Tension Leg Platform
Gas Lift

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• Deepwater TLP completions in the Gulf of Mexico present special challenges because of the water depths, pressures and environment.

• Because each of these completions are unique from one another, equipment is designed to meet specific parameters.

• There are many design variations for gas lift/chemical mandrels already available — I’m sure there’s more to come.

• The gas lift design process and specific equipment used in several deepwater installations will be presented today.
In some instances the riser sections of these completions must be unloaded. There are several methods used:

1. Most TLP’s production casing runs through the riser to the surface. Generally unloaded through gas lift mandrels placed in the production string.

2. Unload through a sliding sleeve placed in the gas lift injection line when production casing does not run to surface.

3. Unload through a control line installed in the riser section when production casing does not run to surface.
The method used in the gas lift design of deepwater wells is essentially the same as in other gas lift installations with a few other considerations such as:

- water depths
- production rates
- tubing sizes
- gas injection system pressures (KO & OP)
- Temperature profiles
- Special metallurgy
1. Water depths = 3,000’ to 6,000’
2. 1500 to 10,000 BLPD
3. 3.5”, 4.5” and 5.5” tubing
4. 1400 psi to 3200 psi kickoff pressure
5. 1400 psi to 3000 psi operating pressure
6. Temperature profiles; Shelf Well vs. Deepwater Well.
7. Inconel, Super 13 Chrome-110 and 13 Chrome-85 material
TYPICAL TEMPERATURE PROFILE FOR ONSHORE OR SHELF (SHALLOW WATER) OFFSHORE WELL
EXAMPLE of FLOWING TEMPERATURE PROFILE for DEEPWATER OFFSHORE
Reservoir information for initial and future production rates are evaluated with various nodal analysis programs (WellFlow, WEM, Prosper) for predicting:

- Optimum tubing size(s) for natural flow conditions
- Predicted reservoir pressure declines
- Gas lift performance (injection depth, injection pressure, injection rates, etc)
- Production system upgrades
• Other parameters can effect the gas lift design and gas lift equipment in deepwater TLP well completions. For this presentation, there are three (3) examples:
  
  - EXAMPLE (1) __ Casing restrictions & H2S Environment
  
  - EXAMPLE (2) __ 2940 ft Water Depth, Casing & Liner restrictions, gas injection pressure upgrade from 1400 psig to 2950 psig
  
  - EXAMPLE (3) __ 3400 ft Water Depth, Casing restrictions, gas lift design & mandrel spacing for unloading purpose
EXAMPLE (1)

- Six control lines are run in the well. 8-5/8” casing is run to 9207’ MD, 7-5/8” to 9300’ and a 5.5” production liner run to depth.

- Production tubing is 4” 10.9# from 0 to 9000’.

- SBHP = 3000 psi.

- Well is located in a water flood field and future H2s production is a possibility. Metallurgy for tubing and accessories is 25 Chrome and Inconel.
PROPOSED MECHANICAL SKETCH

Completion Design Summary

One perforated, gravel packed completion is installed in the N sand. High rate acid jobs and gravel packs were pumped to achieve low skin. 3 1/2" 22 chrome production tubulars are installed due to the H2S expected. A permanent downhole pressure gauge (i.e., PDG) will provide continuous reservoir pressure information. A 4-1/16" bore Xmas tree (10 ksi WP) utilizes a single wing and choke with a 6" Coflexip flow line leading to the TLP hard piped flow line. The production tubulars are installed through a large bore 10 3/4"x8 5/8" dual casing riser.
• The top gas lift mandrel (Hydraulic Valve) is located as deep as possible without going into the 5” liner.

• The depth of the hydraulic gas lift valve is not effective as the SBHP declines to 3000 psi or less.

