Investment Trend and Technology Development Requirements
Traditional Gas Lift Operations to 2,500* PSI Pso

HP Gas Lift Operations to 5,000 PSI Pso

- Depth of Gas Injection

* 2,500 psi is the current operating limit of existing gas lift equipment
Why XLift™ in Deepwater and SubSea

- Application requirements are more aggressive
  - Higher injection pressures at greater depths are required to achieve desirable liquid production rates

- Reliability
  - Equipment that has been dynamically tested for endurance, integrity and reliability (includes liquid flow erosion, high volume gas injection and gas injection performance)

- Operational efficiency
  - Improved gas flow geometry stabilizes liquid production thereby increasing the run life of the system
XLift™ (eXtreme Lift) Gas Lift System Overview

• Fit-for-Purpose Gas Lift System
  • Significantly Improved Reliability and Efficiency

• Application – Deep Water / Sub Sea / High Pressure Gas Lift
  • Development Tested for High Reliability

• Newly Designed Gas Lift Valve and Side Pocket Mandrel
  • Orifice Valve Operating Pressure – 7,500 psi at Depth
  • IPO Valve Operating Pressure Range – 2,000 to 5,000 psi at Depth
  • Patented Edge-Welded High Pressure Balanced Bellows System
  • Optimized Injection Gas Flow Path for Improved Efficiency

• Positive Sealing Check Valve System
  • Tubing Pressure Integrity During ALL Phases of Operation

• Reliable Deeper Injection Depths
  • Higher Productions Rates Achievable
XLift™ (eXtreme Lift) Gas Lift System Benefits

- Analysis of Actual Well Data
- Deeper Gas Injection
- Increased Efficiency
- Reduced Lift Gas
- Increased Production
- Extended Late Life
- Well Integrity
Technical Specifications:
Injection Pressure Operated (IPO), 1-3/4” O.D., OAL w/ Latch = 34.063”
Operating Characteristics – 7,500 psi max, 350°F max / 32°F min
Bellows intensifier arrangement to reduce internal Nitrogen gas charge pressure
  - Maximum dome charged required to achieve 5,000 psi operation = 3,200 psi @ 32°F
Venturi Orifice Size Range – 8/64” to 20/64”
Material Body Parts – Inconel 925
Material O-Rings and Seals – Viton, with PEEK Backups
Material Bellows – Hastalloy c276/c22
Material Seat – Tungsten Carbide
Packing – Modified Campac – Carbon and MolyFilled Teflon w/ PEEK BU & SS RR
R-20 Valve and XLI Valve Comparison

**Traditional 1.5” R-20 IPO GLV**

- Max Dome N2 Charge = 2,500 psi
- Standard 3-Ply Monel Formed Bellows
- Floating Velocity Check Valve

**XLI 1.75” HP IPO GLV**

- Max Dome N2 Charge = 3,000 psi
- Bellows Intensifier Piston Design Allows a 3,000 psi Max Dome Charge to Achieve a 5,000 psi Valve Opening Pressure
- Venturi Orifice w/ Optimized Gas Flow Geometry

**Unique Pressure Balanced Liquid Filled Inconel Edge Welded Bellows Assembly**

**Minimal Load Rates**

**2X R-20 Dome Volume**
Bellows Comparison

- XLift Gas Lift Valve Inconel Edge Welded Bellows
  - Bellows Convolutions Created by Joining Individual Discs (OD & ID) by a Gas Tungsten Arc Weld (GTAW) Process

- Standard Mechanically Formed 3-ply Monel Gas Lift Valve Bellows
  - Bellows Convolutions Formed by Mechanical Compression of Tubular Material
XLift XLO Orifice Valve with Positive Sealing Check Valve

Technical Specifications:
1-3/4” O.D., OAL w/ Latch = 34.063”
Operating Characteristics – 7,500 psi max, 350°F max / 32°F min
Check Valve Test Pressure = 10,000 psi
Venturi Orifice Size Range – 8/64” to 32/64”
Material Body Parts – Inconel 925
Material O-Rings and Seals – Viton, with PEEK Backups
Venturi Orifice Material – Tungsten Carbide
Packing – Modified Campac – Carbon and Moly Filled Teflon w/ PEEK BU & SS RR
XLift XLO Orifice Valve Dynamic Gas Flow Test

