# SPE Webinar

Electrostatic Dehydration and Desalting:
Essential Processes for Reducing Corrosion
During Transportation and Refining Process

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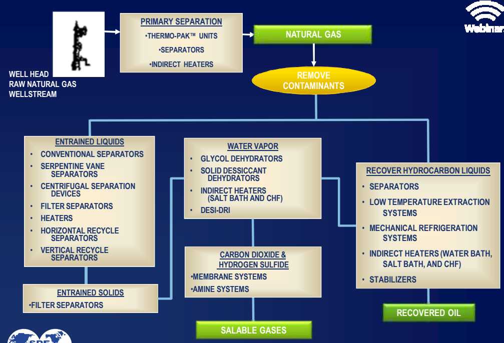
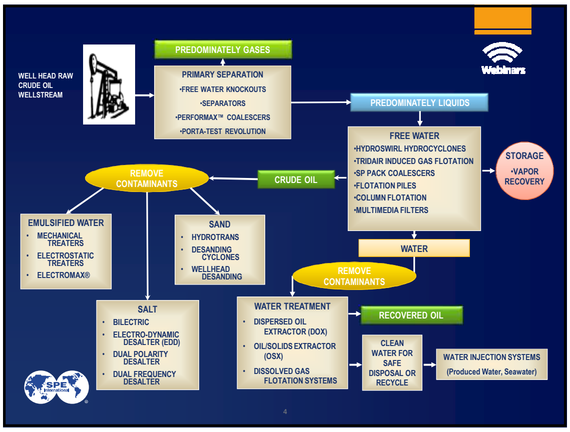
## Gary Sams, P.E.

**Managing Director R&D, Cameron**




WELL HEAD RAW CRUDE OIL WELLSTREAM
PREDOMINATELY GASES
PRIMARY SEPARATION
•FREE WATER KNOCKOUTS
•SEPARATORS
•PERFORMAX™ COALESCERS
•PORTA-TEST REVOLUTION
PREDOMINATELY LIQUIDS
FREE WATER
•HYDROSWIRL HYDROCYCLONES
•TRIDAIR INDUCED GAS FLOTATION
•SP PACK COALESCERS
•FLOTATION PILES
•COLUMN FLOTATION
•MULTIMEDIA FILTERS
STORAGE
•VAPOR RECOVERY
CRUDE OIL
REMOVE CONTAMINANTS
EMULSIFIED WATER
• MECHANICAL TREATERS
• ELECTROSTATIC TREATERS
• ELECTROMAX®
SAND
• HYDROTRANS
• DESANDING CYCLONES
• WELLHEAD DESANDING
WATER
REMOVE CONTAMINANTS
SALT
• BILECTRIC
• ELECTRO-DYNAMIC DESALTER (EDD)
• DUAL POLARITY DESALTER
• DUAL FREQUENCY DESALTER
WATER TREATMENT
• DISPERSED OIL EXTRACTOR (DOX)
• OIL/SOLIDS EXTRACTOR (OSX)
• DISSOLVED GAS FLOTATION SYSTEMS
RECOVERED OIL
CLEAN WATER FOR SAFE DISPOSAL OR RECYCLE
WATER INJECTION SYSTEMS
(Produced Water, Seawater)
Webinars
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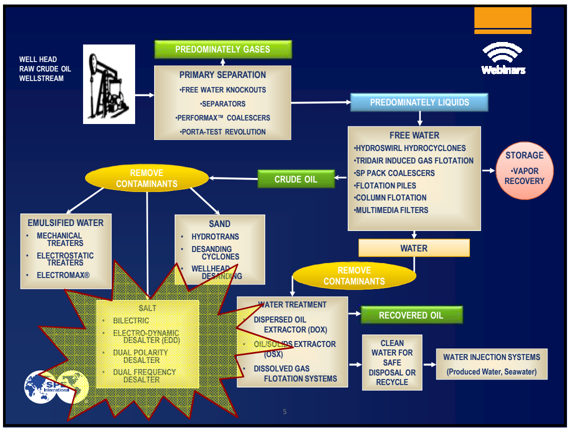
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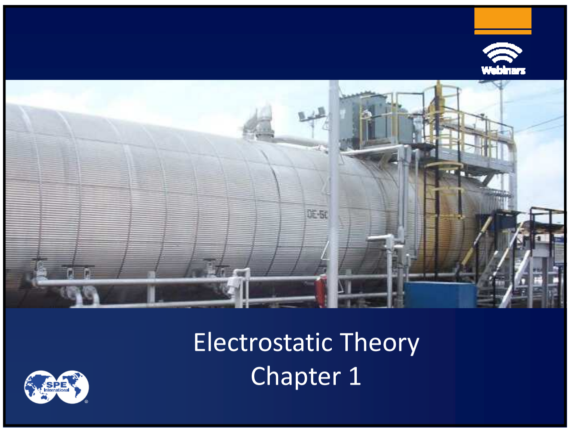
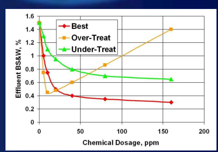

