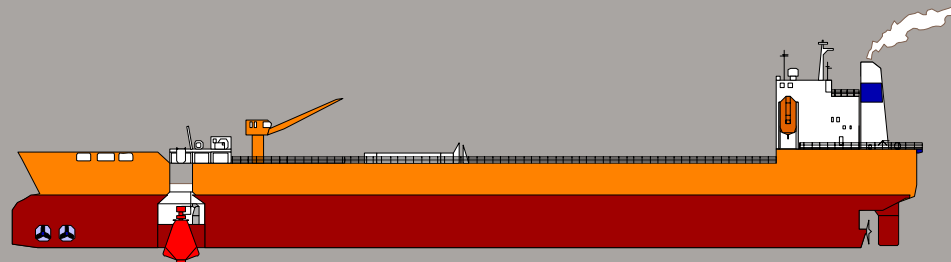




PRODUCED WATER CHALLENGES IN MATURE ASSETS



Facts of the Oil Industry

- ✓ Mature Assets are on the increase
- ✓ Significant number of offshore facilities were built in 80's in the North Sea, meant to last 20 years
- ✓ Significant number of facilities in the GoM were built using old technologies
- ✓ Water production rate in mature assets exceeds 80 – 90 % of the fluid handled

Facts of the Oil Industry

- ✓ Mature Assets, recent OSPAR counts
 - ✓ 540 structure in the UK
 - ✓ 369 in Norway
 - ✓ 148 in the Netherland
 - ✓ 53 in Denmark
 - ✓ 8 in Ireland
- ✓ 10% are floating FPSO
- ✓ Another 30% are sub-sea structure
- ✓ More than 50% are older than 20 years old (conservative count)

More Facts

- ✓ To maximise oil recovery, Produced Water eventually becomes the dominant produced fluid phase in most of the GoM production facilities
- ✓ New recovery methods means more water and in many cases additional challenges

The Reality

- ✓ Deepwater GoM and Offshore Canada position today is where the North Sea was in 80's
- ✓ GoM and Offshore Canada position tomorrow is where the North Sea is today

How the produced water is handled

Globally

- ✓ There are just as many challenges in handling produced water in old assets onshore

May not have the same environmental challenges

The Approach

- ✓ Many mature facilities still produce from the original field with limited investment to upgrade
- ✓ In many cases the optimum solution is to reconfigure the existing process facilities

The Alternative

- ✓ A number of old assets have been utilized for new tie back field development, available investment for upgrade but introduce challenges with fluid compatibility and space limitations

Prolong the Field of life

- ✓ Many mature assets extended the life of field for further 10 – 20 years with new field development
- ✓ Require major revamp of old facilities but still limited in space in case of offshore platforms

Typical Old Facilities / Offshore

- ✓ Basic different stages in oil separation
- ✓ At best Under-designed Water handling facilities based on flotation technology
- ✓ The challenges

Typical Old Facilities / Onshore

- ✓ Basic different stages of oil separation in some cases oil tanks
- ✓ Significant redundancy in the oil processing capacity that can be used for handling produced water
- ✓ At best flotation units and settling produced water tanks
- ✓ The challenges

