Industrial Wastewater Treatment

Water Arabia – 2015
Al Khobar – Saudi Arabia

Welcome
We Are Very Happy To Be Here!!!!!!!!!!!!

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Workshop Agenda

Topic	Presenter	Time
Welcome and Introductions •Introductions to Siemens Water Solutions Produced Water and KHI Treatment Water/Steam Injection Treatment	Bryan Kumfer Bryan Kumfer Venki Ramkrishnan	8:30 AM – 8:45 AM 8:45 AM – 9:30 AM 9:30 AM – 10:15 AM
Break		10:15 AM – 10:30 AM
Shale Gas Water Treatment Refinery, Gas Plant and Ethylene Wastewater Treatment •Oil/Water Separation	Bryan Kumfer Joseph Sebastian	10:15 AM – 10:45 AM 10:45 AM – 11:30 AM
Lunch and Prayers		11:30 AM – 1:00 PM
• Biological Treatment • Wastewater Recycle/Reuse	Joseph Sebastian Joseph Sebastian	1:00 PM – 1:45 PM 1:45 PM – 2:30 PM
Break		2:30 PM – 2:45 PM
Innovations in Wastewater Treatment Spent Caustic Treatment	Bryan Kumfer Bryan Kumfer	2:45 PM – 3:30 PM 3:30 PM – 4:00 PM

Water Treatment is Critical to Industry Around the World

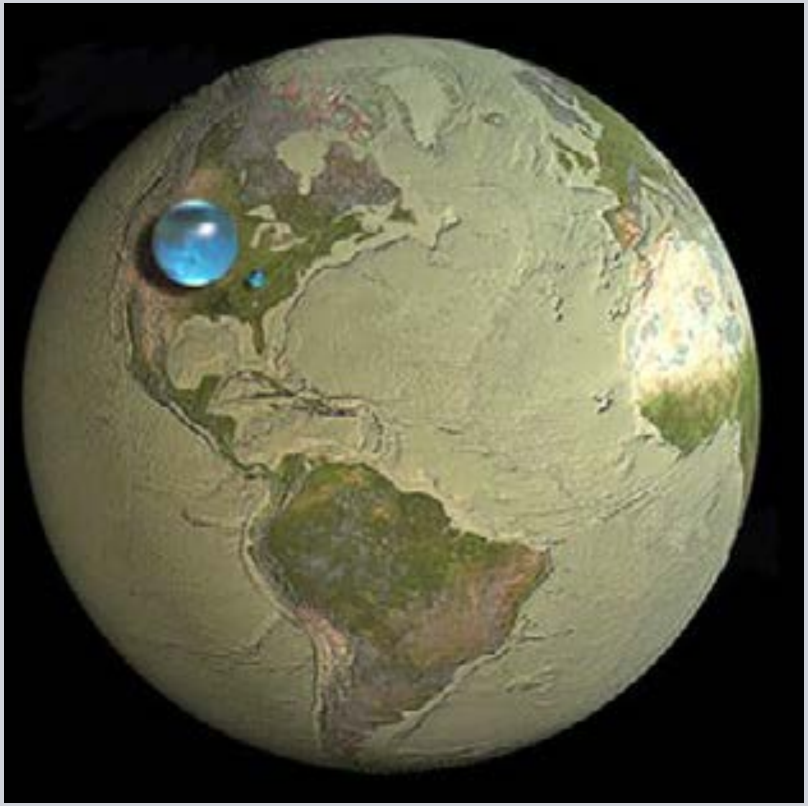
Did you know…………..

- It takes 1 to 2 bbl of water to produce one bbl of oil in some mature oil fields
- In some mature oil fields the water cut is 95%, or in other words, the field produces 20 times as much water as oil
- A petroleum refinery normally uses 1 to 2 bbls of water to process 1 bbl of oil
- A petroleum refinery normally produces 0.5 to 1.0 bbl of wastewater per barrel of crude oil processed

All of this water needs to be treated before it can be used or discharged to the environment.

So… Who is Taking Care of the World's Water?

- Earth's Diameter at the Equator: 7,926.28 miles (12,756.1 km)
- All water (sphere over western U.S., 860 miles in diameter)
- Fresh liquid water in the ground, lakes, swamps, and rivers (sphere over Kentucky, 169.5 miles in diameter)
- Fresh-water lakes and rivers (sphere over Georgia, 34.9 miles in diameter).



Services and Products
Capabilities in Industrial Wastewater Treatment

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- Process driven company: Understand the uses of water, generation of wastewater and environmental requirements.
- Product oriented solutions: Experience with 100’s of water treatment technologies. There is no single technology that fits all applications.
- Service oriented solutions: Process Engineering services; Operations and maintenance services; Temporary treatment services

Siemens Provides Innovative Industrial Wastewater Treatment Solutions to Customers Worldwide

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Siemens Water Solutions has supplied equipment to more than 1,500 water treatment installations in the petroleum industry, dating back to the 1930s.

We provided the seawater filtration systems for a largest seawater flood in the world, located in the Middle East.

We provided the complete water treatment system for the first large commercial SAGD (Steam Assisted Gravity Drainage) project in Alberta, Canada.

Siemens Developed and Introduced Innovations in Industrial Wastewater Treatment

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- Developed the API Separator in the 1930's and the DAF Separator in the 1950's
- Developed the Zimpro Wet Air Oxidation process for treating spent caustic from Petroleum Refineries and Ethylene Plants in the 1960's
- Developed many of the biological treatment processes used in the industry today, including the PACT process, EcoRight MBR, jet aeration, Orbal and RBC technologies
- Pioneered the process water outsourcing and service business in the 1970's for industry, including petroleum refineries and Oil & Gas production sites

The Petroleum / Petrochemical Industry Leader in Technology and Application Experience

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Technologies Developments for the Refining and Petrochemical Industry

- Introduced Tow-Bro Clarifier - 1928
- Introduced API Separator - 1937
- Introduced Wet Air Oxidation - 1950
- Introduced DAF Separator - 1953
- Introduced RBC/SBC - 1969
- Introduced PACT System - 1972
- Introduced Jet Aeration - 1981
- Introduced GAC Fluid Bed – 1987
- Petro MBR - 2005
- EcoRight Biological Trmt - 2011
- Over 1500 Installations Worldwide

So let's get started!!!!!

Water Recycle and Reuse

Oil & Gas Industry
Water Issues

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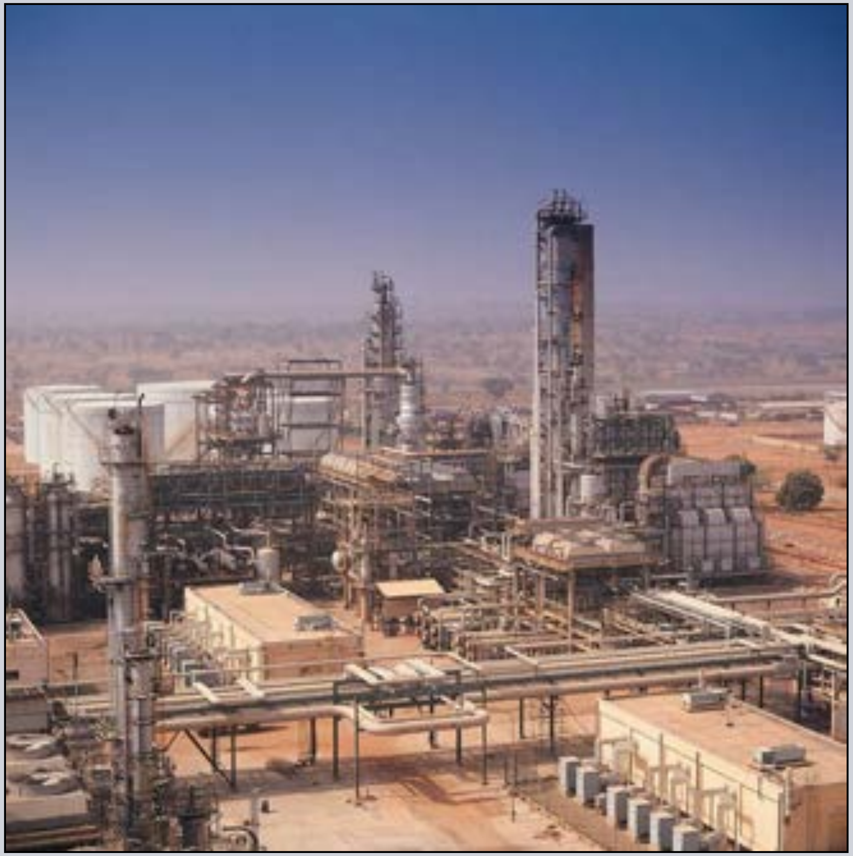
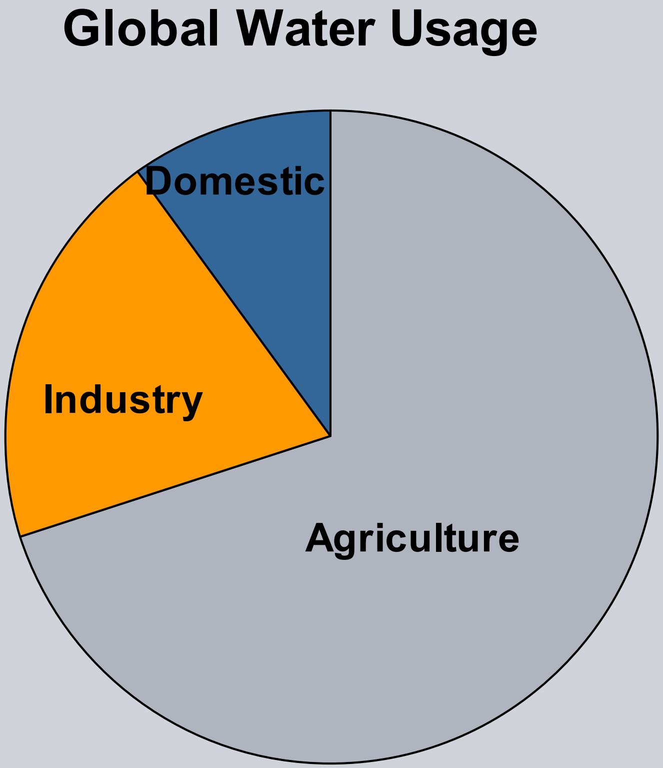
Water Availability/Costs

A Global Issue:

- Middle East
- USA
- Canada
- Latin America
- South East Asia
- China
- India
- Russia
- Australia
- Africa
- Europe