Webinars
Electrostatic Theory
Chapter 1
SPE

## Electrostatic Theory

- **Dipolar Force**
  - AC – TriVolt, Bilectric
- **Electrophoretic Force**
  - DC – MeterCell
  - AC/DC – Dual Polarity, Dual Frequency, EDD
- **Dielectrophoretic Force**
  - None

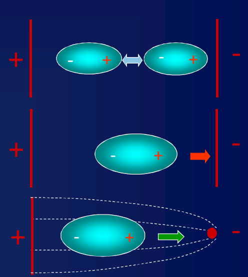
## Dehydrator Fundamental Variables

- **Oil Properties**
  - Density
  - Viscosity
- **Water Properties**
  - Density
- **Process Conditions**
  - Oil flowrate
  - Water content
  - Temperature




## Electrostatic Forces

- **Dipolar Attraction:** Electrical force produced by positive and negative centers on induced dipoles of water droplets.
- **Electrophoresis:** Electrically induced movement of polar bodies in a uniform field toward closest electrode.
- **Dielectrophoresis:** Movement of polar bodies induced by a divergent electric field toward increasing gradient.



## Definitions of Electrostatic Forces

**Dipolar Attraction:**

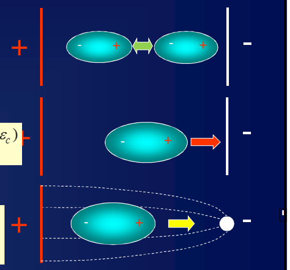
$$F_d = \frac{6K\varepsilon_c E^2 r^6}{d^4}$$

**Electrophoresis:**

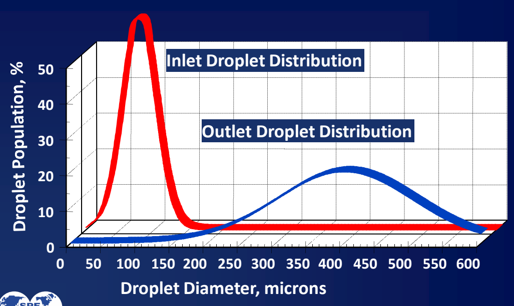
$$F_e = C\eta\pi^3\varepsilon_c r^2 E^2 e^{-(\sigma_c t/\varepsilon_c)}$$

**Dielectrophoresis:**

$$F_{diel} = 2\pi r^3 \varepsilon_c \left(\frac{\varepsilon_d - \varepsilon_c}{\varepsilon_d + 2\varepsilon_c}\right)\nabla E^2$$