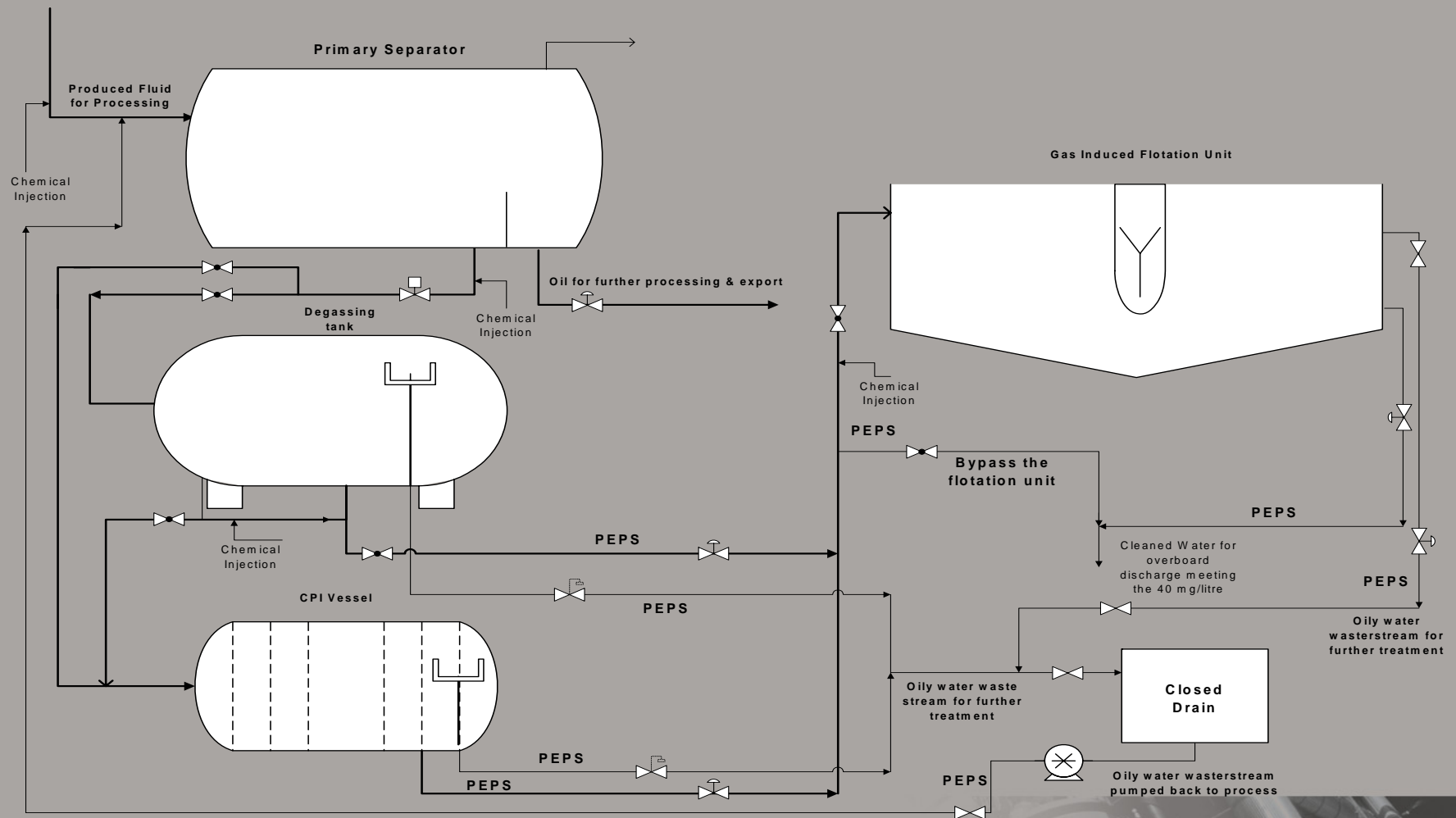
System Performance / Offshore

- ✓ Oil in water out of the Separators
 - ✓ In some cases as high as 1000 ppm and mostly less than 500 ppm
- ✓ Oil in water out of the PW treatment plant
 - ✓ Typically less than 30 ppm but in number of cases consistency in achieving 30 ppm is challenging

