Oklahoma Water Resources Board
PW Feasibility Study Group
Evaporation Workshop

Oklahoma History Center
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Fountain Quail Energy Services
NOMAD and Modular Base Plant (MBP) Systems
Brent Halldorson, CTO
1. NOMAD Evaporators
2. Modular Base Plants (MBPs)
3. Energy Use, %-Recovery
4. Oklahoma Issues
5. Zero Liquid Discharge
Fountain Quail Energy Services

Pioneers...

✓ Recognized leaders in North America.
✓ First commercial recycler in shale wastewater.
✓ First recycling permit in Texas.
✓ First to meet Pennsylvania discharge criteria (Marcellus Shale).
✓ First evaporator in Alberta heavy oil (SAGD).
✓ Founding members of Texas Water Recycling Association (www.txwra.org).
✓ Now over 350 employees (significant growth through downturn).
NOMAD Technology

Fountain Quail’s patented evaporator technology overcomes challenges associated with oilfield wastewater recycling:

- Consistent, High Quality Distilled Water
- Compact, Low Height, Mobile
- High % Recovery
- Capable of Treating Highly Variable Wastewater
- Modular (low installed cost)
- High Energy Efficiency
- Reduced Fouling / Scaling
- Reliable and Serviceable

The Result: NOMAD System
Mobile Evaporator

NOMAD Capacity: 2,000bbl/d distilled water

NOMAD Technology

- Patented & Proven.
- Only system with >15yrs continual service in upstream O&G.
- Capable of treating wide range of wastewater with high recovery (80-90%).
Traditional Falling Film Design:

- Higher Installed Cost
  - Large equipment, requires assembly on site.
- Higher Operating Cost
  - Less efficient, higher hp, more chemicals
- Difficult to Service

Fountain Quail Design:

- Compact
- Efficient
- Reliable & Serviceable
NOMAD Exchangers

- Counter-current heat transfer = more efficient than falling film (co-current).
- Easy to open and clean – ideal for oilfield PW.
- Fountain Quail excels in markets where traditional evaporators fail.
Recycled Distilled Water

High quality distilled water is ideal for re-use.

Suitable for irrigation, re-use or environmental discharge.
NOMAD: The standard in generating freshwater from oil & gas produced water.

NOMAD Example 1
Barnett Shale Texas
Objectives:
- Generate freshwater for frac fluid. Direct to existing freshwater pit network.
- Use PW as source water – minimize use of ground/surface water.
- Re-use residual clean heavy brine (~9.8#) for well servicing.
NOMAD Example 1
Barnett Shale Texas

- Customer: Devon Energy
- Summary: Fountain Quail installed a total of 14 NOMAD™ sites.
- Timeframe: Nov 2004 – Dec 2013
- Volume Recycled: 20+ million bbls recycled back to freshwater.
NOMAD Example 2
Permian Basin, Texas

2 NOMAD™ site. Main power: natural gas.
NOMAD Example 3
Wolfcamp (Permian), Texas

2 NOMAD™ site
Wolfcamp (Permian)
TX Experience

• FQ had the $1^{st}$ recycle permit in TX – intense scrutiny from regulators. Perfect track record.
• New RRC Recycle Rules allow distilled water from thermal evaporation to be handled as freshwater (if kept within oilfield).
• This is a direct result of Fountain Quail NOMAD’s track record with the RRC over 10+ years of submitting water & air test results.
NOMAD Example 4
Marcellus Shale, Pennsylvania

Treatment for environmental discharge.

First system to meet Pennsylvania DEP discharge criteria (250mg/L Cl, 500mg/L TDS)
The NOMADs are designed for mobility. They can be deployed until a larger base plant is needed and then be moved into new areas.

The advantages of the Fountain Quail NOMAD technology apply to MBP plants as well.

- **Easy Cleaning and Service**: Entire system can operate at near capacity and a small portion can be in “clean-in-place” mode without shutting down.
- **Low Height**: Install in a building with overhead crane.
- **Modular Design**: System can be delivered in pre-fabricated skids.
- **Efficient**: High thermal efficiency in compact package.
30,000BPD Modular Base Plant

- Single (1) Vertical Separator Vessel
- Four (4) Pre-Fab Evaporator Modules
- Two (2) Pre-Fab Preheater Modules
- Two (2) Steam Compressors
30,000BPD Modular Base Plant
Cycle any 2 exchangers through “C-I-P” and continue to operate at 100% capacity.
Compact Installations

EnCana SAGD Oilfield Evaporator – Foster Creek, Alberta (Canada)
Feed: Oilfield Produced Water (direct from skim tank)
Product: Distilled Water (6usgpm) for boiler feed water

BP Brine Concentrator - Sarnia, Ontario (Canada)
Feed: 12-22wt% dilute salt brine (100 to 220usgpm)
Product: 26wt% concentrated brine & distilled water (42usgpm)
Sustainability is key.

Example: Start with NOMAD; graduate to base plant as need increases.
• To create a phase-change (liquid -> vapor) requires significant energy: **1,000BTU/lb**
  – Systems that boil steam to atm are very energy wasteful – tend to rely on stranded gas as fuel. Concerns about air emissions (BTEX, etc.).

• To **maintain boiling** requires far less energy:
  – NOMAD theoretical: **25BTU/lb** (1/40th)
  – NOMAD plant historical: **150BTU/lb**

• Some evaporator companies state “energy per feed bbl” then forget to mention that they get only 10% recovery... (1,000BBL in, 100 treated).
FIGURE 1. MVR Evaporator Recovery Based on Feed Gravity for NaCl Brine
Oklahoma Issues

• Very high TDS (often >200,000mg/L).
  – Makes economic recovery a challenge.
  – Lends itself to a crystallizer.
• If evaluating a XLER then managing salt becomes a dominant challenge.
• Offers potential beneficial reuse of salt (chemical feedstock, etc.).
• Discharge permits (NPDES)
  – 98th meridian bisects OK.
ZLD – the alternative to SWDs

• ZLD – “use the whole buffalo”.
• A mighty technical challenge dwarfed by a massive economic challenge.
• Salt becomes the elephant in the room.
• 10,000bwpd XLER – makes 160,000 ton/yr salt (Marcellus example at ~180,000mg/L feed).