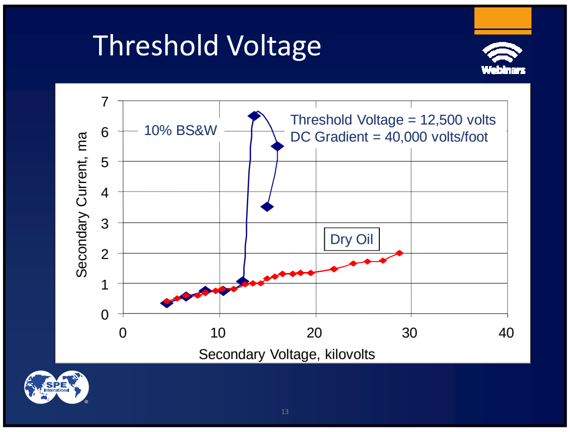
## Droplet Population Growth

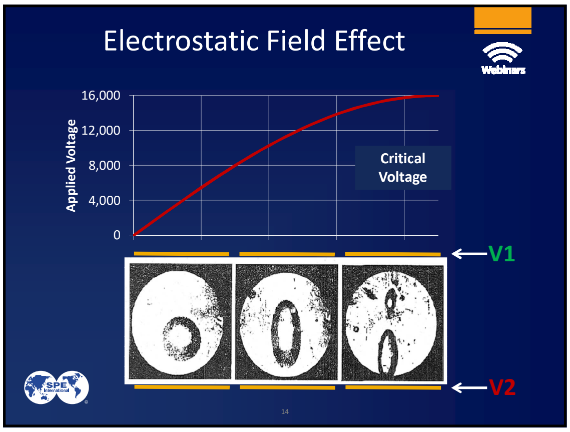


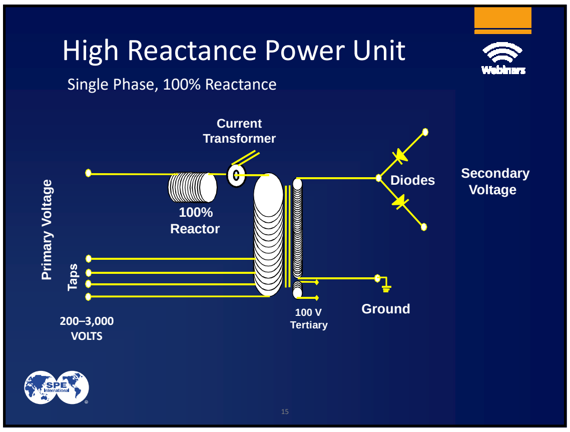

## Force Rankings

Relative to Droplet Weight (X)

- **Electrophoretic** – 7,200 x
  - Electrode to droplet
- **Gravitational** – 1 x
  - Droplet weight
- **Droplet Drag** – 1 x
  - Viscous drag
- **Dipolar** – 0.4 x
  - Drop to drop
- **Dielectrophoretic** - 0.02 x
  - Field gradient to droplet

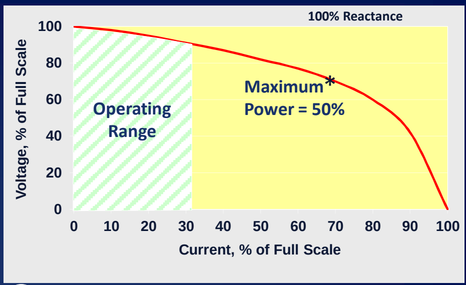

Threshold Voltage
Webinars
10% BS&W
Threshold Voltage = 12,500 volts
DC Gradient = 40,000 volts/foot
Dry Oil
Secondary Current, ma
Secondary Voltage, kilovolts
0
1
2
3
4
5
6
7
0
10
20
30
40
SPE


Electrostatic Field Effect
Webinars
Applied Voltage
16,000
12,000
8,000
4,000
0
Critical Voltage
V1
V2
SPE


High Reactance Power Unit
Single Phase, 100% Reactance
Webinars
Current Transformer
100% Reactor
Diodes
Secondary Voltage
Primary Voltage
Taps
200–3,000 VOLTS
100 V Tertiary
Ground
SPE

## High Reactance Performance

Conventional Transformer Protection




Electrostatic Products
Chapter 2

## Electrostatic Products

**Dehydrators:**

- Low Velocity AC
- Deep Field AC
- AC/DC
- Modulated AC/DC
- High Frequency AC/DC

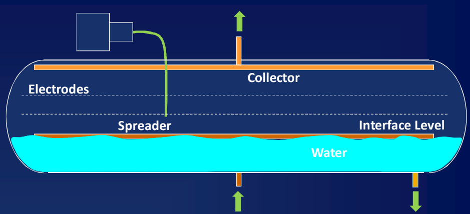
**Desalters:**

- Deep Field AC
- AC/DC
- Modulated AC/DC
- HF AC/DC

## Dehydrators & Desalters

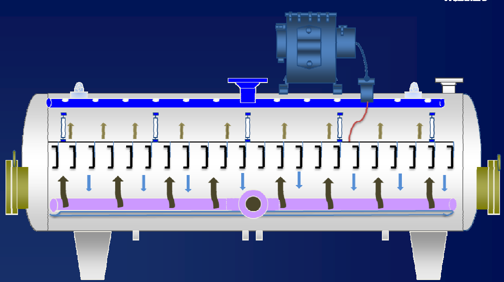
Dehydrators are always desalters, but desalters are not always dehydrators