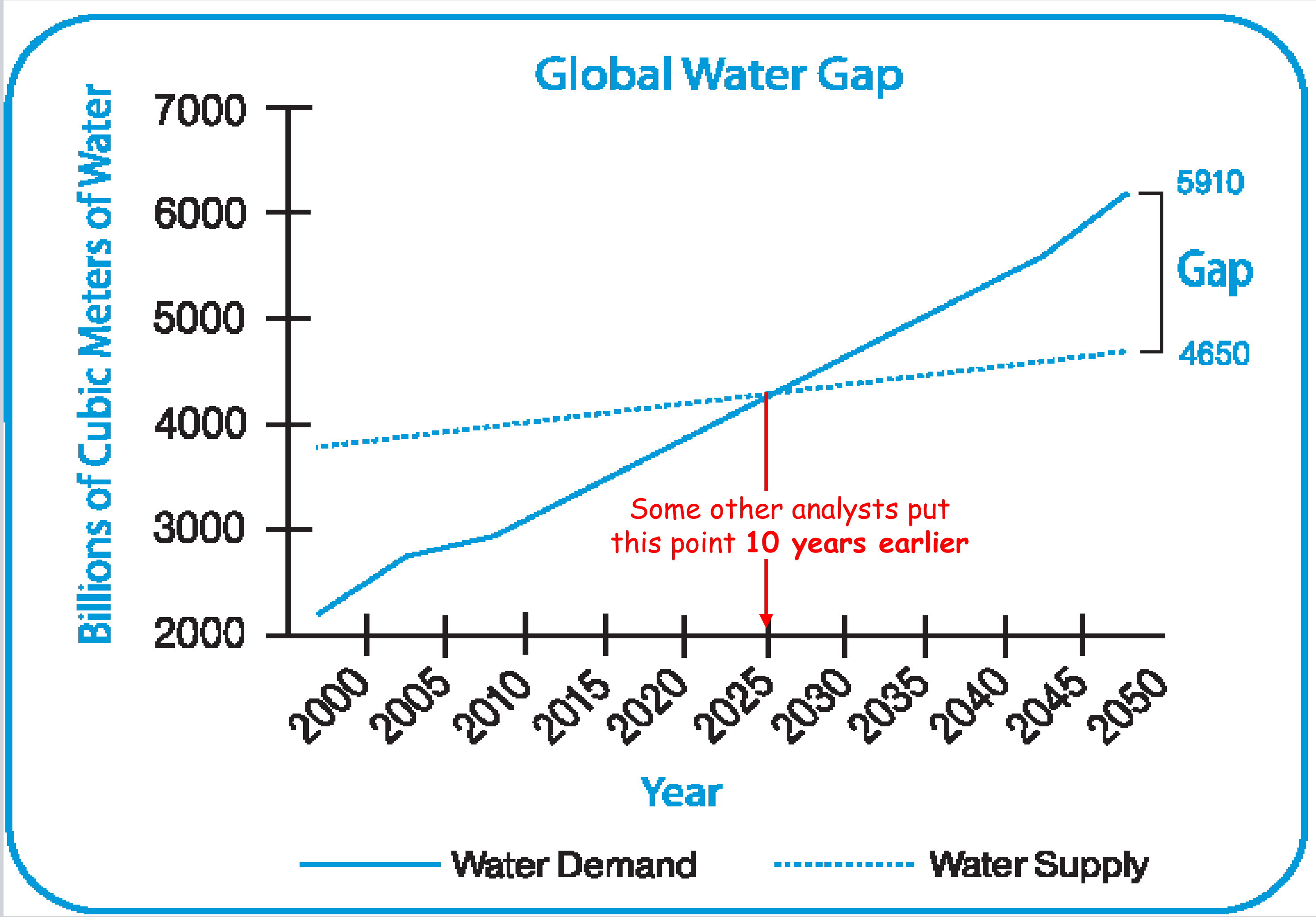


Water – A Precious Resource



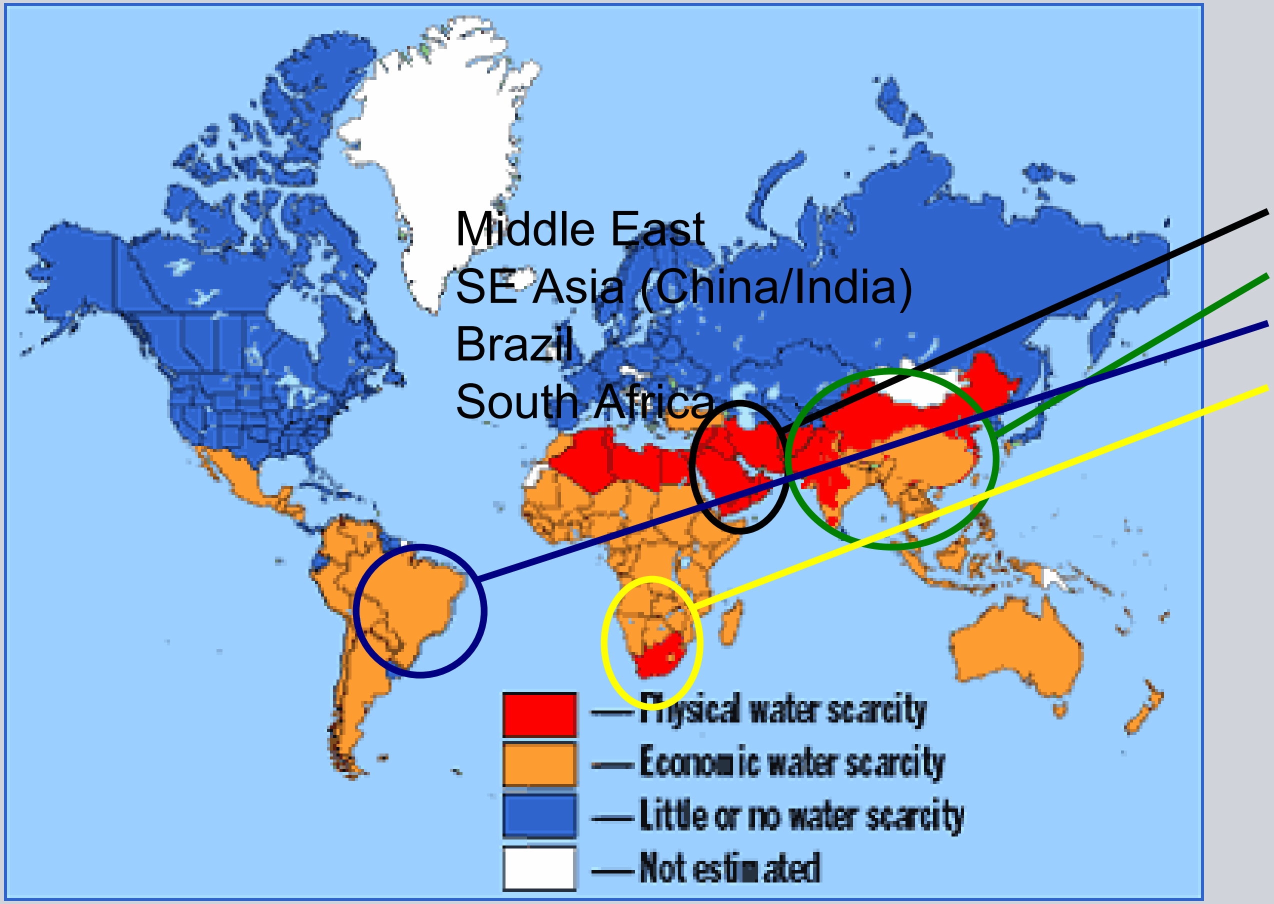
- Water Statistics
  - 97% of all water is salt water
  - <1% of world’s supply is readily accessible for human consumption

Water is a Global Crisis in the Making
By 2025, Demand for Water Will Exceed Supply



Source: Valmont Water Management Group

O&G Growth Areas



Wastewater Treatment and Water Re-use for Environmental Protection and Sustainability

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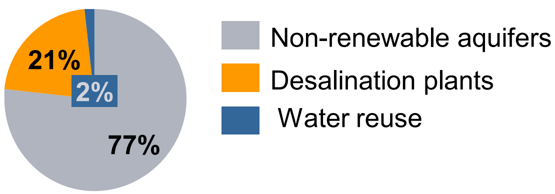
Arabian peninsula

Sustainability

- 77% of total water comes from aquifers
- 4 times more abstraction than renewable water
- 85% of water usage for agriculture



Environment:

- Arabian Gulf temperature and salinity increases
- Depletion of groundwater supplies
- Higher energy consumption and CO_2 emissions

Needed Stewardship

- Conservation of precious resources, including surface and groundwater
- Protect human health and the environment
- Supply needed water, without depleting fresh water sources

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Defining Key Technologies for Recycle/Reuse

What are the objectives of treatment?

To “re-conform” the chemical composition and physical properties of the wastewater to meet/exceed the needs of the facility process water process(s).

The processes may include:

- Removing particulates

  Clarification & filtration; increasingly, MF & UF membranes

- Removing/adjusting organic and inorganic dissolved constituents

  <u>Organic</u> – biological degradation (anaerobic/aerobic), increased use of MBRs or UF polishing

  <u>Inorganic</u> – Reverse Osmosis, Microfiltration Softening, Demineralization (increasingly, Integrated Membrane Systems (UF+RO+CDI)

- Disinfection (pathogen inactivation)

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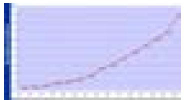
Drivers

Metric	Keys	Impact

 **Freshwater Availability**	▪ Competition for freshwater
	  ▪ Industrial
	  ▪ Population Growth
		▪ Freshwater availability → Ability to operate

 **Cost**	▪ Affordability of water treatment vs. cost of treatment	▪ Treatment cost > Freshwater cost ▪ Difficult to sell to management
 **Population Growth**	▪ Growth places demand on water supply	▪ Population will demand water first rights
 **Regulations**	▪ Discharge quality requirements tightening ▪ Zero Liquid Discharge gaining traction	▪ Discharge quality → reuse quality ▪ No operations if not achieving ZLD
 **Environmental Stewardship**	▪ Environmental incidents in the public domain ▪ Environmental concern on the rise	▪ Companies self imposing strict limitations ▪ New or expansion will need continued political support

