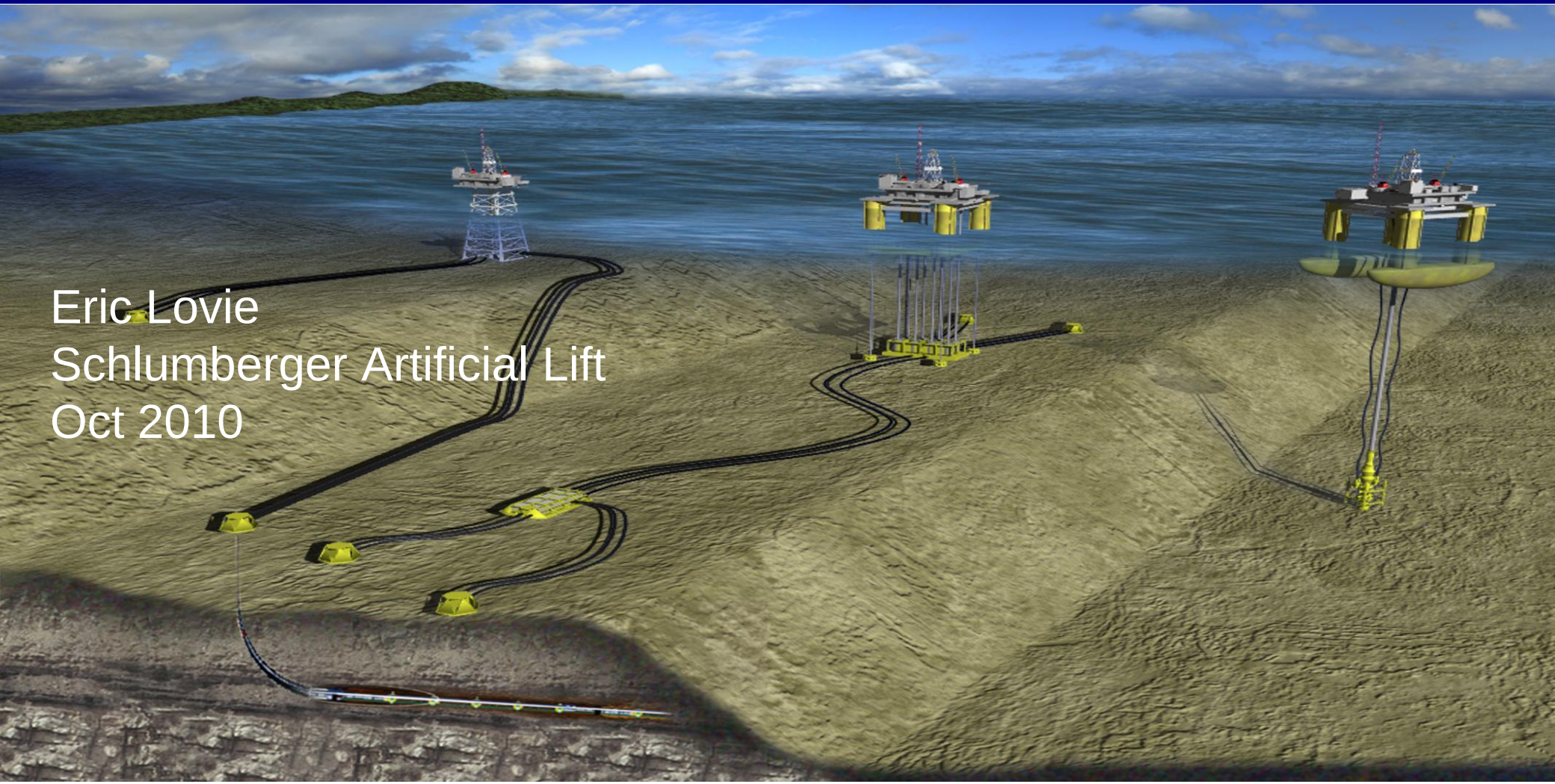
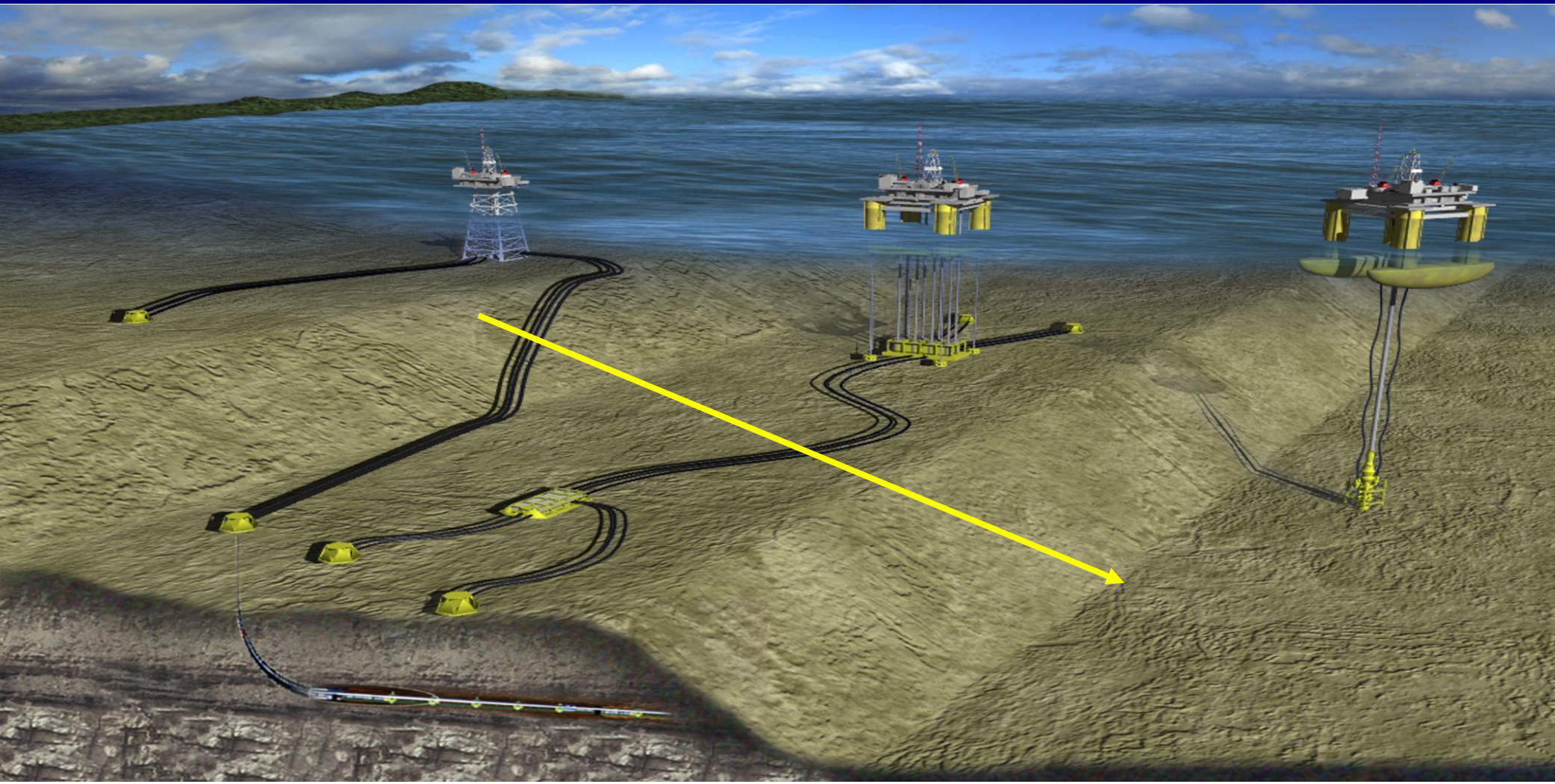
XLift™ High Pressure / High Reliability Gas Lift Systems