## Low Velocity AC Dehydrator (ca. 1965)



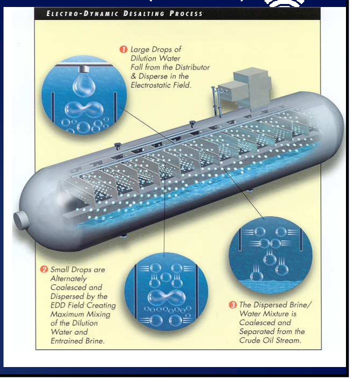

Note: The upper electrode is grounded while the lower electrode is energized by the AC field.

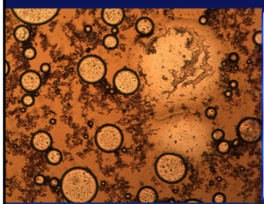
## Dual Polarity Desalter (ca. 1972)

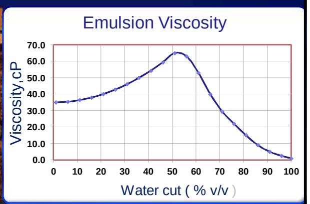


## Electro-Dynamic Desalter (ca. 1988)

- Uses AC/DC field
- Composite electrodes
- 60 kV power unit
- Load Responsive Controller
- Two stages of desalting in a single vessel



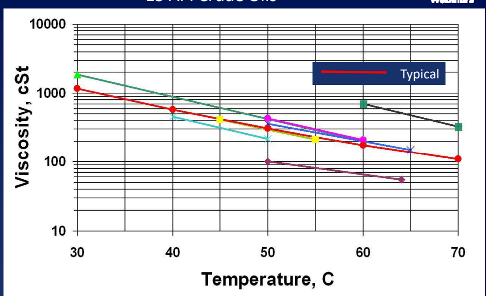





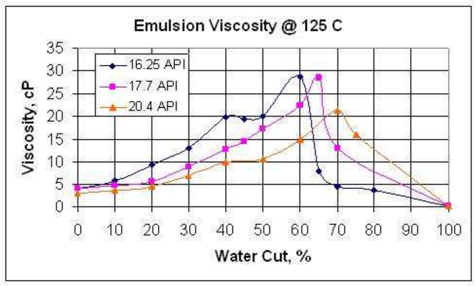

## Oil-Water Properties
## Chapter 3

## Viscosity vs. Temperature

~15 API Crude Oils



## Emulsion Viscosity




## Interfacial Tension

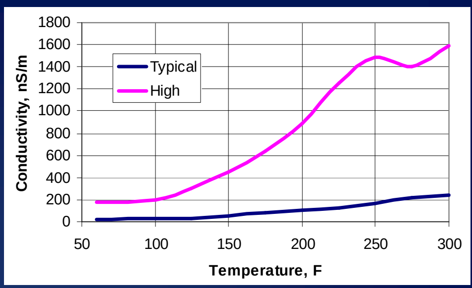
- Numerous Dependencies
  - Temperature
  - Fine solids
  - Water pH
  - > Water-soluble organics
  - > Chemical additives
- Ranges from 10 to 35 dynes/cm

  **Average ~ 24 - 28 dynes/cm**
  - Reduced by temperature
  - Reduced by demulsifiers
  - Reduced by electrostatic forces

## Oil Conductivity

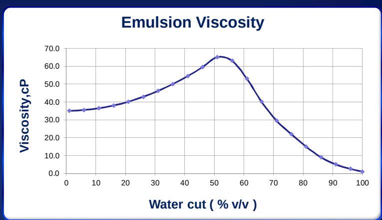
- Emulsion stability is not dependent on oil conductivity
- Modest oil conductivity may promote droplet charge and coalescence
- High oil conductivity may limit electrostatic field strength

