

Produced Water Treatment Project Profile



- ◆ **Project Name: Melut Basin Oil Development**
- ◆ **Client Name: PDOC, Petrodar Operating Company**
- ◆ **Consultant: Mott MacDonald**
- ◆ **Plant Location: Adar/ Agordeed Field – Sudan**
- ◆ **Scope: Design, Build, and installation Super.**
- ◆ **Go Ahead Date: June – 2005**
- ◆ **Delivery Date: December – 2005**
- ◆ **Startup Date: December – 2006**
- ◆ **Capacity: 1920 M3/day (80 CMH)**
- ◆ **Source of Water: Oil Wells – Produced Water**
- ◆ **Sudan Oil Production: 250,000 bbl/d (2004)**
- ◆ **The Field Production: 32,000 bbl/d (2006) – Around 220 CMH**



Criteria for Awarding the Job



- ◆ **Critical Delivery < 5 Months**
- ◆ **Compact Design**
- ◆ **Robust and Reliable Design**
- ◆ **Economic Approach**





Design Conditions

- ◆ **Inlet Pressure:** Atmospheric
- ◆ **Outlet Pressure:** 1.29 Barg
- ◆ **Operating Temperature:** 55 Deg. C.
- ◆ **Design Pressure:** 10 Bar
- ◆ **Design Temperature:** 80 Deg. C.
- ◆ **ANSI Class:** 150#



◆ **Water to Oil Ratio**

◆ **New Well: < 1**

◆ **Old Well: > 3 up to 10**

◆ **North Sea:**

70% water

30% oil

◆ **N. America:**

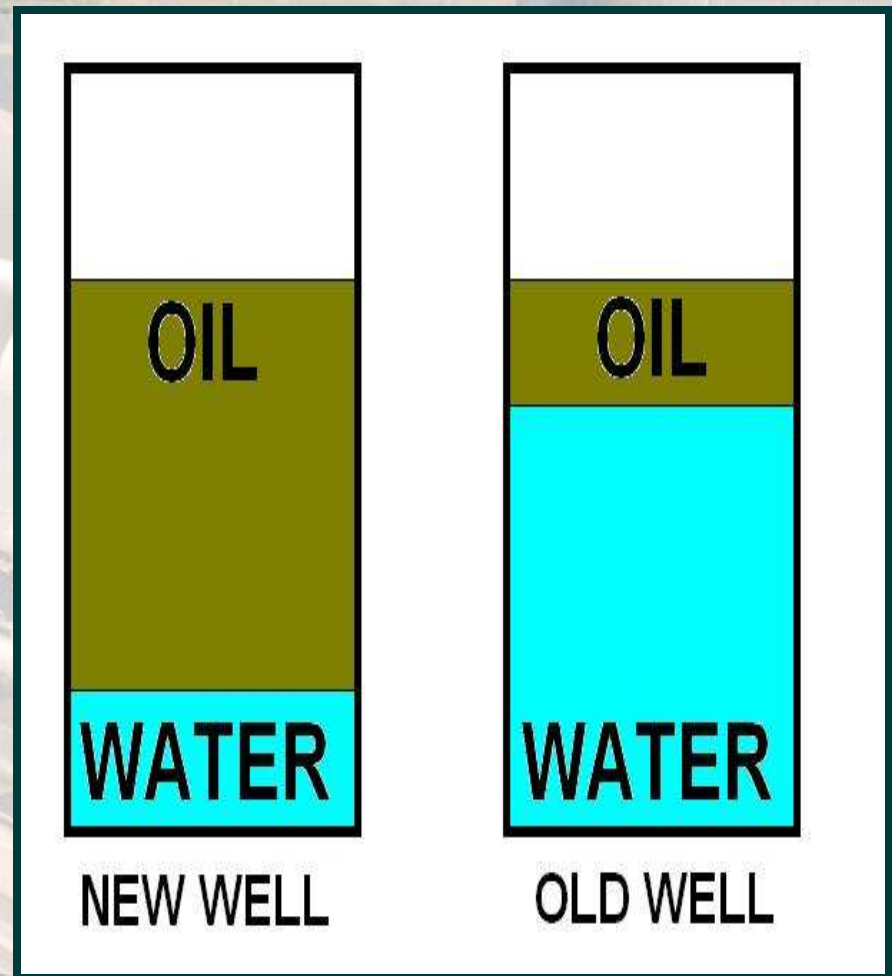
92% water

8% oil

◆ **Our Site:**

50% water

50% oil





Main Impurities in Produced Water

- ◆ Dissolved Solids
- ◆ Heavy Metals
- ◆ Various Oils (emulsified and non-emulsified)
- ◆ Suspended Solids
- ◆ Dissolved Gases (O_2 , CO_2 , and H_2S)
- ◆ Iron Scales
- ◆ Bacteria
- ◆ Phenols, Toluene, and other toxic compounds
- ◆ Rust and Corrosion Byproducts
- ◆ Sand Grains
- ◆ Radioactive Elements
- ◆ Bacteria
- ◆ Treatment Chemicals



WHAT DO WE REMOVE?

- ◆ Free Oil
- ◆ Sand and Turbidity
- ◆ Dissolved Gases
- ◆ Bacteria and Viruses

WHY?

- ◆ Reduce harmful emissions to the environment
- ◆ Protect downstream equipment from erosion
- ◆ Prevent harmful & dangerous gasses from entering the atmosphere
- ◆ Improve well injectivity



Typical Oil Discharge Limits

Location	Limit
North Sea	40 mg/l
Arabian Gulf	15 to 40 mg/l
Gulf of Mexico	29 mg/l
India	48 mg/l
Onshore	0-5 mg/l
Sudan	50 mg/l



Raw Water Analysis

(Year 2005) (After 2006)

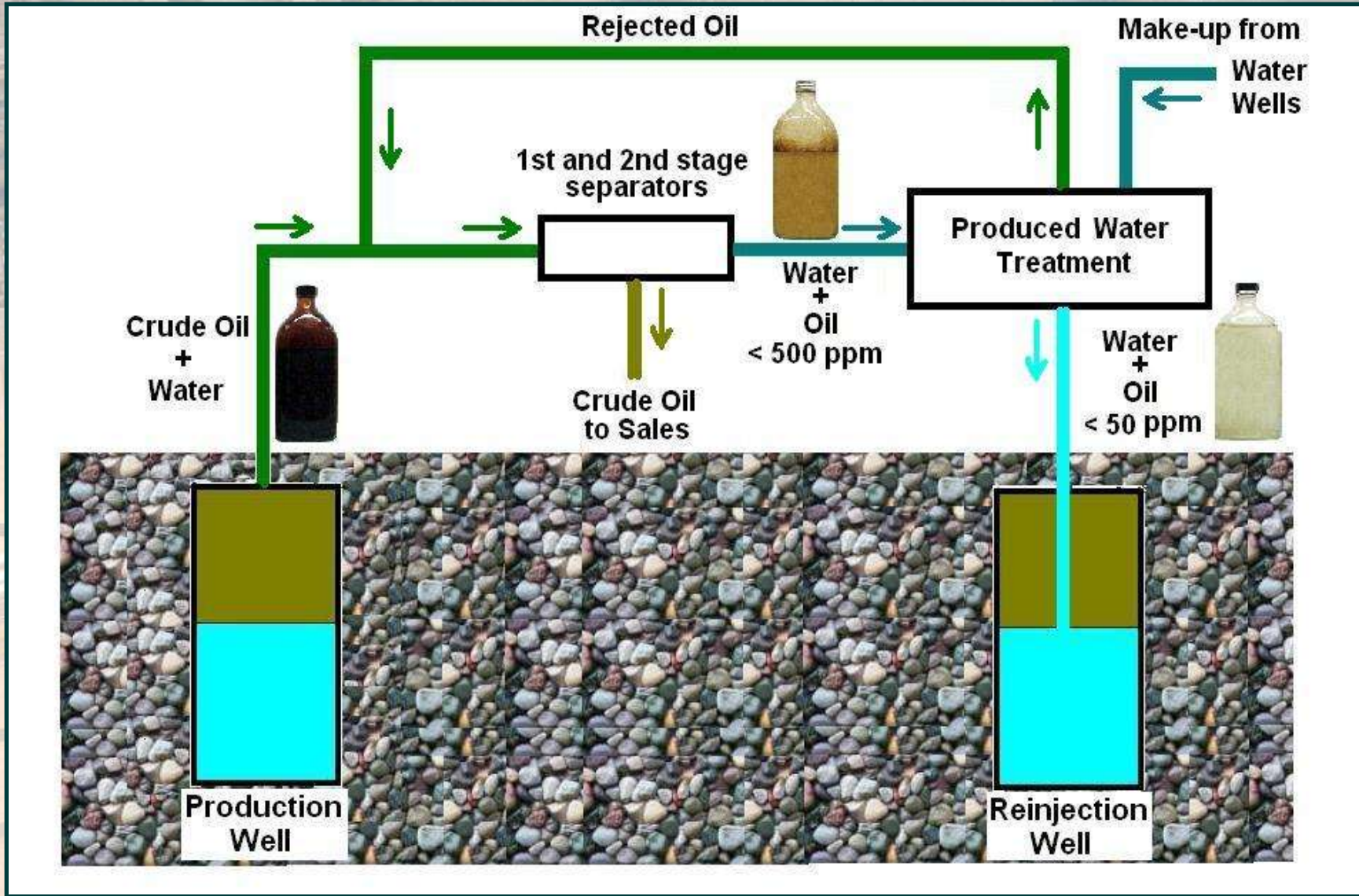
(Year 2005) (After 2006)

