Shell Exploration & Production

# Guidelines for the Selection of a Waterflood Deoxygenation Strategy

C. Deuel
Shell EPT-Projects
Houston, TX

J. Walsh, PhD
SEPCo
New Orleans, LA

17th Annual Produced Water Seminar
Hilton Houston NASA
Clear Lake, TX

Wednesday – Thursday
January 17 – 18, 2007

## Recommended Strategy:

- Design for full chemical oxygen scavenger as a base case

  (minimize CAPEX Size and Weight)

- Add mechanical deoxygenation in order to reduce OPEX
  - Where chemical oxygen scavenger is expensive or
  - may not work due to excessive cold temperatures
  - For Basis of Economics, use:
    - historical / real uptime figures
    - real operating costs including catalyst and other chemical costs

# Historical Involvement in Compact Deoxygenation:

## SeaJect - Extensive field trials

- Developed initially by Norsk Process Inc. in 1980's
  - Initial funding / interest by Conoco
- 1990 Shell testing on shore
- 1990 One week pilot field test on Cognac
- 1992/1993 One year Bullwinkle field trial in parallel train
  - review report - many problems, excessive downtime
- 1994 - 2001 Shell Ram-Powell waterflood - SeaJect on-line
  - many problems, excessive downtime
  - relying on chemical oxygen scavenger
  - extensive well tubing corrosion
- 1998 Axsia Serck Baker acquires SeaJect
  - claims that "system performs to expectations" based on Shell experience
- 2001 Shell selects SeaJect for Bonga
- 2001 Shell decommissions SeaJect on Ram-Powell

# Historical Involvement in Compact Deoxygenation:

## 2001 / 2002 Pivotal Years:

- SeaJect selected for Bonga & GA approved for construction
- Mars WF approved assuming compact deoxygenation
  - GA, weight & space constrained
- Shell acquires Enterprise, inc Bijupira-Salema
  - Minox selected by Modec / Alliance Engineering

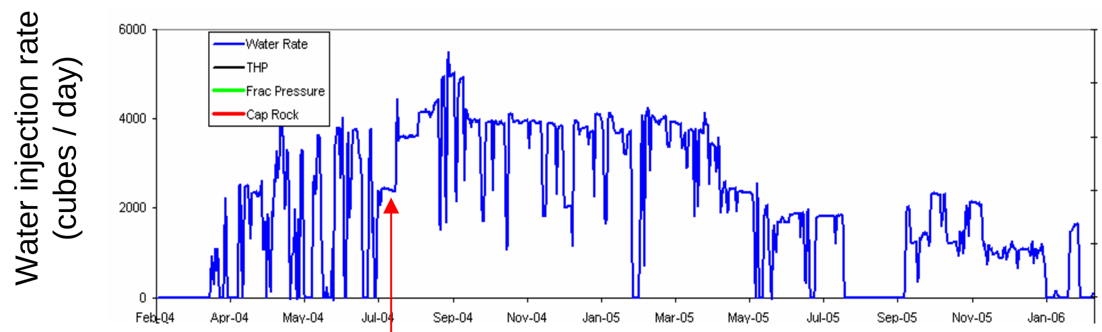
## Shell seeks BP (Mars partner) Advice:

- BP initial good experience with Minox
  - But those designs not representative
- Mustang "evaluation"
- Minox selected for several more BP waterfloods

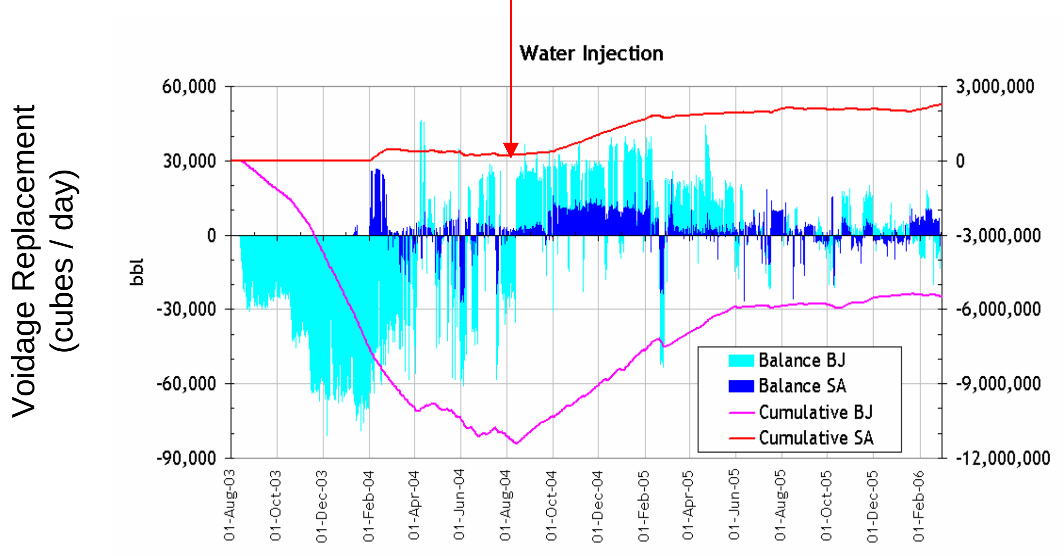
## Shell selects Minox for both Mars and Bonga:

- Failure of SeaJect, and no alternate in the wings
- No direct / first hand experience in Minox

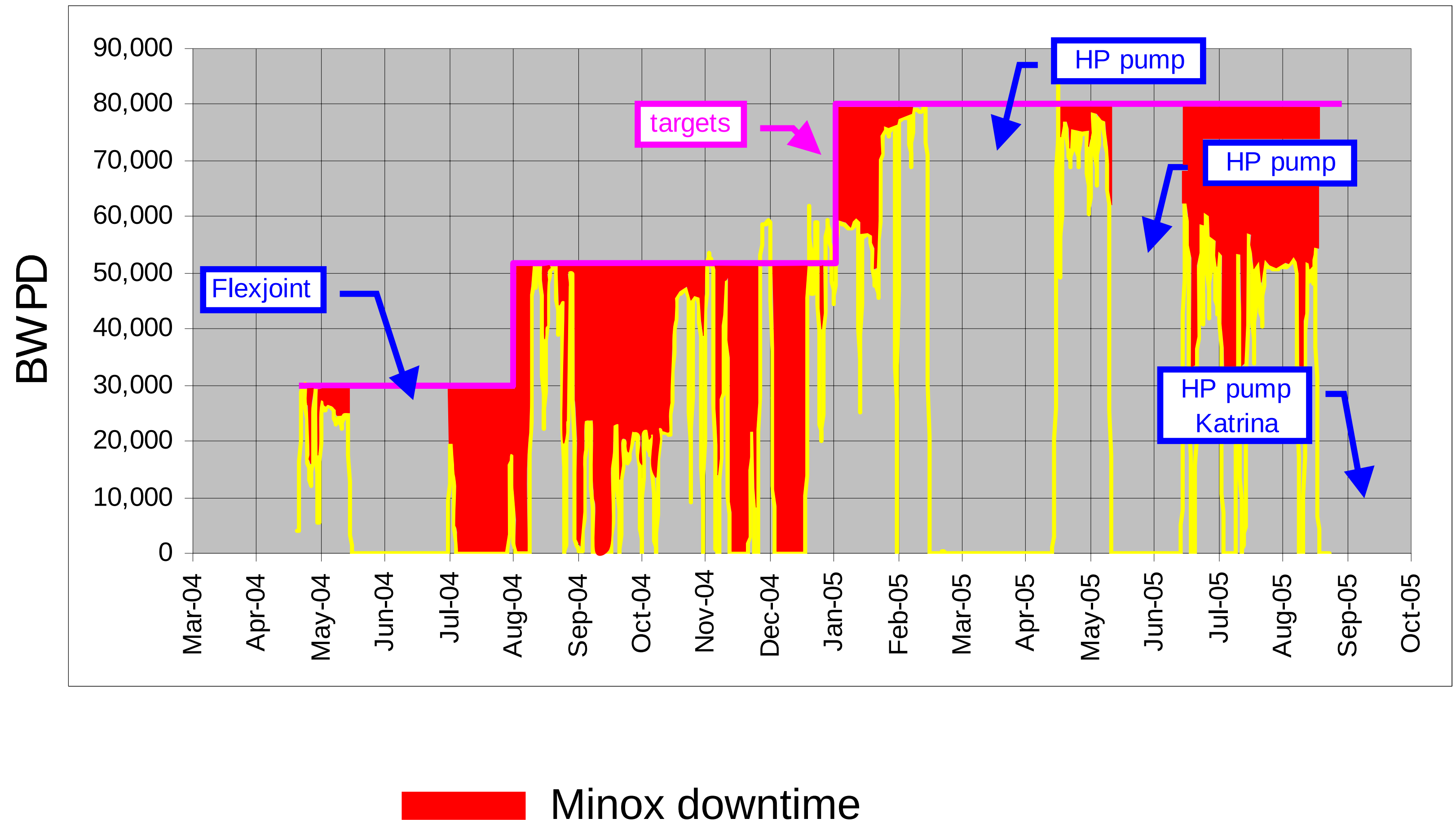
# Shell Brazil Bijupira-Salema water injection performance