## Oil Conductivity vs Temperature

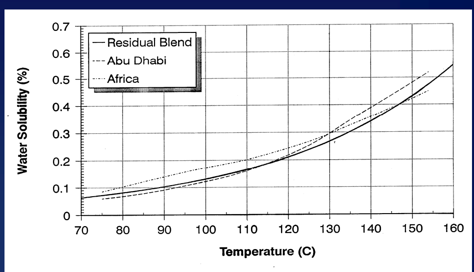



## Inversion Point

- Oil continuous below the inversion point
- Water continuous above the inversion point

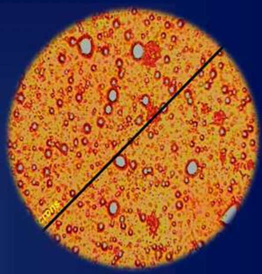



## Water Solubility in Oil



## Emulsions

- Mechanical
- Surfactant
- Solids
- Polymer

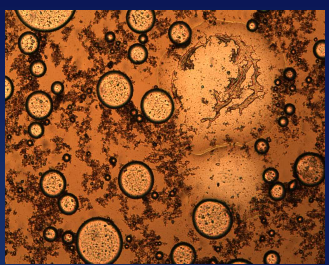


## Emulsion Types

- **Mechanically formed emulsion**
  - Formed by high shear devices, pumps, valves, etc.
  - Easily reversed by electrostatics
- **Surfactant formed emulsion**
  - Formed by the presences of in-situ chemicals
  - Requires an effective chemical program to reverse
  - Benefits obtained by synergy with electrostatic field
- **Solids formed emulsion**
  - Created by the in-situ solids—very stable emulsion
  - Must be handled by use of chemicals and electrostatic
  - Improved vessel hydraulics may be beneficial

## Complex Emulsions

**16 API SAGD DilBit**



$H_2O$ in Oil in $H_2O$

vs.

$H_2O$ in Oil

vs.

Oil in $H_2O$

# Chemicals
Chapter 4

## Chemicals

- Demulsifiers
- Clarifiers
- Biocides
- Scale inhibitors
- Corrosion inhibitors
- Wax inhibitors
- Asphaltene stabilizers
- Organic acids
- Etc.

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## Partnership for Droplet Growth

- *Chemicals Remove the Barriers…*

- *Electrostatics Provide the Muscle…*
- *Hydraulics Provide the Environment …*

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## Process Synergies

*Chemicals – Electrostatic Fields – Hydraulics*

- **Coagulation**
  - Requires chemical reaction
- **Flocculation**
  - Assisted by electrostatic forces
- **Sedimentation**
  - Depends upon vessel flow regime, drop size, and viscosity

## Electrostatic Susceptibility Tester

- Graphically displays electrostatic coalescing process.
- Evaluates demulsifiers using small samples.
- Qualitatively predicts an oil's electrostatic treatability.

## Comparative Results

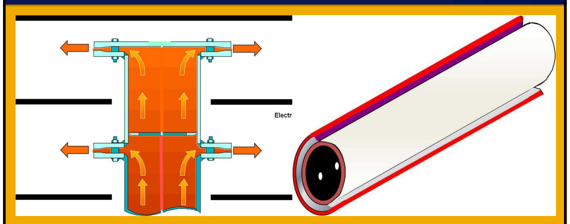
19.5° API Brazilian Crude

| Chemical | Bottle Test | Electrostatic Bench Test |
|---|---|---|
| Best Performance | Water in Oil<br>% By Difference | BS&W<br>Measured % |
| A | 2.2 | 2.12 |
| B | 4.6 | 2.01 |
| C | 5.3 | 1.62 |
| D | 5.7 | 1.20 |
| E | 6 | 2.35 |

## Comparative Results

33.3° API Japanese Refinery Feedstock

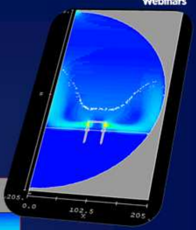
| Chemical | Bottle Test | Electrostatic Bench Test |
|---|---|---|
| Best Performance | Water in Oil % By Difference | BS&W Measured % |
| F | 0.5 | 0.30 |
| G | 1.0 | 0.31 |
| H | 1.5 | 0.15 |
| I | 2.0 | 0.41 |
| J | 2.5 | 0.35 |

