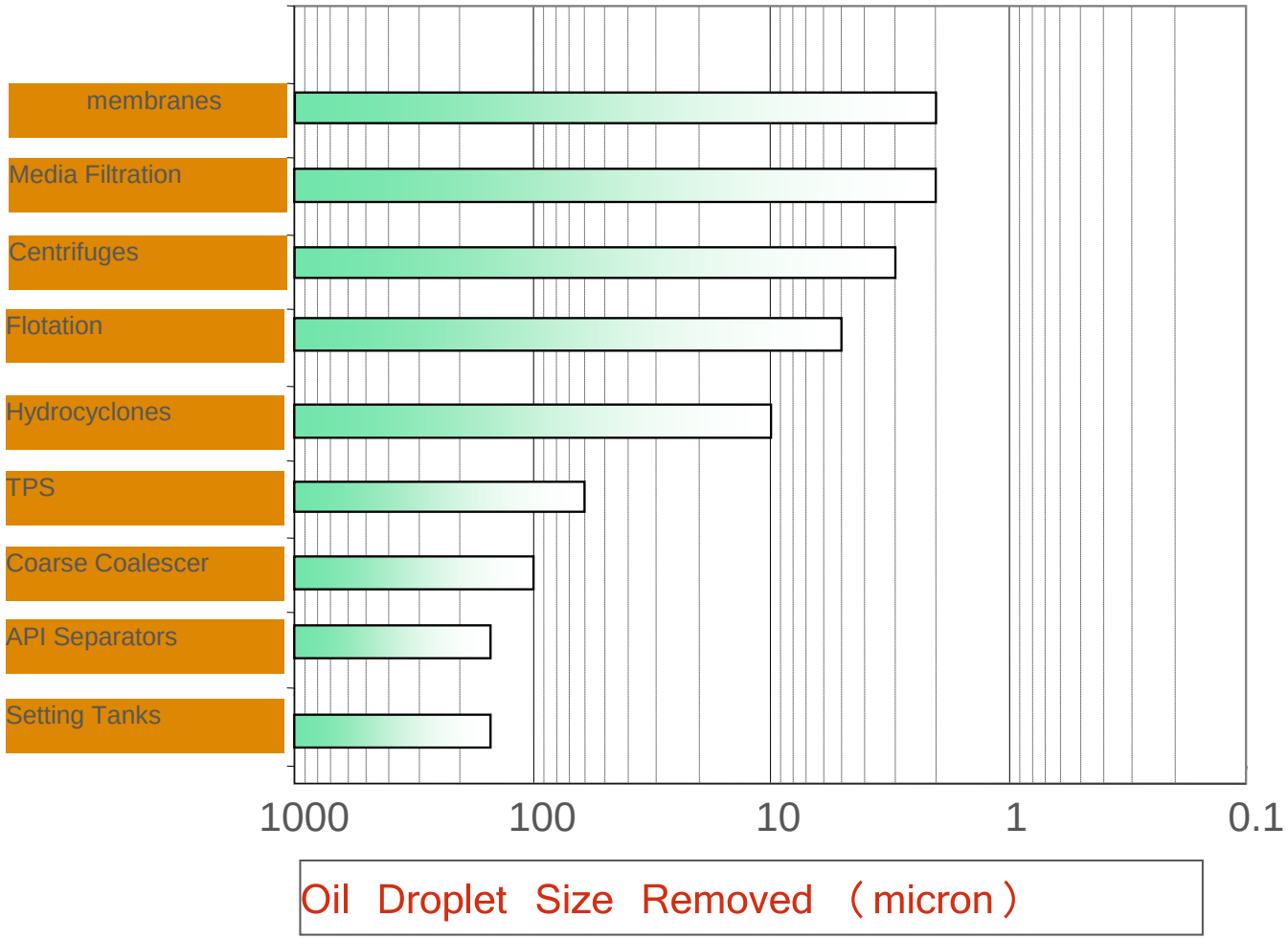
Benzene	0.3 - 440
Toluene	4 - 145
Xylene	0.8 - 84
Phenolics	0 - 200