Oil Content, ppm	67	100			
TSS, ppm	20	Nil	<i>Anions</i>		
TDS, ppm	7304	10600	Chloride, ppm	461	680
Dissolved Oxygen, ppm	2.48	Nil	Sulphate, ppm	28.6	3.3
Total Iron, ppm	1.88	2.8	Bicarbonate, ppm	4630	6660
Free CO ₂ , ppm	1491	2300	Carbonate, ppm	Nil	Nil
<i>Cations</i>			Hydroxide, ppm	Nil	Nil
Sodium, ppm	1815	2610	<i>Additional Comp</i>		
Potassium, ppm	388	580	Boron, ppm	2.75	4.1
Calcium, ppm	34.7	42	Aluminium, ppm	0.13	0.2
Magnesium, ppm	9.83	13	Silicon, ppm	12.1	18
Barium, ppm	2.88	4.3	Fluorine, ppm	0.23	Nil
Strontium, ppm	0.80	1.2	NO ₃ , ppm	2.18	Nil
Dissolved Iron, ppm	0.4	0.06	NO ₂	0.00109	Nil



Injected Water Quality

Average air permeability of water injection formation, mm ²	>0.6
Standard classification	A3
TSS (total suspended solids), mg/L	≤10.0
Median diameter of suspended solid particles, mm	≤4.0
Oil content, mg/L	≤50
Dissolved oxygen, mg/L	<0.05
Average corrosion rate, mm/a	<0.076
Pitch corrosion	Apparent Pitch Corrosion on the Test Piece
SRB (Sulfate reducing bacterium), bacterium/ml	<25
Iron bacteria, 1 bacterium/ml	$n \times 10^4$ (Note)
(Saprophytic bacteria) TGB, 1 bacterium/ml	$n \times 10^4$ (Note)
Membrane filtration factor	10
Total iron content, mg/L	<0.5
Free carbon dioxide content, mg/l	<10
Sulphide content (diatomic sulphide), mg/L	<10

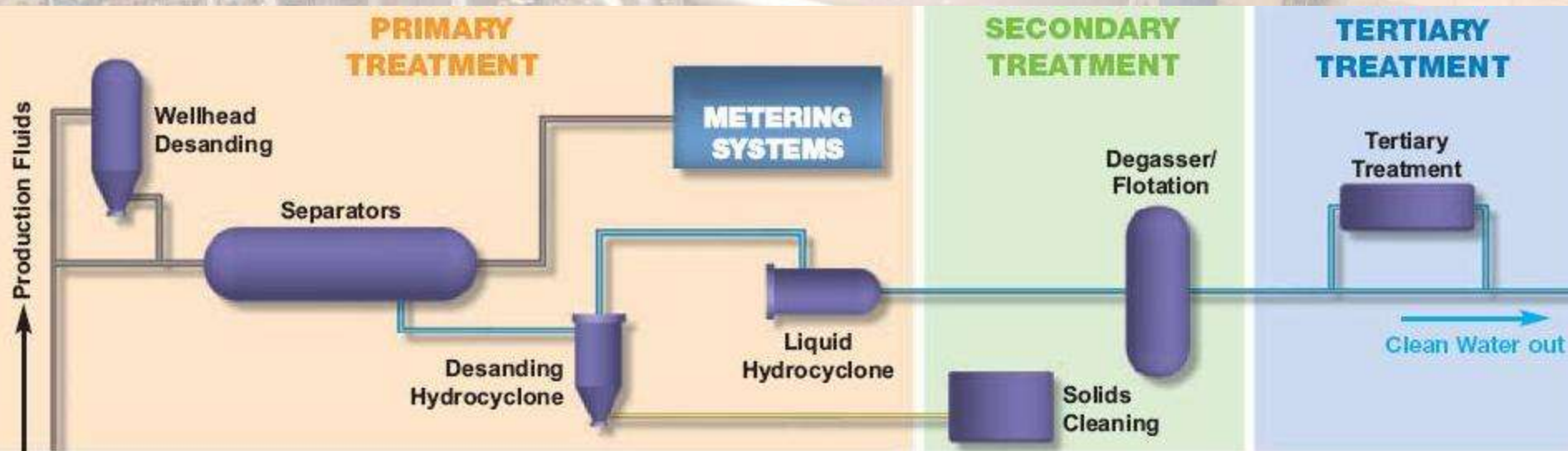




Equipment Typically Used in Produced Water Treatment

- Surge Drums
- 2-phase separators
- 3-phase separators
- Liquid/Liquid Hydrocyclones
- Solid/Liquid Hydrocyclones
- Multiphase Wellhead Desanders
- Degassers
- Single Cell Flotation
- Induced Gas Flotation
- Filter Coalescer
- Cartridge Filters
- Chemical Injection Packages
- Gas Pressure Let-down Stations
- Hydraulic Wellhead Control
- Gas Filters
- Packed Towers
- Gas Cyclones
- Control Panels
- Analyser Houses and Laboratory

Produced Water Treatment Overview





PRODUCED WATER DEOILING EQUIPMENT OPTIONS

Surge Tanks	To collect fluids that are subject to regular surge or upset conditions
Collection Vessels	To collect fluids from multiple sources
Deoiling Hydrocyclones	Primary Separation for the removal of oil from water
Titled Plate Interceptors	Primary separation for the removal of oil from water
Centrifuges	Primary Separation for the removal of oil from water
Degassers	Removal of gas from water and a final polishing stage
Induced Gas Flotation	Secondary Separation for the removal of oil from water
Filter Coalescers	Removal of oil from water
Deep Bed Media Filtration	Removal of solids and oil from water
Adsorption Filtration	Removal of oil from water