Gas Lift Valve Test - Upstream Pressure at 2500 psi
Test Flowrate and Pressures

Chart 1.0 (Gas flow test with 2500 psi upstream pressure)
**Venturi Orifice**
- Venturi Nozzle (various sizes available)
- Gas Entry Holes Tapered to Nozzle Inlet
- Optimized Gas Flow Path
- Critical Flow Achieved with 10% delta pressure

**Reverse Flow Check Valve**
- Normally Closed
- Positive Seal, Only Open During Gas or Fluid Flow from Casing to Tubing
- Metal-to-Metal Seal Surfaces, No Elastomers
- Due to Unique Geometry, Flow Velocity Does Not Affect the Check Dart Sealing Surface
- 10,000 PSI Sealing Pressure (Working Pressure)
- Anti-Rotation Feature Eliminates Velocity Spinning
Comparison of CFD* with Erosion Test Results

- Excellent agreement in location of erosion effects.
- Sealing surfaces are protected by flow path design.
- Leak rated after erosion testing of less than 35 scfd

* Computational Fluid Dynamics
Note the appearance of 3 zones of surface finish. Zone 1 extends to a diameter of approximately 0.6 inches with a surface finish of 63ra. Zone 2 extends to a diameter of approximately 0.9 inches with a surface finish of 32ra. Zone three has been unaffected by the erosive flow (and includes the lapped sealing surface.)
### XLO XLift Orifice Valve Liquid Flow Test

#### Fluid Unloading Qualification Test – 800 Barrels at 1.5 BBL/Min

<table>
<thead>
<tr>
<th>Test #</th>
<th>Date</th>
<th>Time From</th>
<th>Time To</th>
<th>Type of Test</th>
<th>PSI</th>
<th>Amb. temp °F</th>
<th>Leak Rate (scf/hr)</th>
<th>Gal/Min</th>
<th>BBL/Min</th>
<th>Gallons Total</th>
<th>BBL Total</th>
<th>BBL Tested</th>
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<tr>
<td>Initial</td>
<td>01/16/06</td>
<td>1:00p</td>
<td>1:20p</td>
<td>Leak</td>
<td>101</td>
<td>61.1</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>01/17/06</td>
<td>6:00</td>
<td>8:40</td>
<td>Flow</td>
<td>500</td>
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<td>54.3</td>
<td>1.294</td>
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<td>101</td>
<td>66.1</td>
<td>0</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>2</td>
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<td>12:00</td>
<td>Flow</td>
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<td>82.9</td>
<td>n/a</td>
<td>54.3</td>
<td>1.293</td>
<td>17591.9</td>
<td>418.85</td>
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<td>n/a</td>
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</tr>
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<td>1:13p</td>
<td>3:50p</td>
<td>Flow</td>
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<td>88.3</td>
<td>n/a</td>
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<td>1.577</td>
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<td>628.91</td>
<td>210.05</td>
</tr>
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<td>4:15p</td>
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<td>n/a</td>
<td>n/a</td>
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</tr>
<tr>
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<td>10:30</td>
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<td>n/a</td>
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</tr>
</tbody>
</table>

Table 1.0 (Running log of test data and results)
XLO-B Gas Lift Orifice Valve w/ Positive Check Valve & Rupture Disk Option

• Single point of rupture – one valve per well
• Rupture Disc down stream of the Check System
Design Test Specifications:
Tested to Meet Design Verification (Highest Level) – ISO 17078-1
- Strain Gauging to Validate Finite Element Analysis
- Internal Pressure Cycle Testing
- Pressure Testing at Rated Temperature
- Flow Control Testing
- XLift Kick-Over Tool Testing – Install/Pull
- Slickline Operational Test with XLift KOT
- SLB System EQ Testing to Include:
  Axial and Transverse Shock
  Erosion Testing of the Valve/Mandrel System
XLG XLift Side Pocket Mandrel Design

