AccelerateH2O
innovating water in Texas

Oil and Gas - Energy Sector

Technology Introductions: Markets, Opportunities, Investment Scenarios

F. Morris Hoagland, P.E., Director

Produced Water Society

AccelerateH2O
innovating water in Texas

Oilfield Waters

Enormous Volumes

- Source Waters
- HF Flowbacks (Completion Fluids)
- Produced Waters

AccelerateH2O
innovating water in Texas

Oilfield Waters

Largest Volumes

Produced Waters

Texas – 8B bbl/yr

Globally – >200B bbl/yr

AccelerateH2O
innovating water in Texas

Oilfield Waters

Produced Water

Conventional Wells

- Higher volumes/well
- More water from mature fields

Unconventional Wells

- Initial high flowback volume
- Produced water volumes much lower

AccelerateH2O
innovating water in Texas

Oilfield Waters

HF Source Water

High Volumes 100,000 – 300,000 bbl/well

- Fresh Water
  - Surface impoundments – Ranchers
  - Shallow wells
- Brackish Water - Deep wells
- Recycled Waters
  - Flowback waters
  - Produced waters

AccelerateH2O
innovating water in Texas

Oilfield Waters

HF Flowback water / Completion Fluids

100,000 – 300,000 bbl/well

- 5-50% of HF waters recovered
- High volumes during first week
- After four weeks, mostly formation water
- Most complex water to treat and reuse

AccelerateH2O
innovating water in Texas

Oilfield Waters

Water Reuse / Recycling

Pennsylvania - Marcellus Shale

- 90% Recycled
- 8 x Class II SWD Wells

Texas – Multiple Shale Plays

- 10% Recycled
- 14,000 Class II SWD Wells

AccelerateH2O
innovating water in Texas

Oilfield Waters

Markets for Oilfield Waters

Hydrofracturing

- Fresh to High TDS Waters

Fresh Waters Only

- Industrial
- Agriculture
- Municipal

AccelerateH2O
innovating water in Texas

Technologies for Treating Oilfield Waters

- Filtration
- Coalescers
- Membrane Systems
- Floc & Drop
- Electrocoagulation
- Chlorine Dioxide
- Advanced Oxidation
- DAF – Dissolved Air Floatation
- Reverse Osmosis
- Forward Osmosis
- MCV – Mechanical Vapor Compression
- MSF – Multi-stage Flash Distillation
- Evaporators
- HDH – Humidification/Dehumidification

Many technologies in our “Tool Box”

Treating Oilfield Waters

The end user determines water treatment quality and therefore cost

Three basic levels of treatment

1. Remove Oil & Grease and Suspended Solids
   a) Produced Water
   b) Flowback Water
2. Remove most Dissolved Solids
3. Go to Zero Liquid Discharge

AccelerateH2O
innovating water in Texas

Treating Oilfield Waters

The end user determines water treatment quality and therefore cost

Pretreatment

1. Remove Oil & Grease and Suspended Solids
   a) Produced Water $0.3 – 0.8/bbl
   b) Flowback Water $1 – 3/bbl

Upgrading

1. Remove most Dissolved Solids $5 – 8/bbl
2. Go to Zero Liquid Discharge $8 – 12/bbl

AccelerateH2O
innovating water in Texas

Technologies for Treating Oilfield Waters

Pretreatment

- Filtration
- Coalescers
- Membrane Systems
- Floc & Drop
- Electrocoagulation
- Chlorine Dioxide
- Advanced Oxidation
- DAF – Dissolved Air Floatation

Upgrading

- Reverse Osmosis
- Forward Osmosis
- MCV – Mechanical Vapor Compression
- MSF – Multi-stage Flash Distillation
- Evaporators
- HDH – Humidification/Dehumidification

Many technologies in our "Tool Box"