PRODUCED WATER DESANDING EQUIPMENT OPTIONS



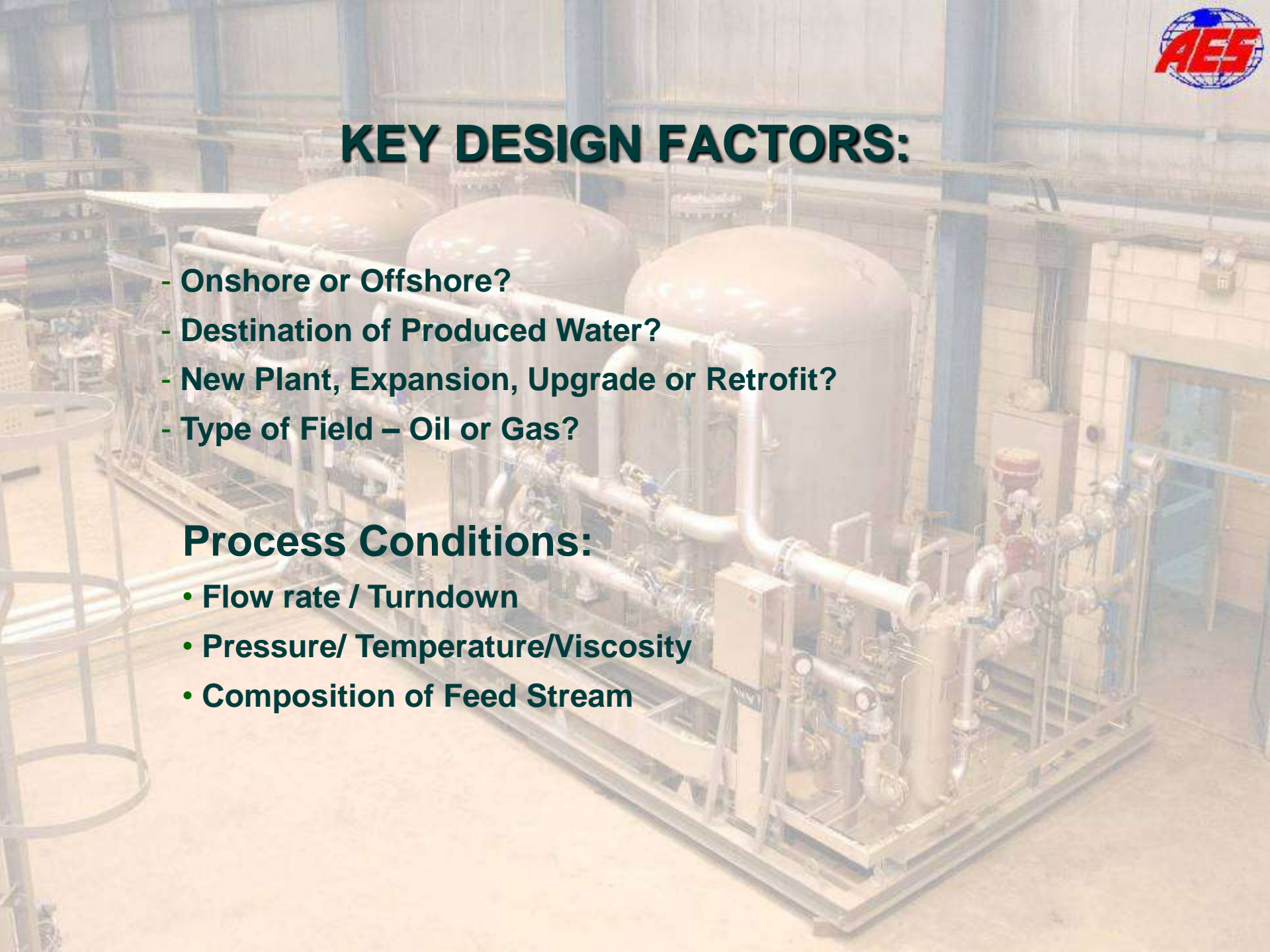
Cyclonic Wellhead Desander	Coarse Sand Removal between 100 to 150 microns
Coarse Strainer	All solids removal down to about 80 microns
Produced Water Desanding Hydrocyclone	Mid range sand removal down to about 30 to 40 microns
Deep Bed Multi Media Filtration	Fine Solids removal down to 5 microns
Cartridge Filters	Coarse to Fine Solids removal

KEY DESIGN FACTORS:

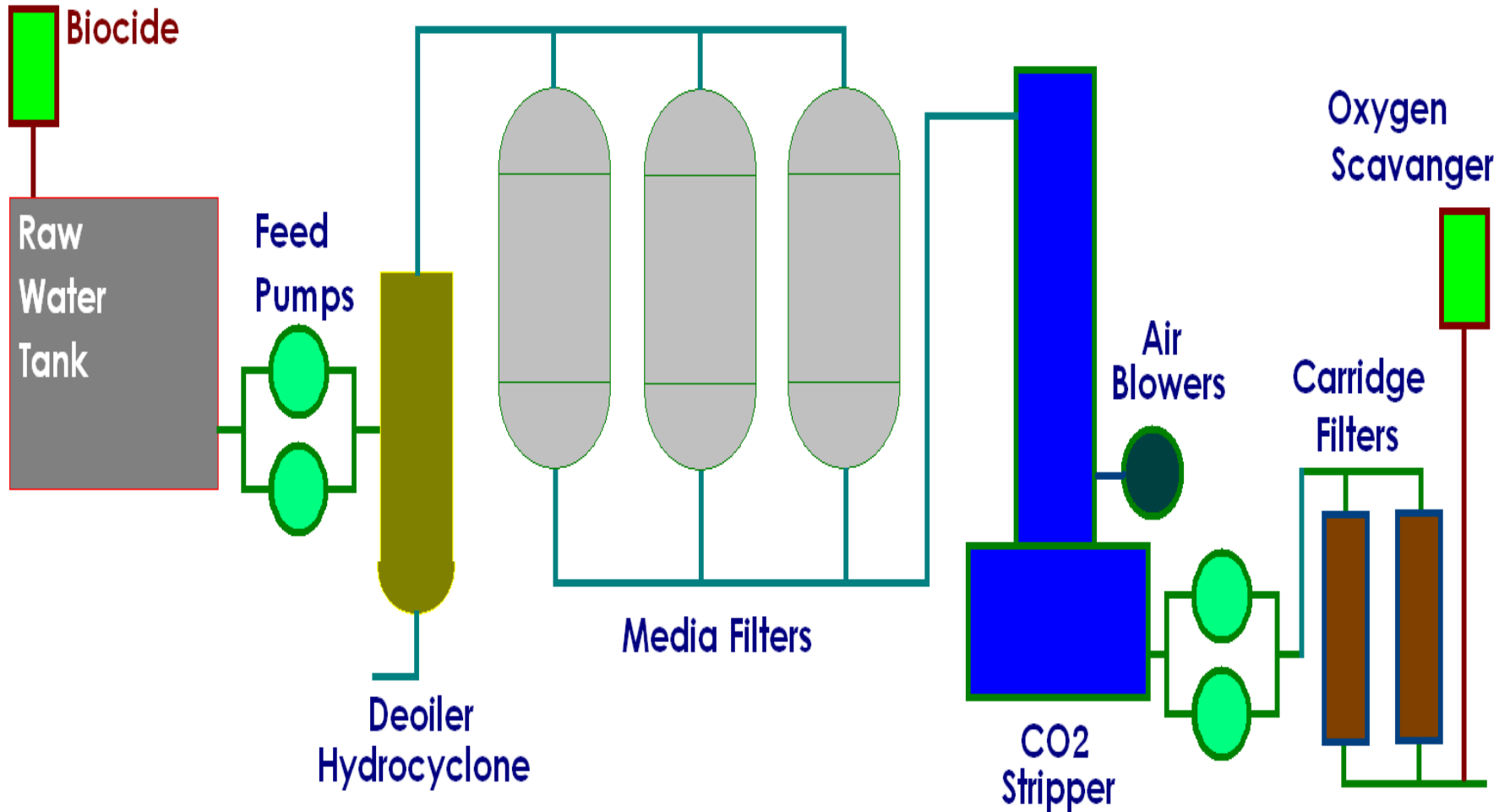
- Onshore or Offshore?
- Destination of Produced Water?
- New Plant, Expansion, Upgrade or Retrofit?
- Type of Field – Oil or Gas?