Eric Lovie
Schlumberger Artificial Lift
Oct 2010

Investment Trend and Technology Development Requirements



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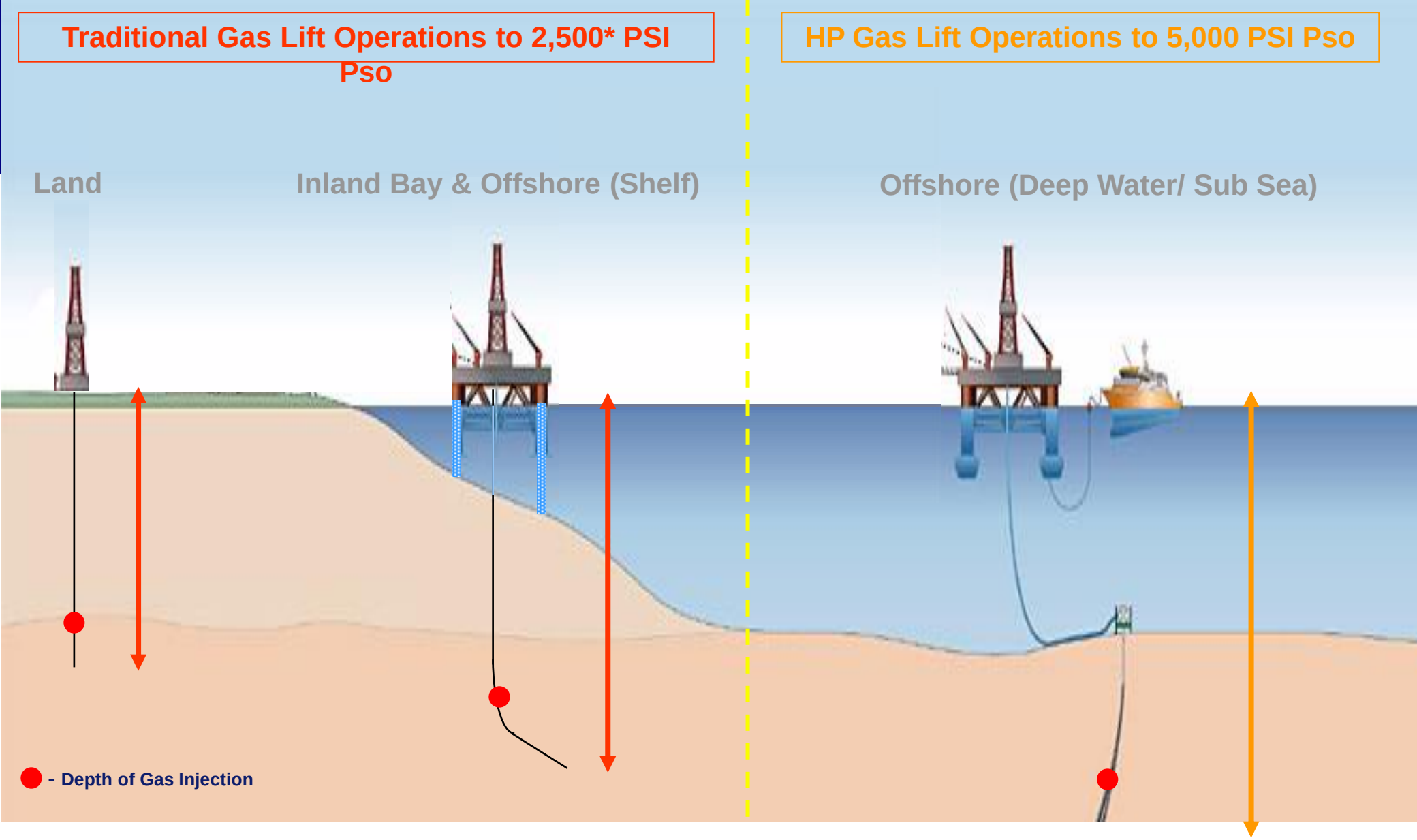
Traditional Gas Lift Operations to 2,500* PSI Pso

HP Gas Lift Operations to 5,000 PSI Pso



* *2.500 psi is the current operating limit of existing gas lift equipment*

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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

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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

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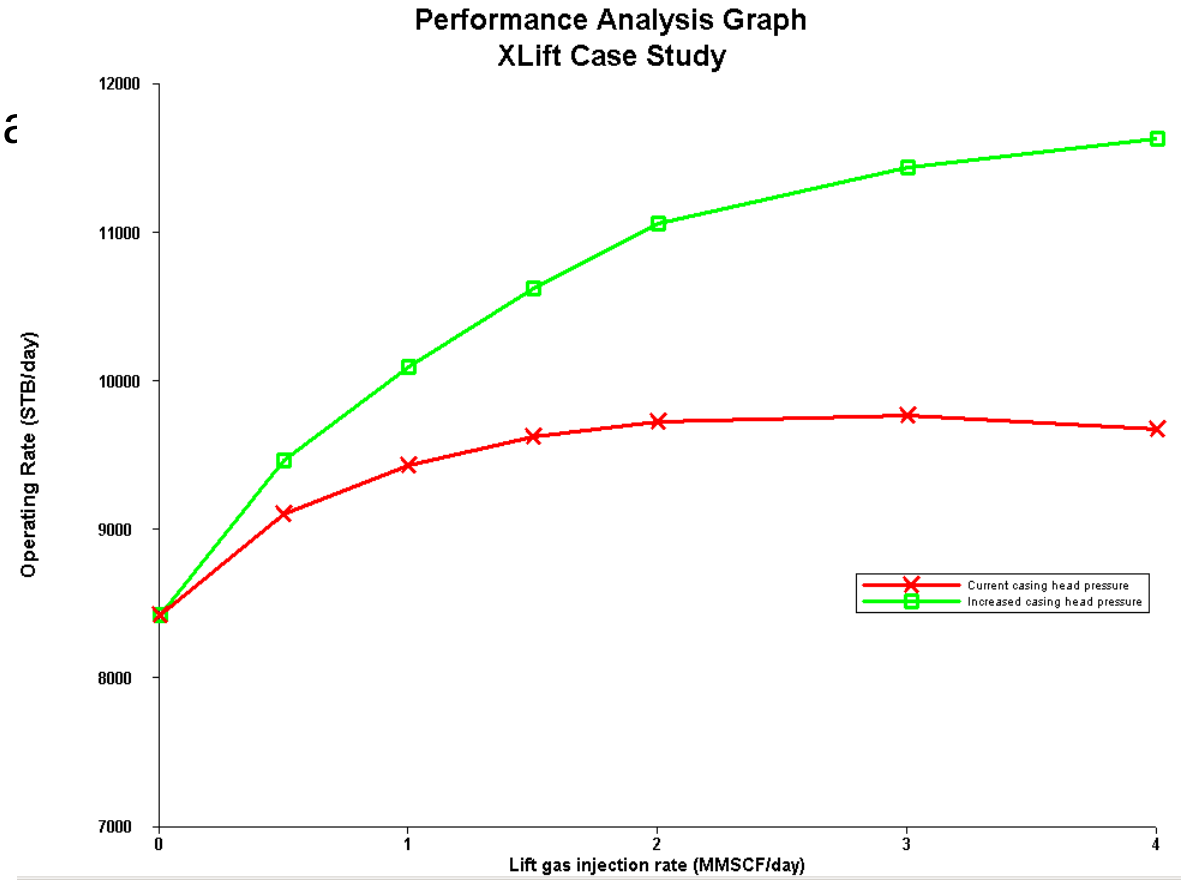
XLift™ (eXtreme Lift) Gas Lift System Benefits

- Analysis of Actual Well Da
- Deeper Gas Injection
- Increased Efficiency
- Reduced Lift Gas
- Increased Production
- Extended Late Life
- Well Integrity



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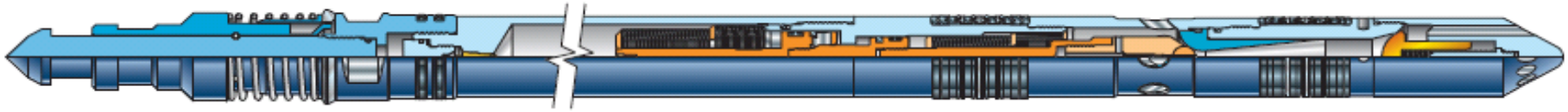
XLift XLI Injection Pressure Operated Gas Lift Valve



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 Moly Filled Teflon w/ PEEK BU & SS RR

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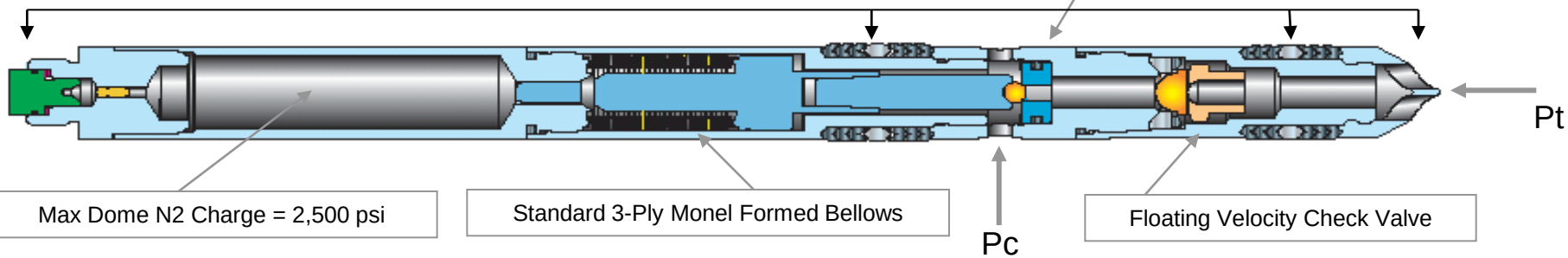
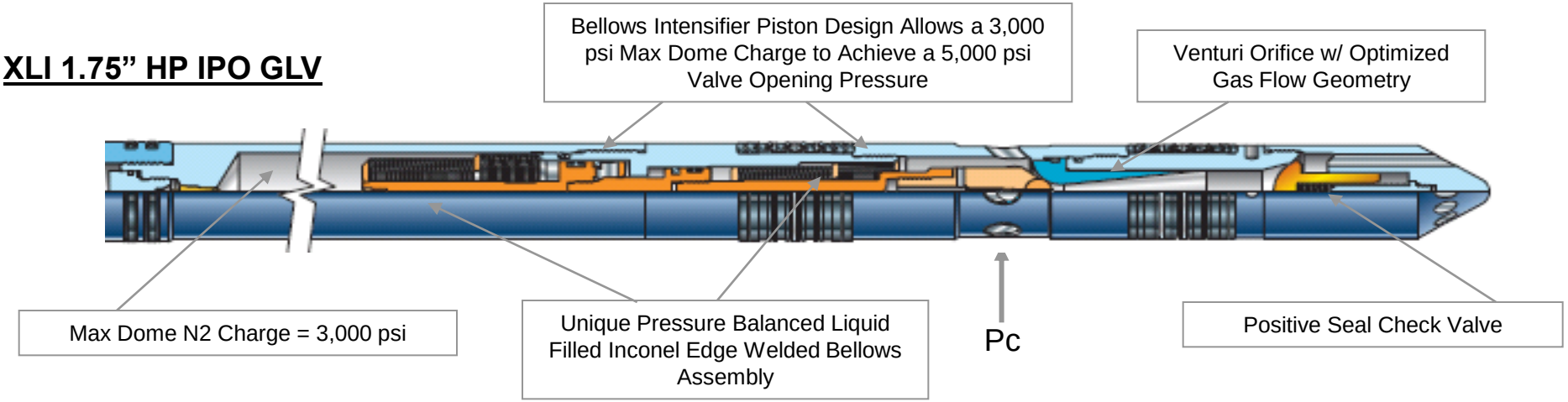
R-20 Valve and XLI Valve Comparison