• For deeper injection depths, retrievable, slimhole gas lift mandrels are positioned in the liner section every 600’ to the top of the packer. This 600’ spacing was selected because it would provide for optimum gas lift operations over a broad range of rates and pressures.
System Deliverability Plot

Fluid Properties:
- Oil Gr = 34.0 API
- Gas Gr = 0.66
- Water Gr = 1.06
- WLR = 50.0%
- GOR = 500.0 scf/bbl

Wellbore Data:
- WHP = 250.0 psig
- TVD = 13029 ft
- Corr = Hage/Brown
- Tbg = 15150
- Csg = 15151

Reservoir Data:
- Pr = 3000.0 psig
- BHT = 220.0 deg F
- PI = 8.0 b/d/psi
System Deliverability Plot

Fluid Properties:
- Oil Gr = 34.0 API
- Gas Gr = 0.66
- Water Gr = 1.06
- WLR = 50.0 %
- GOR = 500.0 scf/bbl

Wellbore Data:
- WHP = 250.0 psig
- TVD = 13029. ft
- Corr = Hage/Brown
  Tbg/4.000/15150
  Csg/0.00/15151

Reservoir Data:
- Pr = 3000.0 psig
- BHT = 220.0 deg F
- PI = 8.0 b/d/psi
• Because H2s production is possible, it was necessary to use a gas lift mandrel that would not allow any produced fluids to enter into the casing annulus in any circumstance, even if the pocket was empty.

• The DVX mandrel was developed to meet this criteria.

• External check valves are installed on the gas lift mandrel and injection gas passes through them into the valve pocket area and out into the tubing string.

• The external checks prevent any flow from the tubing back into the casing regardless of what type of valve or check mechanism if any, is loaded into the pocket. Valve changes can be done without any worry of tubing-to-casing communication path.

• Status: installation of equipment pending.
DVX mandrel features true secondary pressure barrier from tubing to casing provided by external check valves
• **EXAMPLE (2)**
  
  – Water Depth: 2940’
  
  – Production Casing: 7-58” 33.7# , 7-5/8” 39# and 5.5” 20#
  
  – Production Tubing: 4.5” 15.10# to SSCSV and 3.5” 10.2# to depth, 13 chrome 110 ksi
  
  – Gas lift operating pressures of 1400 psi and 2400 psi are evaluated
System Deliverability Plot

**Fluid Properties:**
- Oil Gr = 24.4 API
- Gas Gr = 0.7
- Water Gr = 1.06
- WLR = 80.0%
- GOR = 925.0 scf/bbl

**Wellbore Data:**
- WHP = 300.0 psig
- TVD = 16537 ft
- Corr = Hage/Brown
  - Tbg/4.500/17745
  - Csg/7.63/17888

**Reservoir Data:**
- Pr = 6000.0 psig
- BHT = 181.0 deg F
- PI = 5.0 b/d/psi
System Deliverability Plot

Fluid Properties:
- Oil Gr = 24.4 API
- Gas Gr = 0.7
- Water Gr = 1.06
- WLR = 80.0 %
- GOR = 925.0 scf/bbl

Wellbore Data:
- WHP = 300.0 psig
- TVD = 16537. ft
- Corr = Hage/Brown
- Tbg/4.500/17745
- Csg/7.63/17888

Reservoir Data:
- Pr = 5500.0 psig
- BHT = 181.0 deg F
- PI = 5.0 b/d/psi
• The hydraulic valve at 6208’ is used with the operating pressure of 1400 psi.

• Future platform plans call for upgrading gas injection system to a 2950 psi operating pressure.
• The gas lift mandrels at 7586’, 10409’ and 15433’ will be utilized if the operating casing pressure is increased to 2950 psi; under the assumed production rates of 6500 to 8000 blpd.