**Bypass Minox –**
**Using full chemical scavenger instead**
**Dramatic Uptime Improvement**

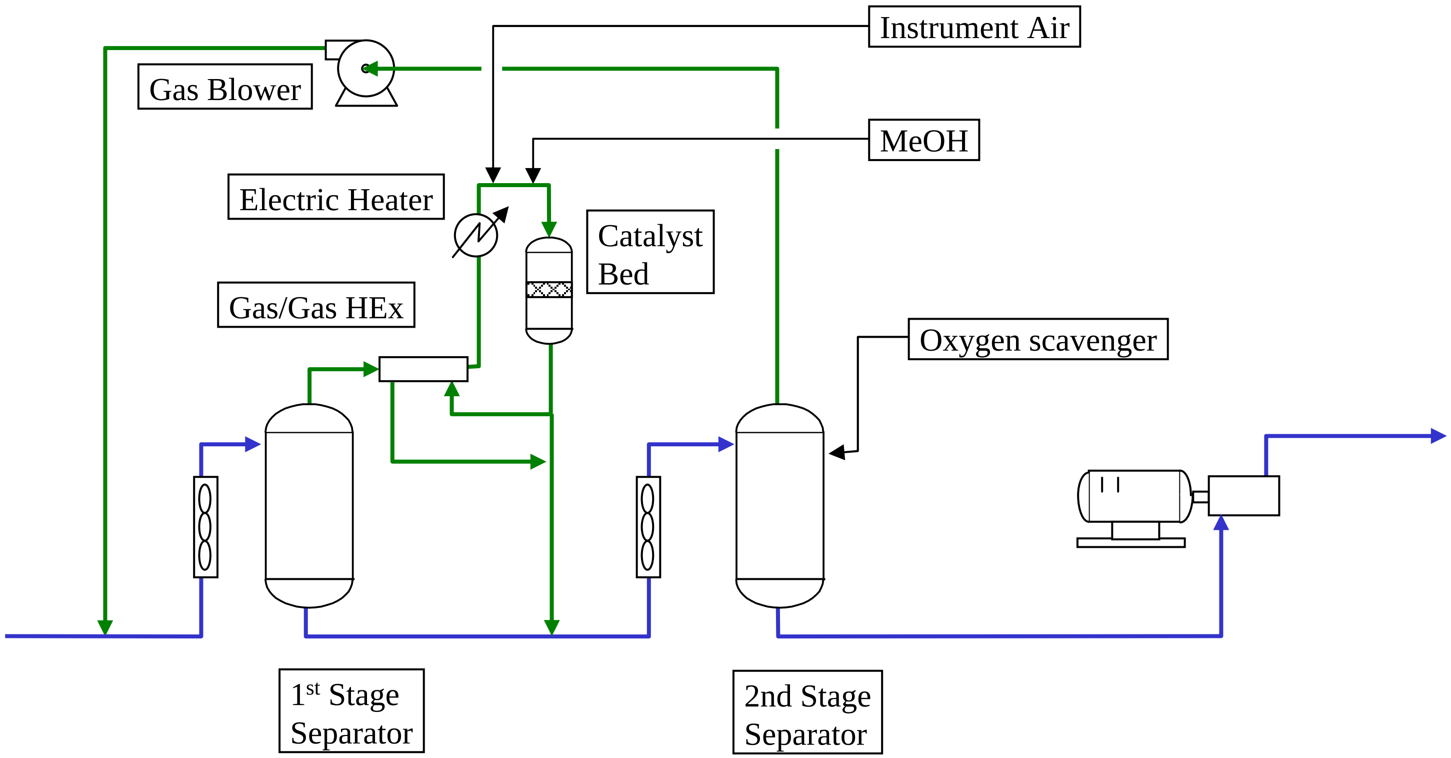


# Mars topsides performance



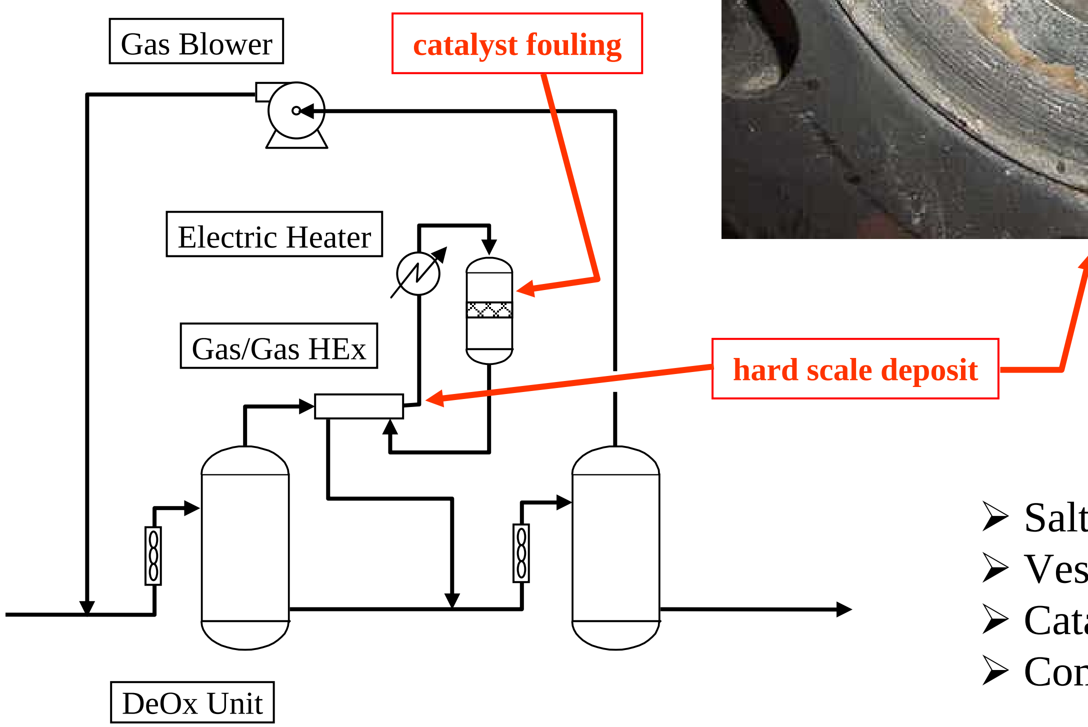

Minox: 40 % average downtime

## WF DeOx System – Common to all 3 DW WF:



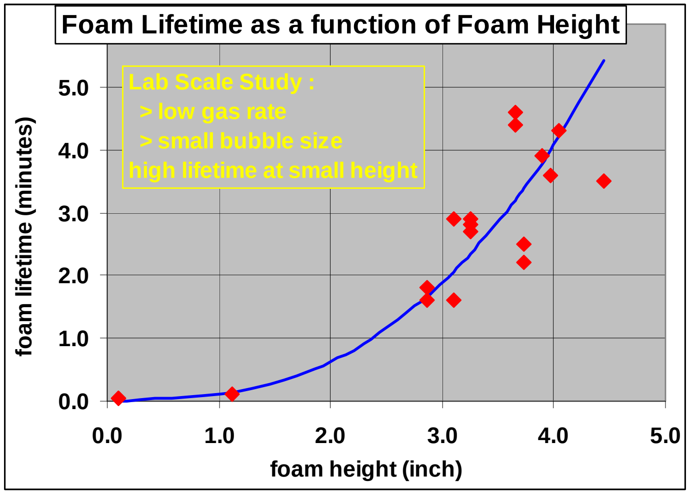

- Overall nitrogen / seawater flow is counter-current
- Local nitrogen / seawater flow is co-current
  - nitrogen / seawater mixing in static mixers
- High efficiency from:
  - small bubble size (high surface area, short gas diffusion length)
  - 2-stage counter-current process