Traditional 1.5” R-20 IPO GLV



Traditional Load Rates

XLI 1.75” HP IPO GLV



Minimal Load Rates

2X R-20 Dome Volume

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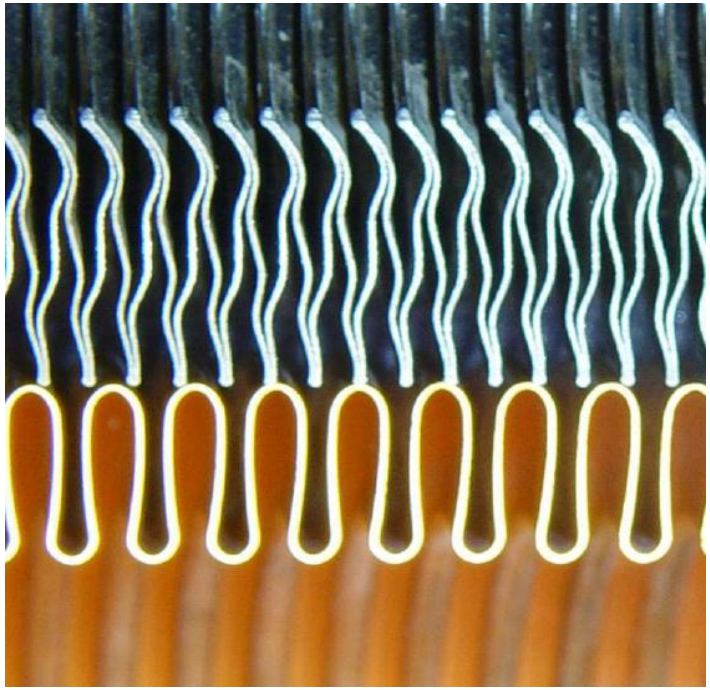
Bellows Comparison



- 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

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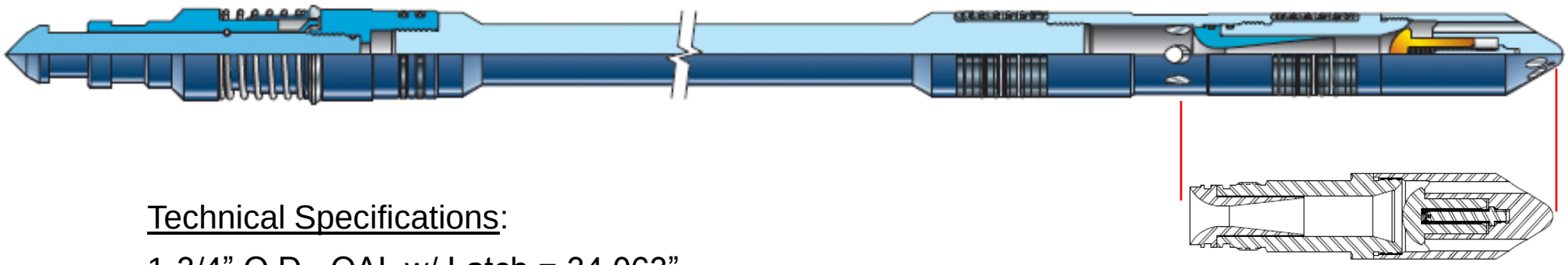
XLift XLO Orifice Valve with Positive Sealing Check Valve



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

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XLift XLO Orifice Valve Dynamic Gas Flow Test

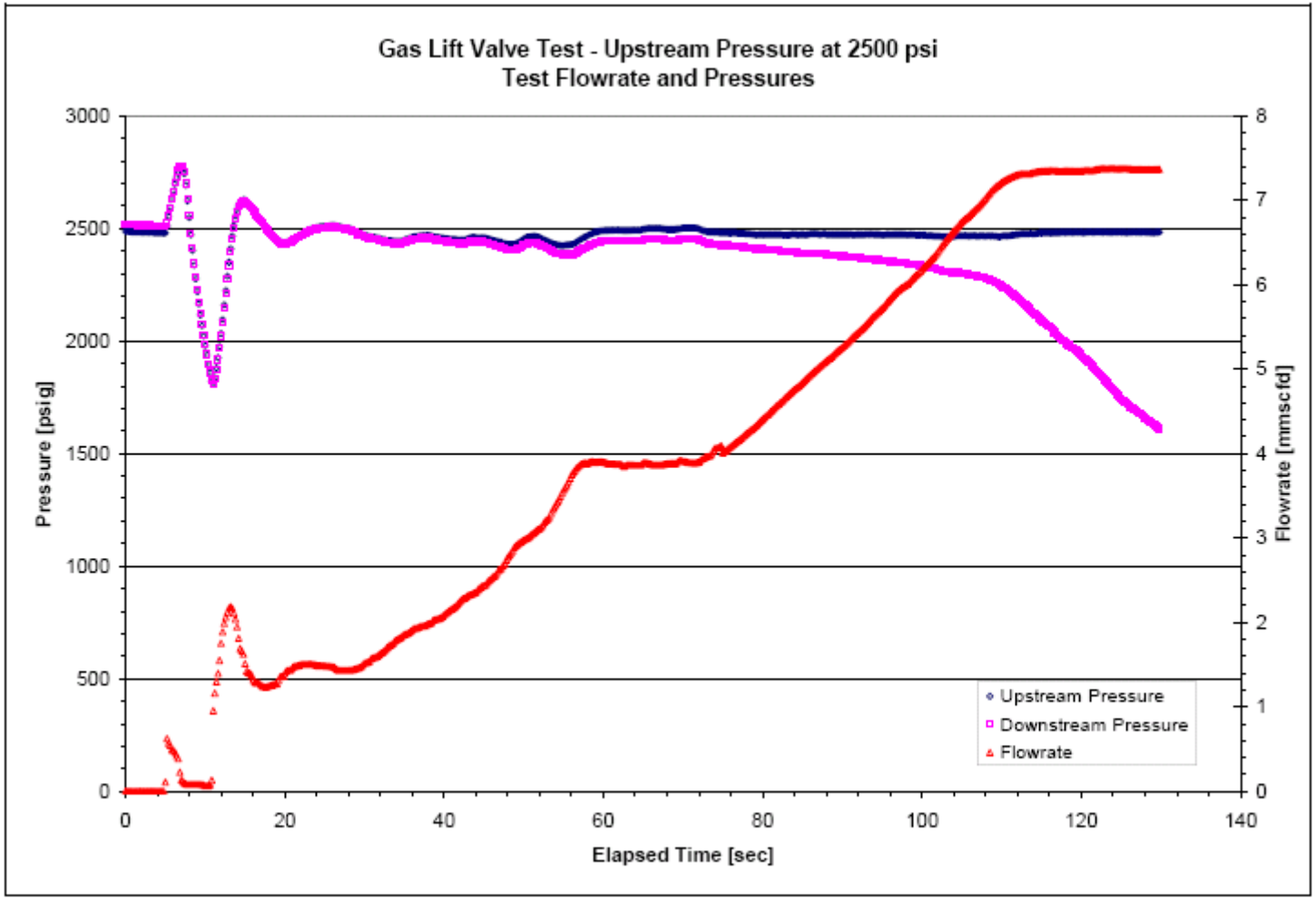

Chart 1.0 (Gas flow test with 2500 psi upstream pressure)

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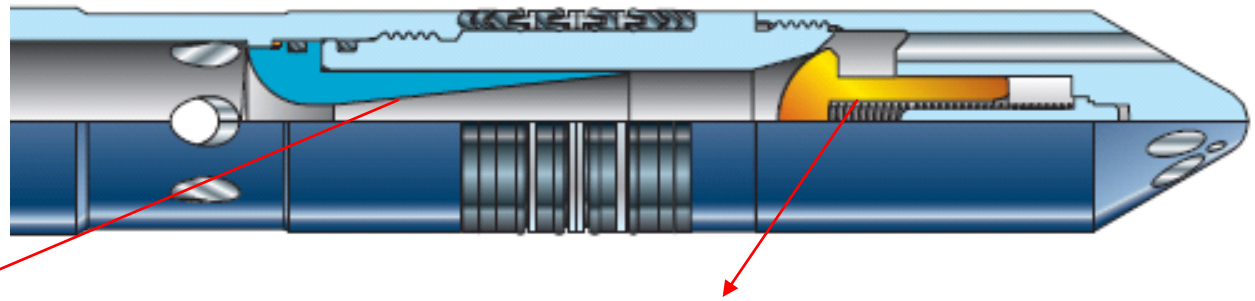
1-3/4” XLift Gas Lift Orifice and Check Valve



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

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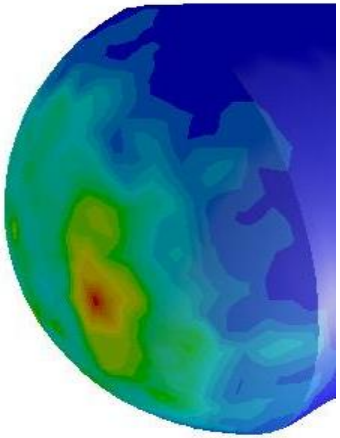
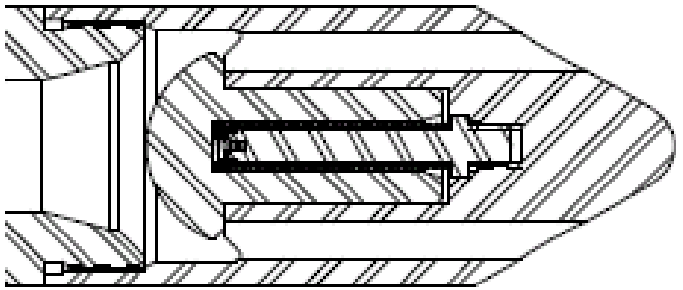
Comparison of CFD* with Erosion Test Results

- 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

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Comparison of CFD with Erosion Test Results

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.)