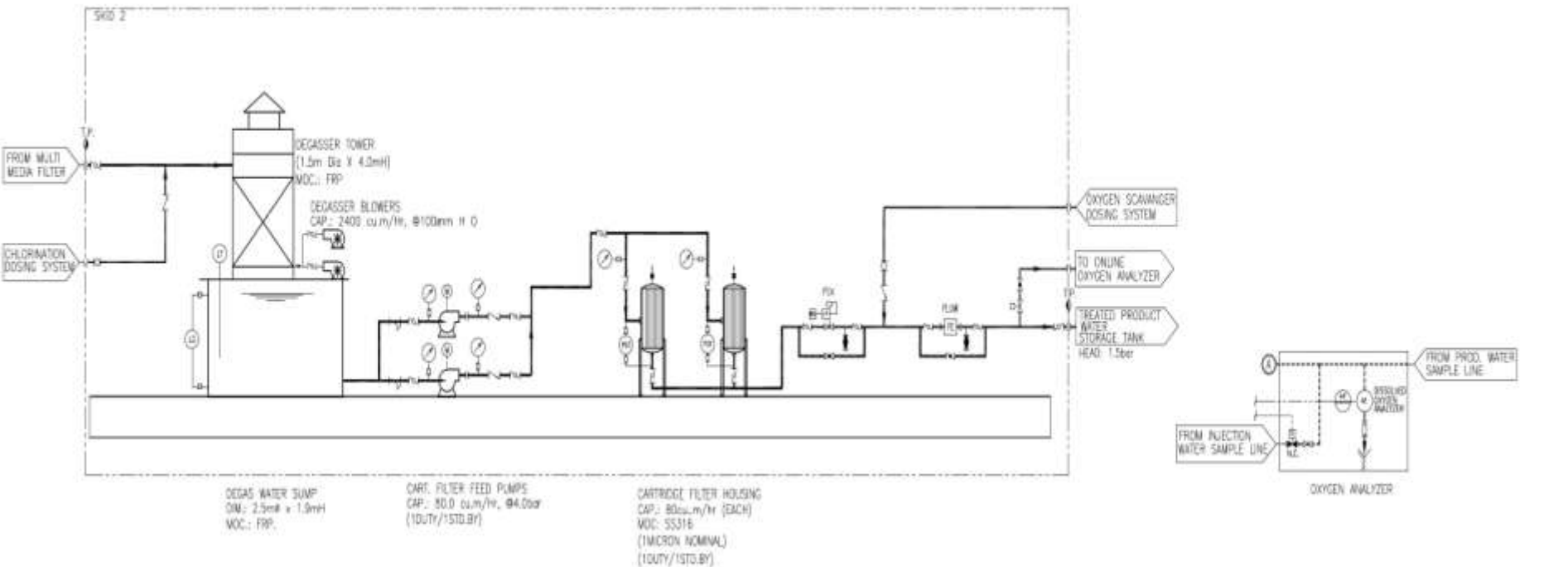
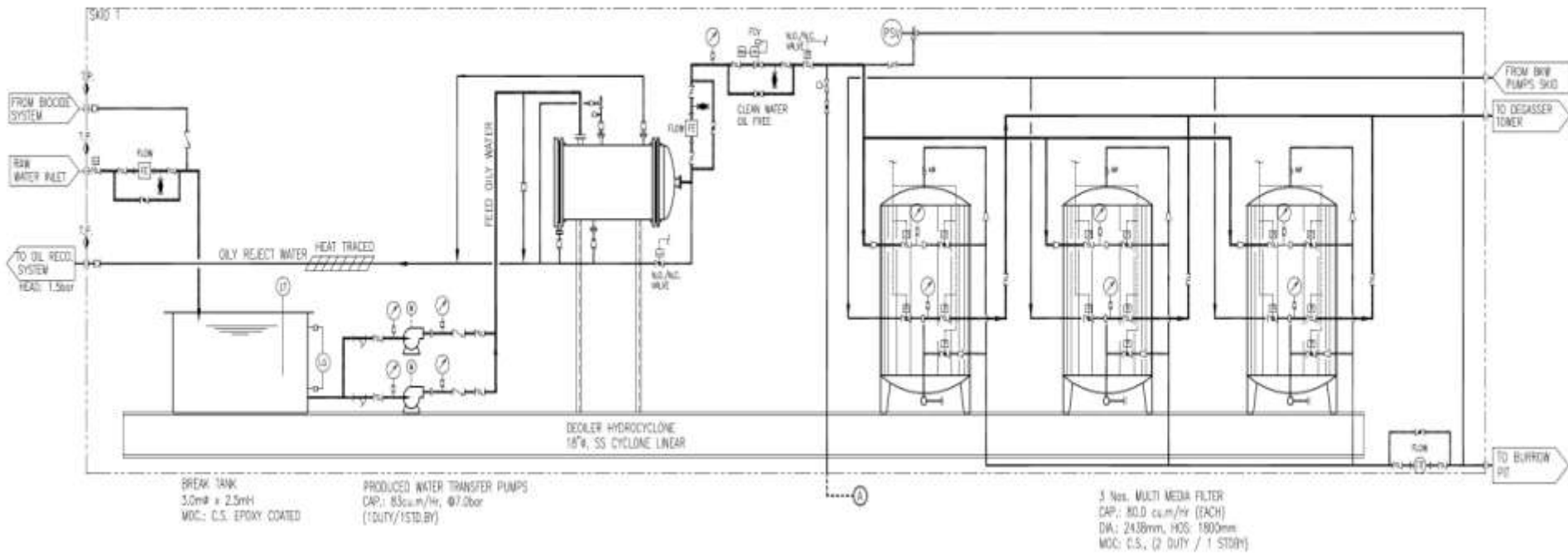
Process Conditions:

- Flow rate / Turndown
- Pressure/ Temperature/Viscosity
- Composition of Feed Stream