Oil-in-water discharge criteria (2002)

Country	Legal limit	Analytical Method for OIW analysis
UK	30 mg/l	IR Spectrophotometer
The Netherlands	30 mg/l	NEN 6675 mod. IR Spectrophotometer
Norway	30 mg/l	NS 4753 IR Spectrophotometer, GC-FID method ISO 9377-2
USA	29 mg/l	EPA 413.1 Gravimetric
Gabon	20 mg/l	ASTM D3921-85, API RP: 45/3.17 UV/Visible Spectroscopy
Nigeria	20 mg/l	UV/Visible Spectroscopy
Brunei	30 mg/l	P047 - Horiba single wave length IR method
Malaysia	100 mg/l	APHA 5520-B Gravimetric
Sultanate of Oman	5 mg/l (coastal)	PECOP 2.017 UV/Visible Spectroscopy
Australia	30 mg/l with a max of 50mg/l	Horiba single wave length IR method

Proven Technology Typical Performance （Based on Oil Droplet Size Removed）



Principle of Gravity Separation: Stokes Law

- Very small oil droplets in bulk water behave like rigid spheres

- Terminal Settling Velocity:

$$V_{Oil} = \frac{g\, d_p^2\, (\rho_w - \rho_o)}{18\, \mu_w}$$

Typical time time	Diam. (mm)	Settling
Gravel	10	0.1 s
Coarse sand	1	10 s
Fine sand	0.1	2-3 min
Oil Droplet	0.1	15 min
Oil Droplet	0.01	1 day
Oil Droplet	0.001 (1 μm)	100 days

Enhanced Stokes Law Equation:

- Enhanced Stokes Law Equation applicable for centrifuges

- Terminal Settling Velocity:

$$V_{Oil} = \frac{\omega^2 r \, d_p^2 \, (\rho_w - \rho_o)}{18 \mu_w}$$

With $\omega = 1000/s$

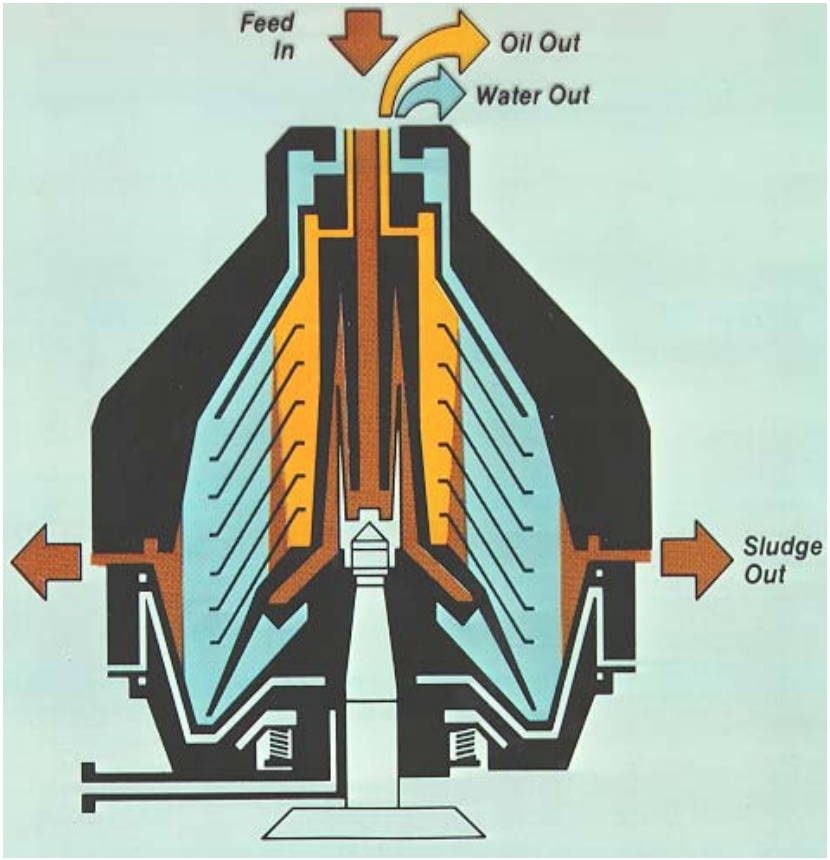
$r = 0.01$ m

=>

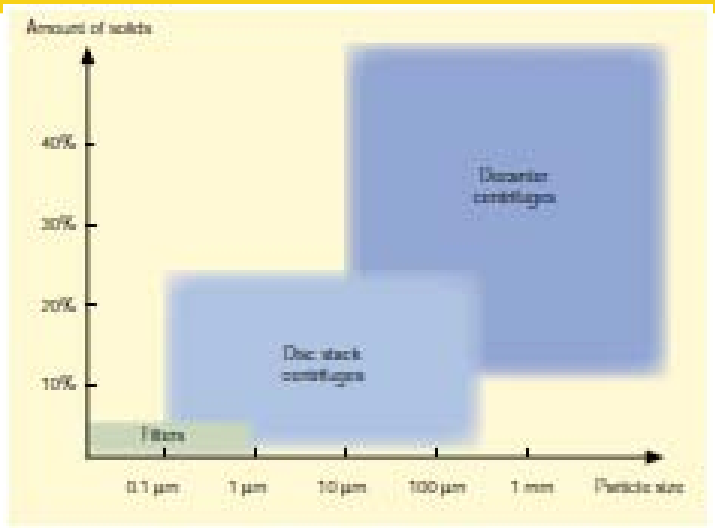
Droplet Diam. (μm)	Typical Settling time
100	1 s
10	1 min
1	1 hour

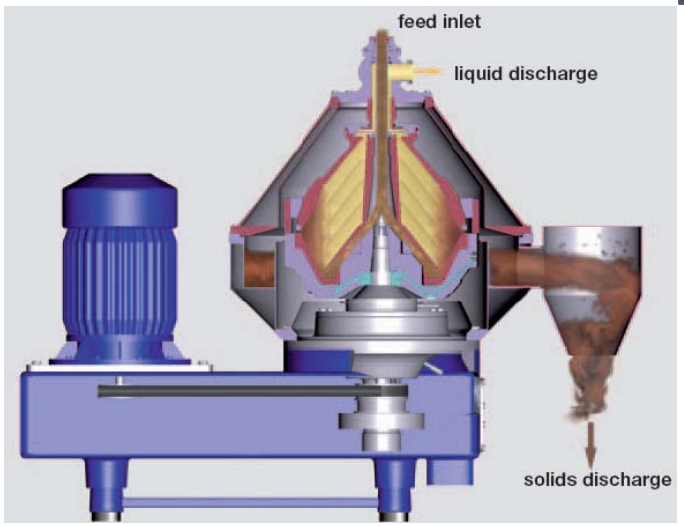
Disc stack Centrifuges

- Remove down to 2 - 5 micron droplets
- Typical capacities of 1,500 to 5,000 BWPD
- Cost approx 10x hydrocyclones
- Can tolerate surges
- Batch removal of solids
- Applied in gas fields



More back ground information





throughput	134.4 L/min
density difference	1.05
liquids viscosity	0.89 cP
sedimentation area	35 m^2
disk diameter	0.33 m
height	0.16 m
speed	5 500 rpm
G	10 400
motor power	6 hp
number of disks	120