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XLO XLift Orifice Valve Liquid Flow Test

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

Test #	Date	Time From	Time To	Type of Test	PSI	Amb. temp °F	Leak Rate (scf/hr)	Gal/ Min	BBL/ Min	Gallons Total	BBL Total	BBL Tested
Initial	01/16/06	1:00p	1:20p	Leak	101	61.1	0	n/a	n/a	n/a	n/a	n/a
1	01/17/06	6:00	8:40	Flow	500	75.9	n/a	54.34	1.294	8766.75	208.73	208.73
2	01/17/06	9:00	9:25	Leak	101	66.1	0	n/a	n/a	n/a	n/a	n/a
2	01/17/06	9:40	12:00	Flow	500	82.9	n/a	54.3	1.293	17591.9	418.85	210.12
3	01/17/06	12:00p	12:20p	Leak	101	65.8	0	n/a	n/a	n/a	n/a	n/a
3	01/17/06	1:13p	3:50p	Flow	300	88.3	n/a	66.25	1.577	26414.1	628.91	210.05
4	01/17/06	3:50p	4:15p	Leak	100	71.6	0	n/a	n/a	n/a	n/a	n/a
4	01/18/06	7:30	10:30	Flow	300	90.6	n/a	66.41	1.581	36365.7	865.85	236.94
5	01/18/06	11:00	11:30	Leak	100	74.6	0	n/a	n/a	n/a	n/a	n/a

Table 1.0 (Running log of test data and results)

Photo 3.0 (Dart after 800 bbl liquid flow test)


Photo 4.0 (Nose ID after 800 bbl liquid flow test)

Photo 7.0 (Venturi Orifice after 800 bbl liquid flow test)

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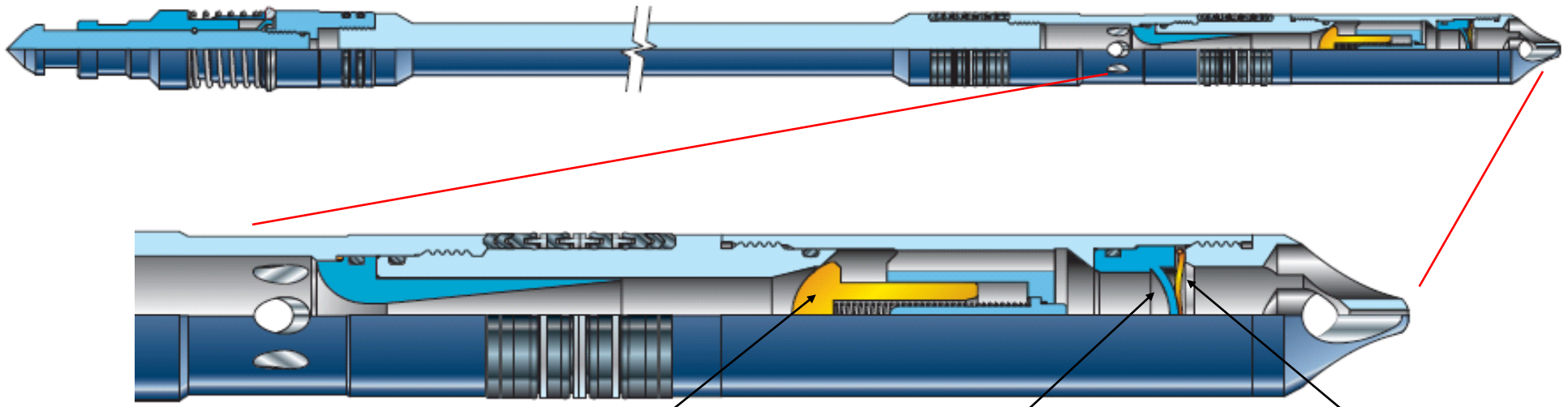
XLO-B Gas Lift Orifice Valve w/ Positive Check Valve & Rupture Disk Option



- Single point of rupture – one valve per well
- Rupture Disc down stream of the Check System

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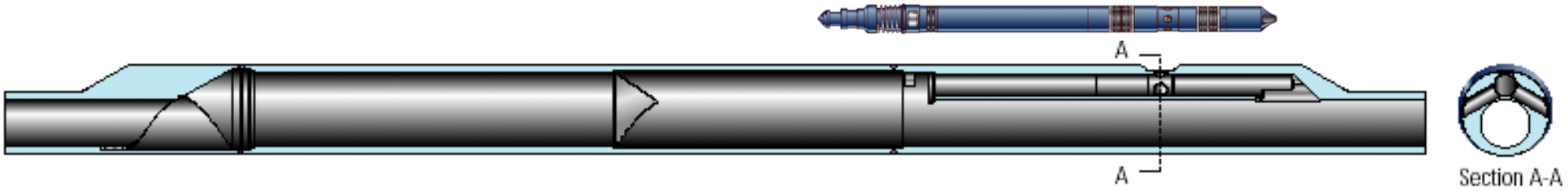
XLift XLG Side Pocket Mandrel



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

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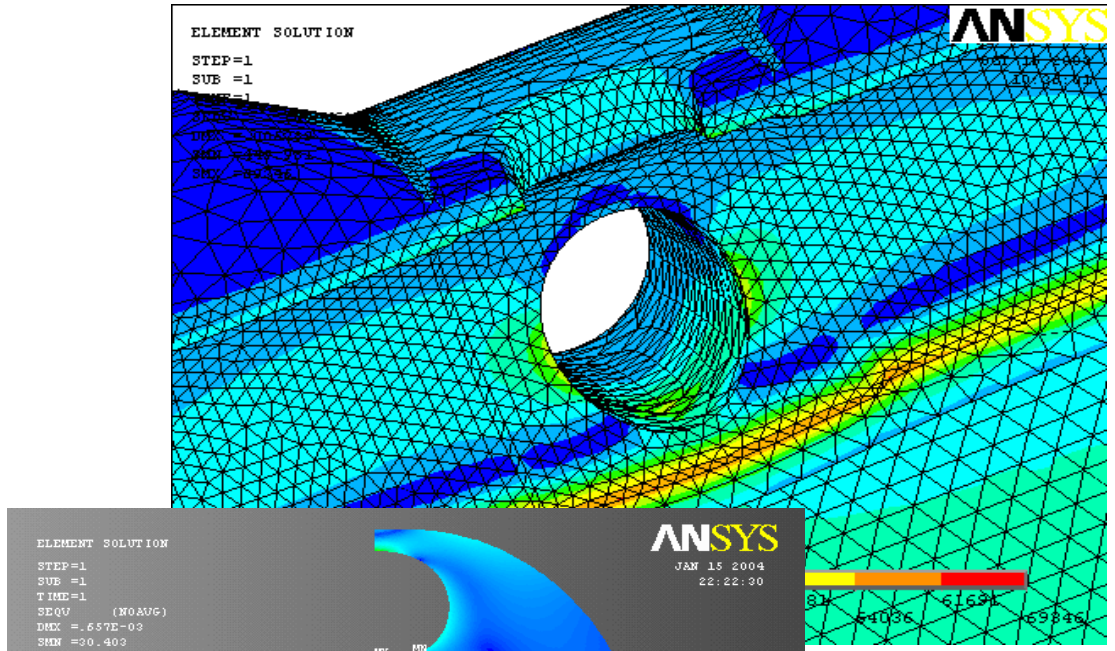
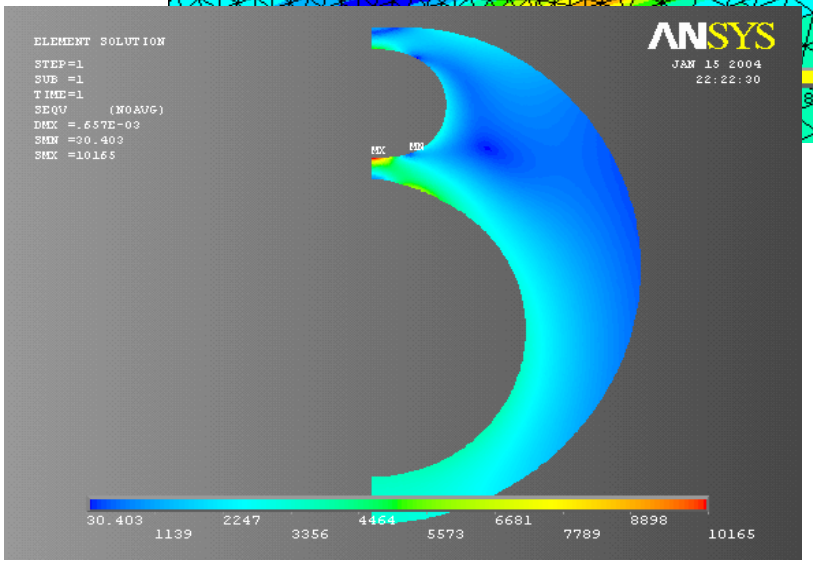
XLG XLift Side Pocket Mandrel Design