AccelerateH2O
innovating water in Texas

Pretreatment Technologies

Filtration and Coalescing

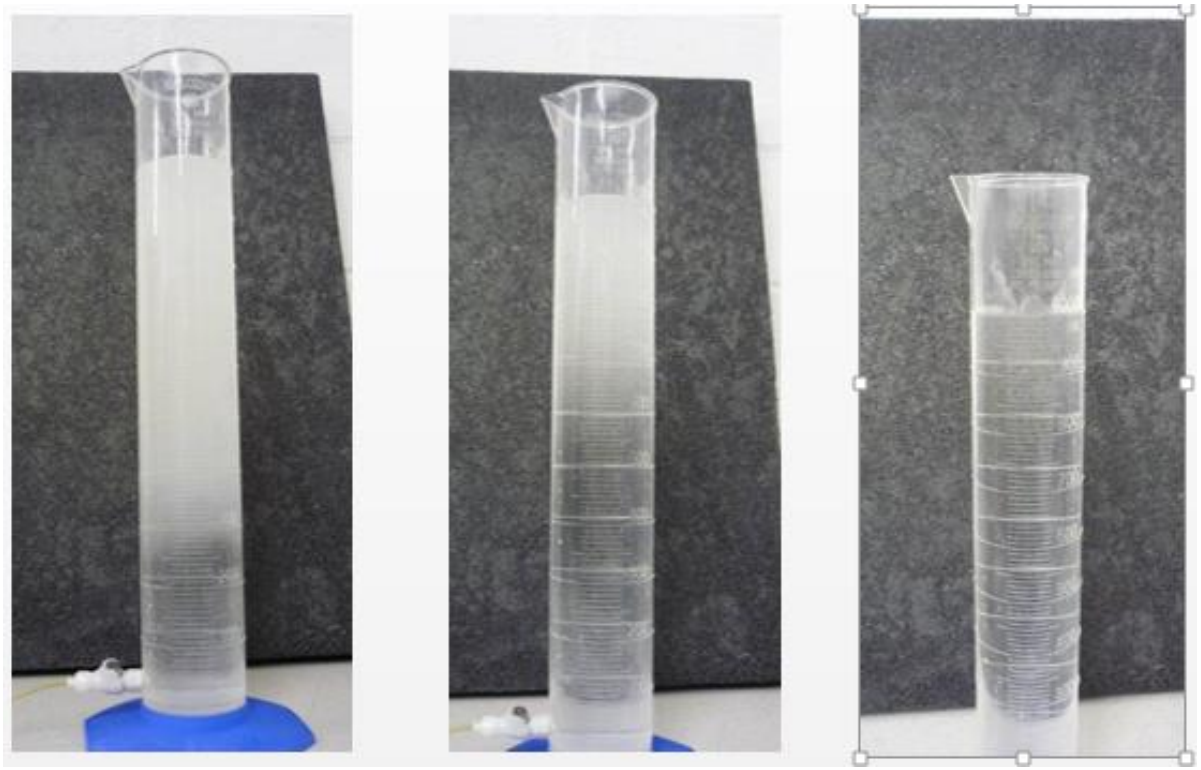
Membrane Systems

- Microfiltration
- Ultrafiltration

AccelerateH2O
innovating water in Texas

Pretreatment Technologies

Floc & Drop

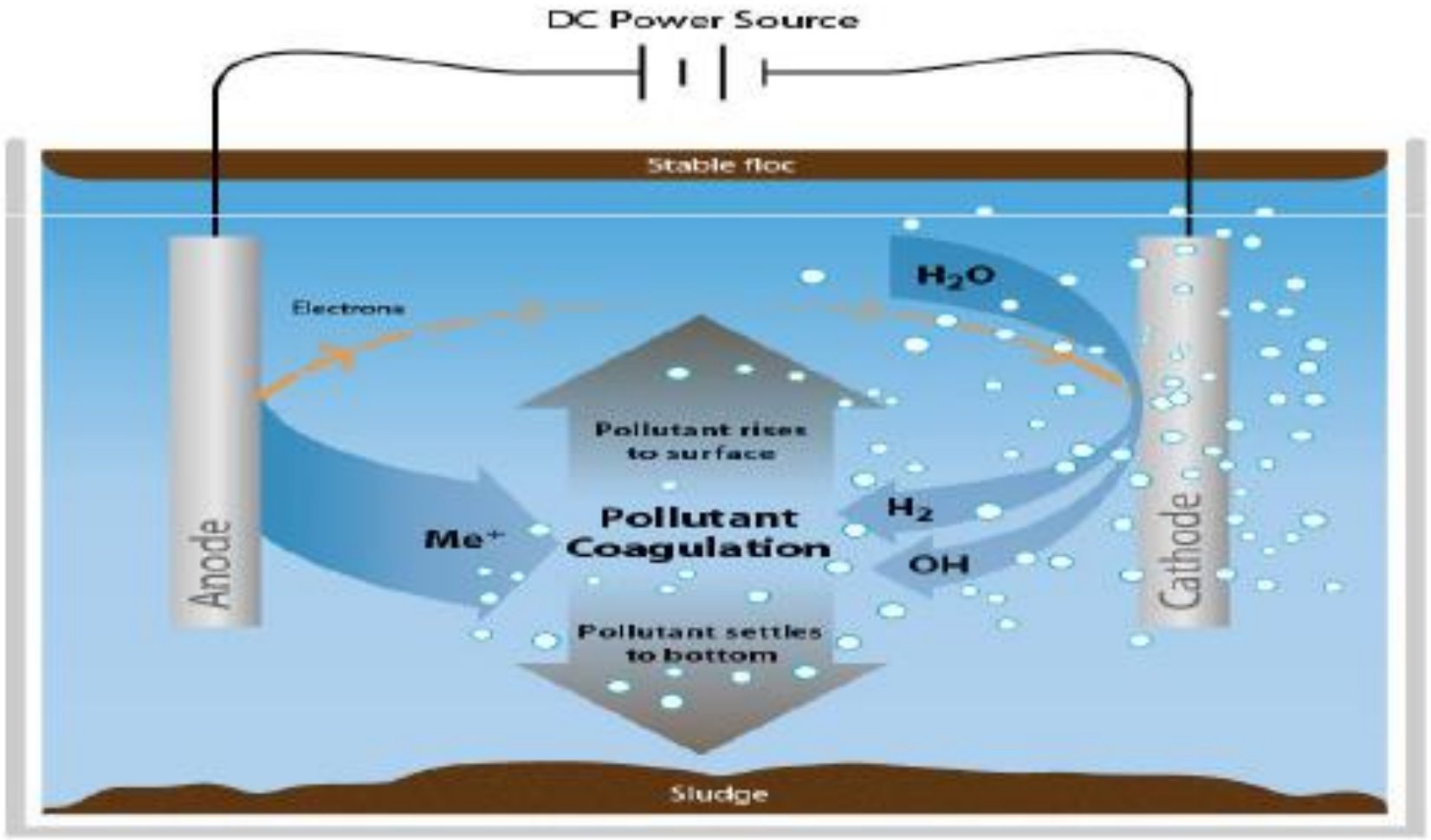


DAF – Dissolved Air Floatation

Pretreatment Technologies

AccelerateH2O
innovating water in Texas

Electrocoagulation