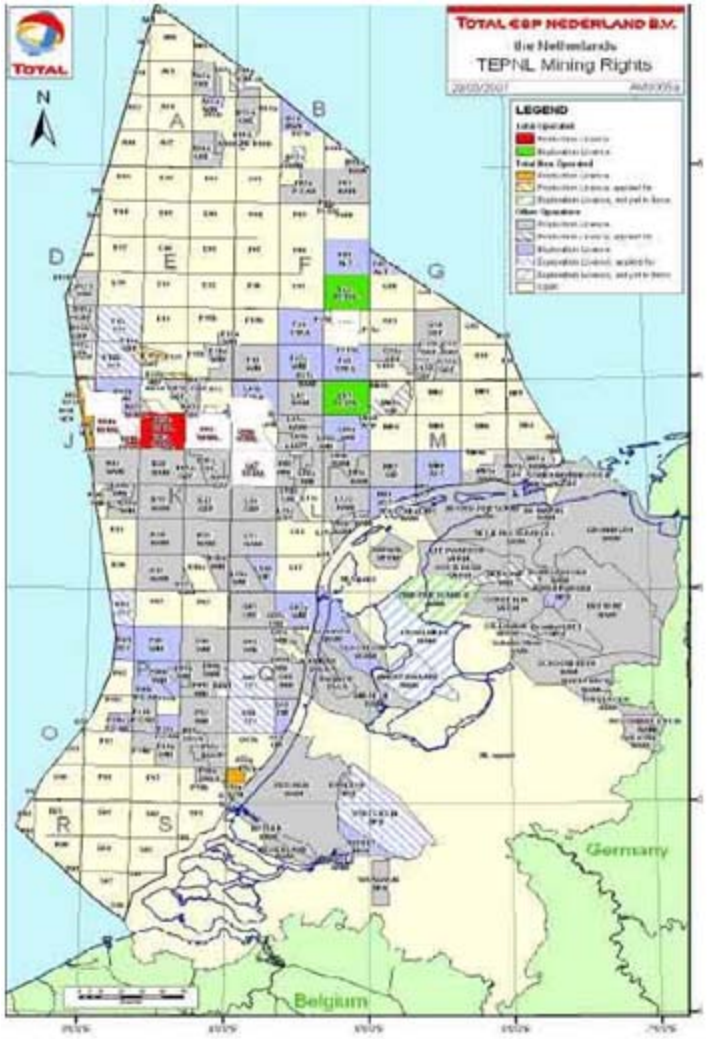
The deepwater US experience with disc stack centrifuges （1）

- High separation efficiency （~ 95 %） over a wide range of drop size and oil concentration.
- Large units （4,000 to 5,000 BWPD） break down very quickly
  - sticky solids building up on the discs and cause the disc stack to spin out of balance.
  - At high speed vibrate violently and destroy themselves in any one of several modes （bearing fault, shaft failure, seal failure, etc）.
  - Availability vendors offshore.

The deepwater US experience with disc stack centrifuges （2）

- Small units （500 to 700 BWPD） work much more reliably
  - still require significant cleaning, maintenance,
  - learning curve for the operators since they are not typical oilfield hardware.
  - Most useful in temporary service such as cold startup （methanol and low dose hydrate inhibitors）, well flow back, periodic cleaning of Wet Oil tank inventory, etc.