- 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





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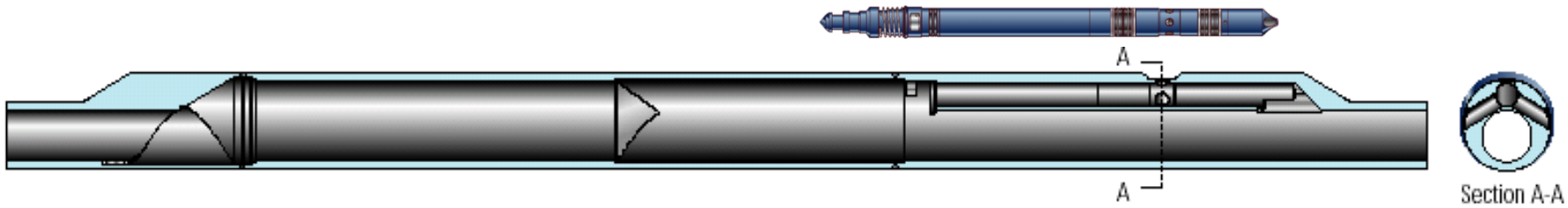
5-1/2” XLift XLG Side Pocket Mandrel – Sample Specifications



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

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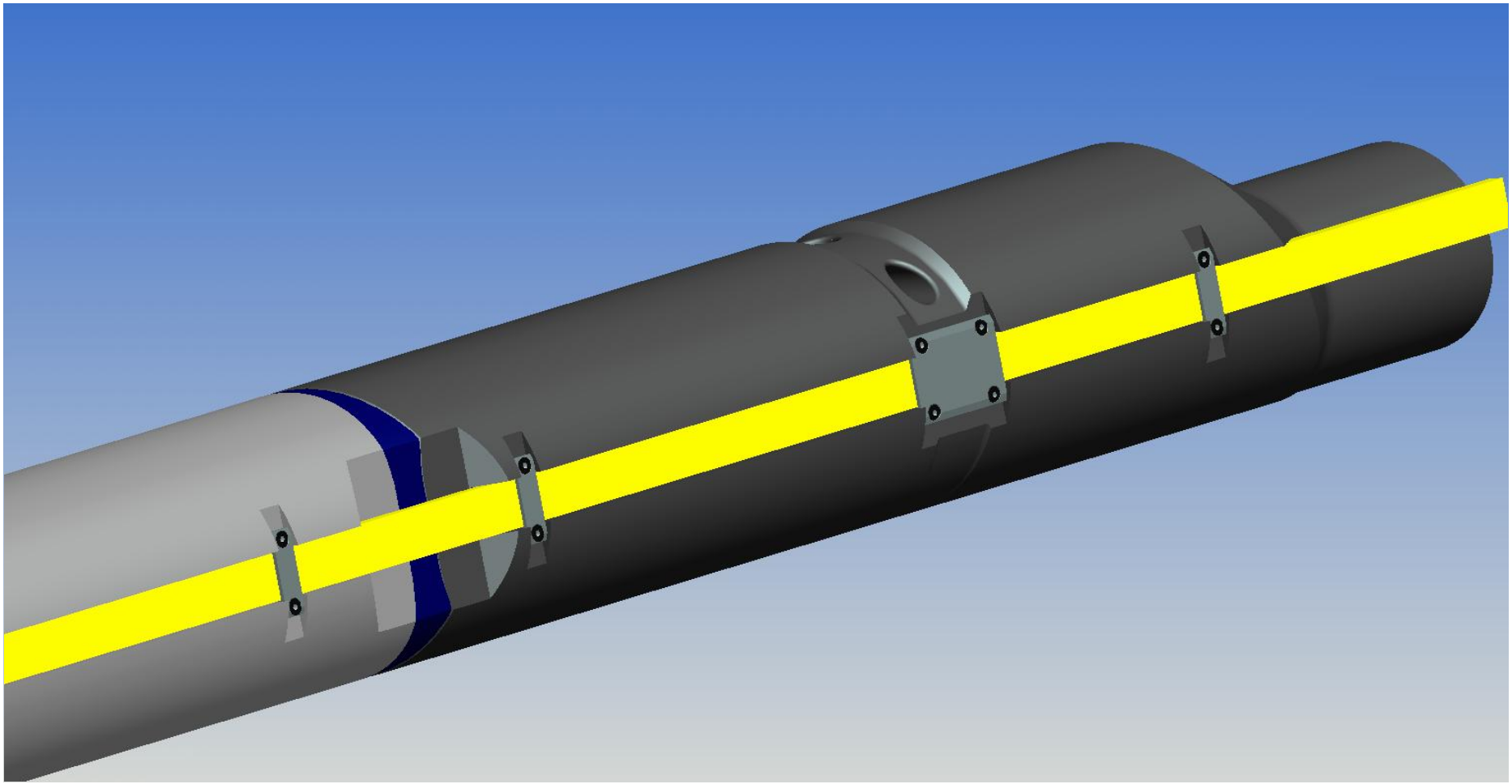
5-1/2” XLift XLG Mandrel Integral Protected External Cable Bypass



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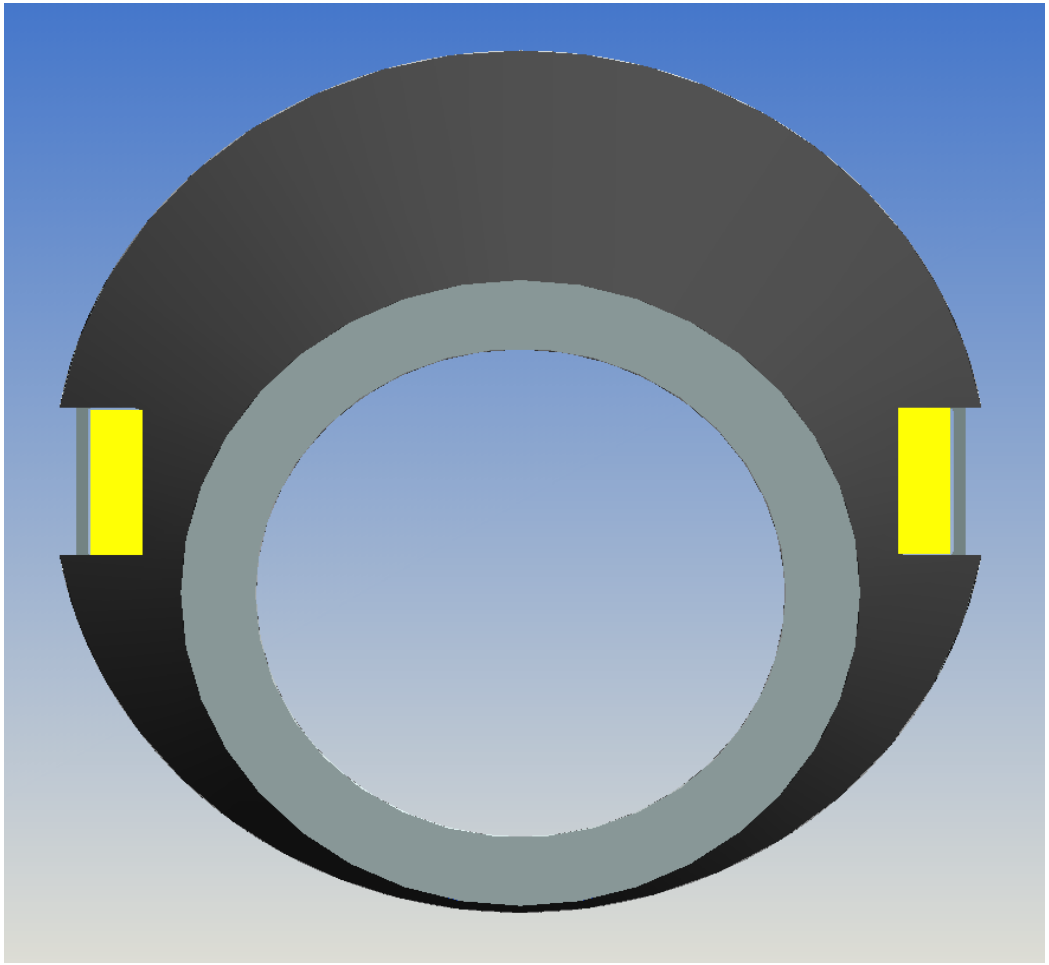
5-1/2” XLift XLG Mandrel Optimized for 9-5/8 53.5ppf Casing

- 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



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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