Conventional Technology for Petroleum Refining Wastewater Treatment System

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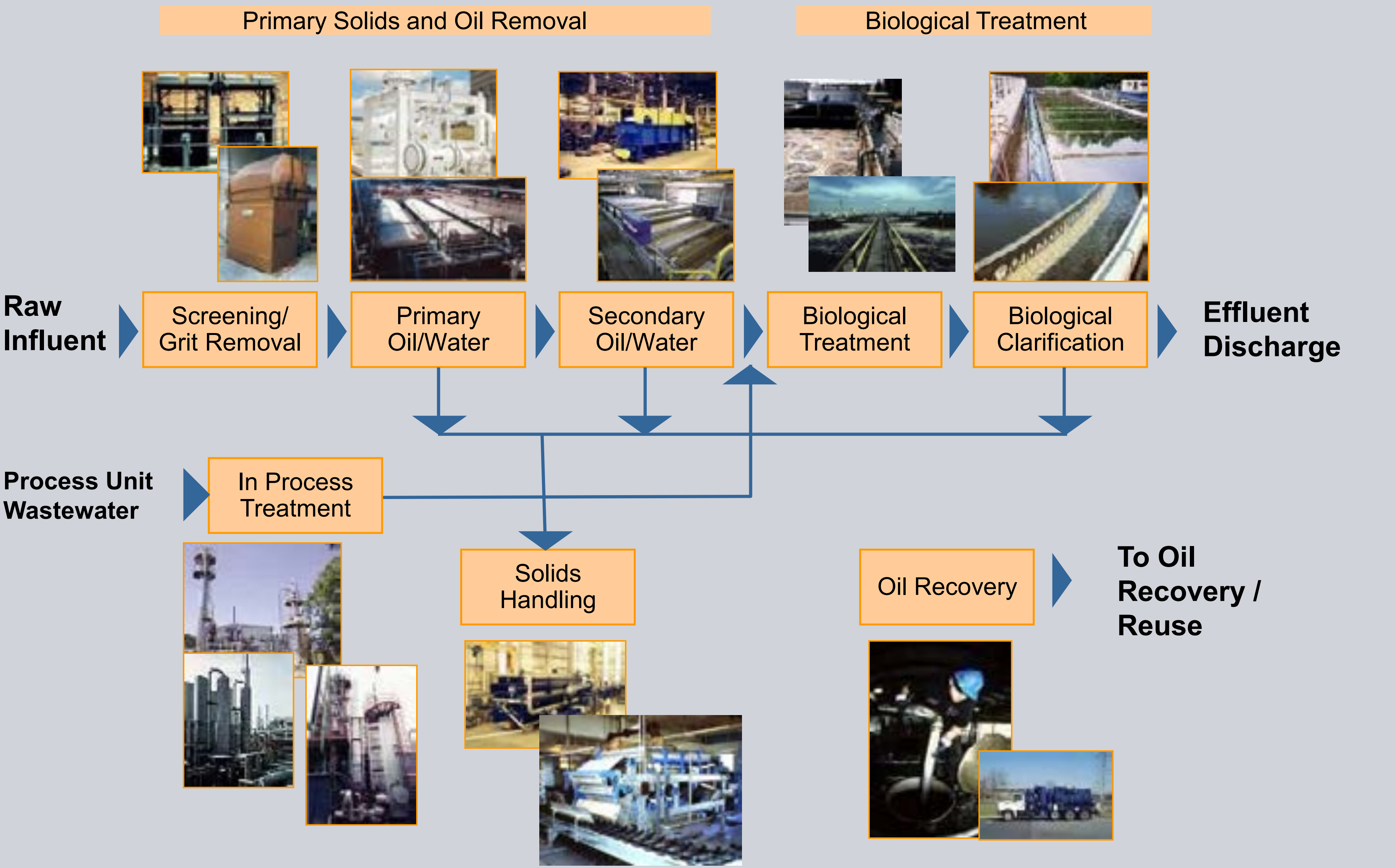
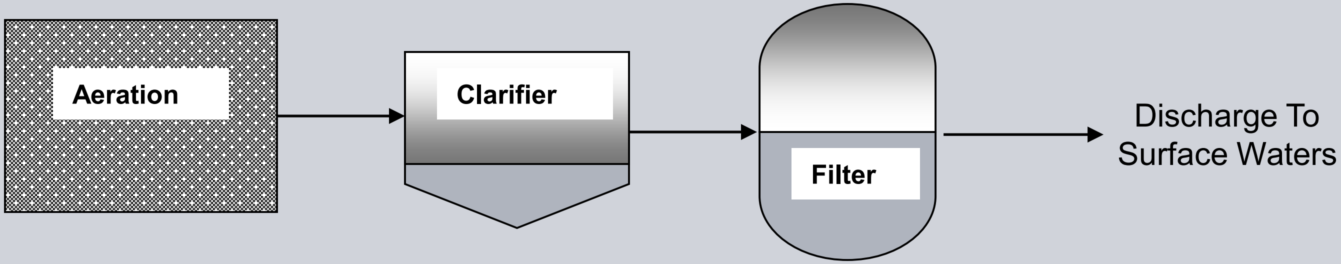
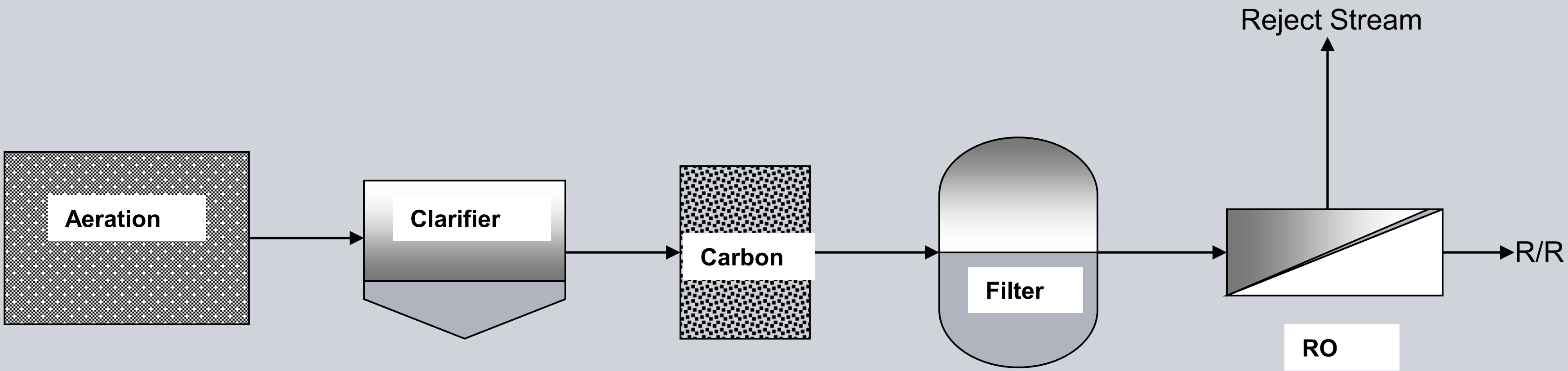


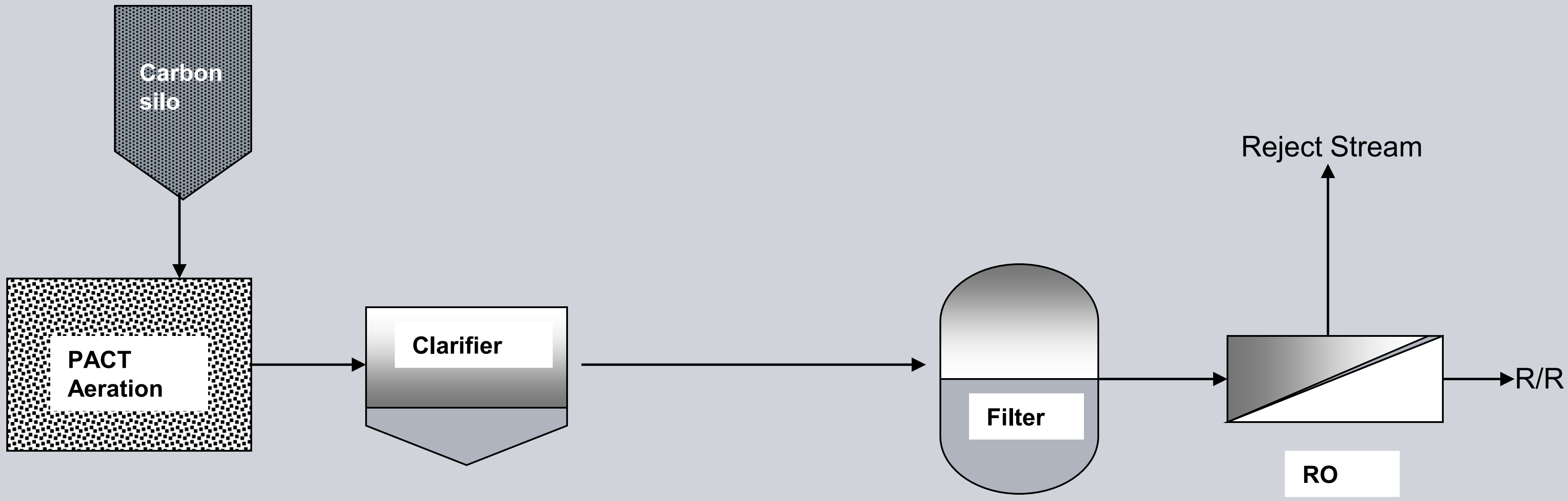
Conventional Wastewater Treatment



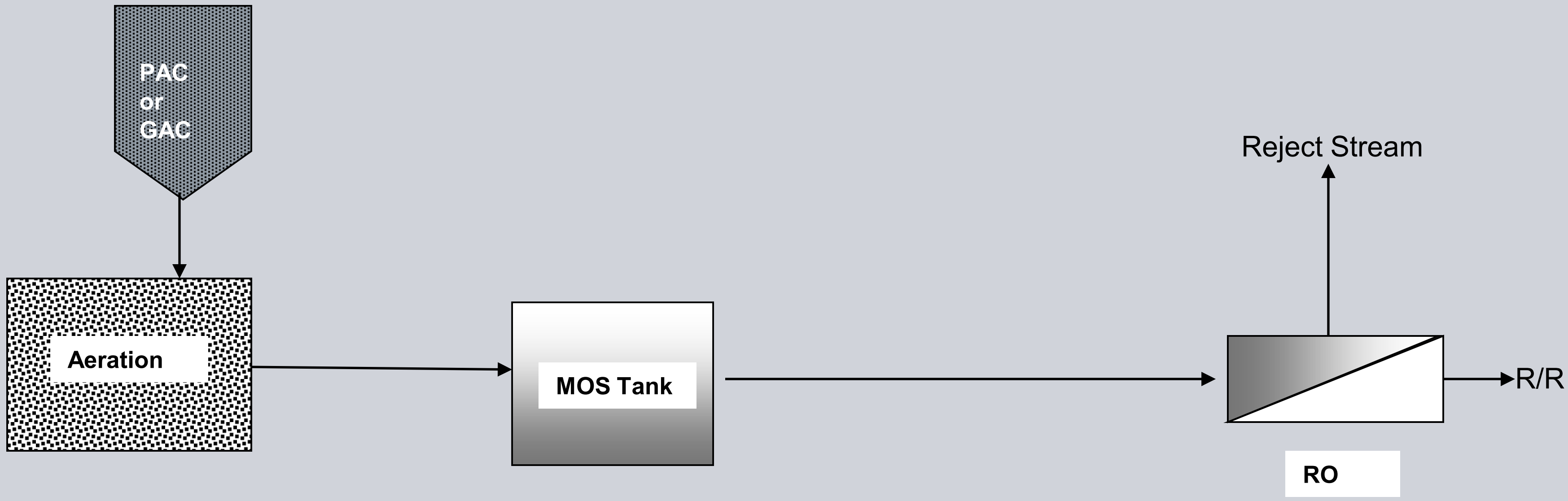
Conventional Wastewater Treatment for Recycle/Reuse