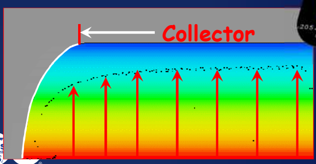


Hydraulics
Chapter 5

## Hydraulics

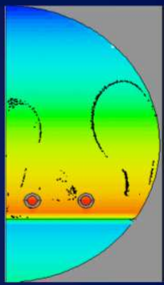
- Emulsion Spreaders
- Oil Collectors





## Vessel Flow Regime

- Inlet Distributor (Spreader)
- Outlet Collector
- Maximize Retention Time
- Reduce Internal Recirculation



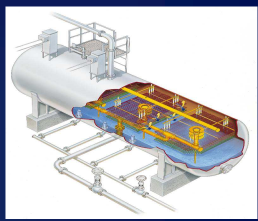
## **Outlet** Collectors

- Multiple Orifice Devices
  - *Perforated pipes*
  - *Perforated trays*
- Conclusions
  - *Good distribution requires full length collectors*
  - *Type of device less critical than inlet*

Desalting
Chapter 6

## Desalting

- Washwater
- Pressure drop
- Multistage
- Water recycle
- Crystalline salt

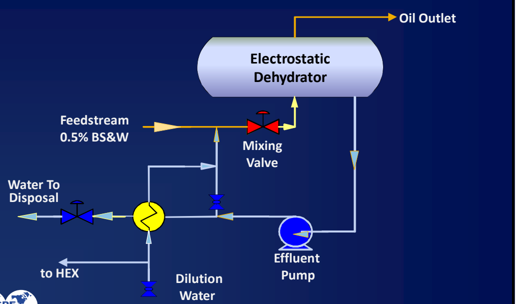


## Why Desalt the Crude ?

- Meet Transportation Specifications
- Minimize Fouling
  - Heat exchangers
  - Crude oil furnace
  - Crude tower trays
- Reduce Corrosion
  - Distillation tower overheads
  - Condensers and receivers
- Reduced Catalyst Consumption
  - Less catalyst poisoning
  - Low catalyst degradation
- Flexibility of Operation
  - Ability to utilize "opportunity" crudes
  - Smoother change of crude slates
  - Increased ability to reprocess slops
- Improved Product Quality
  - Less sodium in residual oils
  - Improved asphalt quality
  - Higher coke quality

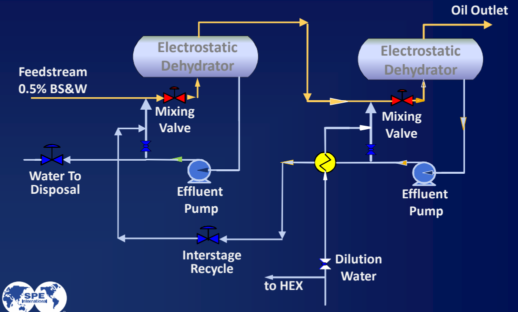
## Electrostatic Desalter

Single Stage Flow Diagram



## Electrostatic Desalter

Two Stage Flow Diagram




## Desalter Troubleshooting

### Excess Salt Carryover

- Inadequate contact efficiency
- Crystalline salt
- Excess water entrainment

### Excess Water Entrainment

- Unresolved Emulsion
  - Chemical dosage/type
  - Excess mixing valve ΔP
  - High pH
- Loss of electric field
- Improper field strength
- Channeling
- Turbulence