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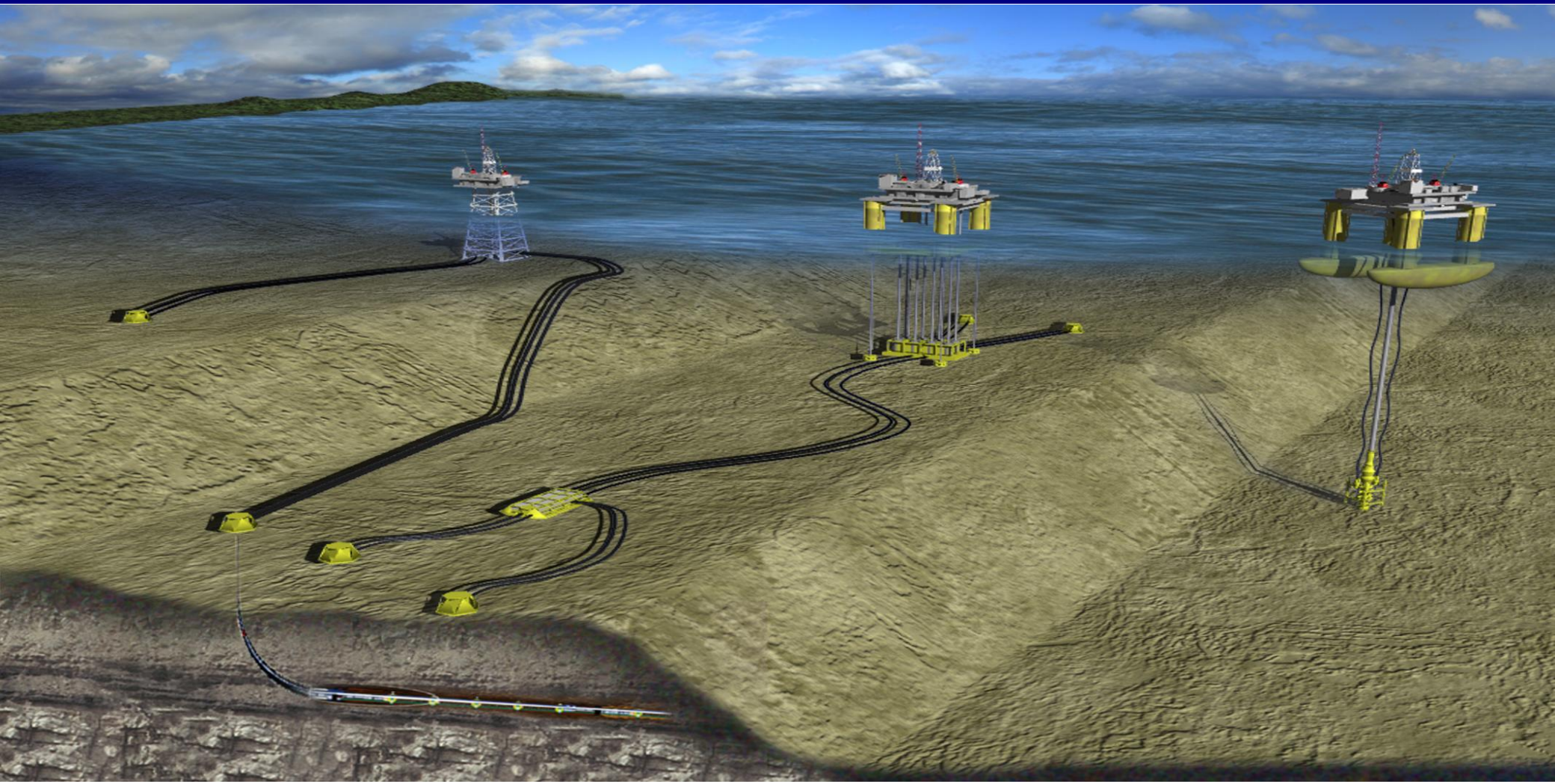
High Reliability Gas Lift Systems – Barrier Back Check



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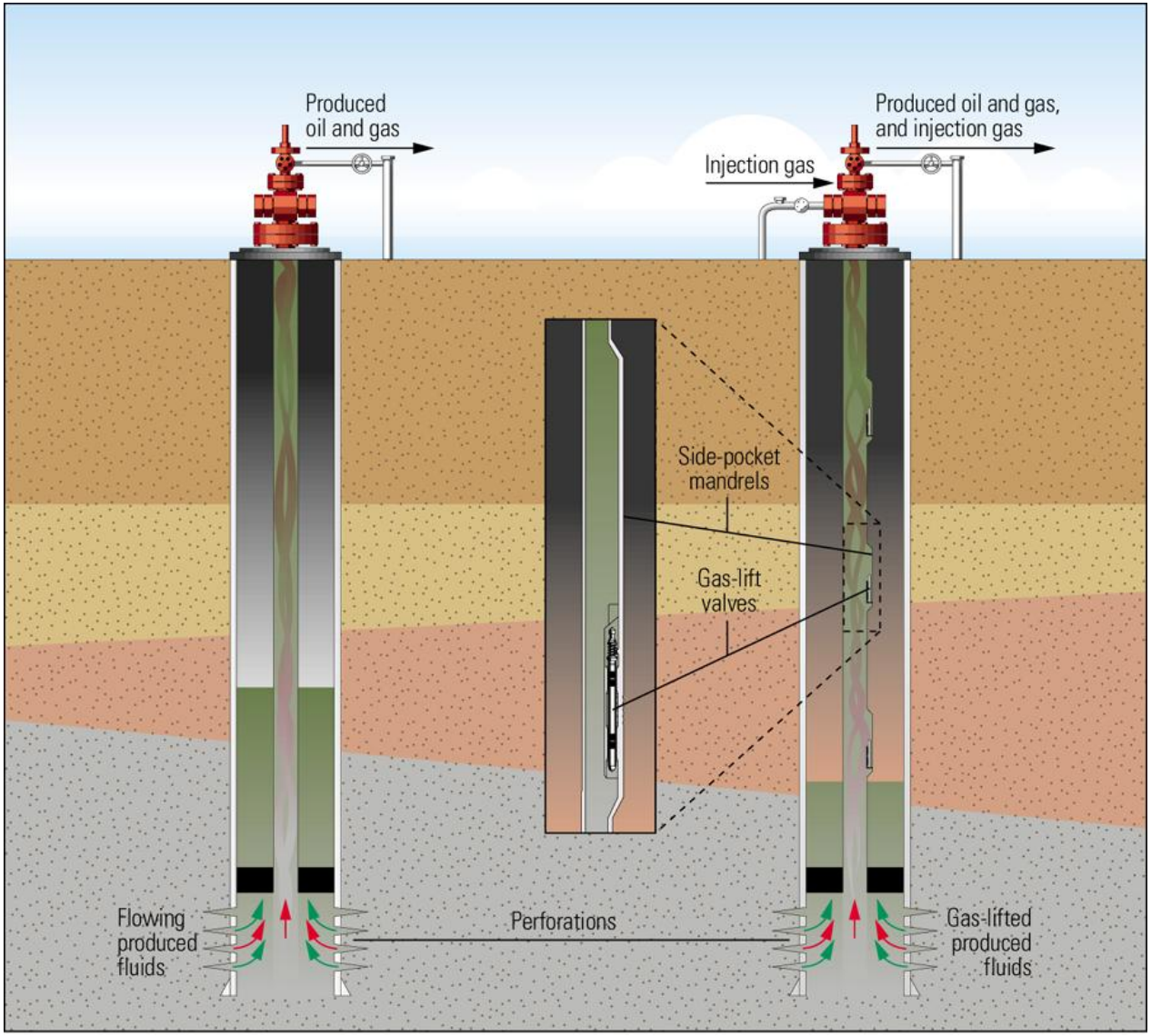
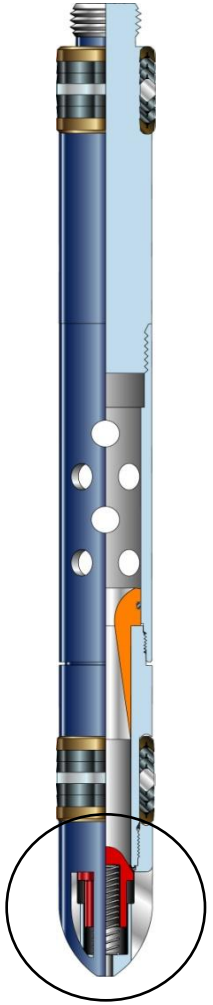
Gas Lift Equipment





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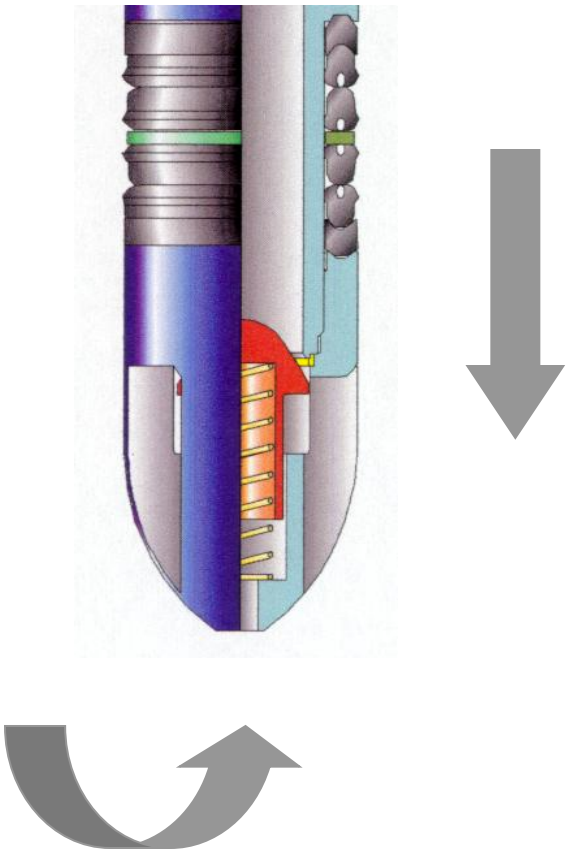
Standard Gas Lift Valve Reverse Flow Check Valve Designs