- Mandrel designed using Finite Element Analysis (FEA) and strain gauges
- 100% of tubing burst, collapse and tensile ratings
- Clean inlet flow path
- Clean tubing flow profile through use of electrode discharge machining processing
TECHNICAL SPECIFICATIONS:
MATERIAL = 13CR
I.D. - DRIFT (IN) = 4.653
I.D. - MIN. (IN) = 4.705
O.D. - DRIFT (IN) = 8.379
O.D. - MAX. (IN) = 8.286
CASING - MIN. RECOMMENDED = 9-5/8 IN.  53.5PPF
OVERALL LENGTH (IN) = 137
POCKET SIZE (NOMINAL)(IN.) = 1-3/4
TEST PRESSURE (INTERNAL)(PSI) = 8,000
TEST PRESSURE (EXTERNAL)(PSI) = 7,500
TENSILE STRENGTH (LB) = 397,000
THREAD (SIZE, WT., TYPE, CONFIG.) = 5-1/2, 17.0, VAM TOP, BXP
FLUSH MOUNTED DUAL EXTERNAL BY-PASS SLOTS FOR 15mm x 38 mm FLAT PACK
5-1/2” X Lift XLG Mandrel Integral Protected External Cable Bypass
5-1/2” X Lift XLG Mandrel Optimized for 9-5/8 53.5 ppf Casing

- Nominal OD 8.286”
- Nominal ID 4.705”
- Flush Mounted Dual external bypass for 15x38 mm flat pack
- Integral keeper plates
- Optimized gas inlet ports
Typical Applications for XLift High Pressure System

**North Sea**
- Subsea application
- Water depth = 1,200 ft
- Surface injection pressure = 2,900 psi (±3,500 psi at valve depth)
- Gas injection depth = 6,000 ft TVD
- Well bore deviation = > 65 deg
- Production rate > 30,000 bfpd

**West Africa**
- Subsea application
- Water depth = 1,370 ft
- Surface injection pressure = 2,450 psi (±3,000 psi at valve depth)
- Gas injection depth = 7,300 ft TVD
- Well bore deviation = > 60 deg
- Production rate > 30,000 bfpd
High Reliability Gas Lift Systems – Barrier Back Check
Standard Gas Lift Valve Reverse Flow Check Valve Designs

**Reverse Flow Check Valve**

Standard check valve designs are intended to prevent fluid flow from tubing-to-casing.

Leak Rate Criteria (API / ISO) 35 scf/d w/ specified differential pressures
Standard Gas Lift Valve Reverse Flow Check Valve Designs

- 02-30R Orifice Valve
- R-20-02 IPO Gas Lift Valve
- Nova 15 Venturi Orifice Valve
**Square Edged Orifice**
Standard Choke (various sizes available)
Gas Entry Holes Perpendicular to Choke
Fairly Turbulent Gas Flow Path
Critical Flow Achieved with 50% delta pressure

**Reverse Flow Check Valve**
Not Normally Closed
Floating Check Dart Seals with Reverse Flow
Elastomer Seal with Metallic Back-up Ring
Flow Velocity Affects the Check Dart Sealing Surface
5,000 PSI Working Pressure
Leak Rate Criteria (API / ISO) 35 scf/d
Standard 1-1/2” Check Valve, Failure Example

Field Example of Reverse Flow Check Valve Failure

Floating Check Dart Damaged

Elastomer Seal and Metallic Back-up Ring Damaged

Flow Velocity Affected the Check Dart and Sealing Surface

SLB standard check valves continue to provide good, reliable service in thousands of installations worldwide.

However, in situations of excessive flow they are more prone to damage
**Square Edged Orifice**
Standard Choke (various sizes available)
Gas Entry Holes Perpendicular to Choke
Fairly Turbulent Gas Flow Path
Critical Flow Achieved with 50% Delta Pressure

**Reverse Flow Check Valve**
Not Normally Closed
Floating Check Dart Seals with Reverse Flow
Elastomer Seal with Metallic Back-up
Flow Velocity Affects the Check Dart Sealing Surface
Soft seal out with the flow path
Anti-Rotation Feature Eliminates Velocity Spinning
1-3/4” XLift Gas Lift Orifice and Check Valve

**Venturi Orifice**
- Venturi Nozzle (various sizes available)
- Gas Entry Holes Tapered to Nozzle Inlet
- Optimized Gas Flow Path
- Critical Flow Achieved with 10% delta pressure

**Reverse Flow Check Valve**
- Normally Closed
- Positive Seal, Only Open During Gas or Fluid Flow from Casing to Tubing
- Metal-to-Metal Seal Surfaces, No Elastomers
- Due to Unique Geometry, Flow Velocity Does Not Affect the Check Dart Sealing Surface
- 10,000 PSI Sealing Pressure (Working Pressure)
- Anti-Rotation Feature Eliminates Velocity Spinning
1-3/4” and 1-1/2” Barrier Check Valve Development
Why Qualify Gas Lift Valves?