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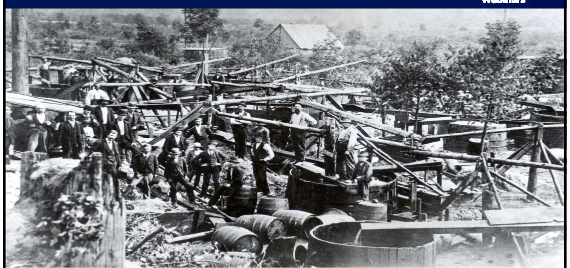
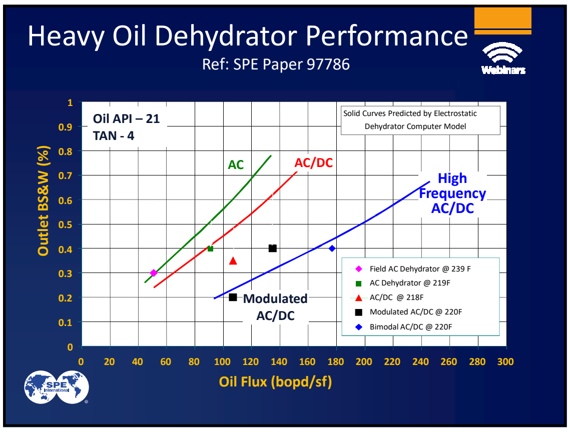
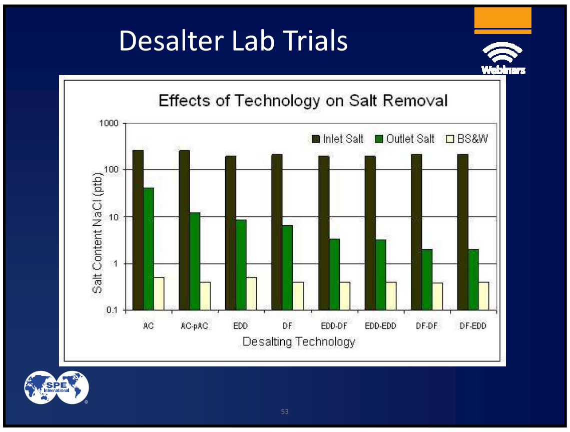
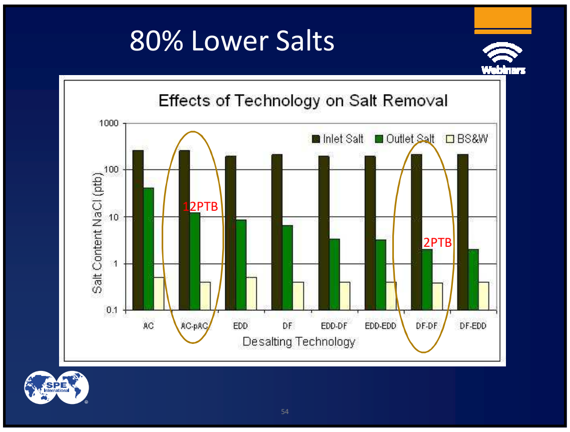


Performance
Chapter 7

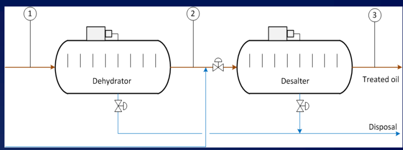

Heavy Oil Dehydrator Performance
Ref: SPE Paper 97786
Oil API – 21
TAN - 4
Solid Curves Predicted by Electrostatic Dehydrator Computer Model
AC
AC/DC
High Frequency AC/DC
Modulated AC/DC
Field AC Dehydrator @ 239 F
AC Dehydrator @ 219F
AC/DC @ 218F
Modulated AC/DC @ 220F
Bimodal AC/DC @ 220F
Outlet BS&W (%)
Oil Flux (bopd/sf)


Desalter Lab Trials
Effects of Technology on Salt Removal
Inlet Salt
Outlet Salt
BS&W
Salt Content NaCl (ptb)
AC
AC-pAC
EDD
DF
EDD-DF
EDD-EDD
DF-DF
DF-EDD
Desalting Technology


80% Lower Salts
Effects of Technology on Salt Removal
Inlet Salt
Outlet Salt
BS&W
12PTB
2PTB
Salt Content NaCl (ptb)
AC
AC-pAC
EDD
DF
EDD-DF
EDD-EDD
DF-DF
DF-EDD
Desalting Technology

## Improved Field Desalting

API 32.6
87,000 BOPD
PW Salinity
231,400 ppm
~7,000 PTB




| | BS&W | PTB | Mechanism |
|---|---|---|---|
| First Stage Dehydrator | 27.7% | 24,500 | Feed |
| Second Stage Dehydrator | 0.20% | 135 | Pure Dehydration |
| Third Stage Desalter | 0.015% | 7 | Desalting |

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## THANK YOU!

Mr. Gary W. Sams, P.E.
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Houston, Texas

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