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

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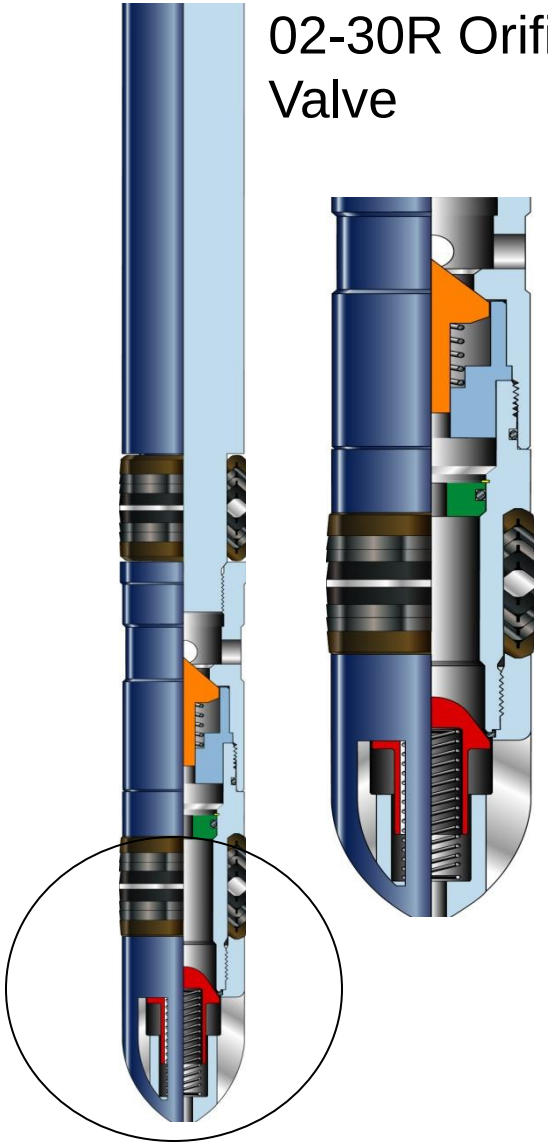
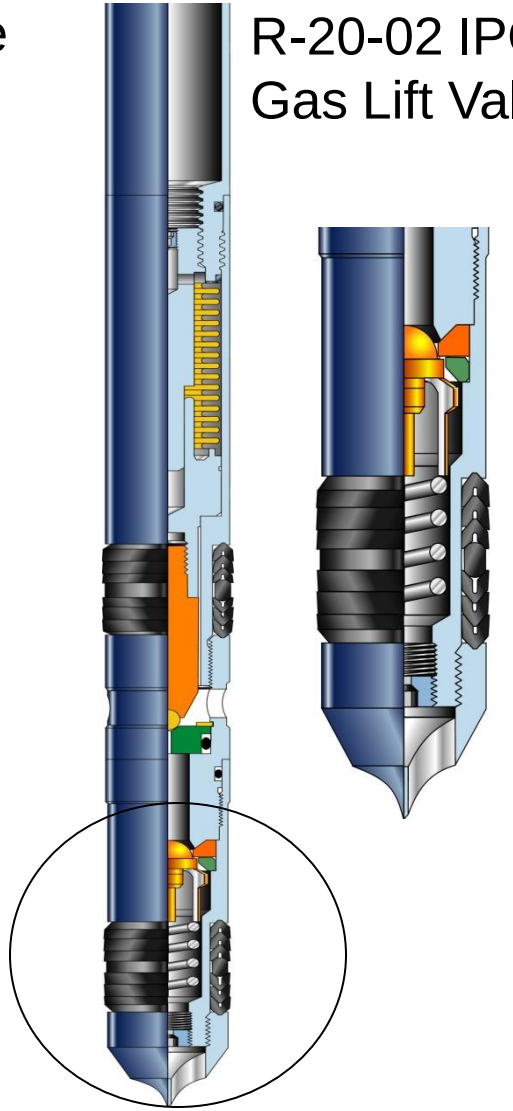
Standard Gas Lift Valve Reverse Flow Check Valve Designs

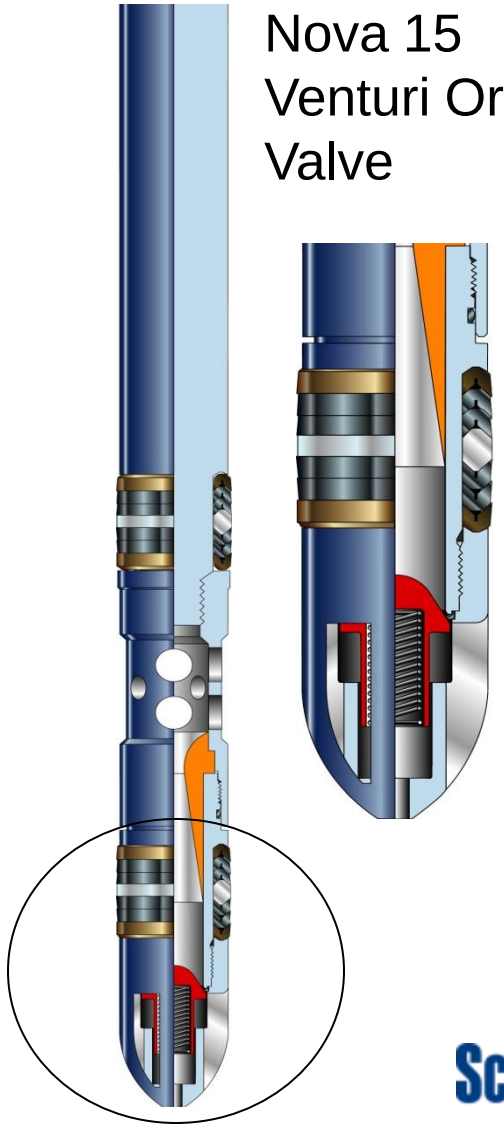
02-30R Orifice Valve



R-20-02 IPO Gas Lift Valve



Nova 15 Venturi Orifice Valve



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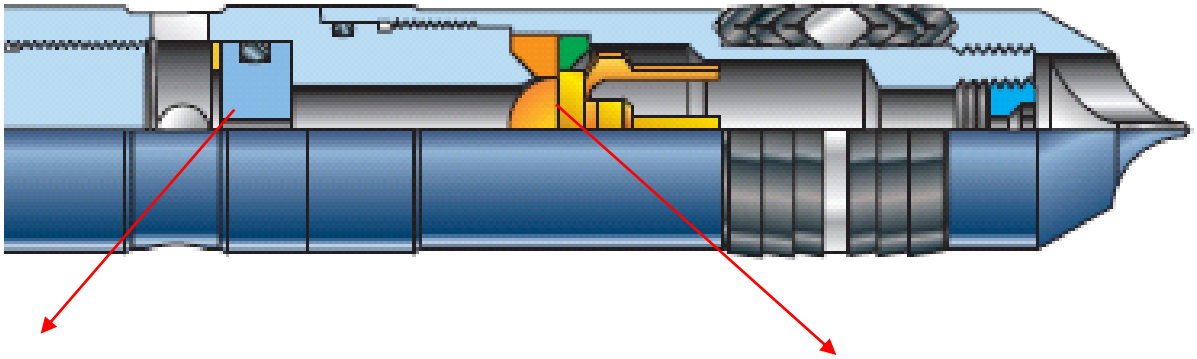
Standard 1-1/2” Gas Lift Orifice and Check Valve



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

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Standard 1-1/2” Check Valve, Failure Example