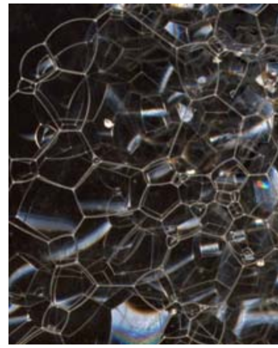
Problems w/
- Mars
- Bijupira-Salema
- Bonga




- Salt deposits
- Vessels full of foam
- Catalyst fouling / short catalyst life
- Compressor fouling / high maintenance

# DeOx Separator Vessel Sizing
# Should Account for Foam Height

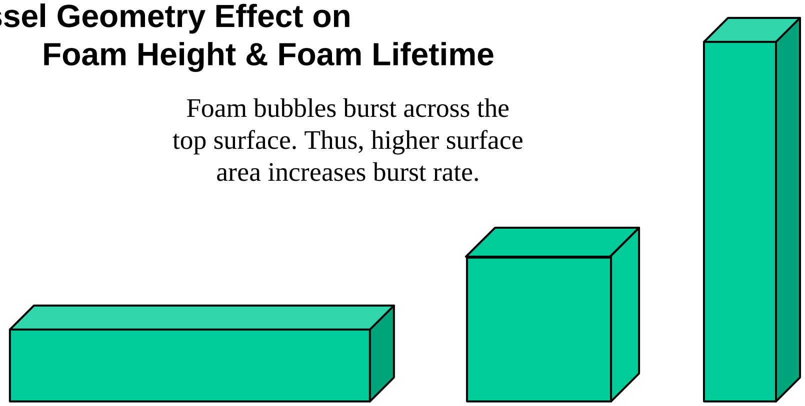


When upper layers burst, liquid drains into lower layers making them stronger. Thus, a tall foam is a strong foam.

## Vessel Geometry Effect on Foam Height & Foam Lifetime

Foam bubbles burst across the top surface. Thus, higher surface area increases burst rate.



| | | | |
|---|---|---|---|
| **Foam Volume ($ft^3$):** | **54** | **54** | **54** |
| **Surface Area ($ft^2$):** | **36** | **18** | **9** |
| **Foam Height (ft):** | **1.5** | **3** | **6** |
| **Foam Lifetime (minutes):** | **0.5** | **3** | **17** |

Vessel Design should include Foam Height:

$$H_V = H_O + \underline{H_F} + H_G$$

$H_O$ = height of oil section (retention time = 1 minute)

$H_F$ = height of foam section

$H_G$ = height of gas section (Shell spec)

$$H_F = V_F / A_V$$

$$V_F = k_1 k_F E_F F_o$$

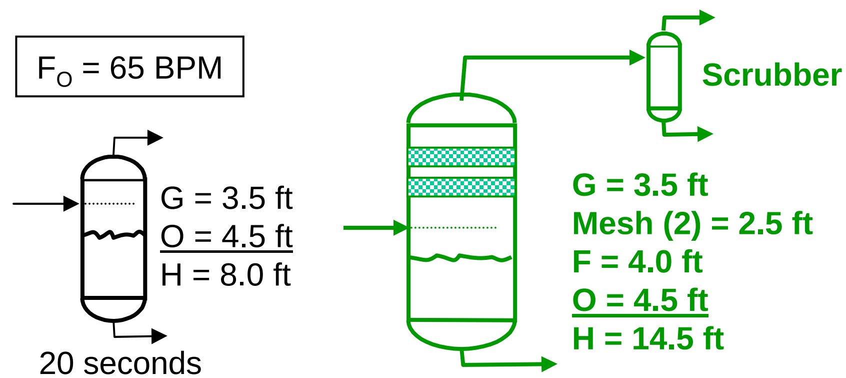
$k_1$ = constant

$k_F$ = Foam Height Geometry Factor (dimensionless)

$E_F$ = intrinsic Foam to Oil ratio ($ft^3$ foam/BPM)

$F_O$ = oil flow rate (BPM)

$F_O$ = 65 BPM




20 seconds water retention ID = 6 ft

**60 seconds water retention ID = 10 ft**

Other options:
Stripping tower
Vacuum tower
Even with these, break dependence on production uptime for power, gas, etc need to switch to chemical to achieve waterflood uptime

However with chemical only systems, need to have high quality injection equipment plant uptime, sparing, automated flow control, alarm measurement, etc.,
Need residence time, and tanks

Weight space cost comparisons logistics storage uptime
Bonga 95% +