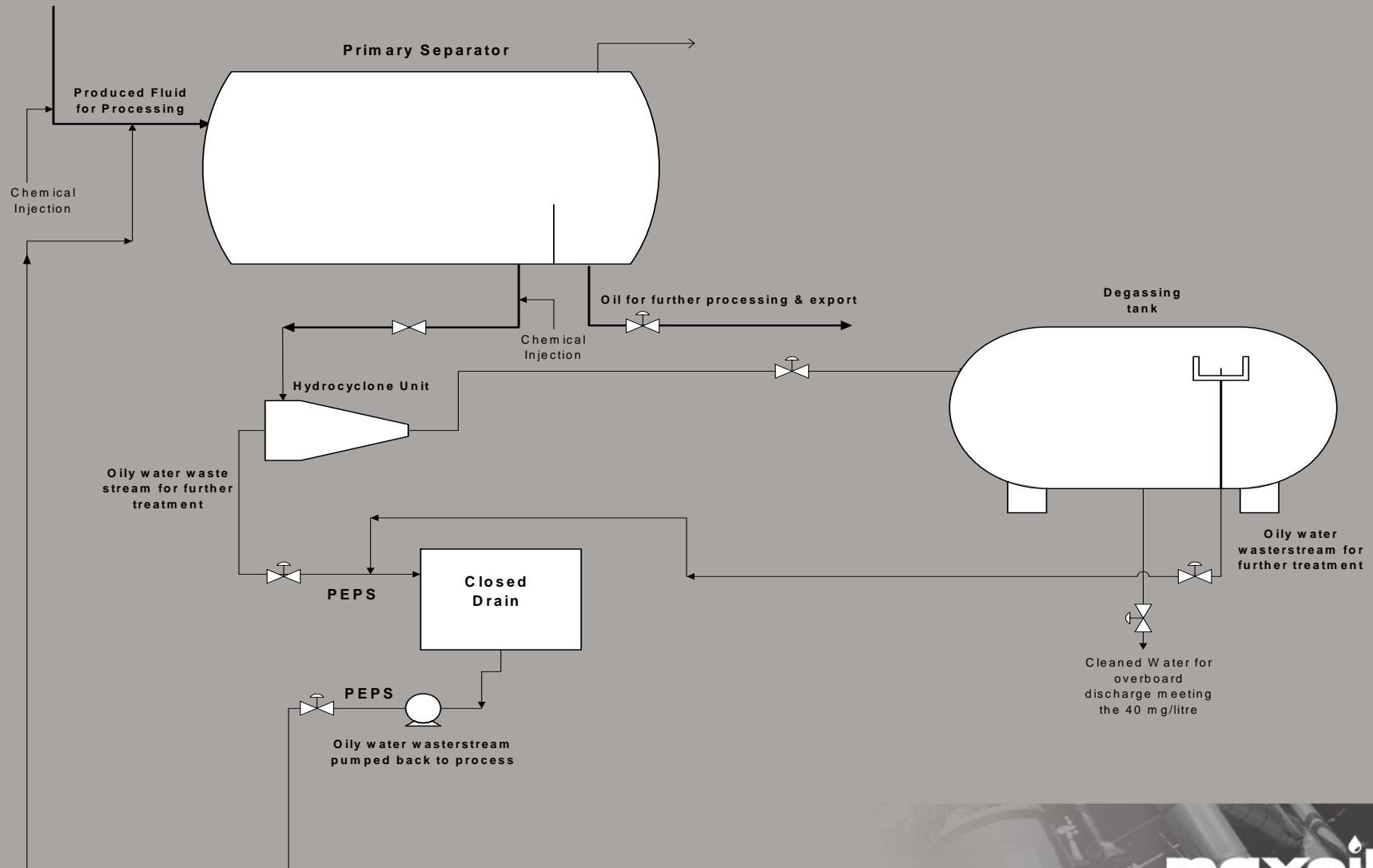
System Performance / Onshore

- ✓ Oil in water out of the Separators
 - ✓ Most mature fields can achieve less 100 ppm oil in water but plants experienced surges with oil in water as high as 1%
- ✓ Oil in water out of the PW treatment plant
 - ✓ Typically less than 100 ppm and higher with surges