Offshore blocks Dutch sector North Sea



NAM offshore platforms （status 2002）

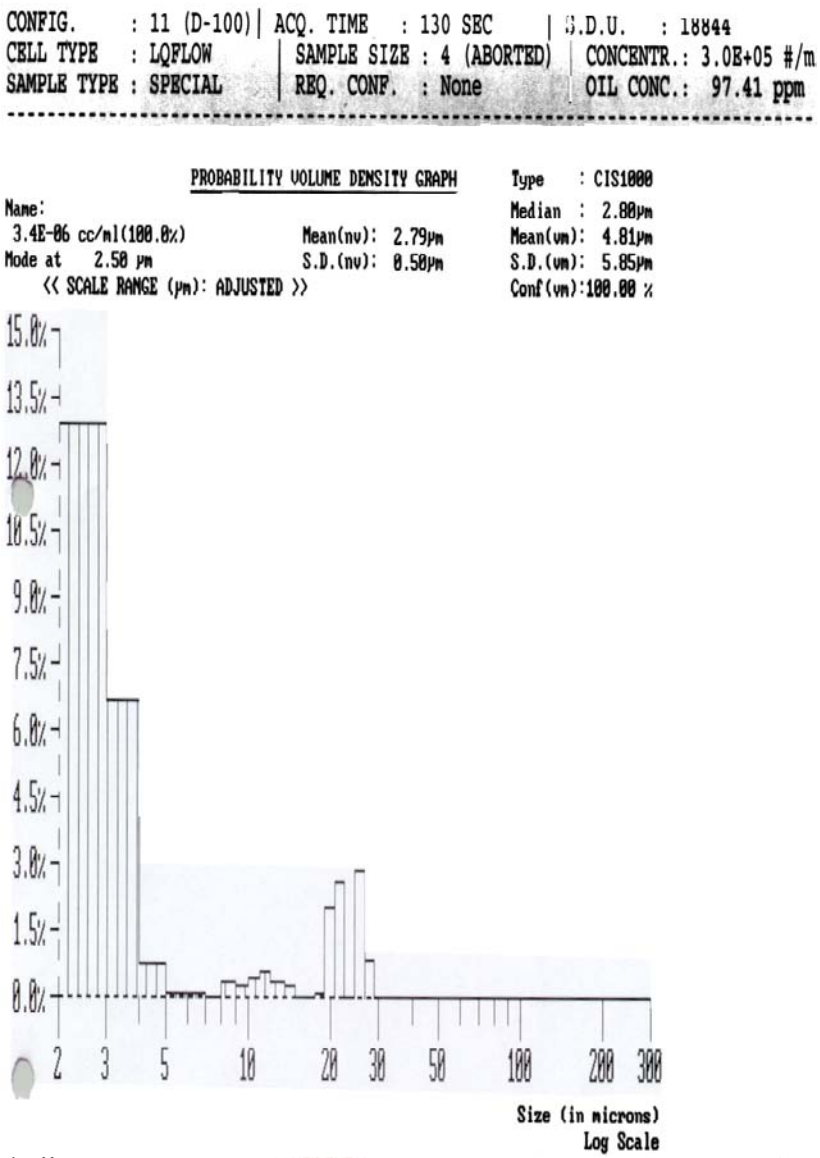
- Gas production via 13 platforms and 14 satellites
- Gas dried to water dew-point specification
- Condensate cleaned and fed back to gas

⇒ gas and condensate piped to onshore gas treatment plant

- Water （condensed/formation） discharged to sea; legal limit 40 mg/l dispersed HC and measured with infra red

Old Generation Platforms

- Water and condensate separation after depressurisation
- Addition of corrosion inhibitor results in low interfacial tension
- ☹ formation of finely dispersed droplets



Discharged water quality

- As a result of the high pressure separation and presence of corrosion inhibitor:
  - Oil in water between 100 and 200 mg/l (1990)
- Extensive selection programme between 1990 and 1996. Eventually centrifuges installed at 6 locations.
- Long (and painful) learning curve:
  - Type of material of the discs: corrosion/erosion
  - Solids removal effectiveness
  - Scale deposition at the discs
  - Operating is more an art then science