Conventional to PACT® an Alternative to GAC Polisher



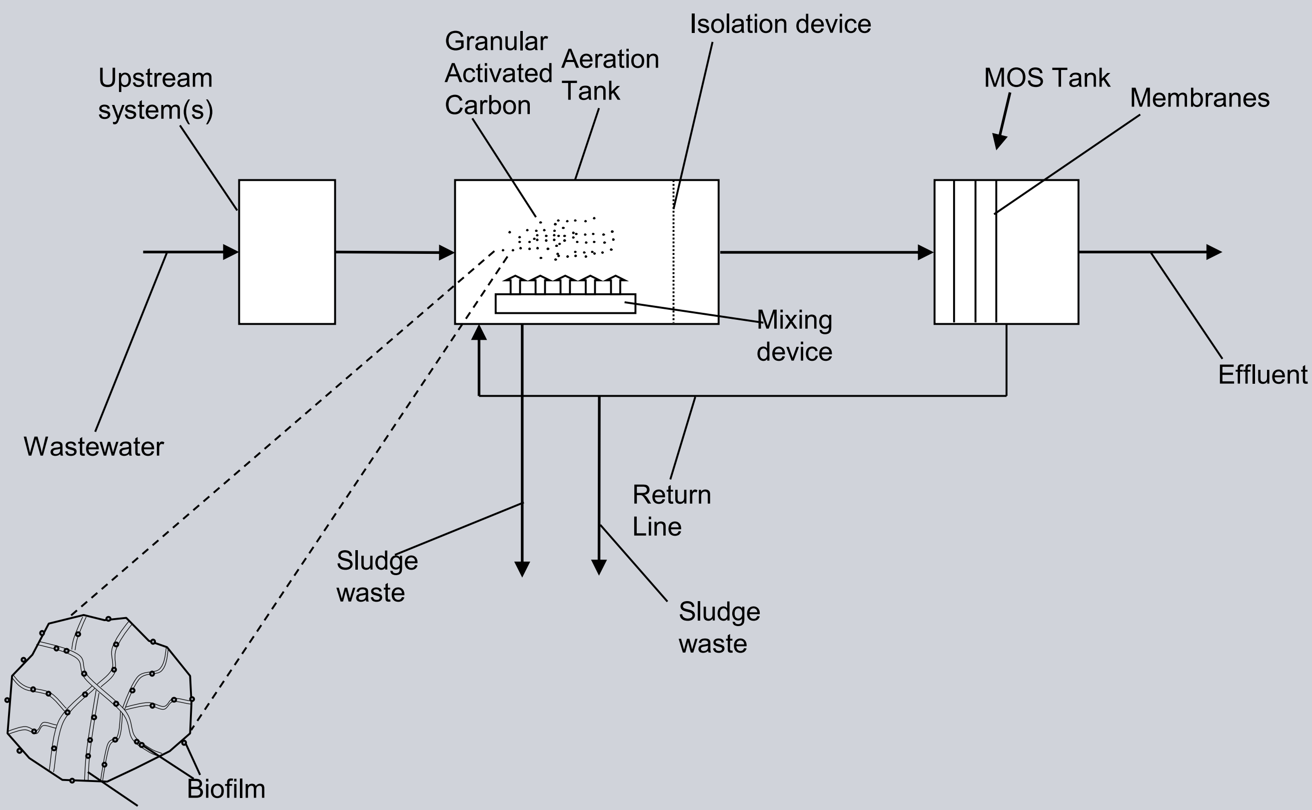
From PACT® to MBR Alternatives



Petro™ MBR Technology = Siemens O&G MBR Design
Petro™ PAC MBR = Powdered Activated Carbon in Aeration + MOS Tank
EcoRight™ MBR = Granular Activated Carbon in Aeration Tank ONLY

EcoRight™ MBR

Technology Update - How it works



Patents

- Carbon assisted MBR – 7,678,268 B2 – granted March 16, 2010 (SWT)
- GAC MBR Process – filed Oct 2008 (Aramco)
- Isolation Techniques – June 2009 (SWT/Aramco)
- Suspension Techniques – June 2009 (SWT/Aramco)
- Alternate processes – July 2009 (SWT/Aramco)

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Technology Development, continued

Product Development;

- EcoRight™ MBR is the culmination of over five years of carbon assisted MBR work between Siemens and Saudi Aramco
- The core idea is based on a issued patent authored by Bill Conner of Saudi Aramco
- The concept is based on the use of Granular Activated Carbon (GAC) with MBR to produce significant operational cost advantages relative to the use of Powdered Activated Carbon (PAC) with MBR or GAC filtration following biological treatment
- Bio-regeneration of GAC within the aeration tank and greater GAC utilization relative to GAC columns results in considerably lower operational costs

2010 - 2011 Field Pilot Study
EcoRight™ GAC MBR

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- Started December 2010 – at a Saudi Aramco Refinery
- The Eco-Right pilot unit treated refinery wastewater
- The biologically treated effuent was then filtered through ultrafiltration and RO membranes.
- Pilot unit operated for approximately 8 months
- The RO unit was operated for approximately the last 2000 hours of testing
- Testing Completed in October, 2011

Findings and Conclusions – Field Pilot Treating Refinery Wastewater

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1. The treated effluent consistently complied with the applicable PME limitations in spite of considerable oil and grease and COD load swings.

2. The presence of activated carbon in the aeration tank provided consistency in effluent treatment performance and appeared to remove some of the recalcitrant COD and the Extracellular Polymeric Substances (EPS) that typically foul UF and RO membranes.

3. There appeared to be bio-regeneration of the granular activated carbon based on iodine and MRE isotherms that showed adsorptive capacity remaining on the carbon withdrawn from the pilot unit. It was estimated that the bio-regeneration resulted in a significant reduction in granular carbon consumption compared to traditional, post-activated sludge activated carbon filtration.

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Findings and Conclusions

4. No damage to the EcoRight™ membrane fibers was observed during the membrane autopsy conducted at the end of the study, further indicating that:

   - the screen system was effective at keeping GAC in the aeration tank and preventing contact with the membrane fibers in the MOS tank; and
   - very little mechanical breakdown of the GAC occurred that could have resulted in GAC fines passing through the screen system and entering the MOS tank.
   - The ability to keep GAC segregated from the membrane fibers increases membrane life over powdered carbon MBR systems by eliminating carbon-related membrane abrasion potential.

5. The mass of GAC measured in the pilot unit at the end of the study accounted for nearly 100% of the GAC added to the system during the study, indicating that very little breakdown and attrition losses of GAC occurred.

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Thank you for your attention!

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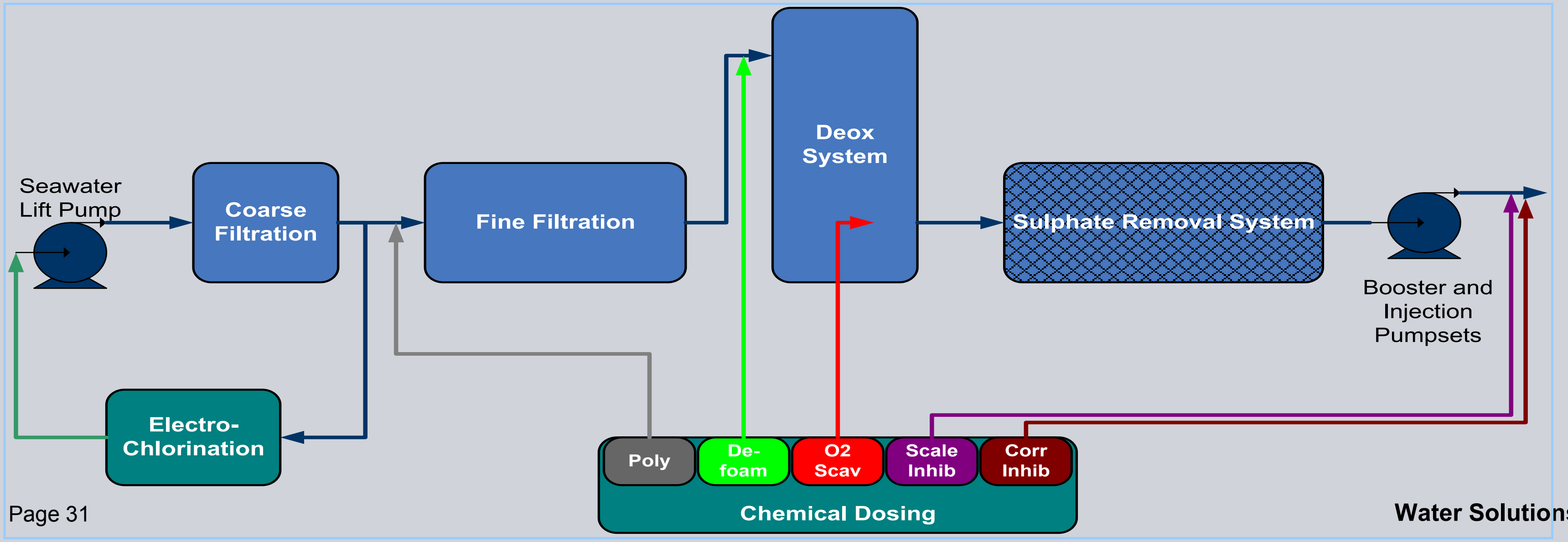
Water/Steam Injection Treatment

Water for Injection

Seawater for Injection

- Enhanced Oil and Gas Recovery (EOR)
  - Pressure Maintenance
  - Displacement
- Treated Water Quality Determined by Reservoir Characteristics and Wellbore Materials
  - Porosity – acceptable particle sizes injected
  - Prevent Downhole Corrosion
  - Prevent Reservoir Scaling Tendencies