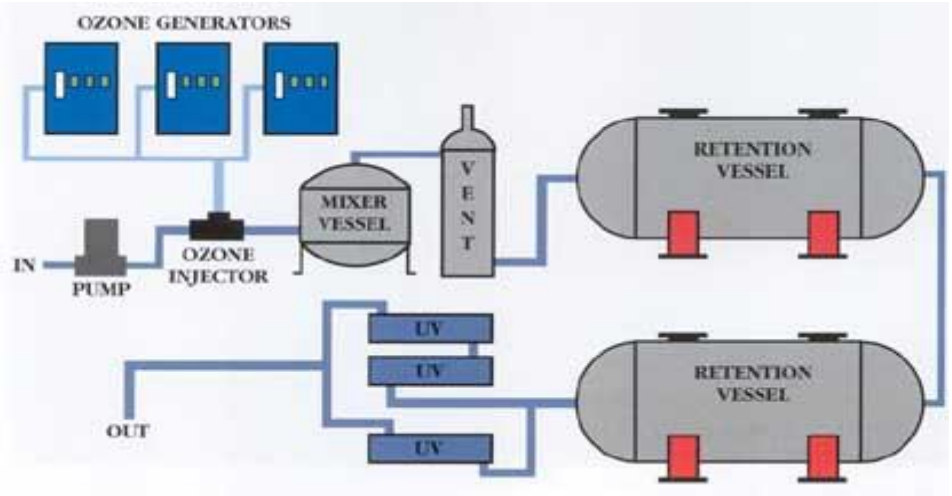
Pretreatment Technologies

AccelerateH2O
innovating water in Texas

- Electricity
- Water
- Sodium chlorite aqueous solution

On-site ClO2 generator

Chlorine Dioxide



Advanced Oxidation

Technologies for Treating Oilfield Waters

Other Technologies with niche application for HF waters

- Hydrocyclones
- Centrifuges
- Biological Treatment
  - Anaerobic
  - Aerobic
- Evaporation Ponds