Field Example of Reverse Flow Check Valve Failure

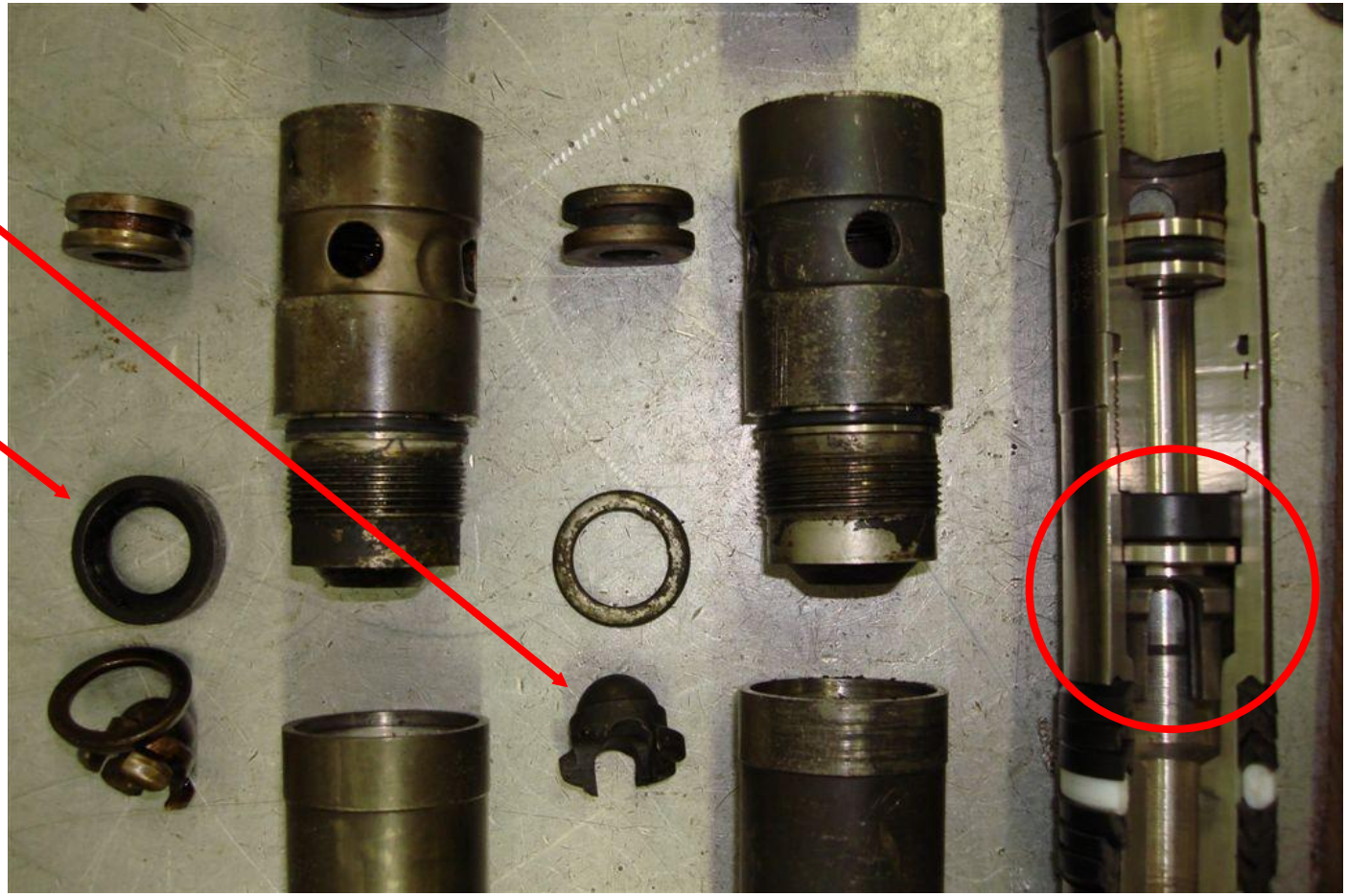
Floating Check Dart Damaged

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



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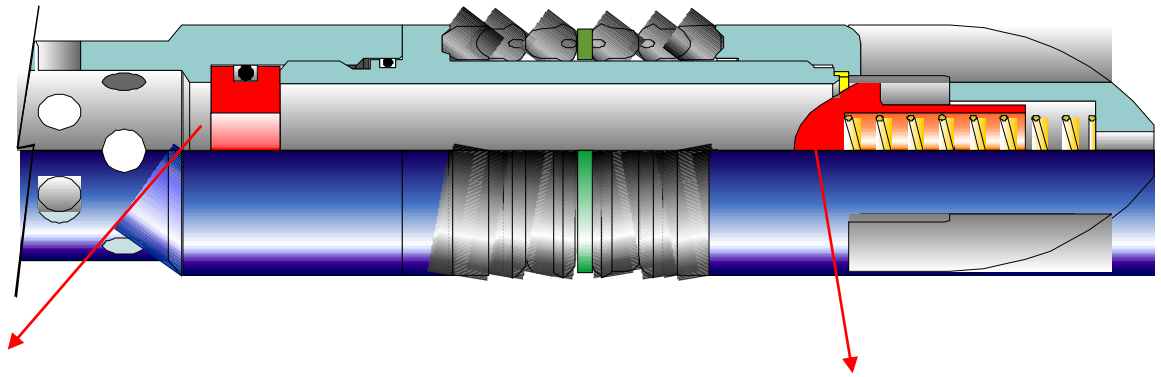
Full Flow Check Valve



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

Flow Velocity Affects the Check Dart Sealing Surface

Soft seal out with the flow path

Anti-Rotation Feature Eliminates Velocity Spinning

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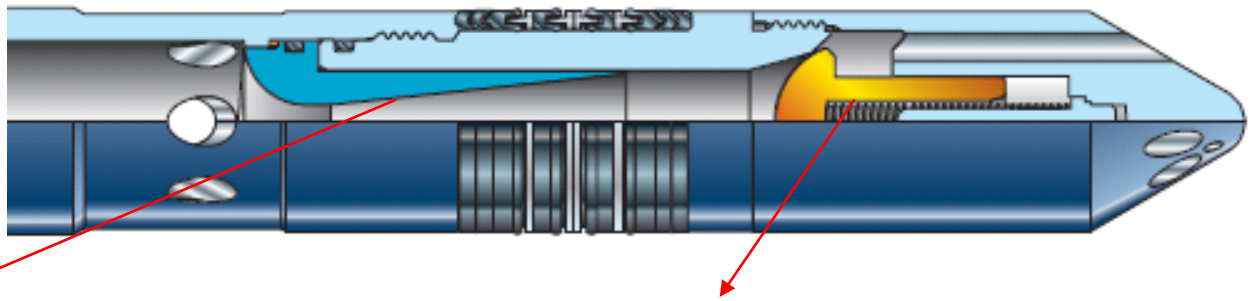
1-3/4” XLift Gas Lift Orifice and Check Valve



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

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1-3/4” and 1-1/2” Barrier Check Valve Development

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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**

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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**

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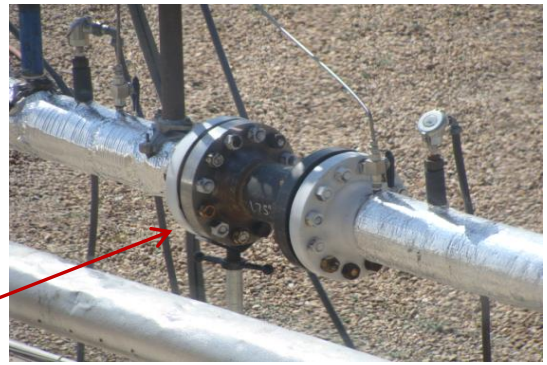
Gas Lift Barrier Qualification Test

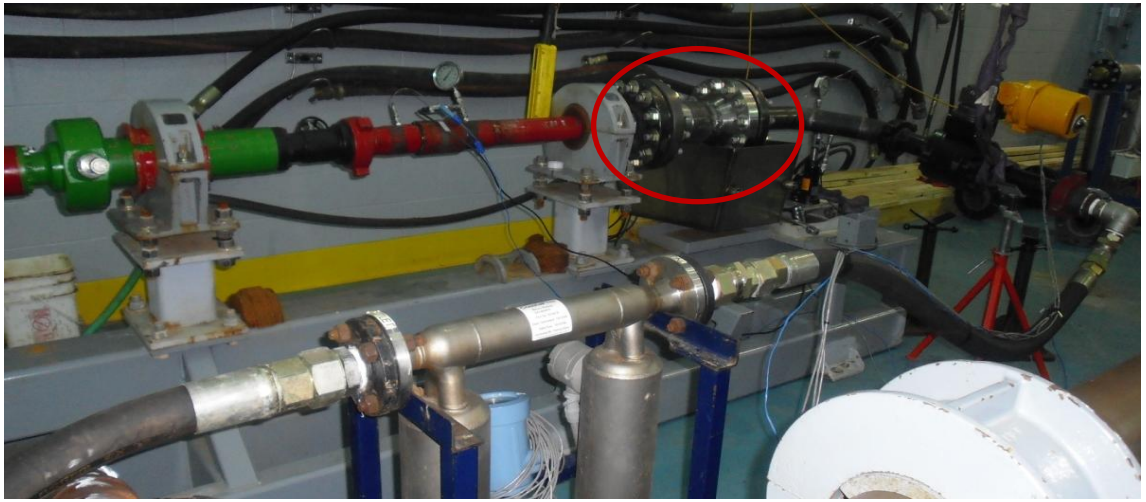
- Test No. 1 – Initial Function Test
  - Perform mechanical function test (open and close) and back flow integrity testing with liquid and gas at ambient and rated working temperatures
- Test No. 2 - Unloading Test
  - Perform liquid unloading test with water - 600 bbls @ 1.5 bbl/min
  - Check valve 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



XLift Test Fixture



Liquid Flow Testing – Schlumberger SRC – Rosharon, TX USA

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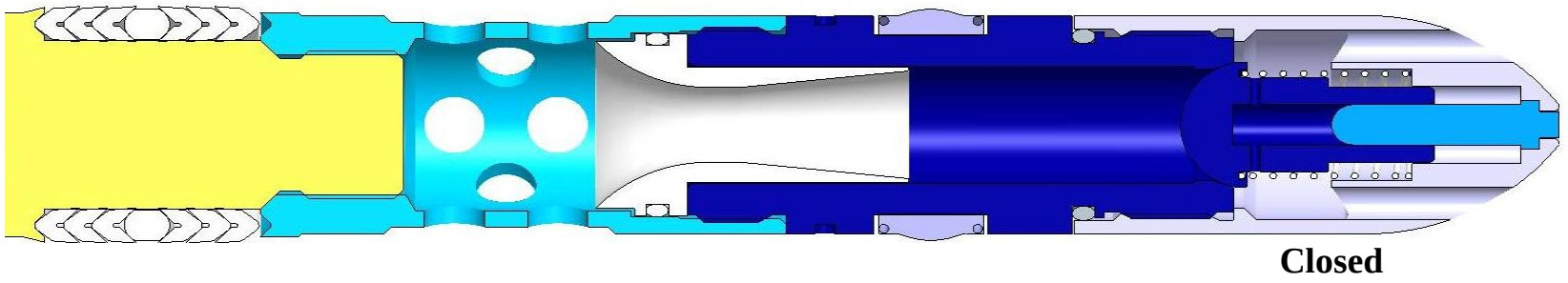
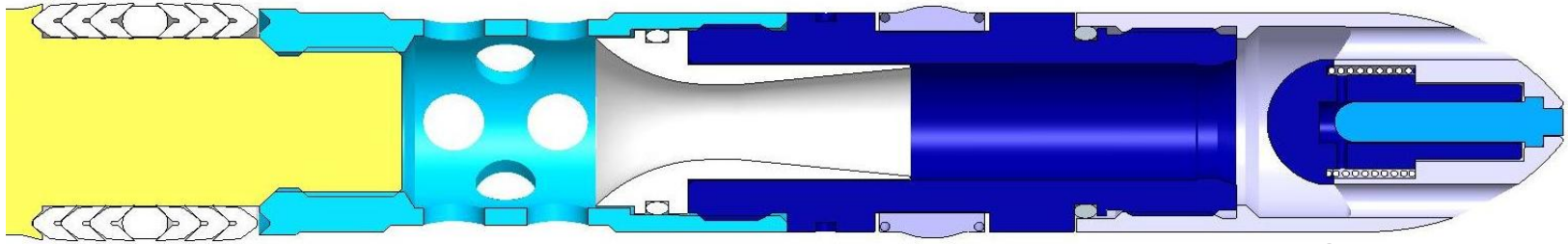
Barrier Check Valve Features

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)



Closed



Open

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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

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

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