Seawater Treating Technologies
Electrochlorinator - Bio-fouling Control

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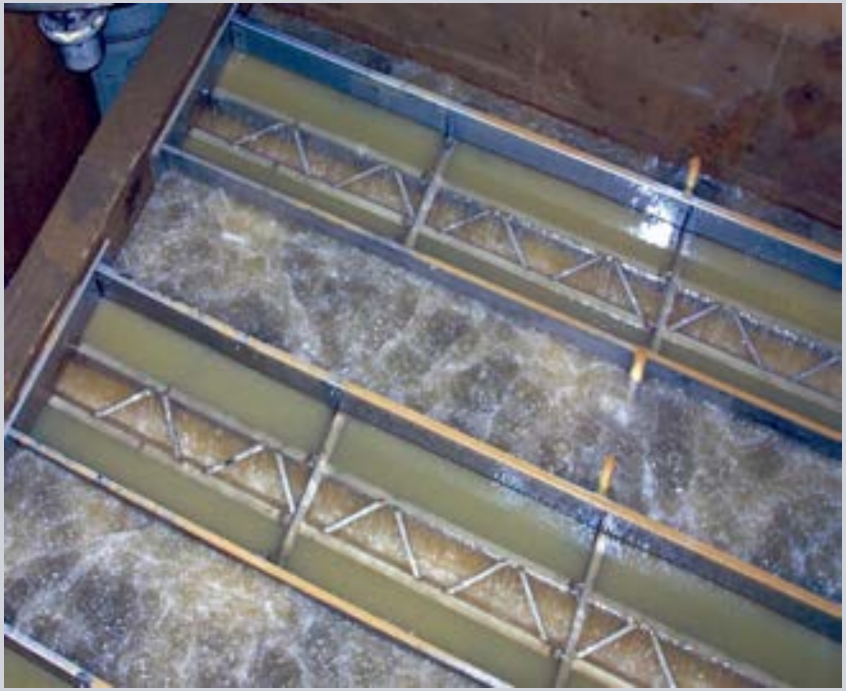
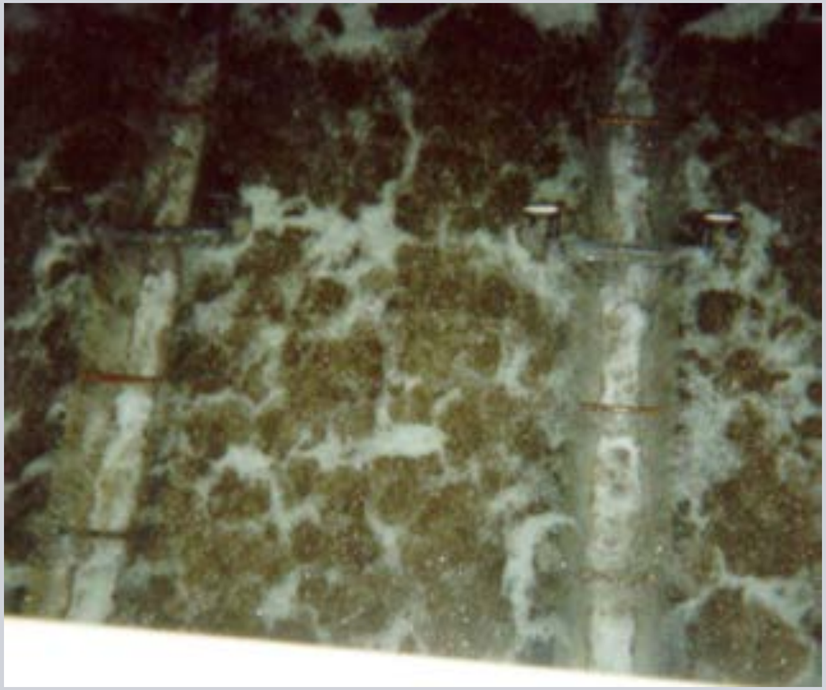
Impact of Biofouling in Systems

- Increased Corrosion
  - Volume captured beneath marine growth is isolated from seawater flow
  - Galvanic Corrosion cells established
  - Highly corrosive situation resulting in accelerated failures
- Restricted Piping
  - Greater pressure head required for pumps
  - Reduced flow
- Reduced Heat Transfer Capability
  - Lowers the efficiency of heat exchangers

Filtration Process

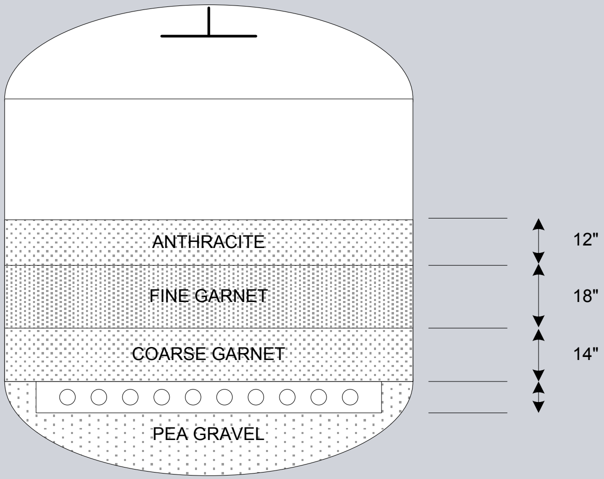




Vertical Pressure Filters

Seawater Treating Technologies
Hi-Rate Media Filters

- Hi-rate filtration of particles down to **2 micron**.
  - Dual Layers for Phased Filtration to Ensure Bed Depth is Utilized
- High Runtime Between Backwashing
  - Deep Bed Technology – high solids volume containment
- Proven Technology



Horizontal Pressure Filters

Horizontal Pressure Filtration – What is it?

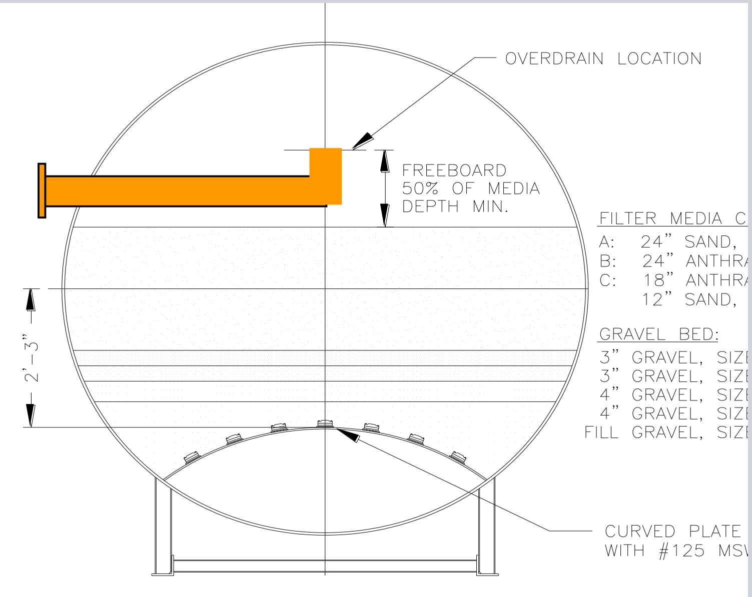
Pressure filter in a horizontal configuration

Media filtration

- Single, dual or mixed media
- ~40% less media depth than vertical pressure filters
- Supported on layered gravel bed

Interior separated at under drain

- Above is divided into 4 filter cells
- Below is common to all cells



Seawater Treating Technologies
Vacuum or Gas Strip Deaeration - Performance

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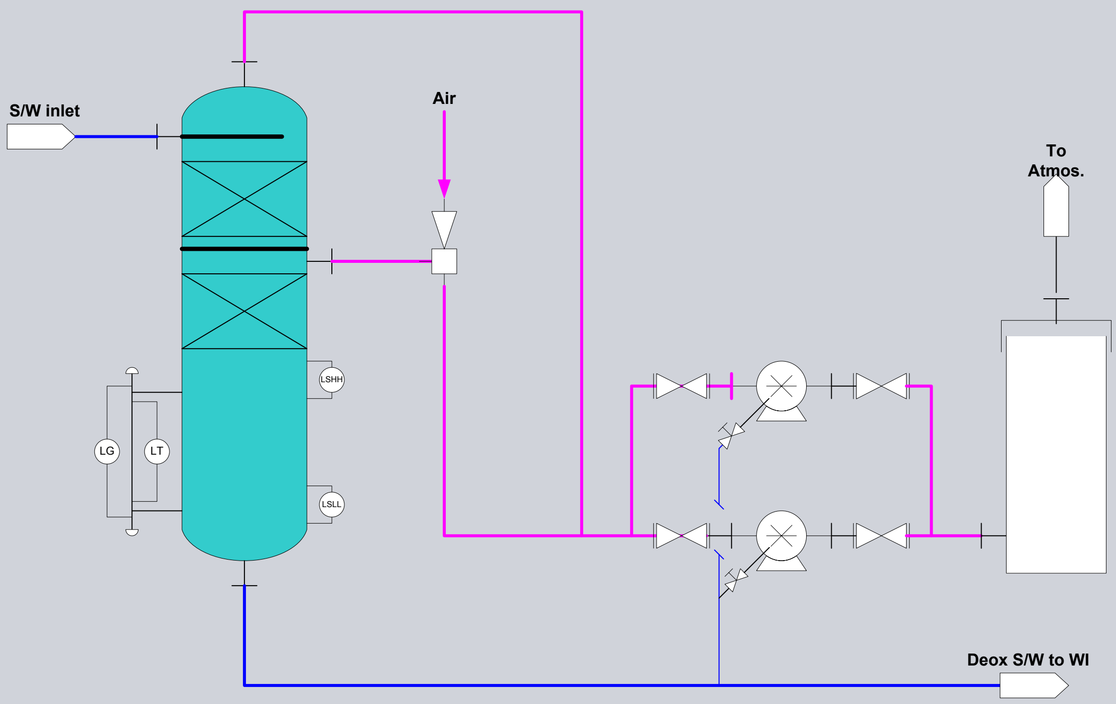
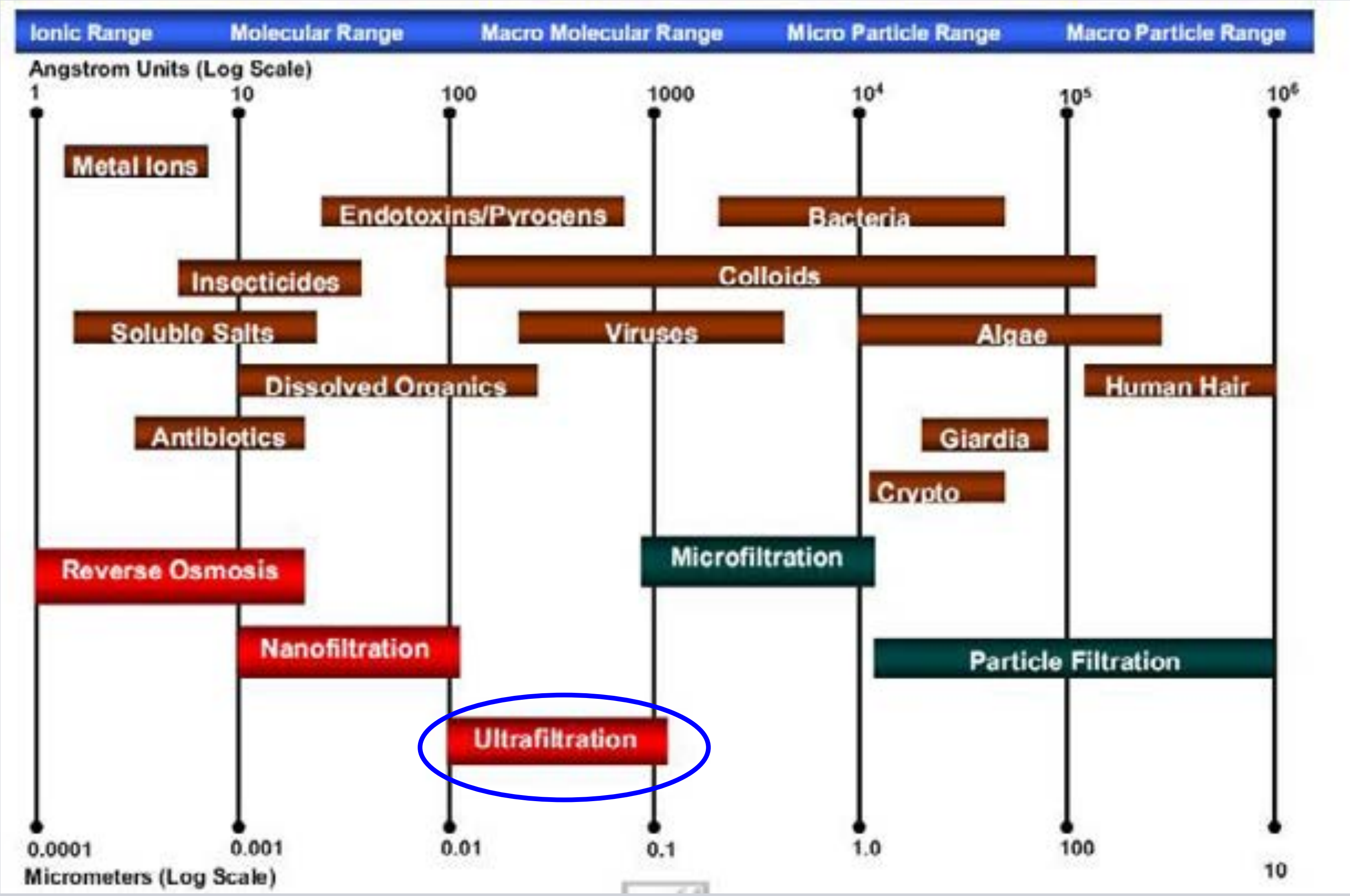
- Removal of O_2 to approximately 30 ppb by gas strip or vacuum.
- 2 Stage with advanced packing and interstage vacuum seals.
- Integral Water Storage in Tower Sump Section
  - Injection of Scavenger Chemical to Reduce Oxygen to non-measurable Levels
  - Provides NPSH for downstream Booster/Injection Pumps