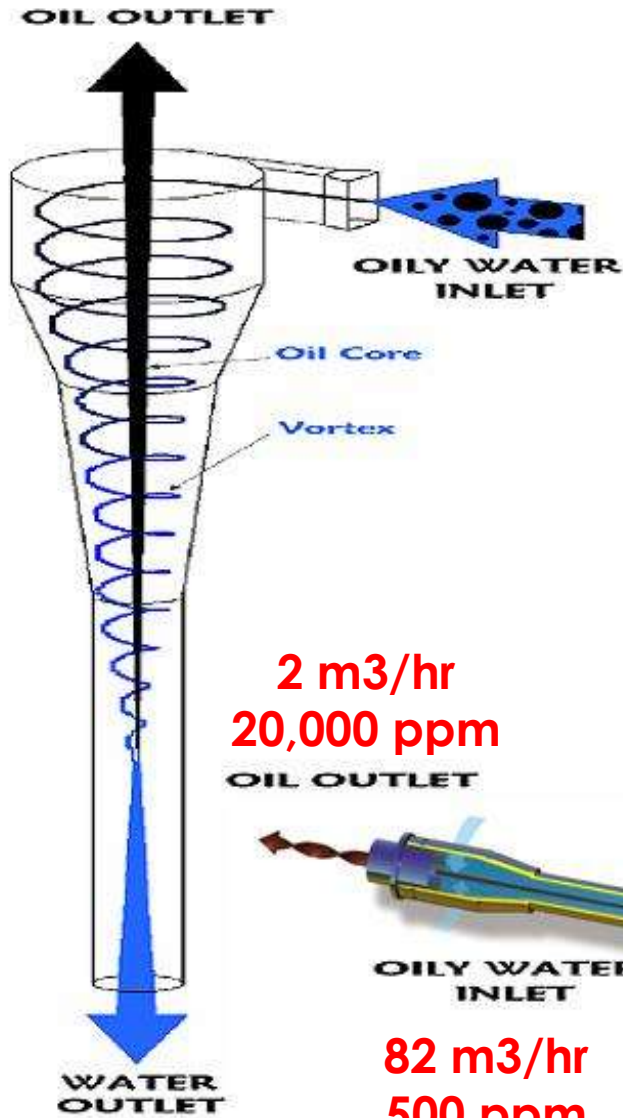


Main Process Diagram



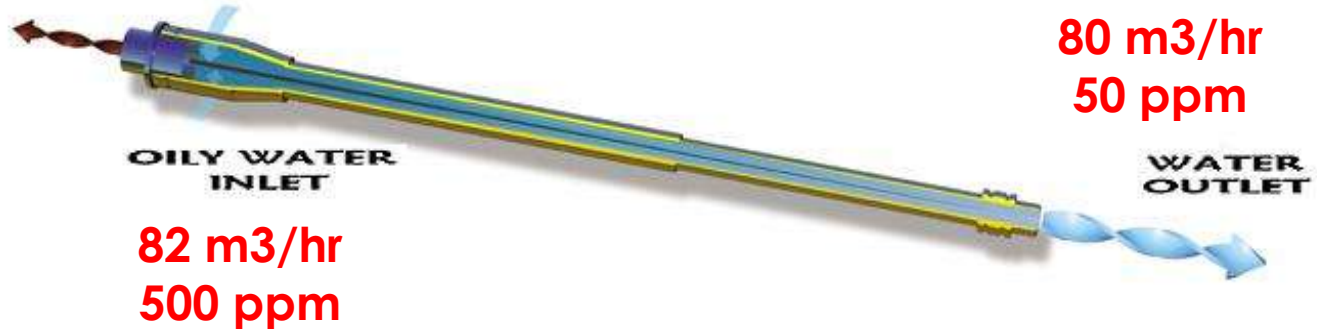


Main Process Diagram



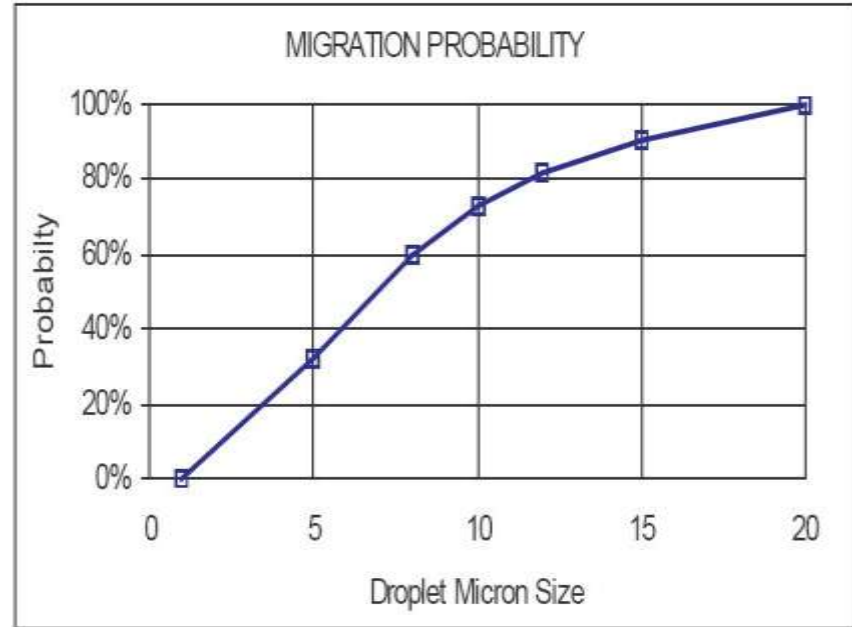
2 m³/hr
20,000 ppm

OIL OUTLET

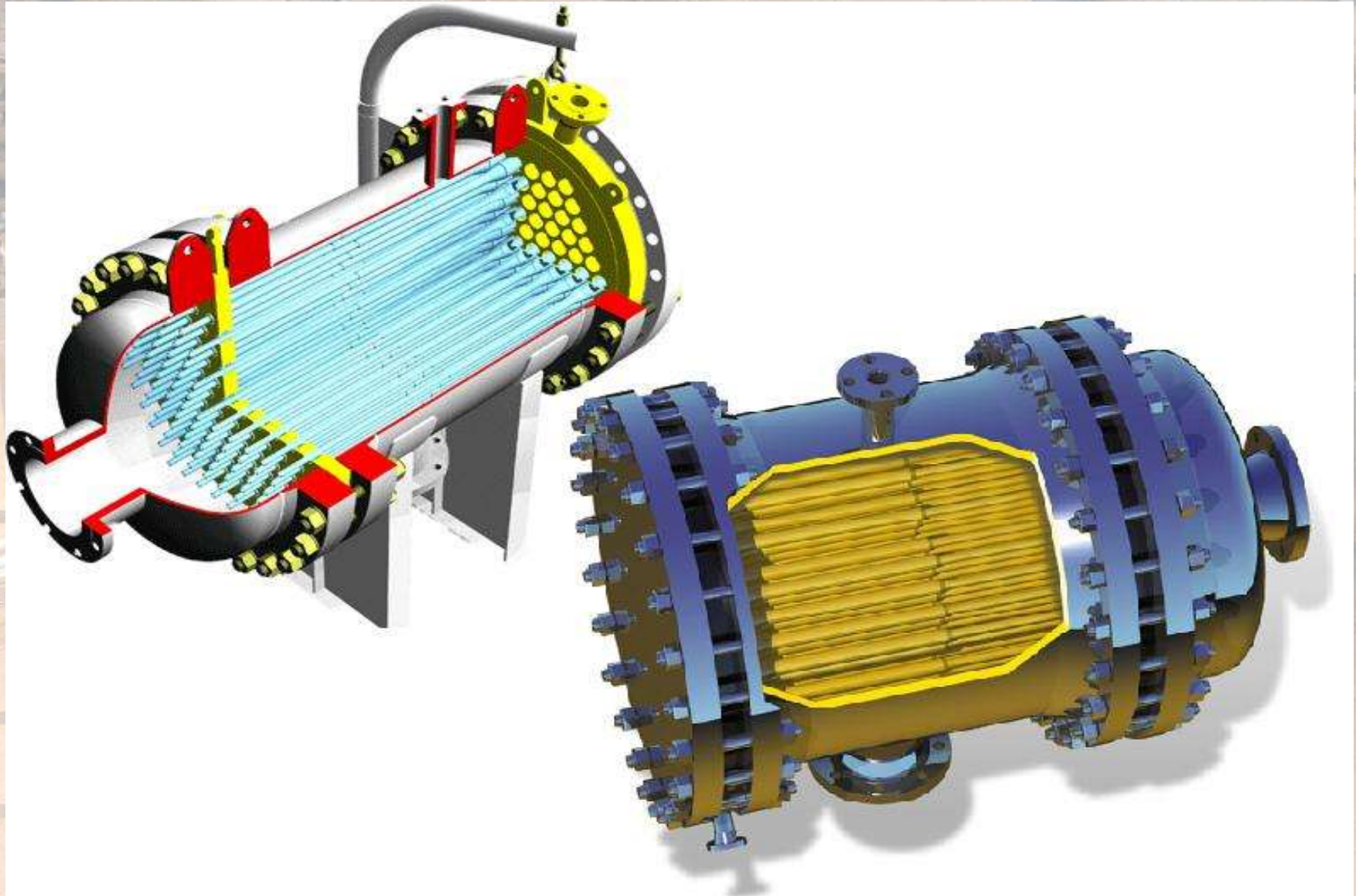


80 m³/hr
50 ppm

82 m³/hr
500 ppm



See Through View





Parameters affecting Performance

$$\text{Speed of Droplet Migration} = \frac{k \times (\text{Density}_{\text{Water}} - \text{Density}_{\text{Oil}}) \times \text{Droplet Size}^2}{\text{Viscosity}_{\text{Water}}}$$