• **NORSOK D-010**
  – “For gas lift valves to qualify as a well barrier there shall be a qualification test demonstrating the valves ability to be gas tight over an operator defined number of cycles”

• **Petroleum Safety Authority (PSA – Norway)**
  – “An operator that wants to use gas lift valves as a satisfactory barrier element against the reservoir must consider these valves to be down hole safety valves”

• **Statoil (WR0534 Requirements to Well Completion Equipment)**
  – “The gas lift valve shall together with the tubing be part of the primary barrier”

* The Camco 1.5” and 1.75” family of IPO and Orifice Valves are qualified as well pressure barriers according to the Norwegian Sector and Statoil governing documents NORSOK D-010 and WR0534
Why Schlumberger Gas Lift Valves?

- **Because Gas Lift applications are in more aggressive conditions**
  - Field proven Camco brand Gas Lift valves are now coupled with *pressure barrier qualified* check valve systems to meet strict Norwegian and North Sea requirements
  - Reliability and functionality of products used for decades now meet the latest industry qualification standards

- **Because Gas Lift product reliability is more important than ever**
  - Robust gas lift equipment dynamically tested for endurance, integrity and reliability including: liquid flow erosion and high volume gas injection testing and pressure barrier qualification testing

- **Because Gas Lift operating efficiency improves NPV**
  - The latest improvements in injection gas flow geometry ensure stable and optimum oil production and increase the run life of the Gas Lift system

* The Camco 1.5” and 1.75” family of IPO and Orifice Valves are qualified as well pressure barriers according to the Norwegian Sector and Statoil governing documents NORSOK D-010 and WR0534
Gas Lift Barrier Qualification Test

• Test No. 1 – Initial Function Test
  – Perform mechanical function test (open and close) and back flow integrity testing with liquid and gas at ambient and rated working temperatures

• Test No. 2 - Unloading Test
  – Perform liquid unloading test with water - 600 bbls @ 1.5 bbl/min
  – Check valve leak tested at each 200 bbl with water and gas

• Test No. 3 - Gas Flow Test
  – Perform 100 open/close cycles with gas flow with the check valve leak rate tested after each 10 cycles
  – Perform 48 hour continuous gas flow endurance test

• Test No. 4 – Final Function Test
  – Perform final mechanical function and pressure integrity test
Liquid and Gas Flow Testing Performed by Schlumberger

Gas Flow Testing – CEESI - Ft. Collins, CO USA

X Lift Test Fixture

Liquid Flow Testing – Schlumberger SRC – Rosharon, TX USA
Barrier Check Valve Features

Available with Injection Pressure Operated and Orifices Valves

• Metal-to-Metal positive sealing check system (no soft seals)
• Flow and erosion protected spring activation
• 10,000 psi working pressure at 350º F (176º C)
Summary

• Schlumberger’s 1.5” and 1.75” IPO Unloading and Orifice Gas Lift Valves exceed all acceptance criteria for barrier qualification

• Qualified to ISO 17078-2, V1.

• The barrier qualified check valve system can be utilized with existing field proven Camco Gas Lift Valves to not only ensure well bore integrity but to also ensure the performance expected from down hole Gas Lift systems
Barrier qualified back check systems currently available:

- NOVA-15-B, 1-1/2” OD venturi orifice
- O-21R-B, 1-1/2” OD square edge orifice valve
- O2-30R-B, 1-1/2” OD dual check orifice valve
- SO2-30R-B 1-1/2” OD dual check shear orifice valve
- R20-02-B, 1-1/2” OD IPO unloading valve

- XLO-B, 1-3/4” OD venturi operating valve
- XLI-B, 1-3/4” OD unloading valve