• Status: Shut in due to storm damage.
### Engineering Data

<table>
<thead>
<tr>
<th>Size</th>
<th>3.5 SBRO-2A 10.2 PPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Major diameter</td>
<td>5.313 inch/mm</td>
</tr>
<tr>
<td>(B) Minor diameter</td>
<td>NA inch/mm</td>
</tr>
<tr>
<td>(C) Drift diameter min. mandrel ID</td>
<td>2.637/66.8 inch/mm</td>
</tr>
<tr>
<td>(D) Overall length</td>
<td>113.0 inch</td>
</tr>
<tr>
<td>(E) Sleeve to pocket</td>
<td>60.00 inch</td>
</tr>
<tr>
<td>(F) Sleeve I.D.</td>
<td>2.716 inch</td>
</tr>
<tr>
<td>(G) Upper packing bore</td>
<td>1.558 inch</td>
</tr>
<tr>
<td>(H) Lower packing bore</td>
<td>1.496 inch</td>
</tr>
</tbody>
</table>

### Running tool
- RK-1

### Pulling tool
- 5/8 JDS

### Kickover tool
- 3.5 OM, TP, KOT-2

### Latches
- RK, RM, RKP, RKS

### Theoretical values
- **Yield**
  - Internal pressure PSI: 9790
  - External pressure PSI: 9350
  - Material: 718 Inconel

- **Test**
  - Internal pressure PSI: 8560
  - External pressure PSI: 8180
  - Yield strength PSI: 110000

- **Working**
  - Internal pressure PSI: 7500
  - External pressure PSI: 7160

### Mandrel API 11 V1 classification
- 2

### Thread blank I.D.
- 74.2 mm

### Standard service
- Class 2: Standard service

### Normal service
- Class 3: Stress corrosion cracking service per NACE MR-01-75

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![Diagram](image-url)
EXAMPLE (3)

- Water Depth: 3400’
- Production Casing: 8-5/8”
- Production Tubing: 4.5”
- Gas lift operating pressure 1800 psi
- Based on information supplied by operator for current and future reservoir parameters, an unloading gas lift mandrel spacing was installed
- STATUS – currently flowing on its own, waiting on rig move so wireline operations be done
**System Deliverability Plot**

**Fluid Properties:**
- Oil Gr = 27.0 API
- Gas Gr = 0.765
- Water Gr = 1.06
- WLR = 0.0%
-GOR = 950.0 scf/bbl

**Wellbore Data:**
- WHP = 392.0 psig
- TVD = 19142 ft
- Corr = Hage/Brown
  - Tbg/4.500/20259
  - Tbg/2.875/20506
  - Csg/8.63/20526
  - Csg/8.63/20850

**Reservoir Data:**
- Pr = 7342.0 psig
- BHT = 182.0 deg F
- PI = 16.64 b/d/psi
System Deliverability Plot

FLUID PROPERTIES:
- Oil Gr = 27.0 API
- Gas Gr = 0.765
- Water Gr = 1.06
- WLR = 5.0%
- GOR = 891.0 scf/bbl

WELLBORE DATA:
- WHP = 392.0 psig
- TVD = 19142. ft
- Corr = Hage/Brown
- Tbg/4.500/20259
- Tbg/2.875/20506
- Csg/8.63/20526
- Csg/8.63/20850

RESERVOIR DATA:
- Pr = 6020.0 psig
- BHT = 182.0 deg F
- PI = 16.64 b/d/psi
Pressure Profile

Fluid Properties:
- Oil Gr = 27.0 API
- Gas Gr = 0.765
- Water Gr = 1.06
- WLR = 5.0%
-GOR = 891.0 scf/bbl

Wellbore Data:
- WHP = 392.0 psig
- TVD = 19142 ft
- Corr = Hage/Brown
- Tbg/4,500/20259
- Tbg/2,875/20506
- Csg/8.63/20526
- Csg/8.63/20850

Rate = 7800.0 bbl/d
• Summary

– As can be seen in the gas lift deliverability plots, gas lift had little impact based on original reservoir data. An unloading design was therefore chosen in the event the well loaded up. An unloading rate of 2000 BFPD was used to space out the unloading mandrels. Had the current reservoir data been used to design the gas lift spacing, a closer mandrel spacing would have been used in order to optimize production with gas lift. The new deliverability plot indicates an increase of 500 BFPD with 4 MMSCF of input gas at a depth of 6,600'.