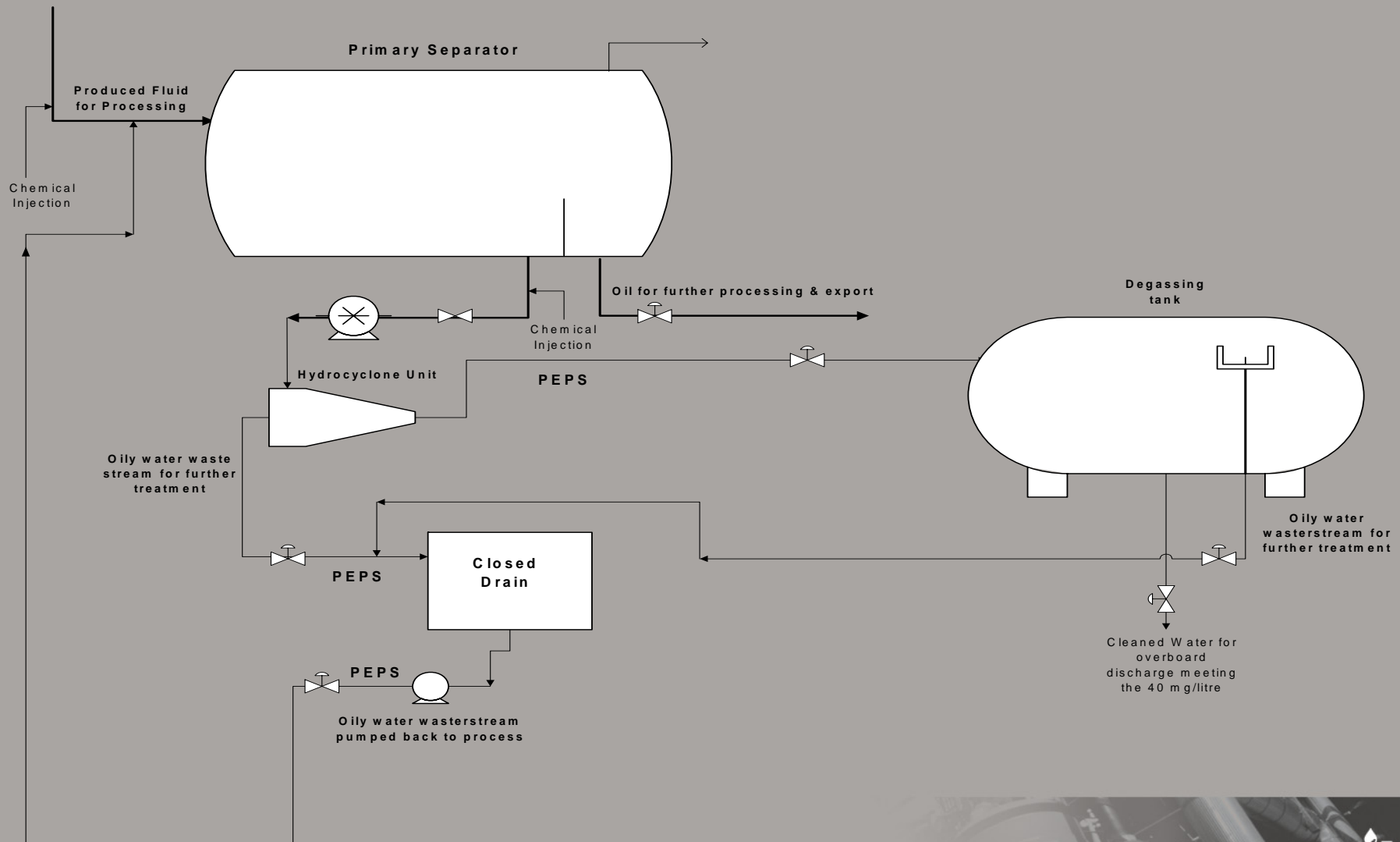
Typically PW handling facilities old offshore Asset



PW handling Offshore Hydrocyclones in HP System



PW handling Offshore Hydrocyclones in MP/LP System



Sources of Produced Water

- ✓ Formation water
- ✓ Produced Water (mixture)
- ✓ Drilling and Completion Brines
- ✓ Solid content and sand production
- ✓ Non reservoir based fluid

Produced Water Handling Issues

- ✓ High oil in water loading factor
- ✓ Solid accumulation
- ✓ Sand, iron Sulfide, scale, bacteria
- ✓ Fine oil droplet size
- ✓ Operation conditions changes
- ✓ Handling of different waste streams
- ✓ Different fluid chemistry issues
- ✓ Compatibility issues

Produced Water Handling Issues

- ✓ Process Control Issues
- ✓ Level instrumentations
- ✓ Valve
- ✓ Slugging
- ✓ Pump Capacity

System Upgrades / Offshore

- ✓ Use existing pump capacity to re-inject the water
 - ✓ It has its challenges in terms of solid handling, compatibility and reservoir souring
- ✓ Limitation in using hydrocyclone technology due to low pressure and high investment
- ✓ For minimum investment more towards polishing units with certain degree of success
- ✓ Equipment can handle the solid issues
- ✓ Dealing with different production chemicals

System Upgrades / Offshore

- ✓ Higher Investment approach
- ✓ Reconfigure the process train and use the redundancy available
- ✓ Upgrade the separators design

System Upgrades / Onshore

- ✓ Re-injection is not the optimum option in many onshore locations
- ✓ The minimum is converting the open pits to lined units
- ✓ Treat the water with additional filtration and flotation units
- ✓ For the optimum environment solution converting the water to fresh water for agriculture use

In Conclusion

- ✓ Compact produced water units of different technologies will be the optimum solution for replacing old produced water facilities offshore
- ✓ Certainly there isn't a simple answer to polish the water and meet the current oil in water limitation
- ✓ Solid handling problem with some of the polishing units
- ✓ For the GoM, the Sheen of the produced water will add to the challenges when water rate will go up