Stokes Low

- Oil Droplet Size (Shear, Valve location, bends)
- Pressure Differential Ratio (PDR = 1.9)
 - Example: Feed 7 Bar; Water: 4.5 Bar; Oil: 2 Bar
- Reject Ratio > 2%
- Water lower viscosity at higher temperature
- Oil viscosity: Low viscosity oil can shear easily...
- Specific Gravity Difference.
- Cyclone Diameter, Length.
- Emulsion breakers, coagulants, surface tension
- Gases up to 10% (Displaces Oil on the overflow)

Advantages of Hydrocyclones



- **High efficiency**
- **Compact design**
- **No moving parts**
- **Low weight**
- **Directly replacement**
- **Low CAPEX and low OPEX**
- **Little or no maintenance costs**
- **Reliable and Predictable**
- **Consistently Performance**
- **Wide material selection (stainless & duplex steels, ceramics, etc)**
- **Modular (parallel to handle changes in treating capacities.)**
- **Portable.**
- **Little instrumentation for automation.**
- **Well-understood**
- **Simple to operate, maintain, troubleshoot.**
- **No special tools and little operator training required.**
- **Insensitive to motion or orientation**

Typical Production Fluids

Fluids in
Separator =
Oil & Water



Hydrocyclone
Outlet
< 50 ppm



PW Package Inlet
(from Separator)
< 500 ppm

PW Package
Outlet
< 30 ppm



Multimedia Filters

Special Design Features

- **Low Operational Flux (6 to 9 m³/hr/m² or 2.5 to 3.5 gpm/ft²)**
- **Extended Media Height (1.7 m or 5.5 ft)**
- **Special Wedge wire collection system**
- **High Backwash flow rate: 35 m³/hr/m² on two intervals**
- **Provision for future air scouring**