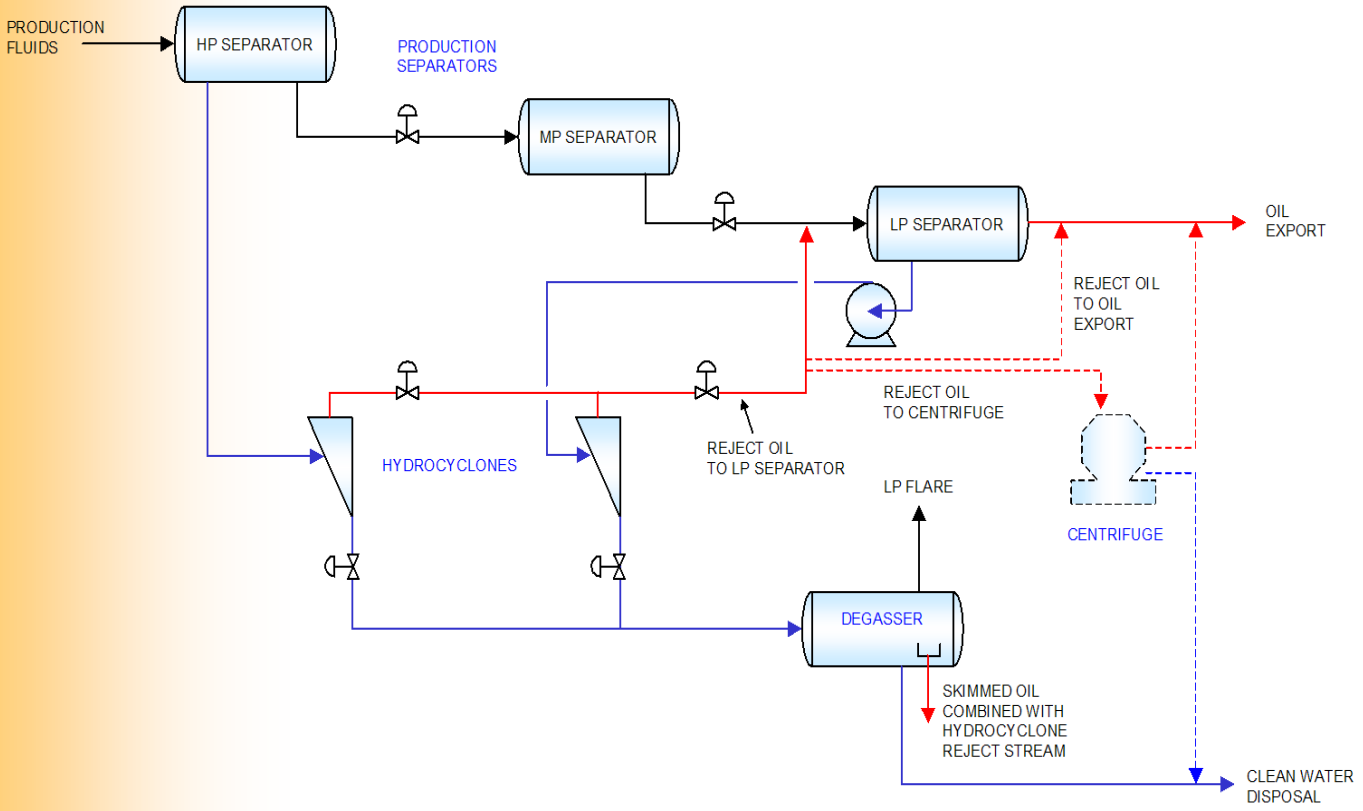
Flow diagram

Process Guidelines
Water Treatment

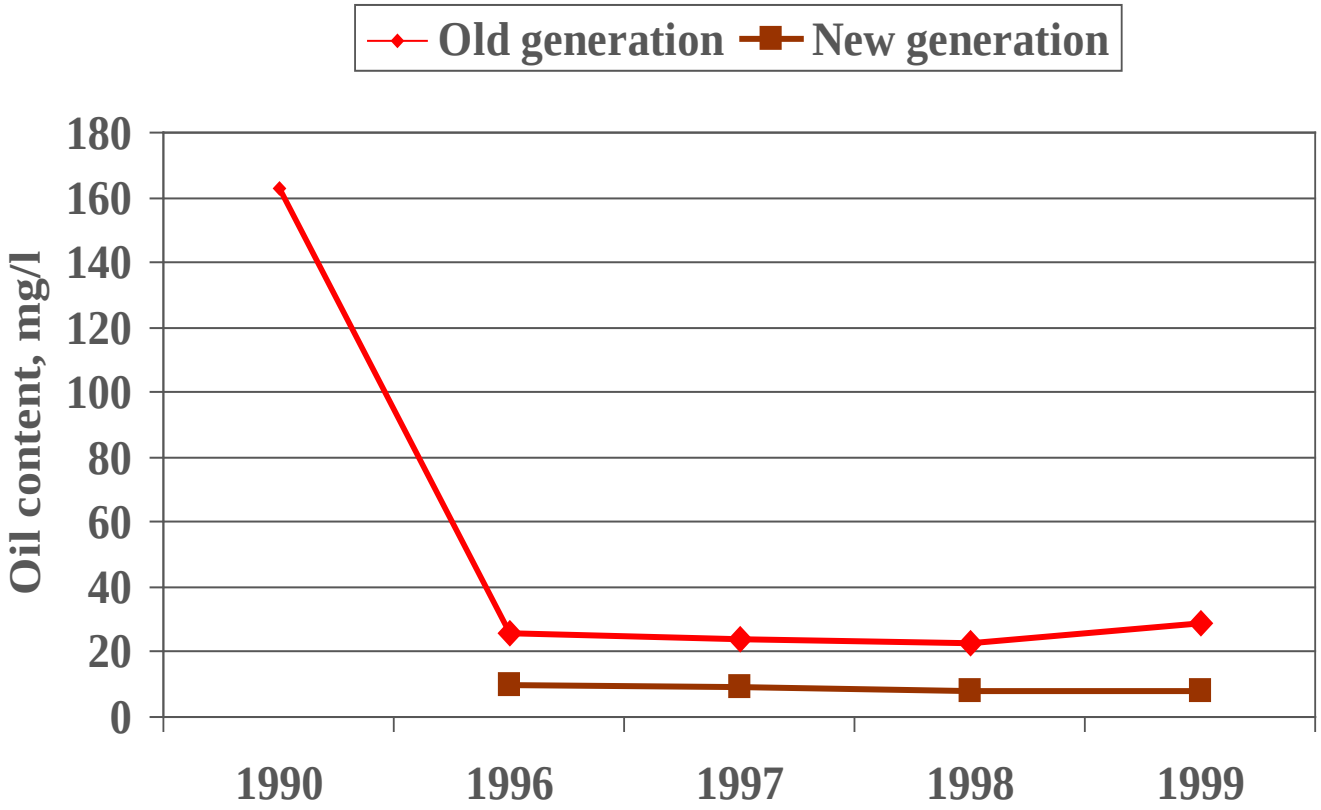
PROCESS SCHEMATIC
DISPERSED HYDROCARBON REMOVAL

GENESIS

BASIC OFFSHORE SCHEME FOR OIL PRODUCTION FACILITIES



Water quality on old generation platforms



New generation platforms

- Design new platforms:

  good water quality without end-of-pipe solutions

1. Corrosion resistant material for wells and facilities

   ⇒no requirement to inject corrosion inhibitor

2. Water condensate separation at high pressure

   ⇒no formation of small droplets

Additional costs for:

- HP separator *and* using SS (duplex) BUT fully compensated for:
  - No centrifuge, no down hole injection, less maintenance, higher availability

Final observations when using disc stack centrifuges

- Running equipment
  - More operational attention required
- Handling, cleaning and waste aspect
  - Radio activity development on disc stack
  - What to do with the removed solids?
- Disc stack material
  - Good results with Incoloy, Inconel
- Noise may be an issue

Concluding remarks

- Water characterization is critical when selecting suitable water treatment equipment.
- Take water treatment into account at the design phase. Limit end of the pipe solutions.
- Disc stack centrifuges do perform BUT
  - Operator intensive.
  - Proper selection of material to be used （disc stacks）.
  - Costs.
  - Most likely as niche application only.
- No major difference between experience GoM and North Sea