Ultra Filtration System for Offshore Environment

Filtration Spectrum



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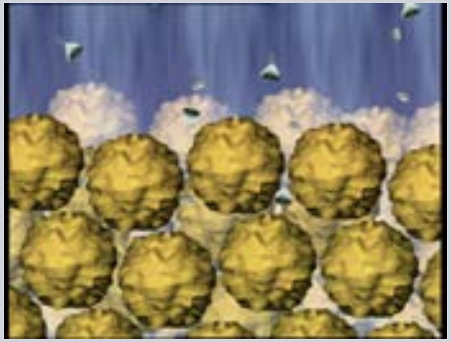
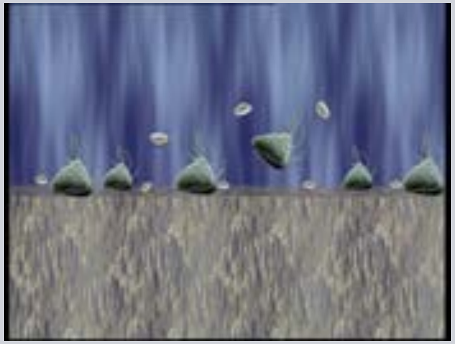
Why use Ultra filtration offshore?

- **Proven and mature** technology
- UF low turbidity filtrate regardless of feed water quality = **optimal pre-treatment** to RO and SR systems.
- Significant **reduction in cost, footprint, weight and chemical usage** compared with traditional fine filter technology.
- Automatic operation = less manual operator interference
- **Simplified and lesser maintenance** = less man/hours offshore
- Handle algae blooming periods = **uptime and reliability increase**

SAND FILTER

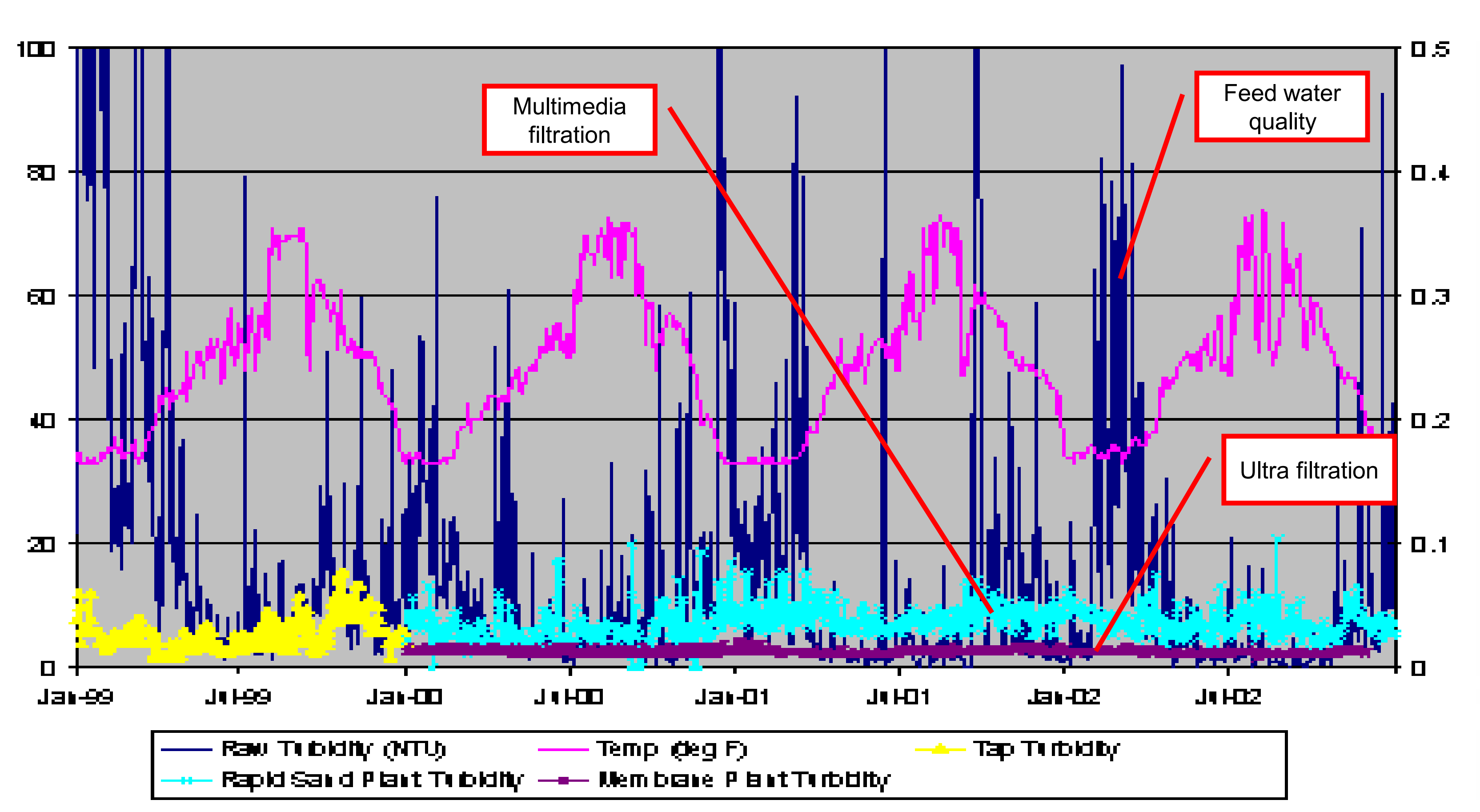


UF MEMBRANE

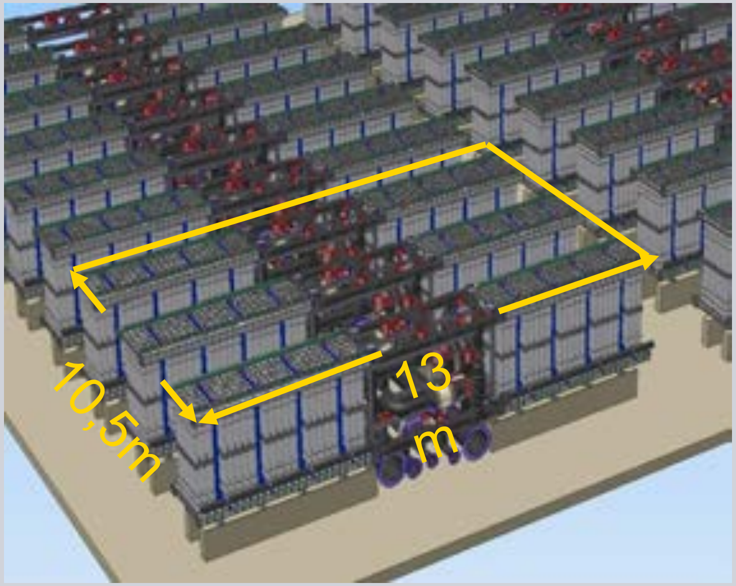


Filtration Barriers - Experience

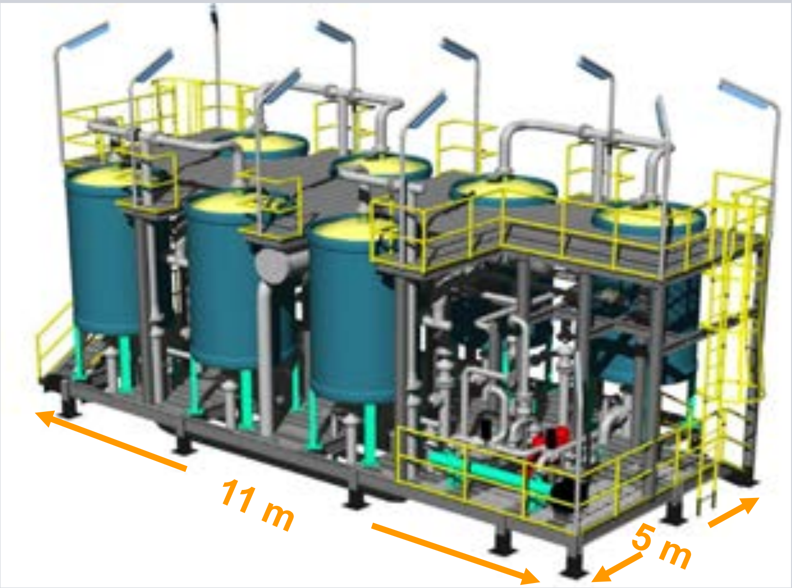
Absolute barrier (0.04 µm): Typical Turbidity Value <0.05 NTU



Ultra Filtration Solution



Optimized for offshore



ONSHORE SOLUTION

OFFSHORE SOLUTION

UF test unit SCUF19

UF System with Single Units (n+1)

Typical data:

- Skid with 7 x17% SCUF units
- Operating capacity: 1000 m³/h (150.000 bwpd)
- Max capacity: 1200 m³/h (180.000 bwpd)
- Dimensions: 10m x 5,4m x
- Dry Weight: 35 ton
- Operating weight: 65 ton