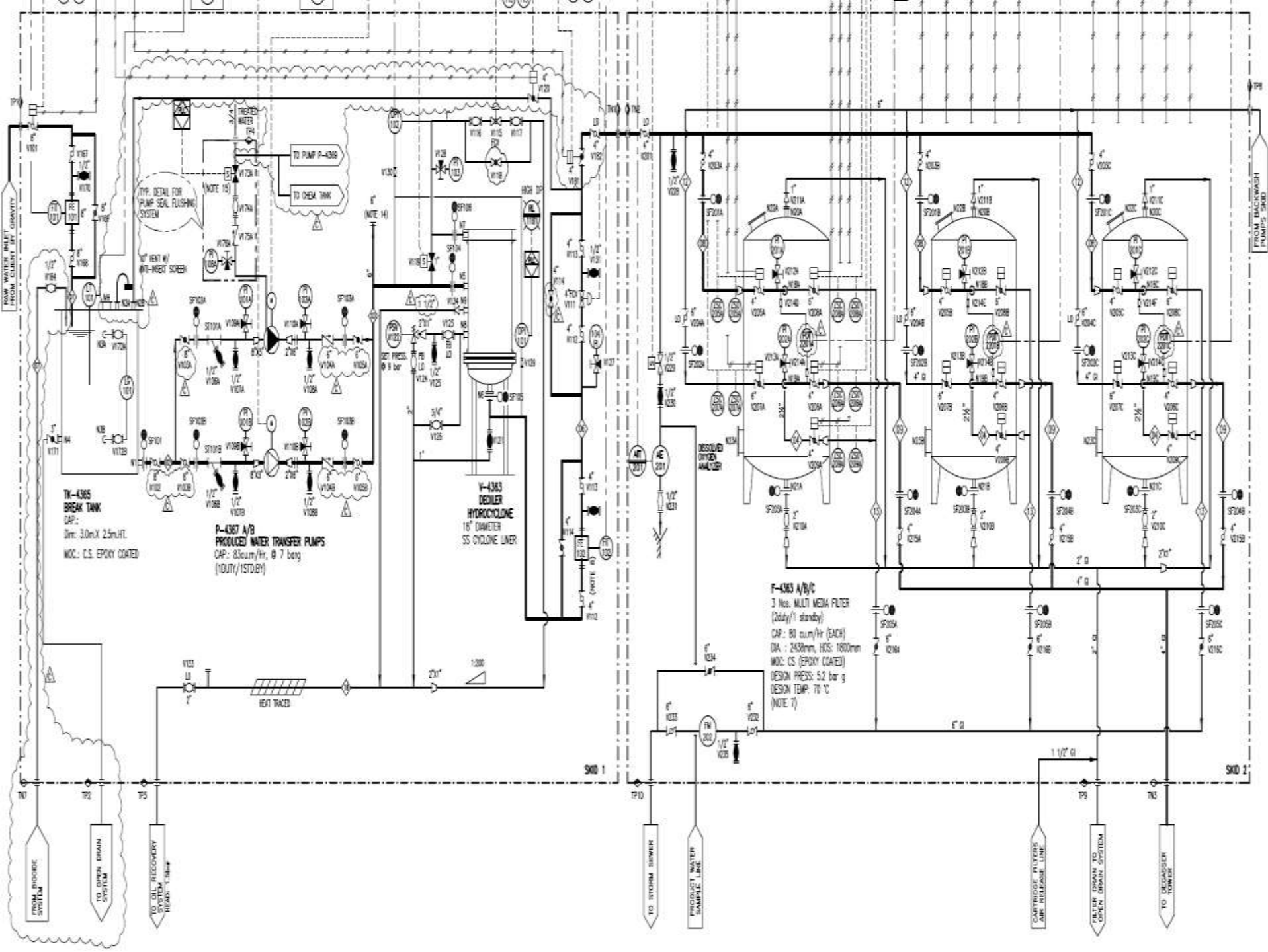


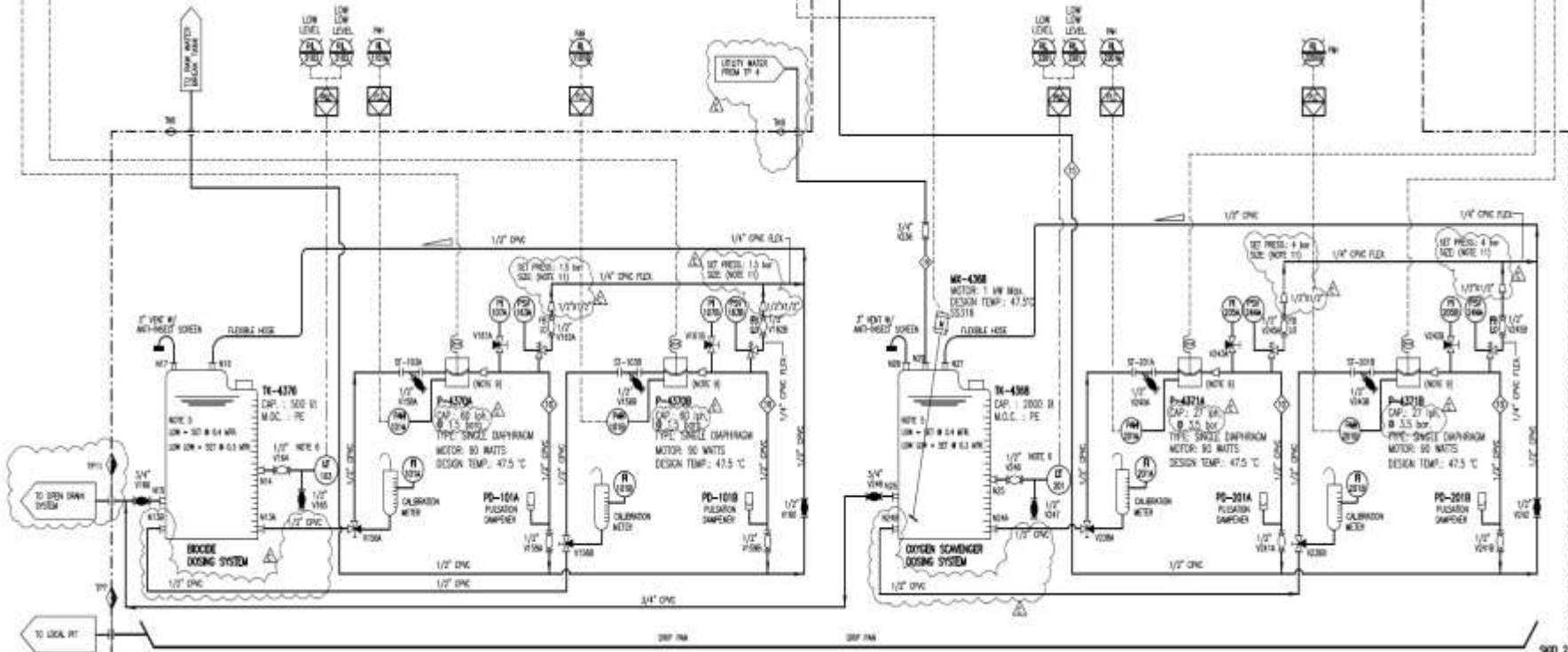
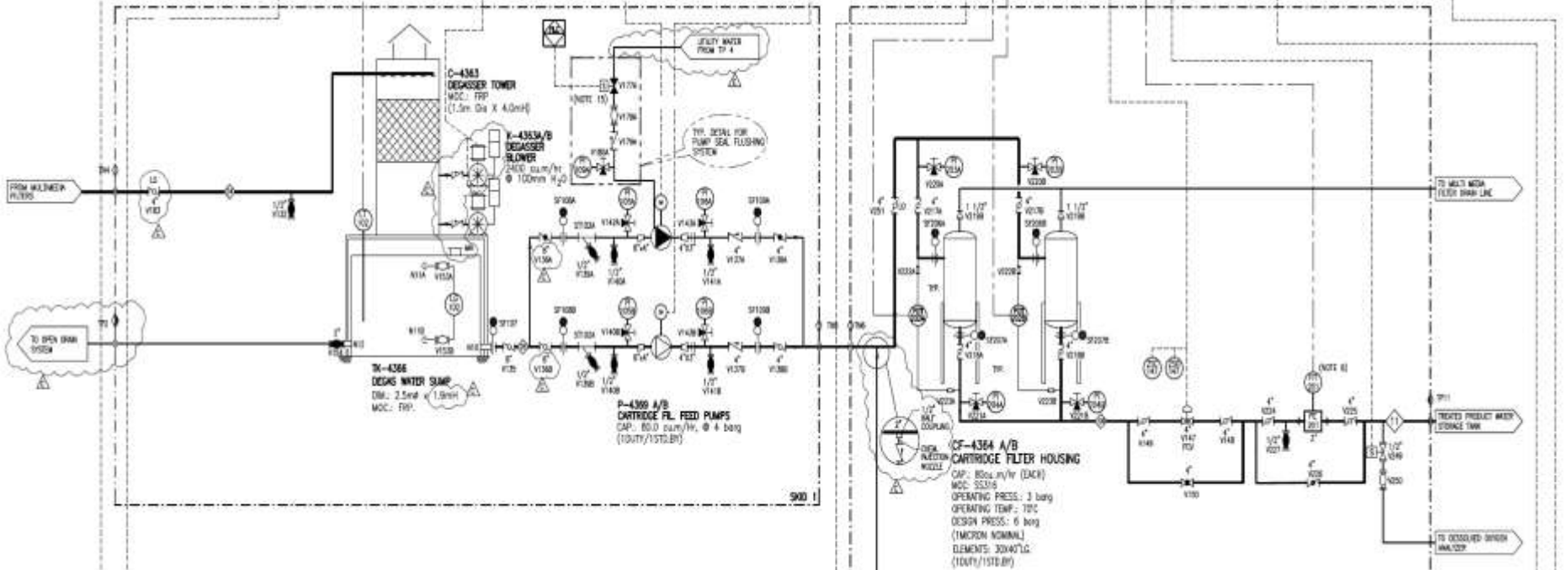


Unique Features



- **Hydraulic simulation calculations.**
- **Two skids only to minimize site activities.**
- **All skid Interconnecting pipe work, one pipe tie piece**
- **Compact skid dimension 14.4 x 3.5 meters**
- **Soft soil Pillars**
- **SST316 ANSI B73.1 pumps (API mechanical seal fitted with plan #62 flushing)**
- **Dosing systems were pre-engineered and skid mounted, complete with dosing pumps, FRP chemical tanks, mixers and corrosion resistant ejectors.**





Raw Water Tank



- ◆ Quantity: One (1)
- ◆ Capacity: 10 m³
- ◆ Make: Carbon Steel

Cyclone Feed Pumps

- ◆ Quantity: Two (2)
- ◆ Capacity: 80 m³/hr at 7 Bar
- ◆ Make: Stainless Steel 316



Deoiler - Hydrocyclone



- ◆ Quantity: One (1) Duty
- ◆ Capacity: 80 m³/hr at 7 Bar
- ◆ Make: Carbon Steel Shell/ SS Duplex Liners
- ◆ Feed Oil Level: 450 ppm
- ◆ Outlet: Less than 20 ppm

Multi-Media Filters



- ◆ Quantity: Three (3) Duty
- ◆ Capacity: 80 m³/hr
- ◆ Make: C. St. Epoxy Coated
- ◆ Diameter: 96"
- ◆ Feed TSS: 20 ppm
- ◆ Outlet TSS: < 1 ppm

Free CO₂ Stripper

- ◆ Quantity: One (1) Duty
- ◆ Capacity: 80 m³/hr
- ◆ Make: FRP
- ◆ Diameter: 1.5 X 4 M H
- ◆ Feed CO₂: 2,400 ppm
- ◆ Outlet CO₂: < 10 ppm