AccelerateH2O
innovating water in Texas

Upgrading Oilfield Waters

Most end users require higher quality water

- Industrial
- Agriculture
- Municipal

This requires different technologies

- Higher CAPEX
- Higher OPEX

AccelerateH2O
innovating water in Texas

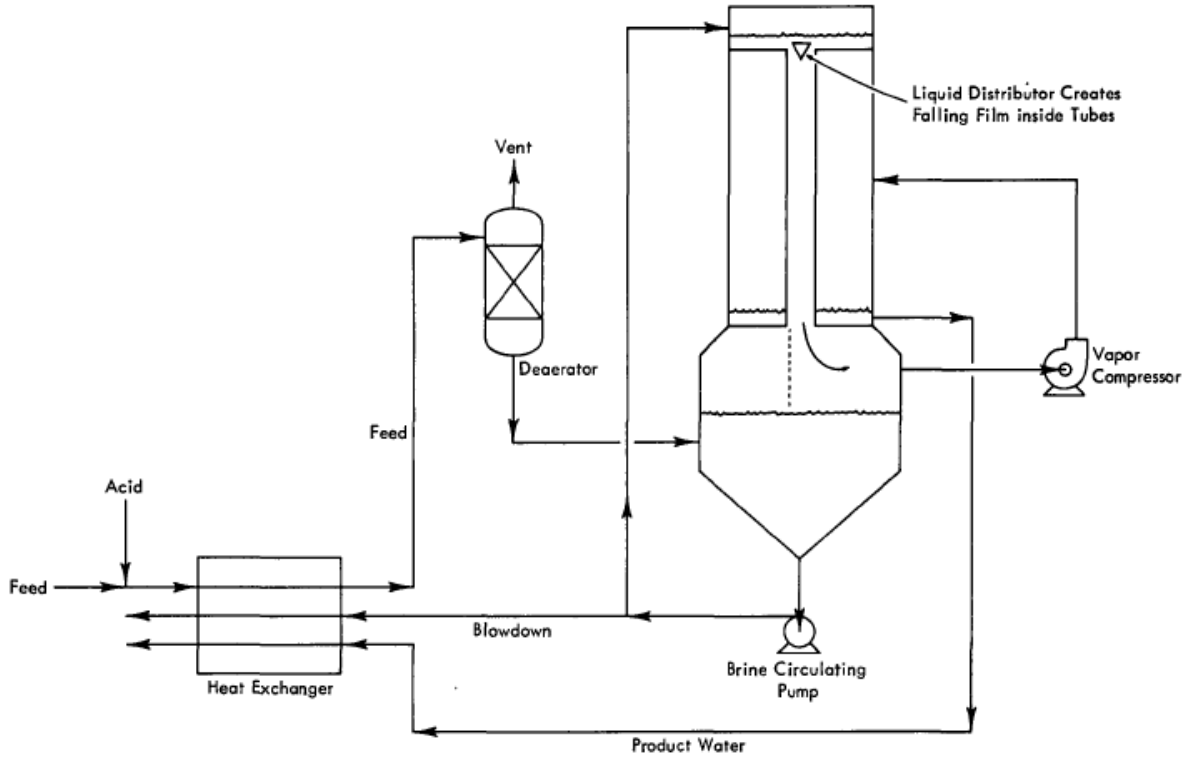
Upgrading Oilfield Waters

Reverse Osmosis

Forward Osmosis

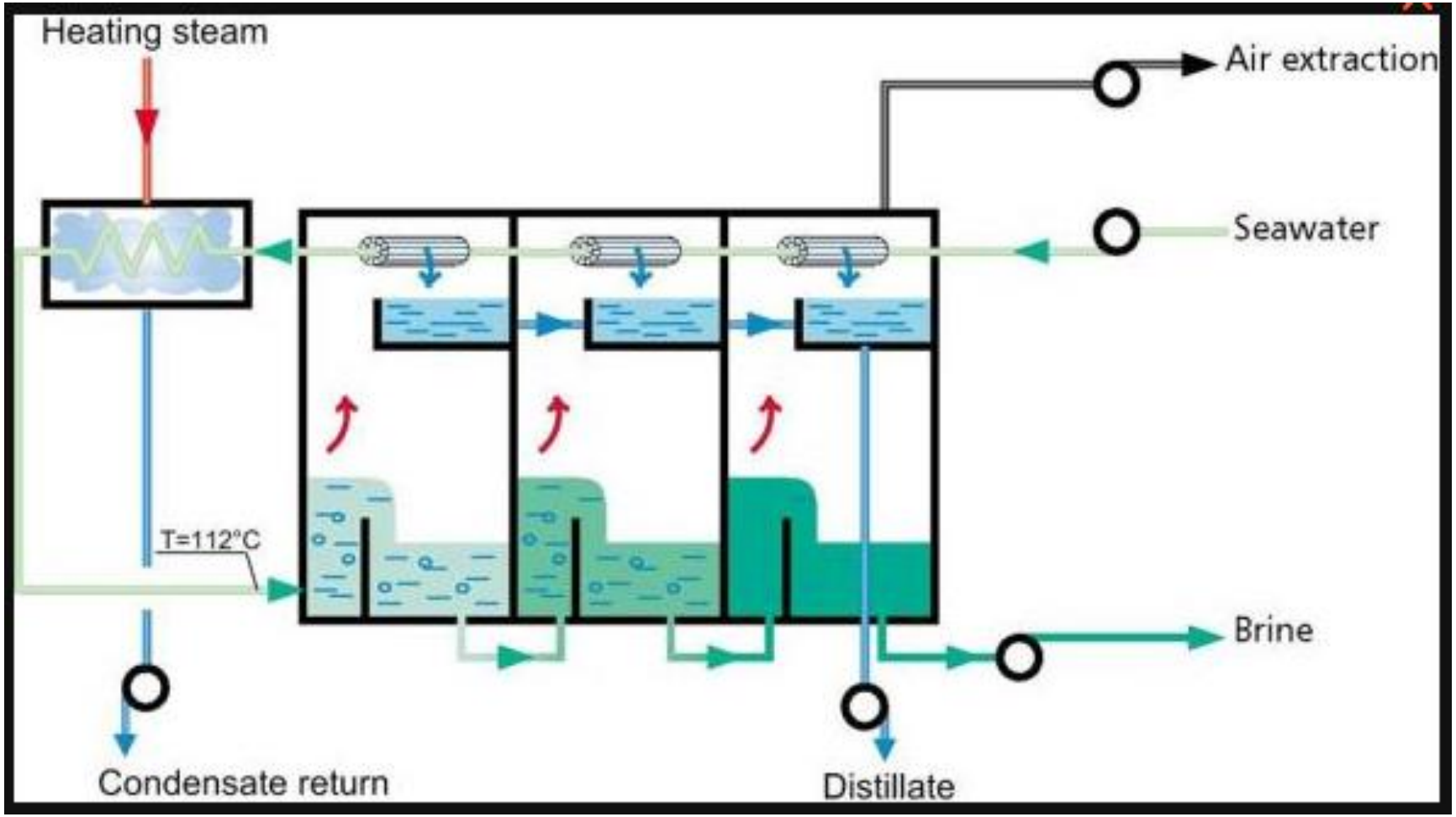
AccelerateH2O
innovating water in Texas

Upgrading Oilfield Waters



Mechanical Vapor Compression

Upgrading Oilfield Waters



Multi-stage Flash Distillation

AccelerateH2O
innovating water in Texas

Upgrading Oilfield Waters

Evaporators – Zero Liquid Discharge (ZLD)

AccelerateH2O
innovating water in Texas

Upgrading Oilfield Waters

Gradiant's 12,000 bbl/d Permian Basin Produced Water Treatment Plant

Humidification Dehumidification - HDH

AccelerateH2O
innovating water in Texas

Oilfield Waters

Technologies exist to upgrade poor quality oilfield wastewaters

What are the barriers to reusing more water?

1. High cost
2. Lack of incentives
3. No standards

Need for reasonable additional regulation?

AccelerateH2O
innovating water in Texas

Oilfield Waters

Recycling generates public benefits

- Seismic activity due to high volumes to SWD
  - OK, OH, CA
- Reduce trucking water
  - Less traffic, dust, and noise
  - Fewer accidents / lower liability
  - Less road damage
- Less competition for fresh water

AccelerateH2O
innovating water in Texas

Oilfield Waters

Is there a role for Government to create incentives for operators to recycling more water?

- Limit permitting of new SWD wells
- Require a percentage of flow back water to be recycled
- Require advance water management plans
- For non-isolated E&P, require piping water around field instead of trucking

AccelerateH2O
innovating water in Texas

Oilfield Waters

Example of Government Action

- March 2016 - Oklahoma Corporation Commission issued directive to SWD well operators
- Reduce injection volumes by 40%
- Immediately created demand for more wastewater recycling

AccelerateH2O
innovating water in Texas

Conclusions

- High volumes of wastewater
- Technologies exist
  - Recycle into HF
  - Upgrade other markets
- High cost - upgrading quality
- Greatest technology challenge – Low cost desalination
- Operators need incentives
- Regulatory action - opportunities

AccelerateH2O
innovating water in Texas

Thank you!