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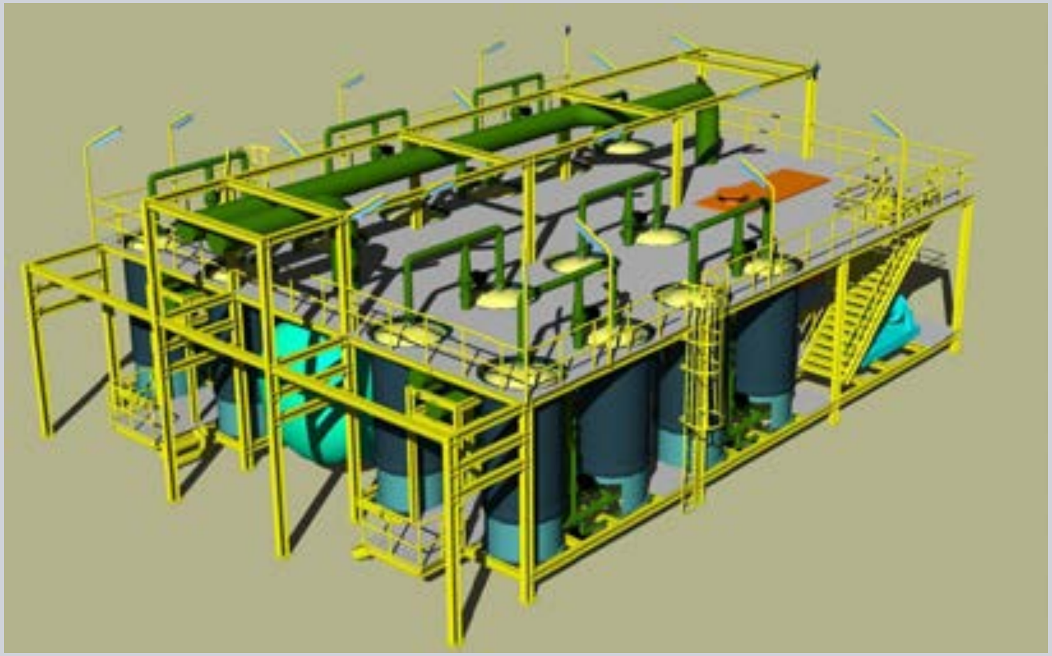
UF System with Twin Units (n+1)



Typical data:

- Skid with 10 x11% SCUF twin units
- Operating capacity: 3200 m³/h (483.200 bwpd)
- Max capacity: 3600 m³/h (543.600 bwpd)
- Dimensions: 15,7m x 10,2m
- Dry Weight: 86 ton
- Operating weight: 158 ton

Benefits of UF

Ultra filtration as pre-treatment to NF/RO membrane systems because:

- Better pre-treatment increases NF/RO membrane performance, membrane lifetime and system uptime.
- Considerable savings in footprint and weight reduces cost and gives lay-out flexibility.
- UF increases the NF/RO membrane flux (15–20 %) leading to less quantity required and more compact design.
- Simplified automated operation and large savings in operation/maintenance cost.
- Problems with sudden algae blooming periods is eliminated with UF system.

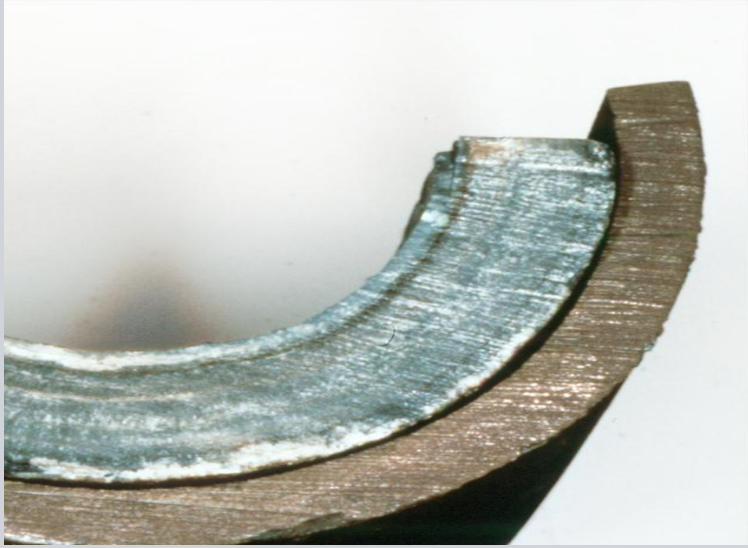
Sulfate Removal System/ Nano-filtration Membranes

Sulphate Removal
Typical Sulphate Removal Units

Sulfate Removal
Customer Challenges

Mixing injected and formation water may result in sulphate/barium scaling

- Limit formation of barium and strontium salts in injection well, piping and equipment
- Production well control
- Radioactive scaling or NORM
- Allows anti scalants to perform on full effectiveness



Example of scaling in piping

Reservoir souring

- Limit well souring at water breakthrough as NF removes all contaminants grater than 1/1000ths of a micron.
- Reduce environmental safety & health issues by less chemical injection
- Lower level of hardness (magnesium/calcium ions

Sulfate Removal
Prevent Barium Sulfate Scaling

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Sulfate from Seawater + Barium from Formation Water = Barium Sulfate Scale

Reduction or elimination of:

- Scale in oil formations
- Scale of piping, equipment and sub-sea safety valves
- “Squeeze treatments”
- Radioactive radium sulfate scale or NORM

Allows anti-scalants (if required) to perform at full effectiveness

Sulfate Removal
Prevent Hydrogen Sulfide Generation

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Sulfate + Thermophilic Sulfate Reducing Bacteria = Hydrogen Sulfide

- Eliminates need for exotic metallurgy for corrosion control
- Reduces safety and health concerns
- Reduces special processing and handling measures needed for processing sour gas and oil
- Eliminates hydrogen sulfide stress cracking
- Reduces environmental problems

Sulfate Removal
System Design Considerations

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CAPEX, OPEX, footprint and weight

- Quality and temperature of feed water
- SO4 permeate target
- Pre-treatment

Design requirements for NF membranes

- Temp. 4 - 450C (below 30C recommended)
- SDI less than 5 and NTU less than 1.
- < 5 micron absolute particle removal
- No chlorine and no oil

Deaeration design

- Upstream of SR90 membranes recommended to control bio-fouling.
- Experience has repeatedly shown that oxygenated SW will lead to severe bio-fouling within 6 months.

Operation design

- No sparing/redundancy is feasible
- Flow/pressure variations is not possible
- Turndown is decided by no’s of trains

Sulfate Removal
Effect of Temperature

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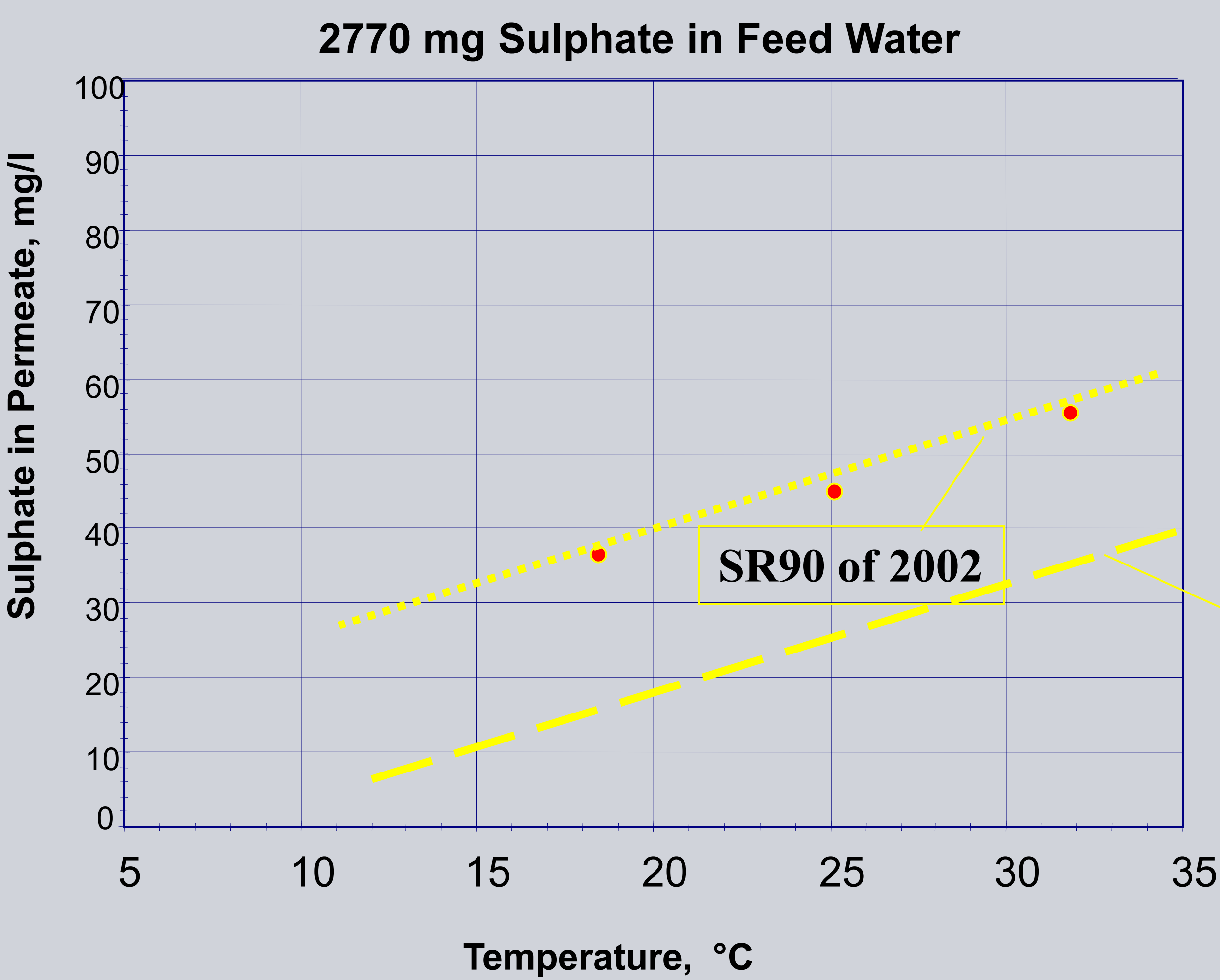