CAUTION
SURFACE HEATING
CAUTION
SURFACE HEATING

Cartridge Feed Pumps



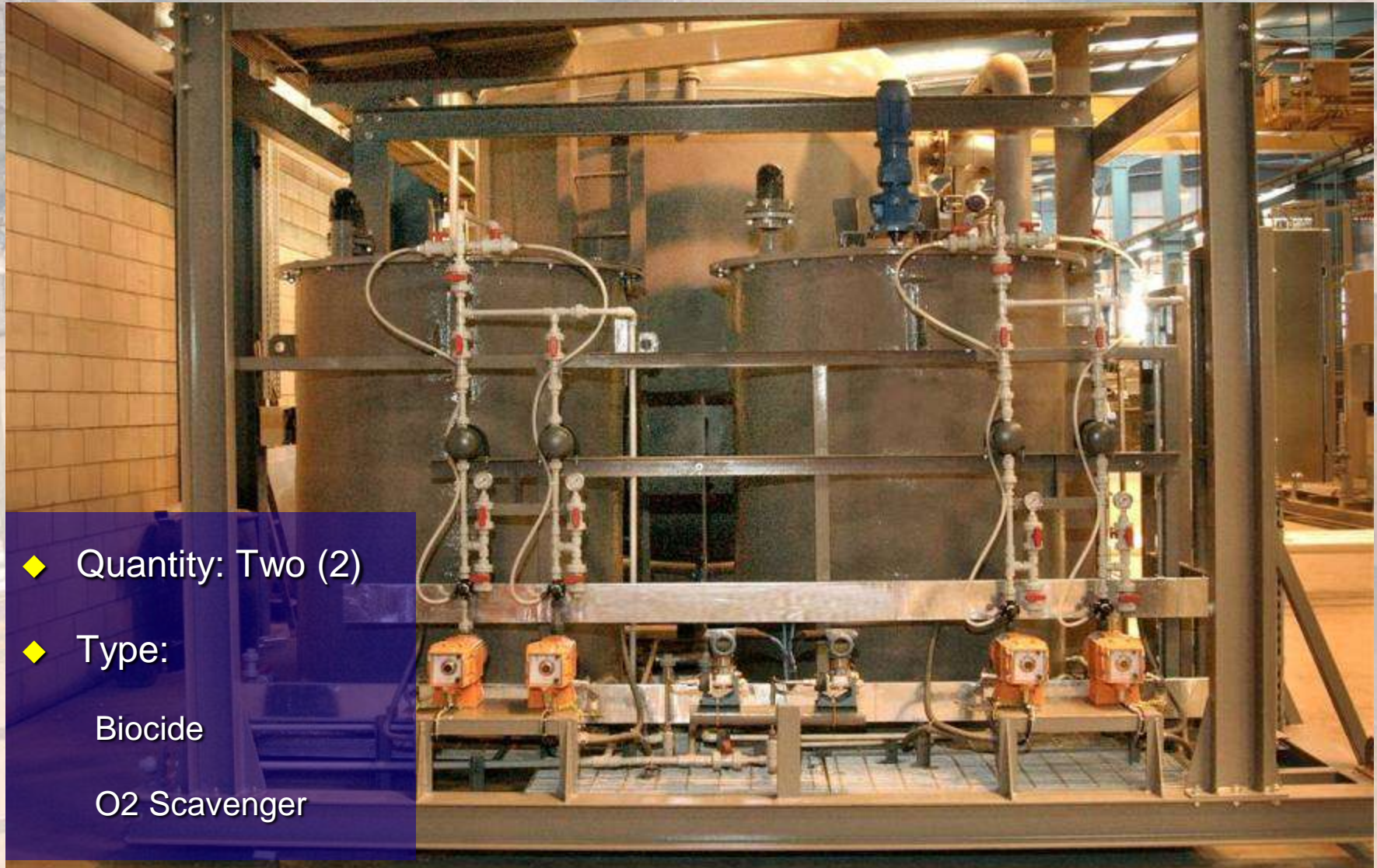
- ◆ Quantity: Two (2)
- ◆ Capacity: 80 m³/hr at 4B
- ◆ Make: C.S.

Micron Cartridge Filters



- ◆ Quantity: Two (2)
- ◆ Capacity: 80 m³/hr
- ◆ Make: St. St. 316
- ◆ Rating: 5 Micron - Abs

Chemical Dosing Systems

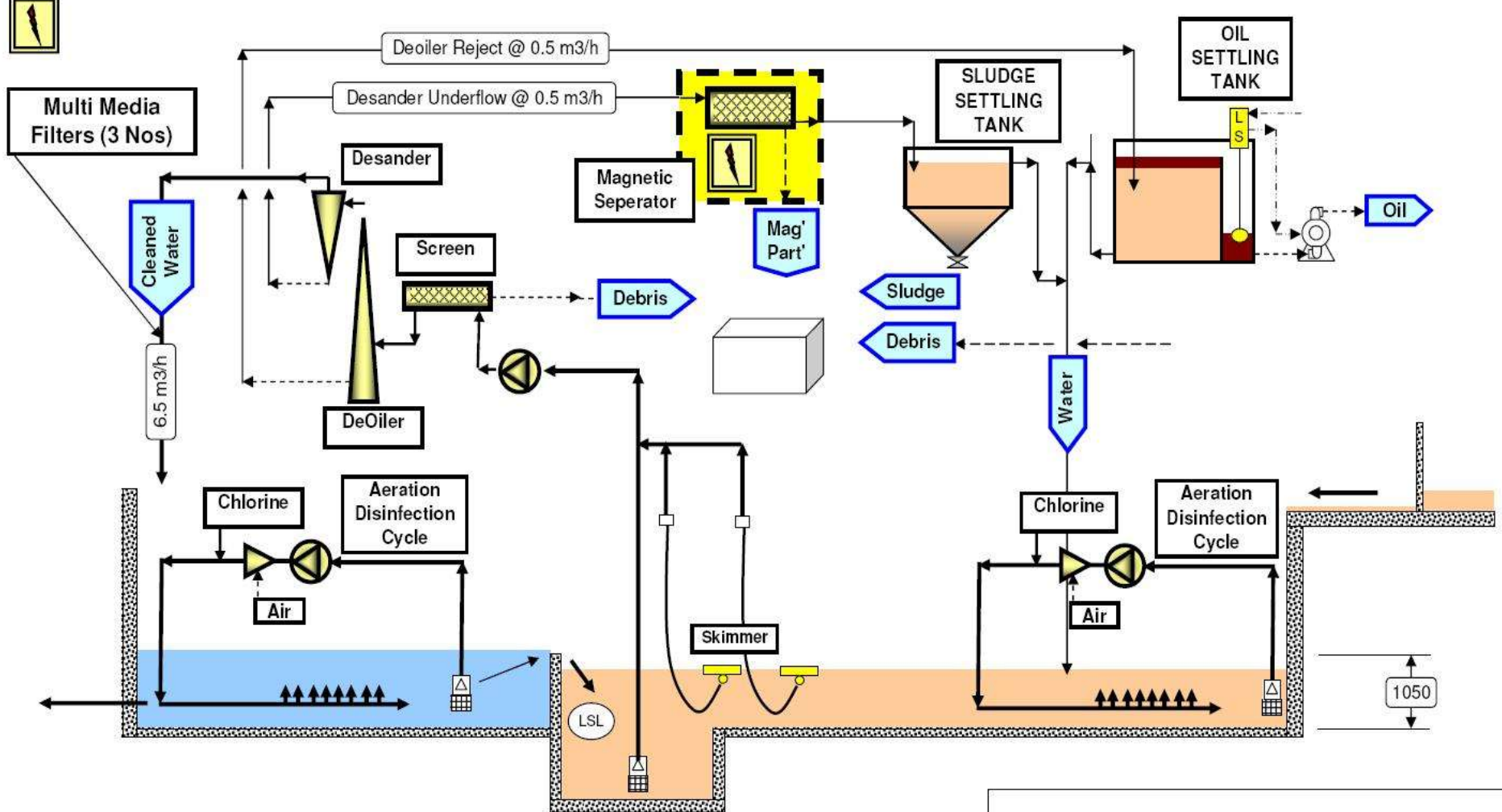


- ◆ Quantity: Two (2)

- ◆ Type:

Biocide

O2 Scavenger



PFD DRAWING
Hydro Test Tank



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