Projected Sulphate Levels for Warranty - Proportion to 2770 mg/l basis multiplied by expected level at various temperatures

$$\frac{2850}{2770} \times 40 = 41 \text{ mg/l}$$

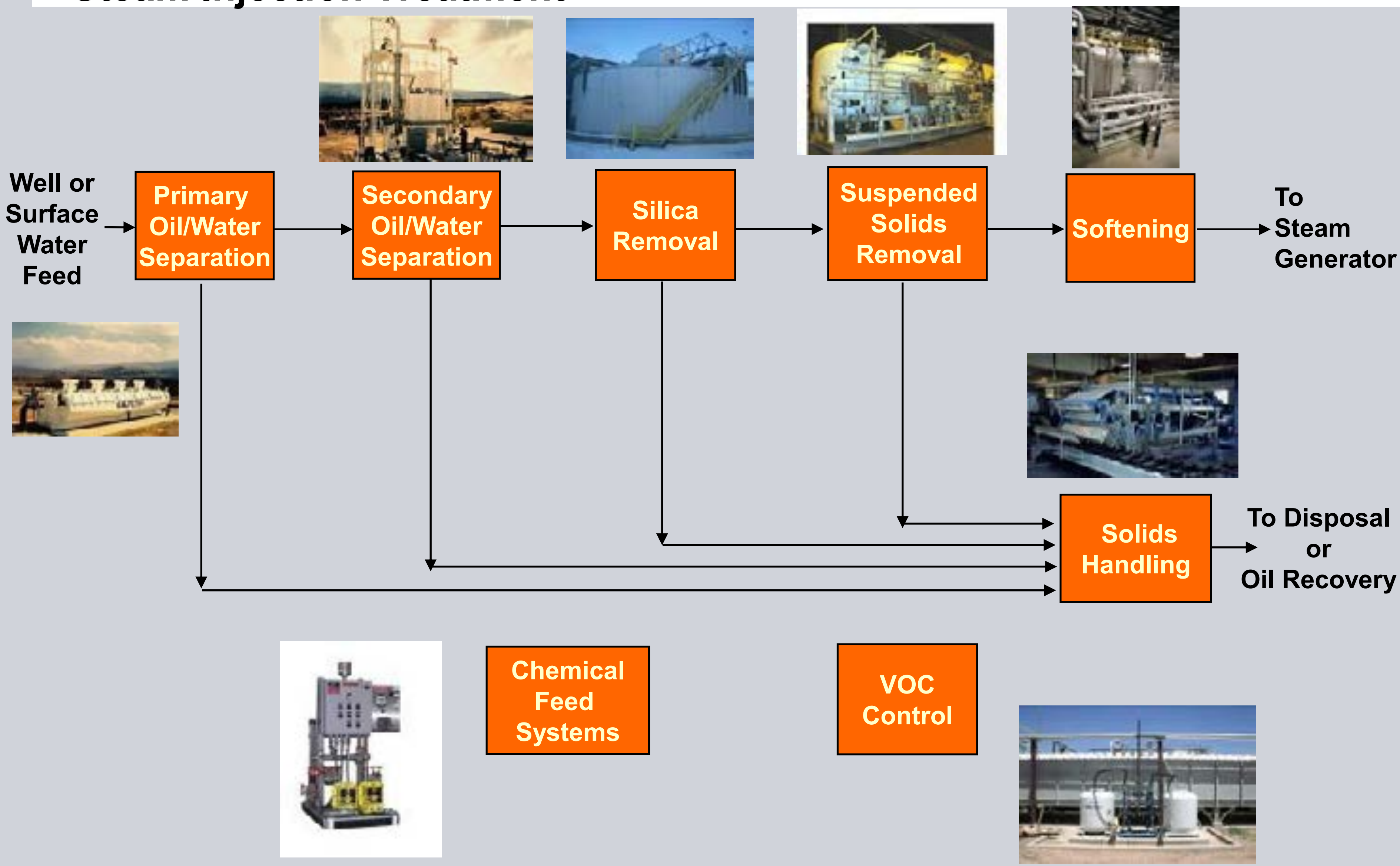
At 20 °C

Sulfate Removal
CapEx vs. OpEx Cost

Major OpEx Cost Contributors

- Membrane Cleaning
- Guard Filter Element Change Out
- Membrane Replacement
- Chemicals for Daily Treatment
- Potable Water Usage
- Labour
- Lost Injection Water Production
- Electrical Usage

Oil & Gas Production
Steam Injection Treatment



Steam Injection Treatment

What is the purpose of steam injection?

- To enhance oil recovery (EOR) from existing formations or to allow for oil recovery found in tar sands.
- The latter describes what is commonly called Steam Assisted Gravity Drainage (SAGD).
- Recycling Produced Water is an alternative or supplemental source of injection water/steam.
- Recycling produced water in-lieu of discharging or deep well injecting could provide a cost effective source of water to supply the steam generators. Produced water treatment is unique to the feed water specifications of the steam generators.

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Design Considerations for Steam Injection

What are some of the considerations associated with produced water treatment for steam injection?

- Initial produced water flow rate and characteristics vs. future
- Future temperature of produced water
- Deoiling pretreatment
- Softener selection: HLS, WLS, CLS, IX
- Caustic vs. lime in chemical softener to reduce solids generation
- Boiler operating pressure
- Type of boiler
- Treated water quality associated with boiler type

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The Equipment Selection Process

What type of steam generator will be used?

1. Once Through Steam Generators (OTSG)

TDS	<8,000 mg/l
Hardness	<0.5 mg/l
Si	<50 mg/l

2. Drum Boilers

TDS	<20 mg/l
Hardness	<0.05 mg/l
Si	<0.25 mg/l

Note: Silica and hardness levels are designated by the type of steam generator and will vary by manufacturer.

Produced Water Management

The produced water treatment system can be considered a 2-Step treatment process:

1. Deoiling Step
2. Boiler Feedwater Treatment Step

Steam Injection Treatment Technologies using Produced Water

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<u>Deoiling Steps:</u>

Primary Produced Water Separation

- Corrugated Plate Separators (CPS)
- API Separators
- Solid/Liquid Hydrocyclone
- Liquid/Liquid Hydrocyclone

Secondary Produced Water Separation

- Induced Gas Flotation Separators
- Dissolved Gas Flotation Separators
- Walnut Shell Filters

Suspended Solids Removal

- Media Filters
- Walnut Shell Filters

Note: TSS removal after deoiling as well as after softening may be required.

Steam Injection Treatment Technologies using Produced Water

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Boiler Feedwater Treatment Steps:

Hardness/Silica Removal Systems

- Warm Lime Softeners (65 C)
- Hot Lime Softeners (109 C)
- Cold Lime Softeners
- Ion Exchange

TDS Removal Systems

- UF-RO
- Thermal Technologies Softening Systems
- Brine Softeners
- Weak Acid Cation Softeners
- Strong Acid Cation Softeners

Solids Handling

- Gravity Thickeners
- Filter Press
- Belt Filter Press
- Centrifuges

Warm Lime Softeners

- The principle purpose is the reduction of harness and silica, however, warm lime softeners will also remove trace amounts of oil and iron.
- The removal of silica by magnesia addition produces magnesium silicate.
- One key advantage in steam injection applications is the operating temperature of 65 C maybe maintained by the formation temperature over time.

Hot Lime Softeners

- The primary purpose of the hot lime softener is the reduction of hardness and silica. Hardness levels of 15 ppm can be attained.
- Another advantage is the removal of dissolved gases.
- One disadvantage is the requirement for steam.

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The Softening Process

- Normally, a two-step softening process will be required to meet the hardness levels required.
- The primary softeners will remove the bulk of the hardness followed by the polishers to capture the remaining hardness.
- The benefit of a two-step process is that the polishing units will have a much longer run cycle, resulting in low OpEx, and will meet the hardness spex.
- The ion exchange polishing step may consist of weakly acidic cation (WAC) exchange resin. The benefit of WAC is its tolerance of high TDS.

Typical Steam Injection Treatment PFD

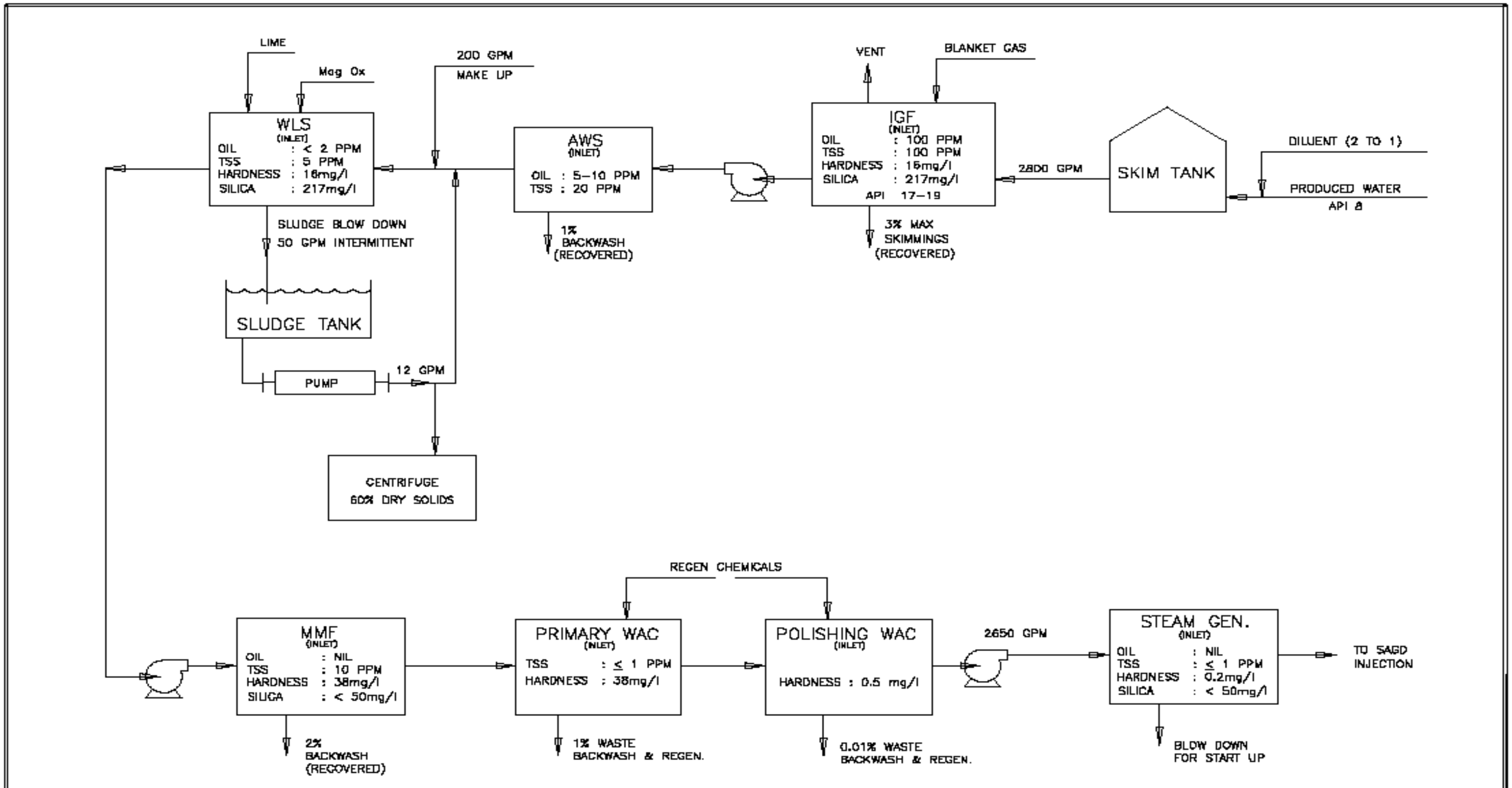

FIGURE 2

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Thank you for your attention!

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